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THE APPLICATION OF PROJECT ANALYSIS TO NATURAL RESOURCE DECISIONS

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FOREWORD

This bulletin is published in furtherance of the purposes of the Federal Water Research and Development Act of 1978, P.L. 95-467. The purpose of the Act is to stimulate, sponsor, provide for, and supplement present programs for the conduct of research, investigations, experiments, and the training of scientists in the field of water and resources which affect water. The Act is promoting a more adequate National program of water resources research by furnishing financial assistance to non-Federal research.

The Act provides for establishment of Water Resources Research Centers at Universities throughout the Nation. On September 1, 1964, a Water Resources Research Center was established (under the Water Resources Research Act of 1964, P.L. 88-379) in the Graduate School as an Interdisciplinary component of the University of Minnesota. The Center has the responsibility for unifying and stimulating University research with water resources programs of local, State and Federal agencies and private organizations throughout the State; and assisting in training additional scientists for work in the field of water resources through research.

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Publication Abstract:

This publication is intended to serve as a guide for the application of water project planning and analysis. Included are a perspective from which to review economic decisions; a brief history of evaluation procedures for U.S. water projects; a description of the Water Resources Council's procedures; the basic economics of project evaluation; problems in cost allocation; and individual applications to irrigation, flood control, navigation and related transportation, and recreation and environmental resources. Emphasis is placed on social benefits measured in terms of additions to real product and savings in terms of real resources.

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PREFACE

This bulletin is written as a guide for the application of project planning and analysis procedures. It does not purport to provide a comprehensive treatment of economic theory but is concerned with whether or not projects meet a basic national economic efficiency criterion. Benefits are measured where possible in terms of consumers' willingness to pay for goods or services. Costs are measured in terms of opportunity costs or what has to be given up to produce the goods or services.

As will be discussed in more detail later, many of the problems associated with project analysis are due to the difficulties of measuring the social value of all benefits and costs. This is particularly true when it comes to measuring the benefits from public programs such as recreation, research, and transportation. Since there are no markets for many of these public services, it is difficult to place a value on a unit of output. Most of the measurement problems on the cost side involve environmental damages and the preservation value of national environments. In the cases where a project is reducing environmental damages or preserving natural environments they become project benefits.

The major purpose of the bulletin is to help readers improve their understanding of how to apply project planning and analysis to a wide range of situations. Readers will find the procedures relatively straightforward. They will also see how project analysis can improve the decision-making process even if there are objectives other than economic efficiency. Project planning and analysis should not be the only information used to make project decisions but it should be an important input.

The most significant information usually not provided in project analysis is the income distributional impacts. In other words who pays for the project and who are the beneficiaries? Are the ones who benefit large farmers, businesses, or consumers? Analysis can be done to provide information about distributional impacts but political and measurement problems limit its application. The chapter on agricultural research provides an estimate of the distribution of benefits between consumers and producers.

In earlier days of project analysis impacts of projects were limited to those that could be measured in dollar terms. Currently the 1970 National Environmental Policy Act (NEPA) requires environmental impact statements for all major federal projects or legislative proposals that significantly affect the quality of the human environment. NEPA has forced the federal government to consider important environmental impacts that had been ignored in the past project analysis. However, the tendency is to prepare huge environmental impact statements that tend to delay decisions while not necessarily adding a useful input into decisions. A balance is needed between no environmental information and too much. Questions must now be asked about what information is relevant and can it be measured and analyzed before the decision must be made. The chapter on environmental damages provides some examples of how willingness to pay can be used to measure the value of a cleaner environment.

The bulletin is divided into twelve chapters. The first chapter presents the economic setting for viewing resource decisions. Chapter II, which is divided into two major sections, first presents a brief history of how project evaluation procedures have evolved for U.S. water projects starting in 1902. The second section reviews the project planning and analysis procedure suggested in the Water Resources Council's 1973 Principles and Standards. Chapter III presents a planning and analysis procedure for evaluating projects that will be generally used in the bulletin. The next six chapters deal with project analysis as it is applied to irrigation, flood control, navigation, rail line improvement, recreation and environmental resources, and agricultural research. The emphasis in these six chapters is on how benefits and costs can be measured in project analysis. Chapter X does a more qualitative economic analysis of the many impacts of the diversion of water from Lake Michigan. Chapter XI suggests approaches for including uncertainty in the analysis of projects. Finally, Chapter XII provides a summary along with some thoughts concerning environmental impact statements, ex-post analysis, and the application of project analysis in developing countries.

CHAPTER I

ECONOMIC SETTING FOR DECISION MAKING

Economics, as every beginning student is told, is the social science involving the allocation of scarce resources. Resources are generally divided into four classes: land, labor, capital, and entrepreneurship. Labor and entrepreneurship are human resources; land and capital are non-human resources.

Labor includes the entire range of services performed by humans--from assembly operations in factories to the entertainment provided by professional athletes. Entrepreneurship, the other human resource, is the factor which involves combining the other resources in production, provision of capital, risk taking, and innovation.

Capital is the man-made resource which is used in production of other goods. Capital goods do not satisfy wants directly, but satisfy them indirectly through production of other goods.

The remaining resource, "land", is the traditional term in economics referring to natural resources or "gifts of nature". It is this class of resources with which this publication is most concerned.

The term "natural resources" traditionally refers to naturally occurring resources and systems that are useful to humans, or which could be useful under plausible technological, economic and social circumstances. A partial list includes agricultural land, forests, waters, fish and wildlife, minerals, tides, winds, and solar energy. The waste-assimilative capacities of the environment must also be considered as a natural resource. Open lands and areas having scenic or aesthetic uses as their major purpose must also be considered as part of the earth's natural resource endowment.

It is common to think of natural resource problems and issues in physical or biological terms. However, a major concern is the availability of these resources, and their allocation among competing uses. These concerns are not new, but have been accentuated by earth days and a new concern for the environment of the early 1970's, the world food shortages of 1972 and the increased level of concern for energy supplies in 1973. The basic controversial issues involving natural resources revolve around "scarcity", the fact that there are competing uses for limited amounts of natural resources.

Scarcity: A Pervasive Reality

A resource is said to be "scarce" if there are competing uses for it. That is, if there is enough of a resource that one use does not preclude any other use, then there is no scarcity problem. Therefore most resources have some degree of scarcity and, hence, decisions must be made regarding their use.

A resource which is available in such abundance that it is available in unlimited quantity for any use is known as a free resource. It is difficult to think of examples of "free resources". Certain "gifts of nature", such as sunshine are sometimes thought of as free goods. However, even most "gifts of nature", are scarce relative to demand for them. That is, there is not enough for everyone for all conceivable uses of these resources. For example, at one time, it was thought that water was a free good. Yet, use of water to transport and dilute waste may preclude its use for recreation. The same is true of the earth's air mantle. The use of the atmosphere for discharge of wastes interferes with its use for breathing.

The degree of scarcity is dependent on a combination of its usefulness in human endeavors relative to its supply. This can be illustrated by the classic diamond-water paradox. Everyone agrees that water, being essential to life,has a higher degree of want satisfying power than diamonds. Diamonds, aside from some industrial uses, are used largely for decorative purposes and adornment.

Still, the market value of water is low compared to the market value of diamonds. Why? Because the supply of diamonds is limited relative to demand compared to the supply of water relative to its demand. Hence, although the market value of water is positive, it is relatively low. If a person was [1/] stranded in the desert, the value of water would become high relative to that of diamonds, because of the change in relative supply-demand conditions.

The reality of scarcity suggests that decisions must be made regarding use of resources. Since not enough is available for everyone for every purpose, decisions must be made on how these resources are to be used. The focus of this publication is on economic aspects of these decisions.

Role of the Price System.

The condition of scarcity is basic to the economic problem. The existence of scarcity means that decisions must be made with respect to the economy's limited resources. To what types of questions are we referring?

In every economy, there are the basic questions of "what to produce", "how to produce", and "for whom to produce"? These questions may be answered in various ways and by various mechanisms, but they must nevertheless be answered.

"What to produce" means does the economy produce beans, corn, planes, tanks, guns, patent headache remedies, etc., and in what combinations?

1/ A more sophisticated explanation can be made by use of the "consumer surplus" concept by which it can be shown that the "value in use" (represented by the area under the demand curve) for water is much greater than the "value in use" for diamonds, even though the price, indicating value at the margin, for diamonds is relatively high. We also note the measurement problem in that the physical units of diamonds and water are not comparable. For a more detailed explanation of this concept, see Hirschliefer, 1976, p. 185. The concept of consumer surplus is further discussed in this publication in Chapter II.

"How to produce" refers to the combinations of factors of production to use in production.

"For whom to produce" refers to who gets the fruits of production.

These are basic questions which every economy must answer. The primitive or traditional rural society answers these questions initially through processes based on custom and tradition. The more advanced industrial society determines answers to these questions through a range of alternatives to be discussed shortly. The notion of a more advanced society poses two additional questions. These are "How does the economy achieve flexibility?" and "What is the level of production?"

The level of production refers to both natural and human resources. What is the level of employment to strive to attain? What age do people enter the work force and at what age do they retire? Questions on the level of production concern the rate of natural resource use.

Again these questions are not unique to any specific economy - U.S., U.S.S.R., Canada, or Germany. They are pervasive. It can be said that any issue of economic controversy relates to at least one of these basic questions.

It is the manner in which these questions are answered which differs. In the American economy, there is a strong emphasis on the price and market system. In other economies, there is more emphasis on central planning. In a price and market system, the answers are as follows:

What to Produce: Business firms have the incentive to produce those goods for which they see a potential profit. In a market economy, these decisions are based on factors such as consumer demand and cost of production.

How to Produce: Firms have the incentive to use the least monetary cost for a given level of output.

For Whom: Those who have the dollar votes command the means to acquire goods and services, and thereby exert their preferences through the market.

It should be emphasized that in reality, there tends to be a mixture of market systems and central planning. Even avowed Socialist nations use some proxy for a price system,and a profit and reward system, although great care is used to avoid the specific terminology. And certainly, in nations professing to rely on a price system, there are numerous decisions which are made or influenced through government action. The reason is that while there are many advantages to the price and market system, there are some circumstances under which the price system by itself does not perform well, or does not achieve the goals of society.

The basic tenet of the price system is that each person acting in his own self interest automatically furthers the welfare of society as if guided by an "invisible hand". In many cases this is accurate, and indeed, the price system performs well in many ways. For example, there are numerous decisions made through the price and market system regarding what to produce and how to produce which lead to an efficient allocation of resources. The decisions of producers and consumers initially through the marketplace do in fact effectively make many decisions. And these decisions are made with a great degree of economic freedom by the participants.

If the "invisible hand" worked so well for all economic decisions, the matter would be simplified and the price system could simply be allowed to take its course. However, there are a number of alleged shortcomings of the price system which suggest public policy remedies. Some of these difficulties have specifically to do with decisions regarding the use and management of natural resources. This is not to say that the price and market system should have no bearing on resource decisions. The point is that the price and market system does not always provide optimum results in terms of the goals of society. Let us examine in greater detail some "market imperfections"

Market Imperfections

The first point is that the price system is conducive to the destruction of its main regulating force, competition. Economies of scale result in large firms having an advantage in production. This tends to result in few, but very large firms. Furthermore, if competition is the regulating force, and each individual acts in his own self interest, it stands to reason that individual entrepeneurs will tend to either eliminate rivals or band together to limit competition. Either way, the end result will be the possibility of monopoly power. With monopoly power, prices are distorted upward as compared to competive conditions.

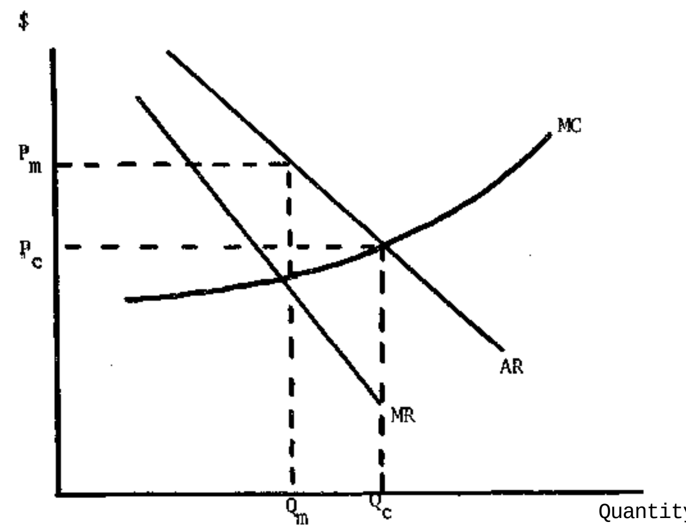
A second point centers around the matter of "What is produced" and "How it is distributed". "What is produced" is based largely on private dollar votes. This produces a "bias" toward goods produced in the private sector. There is another class of goods, public goods, which the private sector does not have the incentive to produce in sufficient amounts. The price system tends to underemphasize these goods, even though society may value them highly.[2]

A third point involving "what to produce" and "how to produce" stems from external costs of production. Not all costs of production are incident upon those who make the decisions. Hence there is a tendency to produce those goods and to use methods of production which push costs of production onto other sectors of society. Pollution is the classic example of such an external cost which is pushed onto the rest of society.

[2] It can be argued that some public goods are overproduced. However, this is a limitation not of the price system, but of the political system. The point to be emphasized here is that the price system will tend to underproduce certain public goods.

A fourth point, again regarding "what is produced" stems from the monopoly problem cited earlier. Output under a monopolistic market structure is where marginal revenue equals marginal cost. The optimum output for the economy is where the marginal cost equals price. Therefore, a monopoly does not produce enough goods *Qm,* producing the price P_m rather than Qs goods at the competitive market price P_c (see Figure 1).

Figure 1: Pricing Under Monopoly Conditions



A fifth point involves the distribution of output, as well as the composition of output. Under capitalism, income will be impersonally and unequally distributed. Those who have the dollar votes dictate what is produced. Thus, there is a bias in production of goods towards those desired by the more affluent.

A sixth point relates to the level of output. With respect to human resources, the economy does not automatically attain full employment. With respect to natural resources, there is no assurance that the market system will automatically give us the proper signals for long term use of these resources. Should we produce less now and reserve our stock resources, or should we use these resources rapidly? The matter of timing in use of resources is paramount to this issue.

Another point to bear in mind is that resources are not perfectly mobile. When conditions change, resources may be slow to adapt, e.g., the energy crisis should cut down the demand for automobiles. It may be difficult for labor to shift from making automobiles to other economic activities. Thus the U.S. could be faced with unemployed auto workers in the short run.

The above are some examples of areas where public policy is sometimes required to augment the price system. Let us now turn to some specific examples concerning natural resource decisions.

External Effects

In a price and market system, each participant acts in his own self-interest. The difficulty is that not all the costs of individual actions fall upon that individual. The classic example with respect to natural resource problems is that of pollution. The costs of the action of the polluter are incident on society as a whole (Freeman et.al., 1973, pp. 72-76).

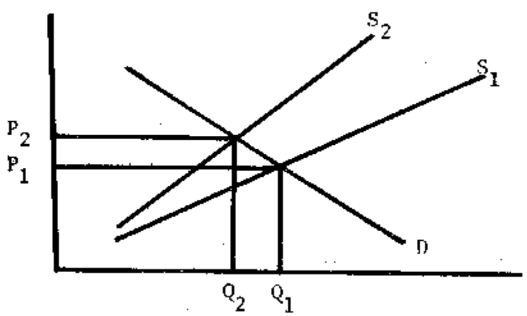
Consider the case of a manufacturer who produces some product such as paper or steel. In the process of production, the firm selects those combinations of inputs for which a given amount of product can be produced at least cost. This is according to the conventional cost minimizing condition.[3]

In this case, the atmosphere or the natural environment is used as a factor of production. To the firm, since the price of the environment is zero, it will be used very heavily. However, even though use of the environment posts no costs to the firm there is a real cost to society. This cost may be in terms of less fishing, swimming and boating, reduced property values, and a less pleasant atmosphere.

In this case, the firm, acting in its own self-interest, does not further the welfare of society by using the environment as a receptor of wastes or residuals. Although it is producing a useful product at a low monetary cost, the firm imposes damages on households or other firms which the polluter and the consumers of that firm's product are not forced to take into account.

This situation can be visualized as a supply and demand curve where S_1 represents the supply produced by the firm which envisions only cost incident upon itself. Q_1 goods would be produced at a price P_1. (see Figure 2),

Figure 2: The Effect of External Costs



[3] This condition is that the ratio of marginal physical product to factor price is equal for all factors of production.

If, however, the firm had to take into account all the social costs of production and produce in such a manner that damage to the environment was accounted for, then S_2 would be the supply curve. To put it differently, to increase pollution control would increase the cost structure of the firm and cause a reduction in amount produced at any given price.

The net result would be a reduction in the amount produced from Q_1 to Q_2, lower producer profits, and higher consumer prices, P_2. It might be argued that in the absence of rules and regulations to the contrary, the market system will produce more goods at a lower monetary price, but at a higher real cost in terms of pollution.

The above is one justification of government intervention in certain economic decision: to adjust outnut of producers whose production create external costs. The opposite holds for external benefits. In this situation, demand for these goods is understated.

In summary, an externality is the effect (negative or positive) of some action upon a third party that is not reflected in the market. The impact is not intentional and is not under the control of the third party. As we will see later the over use of common property resources is another example of an externality.

Public Goods

Public goods represents a special case of externalities. In general, public goods are those goods which have elements of collective use. That is, consumption of that good by one person does not subtract from the consumption by another person.

A purely private good is sold in small units and is generally available in the market system. Examples are food, distilled spirits, automobiles, appliances, and many services. An important characteristic of private goods is that consumption of the good generally precludes its consumption by some one else.

In contrast public goods are available primarily in large bundles. And, in the polar case, an individual's consumption does not reduce the consumption by others. Such goods are characterized by jointness in supply or being able to serve another consumer at zero marginal cost (Herfindahl and Kneese, 1974, pp. 48-49). Two extreme examples of a public good are an anti-balistic missle system and the classic lighthouse example. Both are items which must be built at some minimum level of magnitude and are not feasible to be financed by private individuals. More importantly, one person's use does not reduce the use to another individual. The "use" of the ABM system by one individual does not subtract from its value to another. The use of the lighthouse by one ship does not subtract from its value to another (barring crowded shipping lanes).

While the above represents pure cases of public goods, many goods fall into an intermediate stage where there is some degree of reduction in another's consumption. For example, the enjoyment of rights offered by a system of police protection and a court system generally does not lower that use by others. However, when the police force becomes understaffed and overworked and the court docket becomes crowded, the use of the system by one does interfere with its availability to others and reduces the services they obtain.[4/]

Public goods will not be produced in the optimum quantities by the private sector. Since benefits for public goods are non exclusive, the private firm usually is unable to "capture" the benefits in sufficient quantity to have the incentive to provide these goods in sufficient quantity.

The failure of the price and market system to produce sufficient public goods may necessitate government production of these goods. This, of course, means financing through taxation. In addition there are possible biases on the part of taxpayers against these goods because of the separation of benefits received from costs incurred. People differ in their response to wishes to finance tax supported services. Somewhat countering this trend would be the tendency of people to demand these services because of a failure to connect them with taxes paid, or because of a belief that someone other than themselves will pay the bulk of the taxes.[5/]

The market demand for public goods has a unique feature because of the zero marginal cost of supplying additional consumers. A given quantity of a public good is consumed jointly by a number of individuals. Market demand derived for a private good is obtained by summing individual demand curves horizontally. In the market for private goods, consumers take price as given and adjust quantity consumed. In contrast, the quantity of public goods is taken as given and individuals adjusted the price (costs of using the public good) they are willing to pay. Market demand for a public good is a vertical summation of individual demands (See Figure 3).

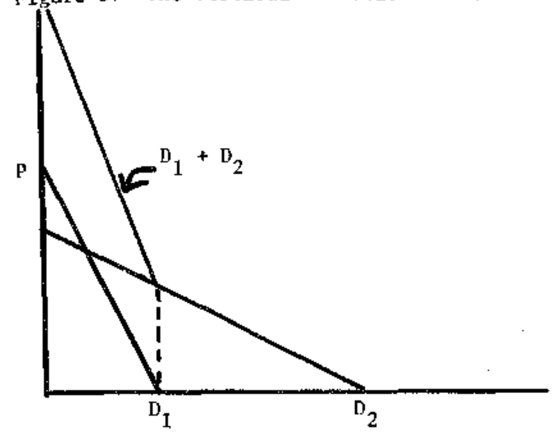
Common Property and Fugitive Resources

A further externality exists in situations where there is an indefiniteness of property rights. This refers to a broad class of resources which the user has to "reduce to possession" or "capture" before owning them. Examples are wildlife in the U.S., migratory waterfowl, fisheries, public range forage on the public domain prior to the Taylor Grazing Act, and oil, natural gas, and ground water under tenure conditions in which overlying surface lands are in several separate ownerships and where control of subsurface resources is vested in the surface owners. In such

4/ For a theoretical exposition, see P.A. Samuelson, 1955 or Mishan, 1971a, p. 1-28.

5/ The understatement of demand due to anticipated connection between preference and payment, and the overstatement of demand based upon anticipated separation of demand and payment is known as the "free rider" problem. Once the goods are produced, it may be difficult or even undesirable to exclude individuals from use in proportion to their contribution of them through taxes.

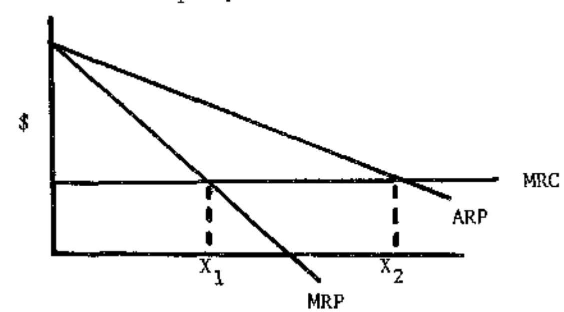
Figure 3: The Vertical Summation of Demand Curves



cases, definite property rights belong only to those who are in possession. There is an incentive to protect oneself against others by acquiring ownership through capture in the fastest possible way. To defer use would be to risk loss through capture by others. Because of this, these are sometimes referred to as fugitive resources. The situation of fugitive resources leads to a more rapid depletion of resources than would be the case where there was more definite property rights involved.

A classic case of the fugitive resource with indefinite property rights is that of the fisheries to which there is unlimited access (Gordon, 1954, pp. 124-42). According to conventional economic theory, the firm will continue to employ additional units of a resource until the return attributable just covers the marginal resource cost (MRC) of that unit, (MRC = MRP). Marginal revenue product (MRP) will decline as more is used because of diminishing marginal productivity of the resource. This can be seen in the average revenue product (ARP) and MRP curves of Figure 4. However, to the individual, the ARP actually represents the MRP because he/she ignores the loss in revenue to other producers caused by his/her harvest of fish. Hence the fishing ground will be exploited to X_2 instead of to point X_1.

Figure 4. Illustration of Inputs to MRP and ARP for a Common Property Resource



The net result is low returns to the industry and the resource is used at a rate exceeding that which is economically optimum for society. While there is a tendency to "exploit" common property resources, there are many examples of institutions which have been established for the protection and maintenance of sustained use of these resources (Ciriacy-Wantrup and Bishop, 1975 pp. 713-727). The point remains, however that these institutions were necessary so that the incentives of individuals did not result in destruction of the revenue.

It is instructive to view the same concept from the output side, using total revenue and total cost.

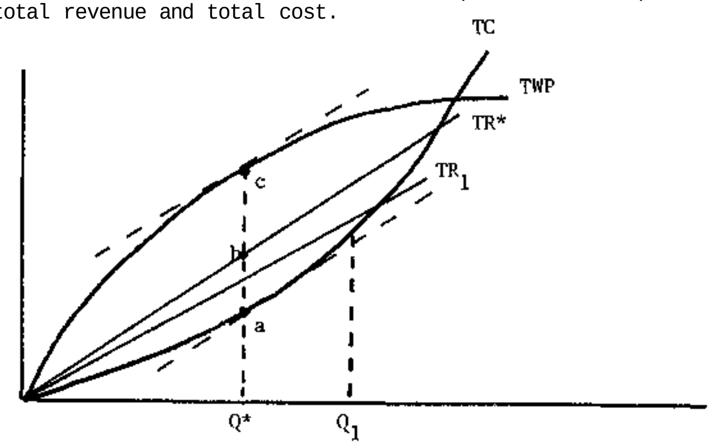


Figure 5. The Static Common Property Model.

Consider the case of a fishery which is fished by a number of independent operators. The curve, TWP represents total willingness to pay, or the area under the demand curve for the fishing as a whole. The curve, TC represents total costs of extracting additional quantities of fish. TC increases at an increasing rate, the increasing marginal costs directly reflecting diminishing marginal physical productivity because of possible crowding at the resource site. The shape of the TC curve also could reflect stock effects as decreasing stocks will cause greater effort to be expended for another unit of catch. The curve, TR* reflects revenue as perceived by individual fishermen at a given price. The fishery as a whole faces a downward sloping demand curve, but individual operators are "price takers." There is a different TR curve for each point on the TWP curve. Note that the slope of the TWP curve at any point is the price at that point, and hence, the slope of TWP must equal slope of the TR curve (See Appendix).

From the viewpoint of society, efficient allocation of resources occurs where P = MC, or in terms of figure 5, where the slope of the TWP curve equals the slope of the TC curve. Also at that point, there are

producer profits, ab, and a consumer surplus in the amount, be. The total "surplus" to society, including producer and consumer surplus, is maximized at Q*.

The problem is, however, that if the fishery had unrestricted entry, there would be no incentive for the fishery to be in economic equilibrium at Q*. The existence of producer profits, ab, provide an incentive for additional firms and resources to enter the fishery.

Increased fishing would increase output, but results in a TR curve of lesser slope than TR*. The individual only considers the revenue he or she obtains and ignores the impact of increased catch on the revenue of other operators.

In addition, the curve TC, which is increasing at an increasing rate, represents increasing costs of extracting another unit of product. However, as these costs are borne by a large number of independent operators, the new entrant to the fishery considers only the cost to himself or herself, and not the increased costs imposed on previous fishermen. In other words, the individual perceives society's marginal cost as his or her average cost!

The net result is that greater output generates a lower price exhibited by TR_1. Note that the slope of TR_1, is the same as the slope of TWP at point Q_1. Also, since the individual operator perceives society's marginal cost as his or her average cost, fishing is expanded until the average cost equals average revenue (price) for the producer. Fishing is increased until producer profits are reduced to normal profits. There remains some consumers surplus. (In fact, it is larger than at Q*). However, note that the slope of TWP (price) is less than the slope of TC at Q_1. In other words, since price is less than marginal cost, too much of the product is being extracted and too many resources are being allocated to the fishery.

Another class of common property resources are "ubiquitous" resources.[7] These are resources which, at least up to some stage of economic development, are not scarce, and there are no exclusions regarding use. Examples are air, solar radiation, and wind. However, at some point, these resources become scarce, as in the case of air, and institutions must be developed to regulate use.

Normal profits are defined as those for which total costs equal total revenue. Included in total costs are returns to resources sufficient to keep them in a given employment.

[7] See S.V. Ciriacy-Wantrup and R.C. Bishop, 1975, p. 727 for a more detailed explanation of this distinction and implications for public policy.

The important point here is that for both fugitive and ubiquitous resources, the conventional market mechanism fails to allocate these resources efficiently. Institutions to replace or supplement the market approach have been and are being formulated, with varying degrees of success. In any case, these resources will require institutional solutions, and do not lend themselves to a conventional market approach. These institutions need not be governmental institutions per se, but in any case, will require the sanction of government.

Comparing Values in Different Time Periods

Both costs and benefits associated with natural resource projects generally occur over long periods of time. Accordingly, these must be weighed to reflect the fact that a given sum in the future is worth less than the same amount today. Simply put, if individuals defer consumption today, they expect to be rewarded with higher consumption in the future. From a purely financial viewpoint, a given sum of money can be invested today and a higher monetary amount will be realized in the future.

A critical issue in decisions involving the timing of resource decisions is the selection of the interest (or discount) rate. That issue is not treated in this section. Rather, the purpose is to give the rationale of selecting a rate, and to outline the mechanics of its use.

Consider the following question. What will be the amount, F, three years from now if $100 is invested for that period at 5%?

$100.00 —— $105.00 —— $110.25 —— $115.76

At end of year one, we have $100 + 100 (.05) = $105.00. At end of year 2, we have the amount at end of year 1 plus the amount at end of year 1, times the interest rate, or [100 + 100 (.05)] + [100 + 100 (.05)] .05 = $110.25. At end of year 3, we have the amount at end of year 2 plus that same amount multiplied by the interest rate.

$$[100 + 100\,(.05)] + [100 + 100\,(.05)]\ .05$$
$$+\Big[[100 + 100\,(.05)] + [100 + 100\,(.05)].05\Big]\ .05 = \$115.76$$

This seemingly complex process can be collapsed into a far simpler form. Consider the original principal P and interest rate i. Interest due at the end of the first period is Pi. The new principal at end of first period is principal plus interest, or P + Pi. This can be written as $P\,(1 + i)$. Interest due at the end of the second period is principal times interest or $P\,(1 + i)\,i$. The new principal at the end of 2 periods is the principal at beginning of period 2 plus interest from period 2 or $P\,(1 + i) + P\,(1 + i)\,i$. This can be simplified to $P\,(1 + i)\,(1 + i) = P\,(1 + i)^2$. Interest due at the end of the third period is $P\,(1 + i)^2\,i$. New principal at the end of the 3rd period is $P\,(1 + i)^2 + [P\,(1 + i)^2]\,i$. This can be rewritten as $P\,(1 + i)^2\,(1 + i) = P\,(1 + i)^3$. The generalized formula for capitalizing or cumulating an amount P, invested for n periods at i, is $F_n = P\,(1 + i)^n$.

Discounting

The opposite of the cumulative process is the discounting process. In project analysis, costs and benefits are discounted over an appropriate time period to account for the time-value of money. For example, what is an amount F in the future worth today? Consider the amount $100 one year from now at the rate of 5%. If $F_n = P\,(1 + i)^n$ then

$$P = \frac{F_n}{(1+i)^n},\quad P = \frac{100}{1.05} = \$95.238.$$

In other words, if $95.24 were invested at 5% it would cumulate to $100.00 at the end of the first year. For any amount, F, in the future its present value, P, is equal to F, divided by 1 plus the interest rate, taken to the power of the period, n, or $(1 + i)^n$.

For i = 5%, n = 3 and F = 100 for each of 3 years, the present value

$$(P) = P_1 + P_2 + P_3 = \frac{100}{(1+i)} + \frac{100}{(1+i)^2} + \frac{100}{(1+i)^3} = \$95.24 + \$90.70$$
$$+ \$86.38 = \$272.32.$$

This is the present value of three payments of $100 at the end of years 1, 2 and 3.

	1	2	3
$P_1 = \frac{100}{(1+i)}$ ←	100 F		
$P_2 = \frac{100}{(1+i)^2}$ ←		100 F	
$P_3 = \frac{100}{(1+i)^3}$ ←			100 F

The present value of benefits and costs diminish as they are realized further into the future. In estimating present value of benefits (B) and costs (C), the estimated benefits and costs in the future are discounted back to the present, and summed.

$$\text{Benefits} = \frac{B_1}{(1+i)^1} + \frac{B_2}{(1+i)^2} + \frac{B_3}{(1+i)^3} + \cdots + \frac{B_n}{(1+i)^n} = \sum_{t=1}^{n} \frac{B_t}{(1+i)^t}$$

$$\text{Costs} = \frac{C_1}{(1+i)} + \frac{C_2}{(1+i)^2} + \frac{C_3}{(1+i)^3} + \cdots + \frac{C_n}{(1+i)^n} = \sum_{t=1}^{n} \frac{C_t}{(1+i)^t}$$

For years t = 1, 2, ..., n.

Another way to look at the problem is to say that each year is given a weight and this weight decreases the further the year is in the future. From the example above, when i = 5% and P = 100 the weights are as follows:

$$\text{Year 1, } \frac{1}{(1+i)^1} = .952; \quad \text{Year 2, } \frac{1}{(1+i)^2} = .907 \text{ and Year 3, } \frac{1}{(1+i)^3} = .864;$$

therefore, P = \$100(.952) + \$100(.907) + \$100(.864) = \$272.30. Benefits three years from now are worth less today than benefits two years hence and therefore have a lower weight (.864). As $(1+i)^n$ gets larger due to a higher n, the present value gets smaller. The present value is also decreased by higher interest rates, i, since the value of the denominator grows larger with larger interest rates.

CHAPTER II

THE DEVELOPMENT OF U.S. WATER PROJECT PLANNING AND ANALYSIS

This chapter considers the historical development procedures for planning and analyzing U.S. water resource projects. First is a brief history of how project evaluation procedures have evolved for U.S. water projects since 1902. Second is a description of the project planning and analysis approach suggested by the Water Resources Council's Principles and Standards (U.S. Water Resources Council, 1973). Project analysis will be restricted to mean the economic evaluation of projects through the calculation of benefit-cost ratios and internal rates of return. Project planning is a much broader concept and involves the whole process from problem identification to the selection of alternatives.

In project planning and analysis a number of assumptions are usually made to simplify the analysis. This is particularly true for water projects in the U.S. These assumptions include: (1) input and output prices are determined by the free play of supply and demand with no individual buyer or seller able to influence price, (2) no economies or diseconomies (i.e. externalities do not exist), (3) interdependencies do not exist among producers and consumers, (4) a full employment economy, and (5) complete mobility of resources.

For certain projects one or two of these assumptions may be relaxed. This would be particularly true for projects in high unemployment regions. Also for large projects the question of externalities are often important. Finally projects involving agricultural commodities whose prices are supported by the federal government cannot rely on prices determined by free market forces.

History of Water Project Planning and Analysis

Before starting a discussion of project evaluation, it is instructive to understand how it has evolved in the United States. Since project planning and analysis grew out of the need to evaluate large U.S. water projects, this is a good place to start. Study of the historical development helps to highlight the problems associated with project planning and analysis. More specifically, it will show that most of the criticisms of project analysis stems from political and institutional considerations rather than from the application of analytical techniques. If properly applied, project analysis will provide a consistent range of outcomes. The major problem is not with the basic methodology but with how it is applied.

If you desire an unbiased estimate of project returns, would you depend on the people wanting to build the project to do the analysis when they do not have to pay project costs? Of course not; you say that would be ridiculous. You want an independent agency to evaluate the project.

But in the U.S. we actually let those who want to build water projects do the project planning and analysis. Thus, just as anyone would expect, the analysis is distorted in favor of building water projects.

In fact, the three U.S. water agencies have been important in the early development of techniques for project planning and analysis. Not because they necessarily wanted to but because the projects they wanted to build had to meet certain criteria dictated by legislation. These three water agencies are the Corps of Engineers, the Bureau of Reclamation and the Soil Conservation Services. Each has a vested interest in building more water projects.

The major economic issues involved in the historical development of project planning and analysis can be classified under five headings: (1) length of repayment period, (2) who pays for the project (cost-sharing), (3) consistent procedures for project evaluation, (4) selection of discount rate to be used, and (5) project objectives. Each issue has been addressed many times during the development of U.S. project planning and analysis procedures.

Repayment Period

One can date the beginning of project evaluation in the U.S. from about 1902 with the passage of the Rivers and Harbors Act and the Reclamation Act. The former established the Board of Engineers for Rivers and Harbors under the Chief of Engineers of the Army. The function of the Board was and is to investigate the engineering and economic feasibility of proposed waterway projects to be constructed by the Corps of Engineers as directed by Congress.

The Reclamation Act established the Bureau of Reclamation to build irrigation projects in the western U.S. The Act required that water users meet the reimbursement test. The charges to the water users (irrigators) were to be determined with a view to returning to the Reclamation Fund the project's estimated cost of construction within ten years. This is not a requirement for overall economic feasibility and does not consider time costs. In other words, funds were made available from the Reclamation Fund for project construction free of any interest charges. Yet, present day irrigators find the repayment provisions more lenient than those in the Act of 1902.

The primary efforts to ease the reimbursement standard for the next three decades involved lengthening the repayment period. In 1914, the repayment period was extended to 20 years with 15 annual installments or payments starting in the sixth year. The first five years were designated a development period during which time no payments were required. By 1950 the repayment period had been extended to 50 years with a 10-year development period.

This does not mean that the irrigators pay the capital costs allocated to irrigation. They actually pay only a share of this interest free capital cost. Repayment capacity is determined by budget analysis

that the Bureau of Reclamation conducts. The difference between repayment capacity and the capital costs allocated to irrigation is financed through the basin account. The basin account includes excess power revenues generated by older more profitable projects.

In 1926, the Adjustment Act reduced the reimbursable costs on a number of operating projects by flat amounts. These were projects in which farmers could not make a go of it at the existing water charges. In other words the benefits to farmers from the project were not high enough to cover costs. This suggests that the project should never have been constructed since the benefits did not exceed the costs, unless there were significant external benefits. At the very least, the projects were built too early or should have been designed differently. By reducing the reimbursement, Reclamation was adding part of the construction costs to the time cost which the general public had to pay.

The 1936 Flood Control Act established economic feasibility as a condition for federal participation in navigation or flood control projects. The Act applied to the Corps of Engineers and the U.S. Department of Agriculture (USDA). In contrast to the Reclamation Act, there was no provision for repayment. Prior to the Act, Congress required full information regarding the present and prospective commercial benefits and a statement about which local interests received benefits. The Act was primarily of concern to the Corps since the Soil Conservation Service (SCS) in USDA had just been established in 1935.

Cost-Sharing

In 1939, the Reclamation Act provided a new way to shift costs from the beneficiaries to the general taxpayers. It provided that a portion of the project costs could be allocated to flood control and navigation purposes served by the project. These costs the irrigators did not have to repay and were called non-reimbursable purposes. This was probably an attempt to make Reclamation projects competitive with the Corps and SCS who already had flood control and navigation purposes. Since allocation of costs among objectives is fairly arbitrary, as will be shown in Chapter III, this allowed Reclamation quite a bit of flexibility in determining the magnitude of project reimbursement.

The next major change in cost-sharing came in 1946. This statute provided for an allocation of Bureau of Reclamation project costs to the preservation and propagation of fish and wildlife. Again, these costs were non-reimbursable. The end result was that power revenues were able to cover most of the reduced reimbursable costs and Reclamation irrigation charges were kept low.

One must keep in mind that low irrigation charges were important to the Bureau of Reclamation. Given the 160 acre limitation on farm size in the Reclamation Act, some of the reclamation farms were probably too small to pay the full cost of irrigation. In the mountain states of the West, the short growing season tended to make irrigated farming a very marginal investment. Thus, the low water charge helped keep some of the small farms in business. On the other hand, the 160 acre limit was not applied in all cases, particularly if land ownership was in large holdings before the irrigation project. In the cases where the 160 acre limit was not enforced, sizeable income transfers (economic rent created by irrigation) were made from the general public to large land owners (Howe and Easter, 1971). If questioned about these income transfers the Bureau of Reclamation argued that the transfers were only going to small 160 acre farmers. They conveniently ignored their non-enforcement of the acreage limitation or that husband and wife can own 320 acres and rent another 320 acres.

Consistent Project Evaluation

By 1946, there was general recognition that a consistent method of evaluating water projects was needed. This led to the establishment of the Benefit-Cost Subcommittee of the Federal Inter-Agency River Basin Committee. Their most notable output was the "green book" -- Proposed Practices for Economic Analysis of River Basin Projects, published in May 1950 which was the first formal guide for water project analysis. During the 1950's it was to guide project analysis in the federal agencies.

This was followed in 1952 by the Bureau of the Budget (BOB) Circular No. A-47. It spelled out for the federal agencies what would guide BOB in its evaluation of projects. Ten years later Circular No. A-47 was replaced by Senate Document 97 which provided for a more rigorous application of economic concepts in plan formulation. This document had been requested and approved by the President.

The next major act was the Water Resources Planning Act of 1965 which among other things established the Water Resources Council (WRC). This council was authorized to: (1) prepare a national water assessment, (2) recommend water policies, (3) establish planning and evaluation standards for land and water projects, (4) coordinate and manage comprehensive water planning, (5) recommend river basin commissions, (6) review river basin plans and (7) assist state water planning.

In 1968 the WRC established a task force to review project planning and analysis procedures for water and related land resources. The task force made several preliminary reports on evaluation procedures to test the reaction of Congress and other interested parties. The first draft came out in June 1969 and was followed in August 1970 by a second draft. This latter report contained in essence the structure that would become the WRC's Principles and Standards. The final report on Principles and Standards was approved by the President in September 1973 and became effective October 25, 1973.

Discount Rates

One of the primary considerations of the WRC task force on water project planning and analysis procedures was the selection of an appropriate discount rate. The discount rate question had been raised when WRC established a new method of calculating the discount rates. Before

1968 the discount rate had ranged from zero to about 4 percent.[1] The [illegible]-zero rates were based rather loosely on a coupon rate of marketable government securities which had 15 years or more to maturity. With a growing economy and rising interest rates the coupon rate was lower than the actual cost of borrowing for the federal government.[2]

The new procedure for estimating the discount rate had been established by WRC at the Bureau of the Budget (BOB) insistences and was based on the yield rate of marketable government securities with 15 years or more remaining maturity. This raised the discount rate since yield rates were above coupon rates. It was an attempt to raise the discount rate to the cost of federal borrowing. Most economists agree that the cost of federal borrowing is the lowest discount rate that would be consistent with a national economic efficiency. The yield rate on long term securities is essentially the low end of the cost of government borrowing.

The 1970 President's Budget specified that a higher discount rate would be used for water resource planning and evaluation starting in January 1969.[3] This new rate was to be approximately equal to the average yield on long term U.S. Bonds (U.S. Bureau of the Budget, 1969, p. 101). This was followed in 1971 by a WRC recommendation to base the rate on the opportunity cost of capital. The new rate would be 7 percent to be used for 5 years. In WRC's final report the procedure for estimating the discount rate changed to the average cost of federal borrowing during the 12 months before the water project decisions are to be made or 6 7/8 percent in 1974. The rate was established for the fiscal year and changes up or down are limited to 1/2 of 1 percent per year. However, Congress felt the 6 7/8 percent was too high and in the Water Resources Act of 1974 the discount rate formula went back to the pre-1968 formula of the coupon rate of government securities. This reduced the rate to 5 7/8 percent in 1975.

The interest rate in effect for October 1, 1976 to September 1, 1977 was 6 3/8 percent as established by WRC. It is based on the average yield during the preceding fiscal year on interest-bearing U.S. marketable securities which, at the time of the computation, have terms of 15 years

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1/ A discount rate of 4 percent yields a new present value (NPV) of $214,822 for a project with annual net benefits of $10,000 for 50 years. The same project yields a NPV of $99,148 with a 10 percent discount rate and a NPV of $66,605 at a 15 percent discount rate. In other words, the lower the discount rate the higher will be the value of future benefits.

2/ Securities were sold at less than the face value and therefore earned a higher rate on the investment than the coupon rate.

3/ In the same budget, funds were included for the advanced plan of the Central Arizona project by the Bureau of Reclamation. The Budget claimed that the project would provide supplement irrigation water to 1.2 million acres (U.S. Bureau of the Budget, 1969).

or more remaining to maturity. The formula also provides that the rate cannot be raised or lowered by more than 1/4 percent for any year.

The Department of Treasury notified the WRC on October 15, 1976 that the average yield on marketable securities was 7 percent during the last fiscal year. Since the rate for fiscal year 1976 was 6 1/8 percent the rate for fiscal year 1977 was raised to 6 3/8 percent.

In the formulation of the various recommendations concerning discount rates during the 1960's and early 1970's, three basic options were suggested. They were (1) the opportunity cost of capital, (2) the cost of government borrowing as related to either long-term bonds or all Treasury securities, and (3) the social rate of time preference.[4] The social rate of time preference got little support because no methodology was available for empirically measuring it. Congress and federal water agencies favored the cost of government borrowing since it provides the lowest possible rate. They also favored coupon rate over the yield rate for the same reason. In contrast, many economists and the Office of Management and Budget (OMB, formerly BOB), favored the opportunity cost of capital adjusted for income taxes. This they argued more nearly measured the cost to society of using federal funds to build water projects.

These changes in the formula for calculating the discount rate highlight the different factors involved in approving water projects. On the one hand the President through OMB was pushing to raise the discount rate and hold back on the development of water projects. The water agencies independently and through WRC argued for low discount rates since they are in the business of building water projects. The Congress with the support of the water agencies continues to push for lower discount rates and more funds for water projects in their local areas. Finally, the WRC which has representatives from the Bureau of Reclamation, Corps of Engineers, and the Department of Agriculture tends to get caught in the middle.

Project Objectives

Another major question considered in WRC Principles and Standards was what objectives to include. Before 1968 the primary objective recognized by BOB was national economic efficiency. In order to be able to justify water projects given the higher rates of discount, federal agencies began to push for multiple objectives. The WRC considered four: (1) national economic development or efficiency, (2) environmental quality, (3) social well-being and (4) regional development. The final report recommended the first two as objectives while the latter two would be used only under special conditions. However, accounts of benefits and

[4] The social rate of time preference is an appropriately weighted average of the different marginal time preferences of the individuals who compose the society (Harberger, 1972, p. 94).

costs would be developed for all four. The environmental quality objective is an indication of the increased concern for the environment which many felt was not being adequately accounted for in project planning and analysis.

Social well-being was rejected as an objective because it was too nebulous and difficult to define. Adequate methodology was not available to measure the impact of this very general objective. The regional development objective was rejected since it would involve substantial interregional transfers of income resulting in a net loss to the nation as a whole. Very likely if both had been made objectives there would have been double counting of benefits already attributed to national economic development or environmental quality.

Congress felt that WRC's Principles and Standards were too strict and asked the President to reconsider the two objective decisions. Congress also asked that WRC reconsider the questions of federal cost-sharing and the discount rate. All three subjects are key to whether or not water projects meet economic and repayment requirements. Congress and the federal water agencies do not want strict economic efficiency criteria hindering their development of federal water projects.

National Water Commission

While the WRC's task force was working on the Principles and Standards, Congress created a National Water Commission to analyze the nation's water problems and needs. It was approved by the President in September 1968 for a five-year life. The objective was to recommend national water policies to help obtain the highest measure of utility for society from the finite water supply.

Several of the commission's recommendations were concerned with basic changes in the project planning and analysis process. The major change was in who participates, evaluates and pays for the water projects (see Table 1). An independent agency with no projects to construct was recommended as a primary project evaluator. The federal water agencies would still build the approved projects but state and local governments and the nonconstruction federal agency would play a much larger role than in the past. In fact, the state and local governments along with the direct beneficiaries would pay for the project. Federal funding would be eliminated (Bromley, Butcher and Smith, 1974).

As expected Congress did not buy these radical changes. However, the idea of beneficiaries paying project costs seems to be gaining more interest while the idea of an independent agency to evaluate projects may have a chance in the future. Such recommendations are the only real hope of improving the application of project planning and analysis procedures. If those who benefit from the project have to pay for it, they will be much more concerned about the return from the investment. In addition, the nonconstruction federal agency would not feel obligated to have the analysis justify the project. Thus the bias towards building

Table 1. Mode of Evaluating Water Resource Projects

Actual and Proposed

	PUBLICS				AGENCIES					
	General public		Direct beneficiaries		Federal construction agencies		State & local government		Non construction federal agencies	
	Actual	Proposed	Actual	Proposed	Actual	Proposed	Actual	Proposed	Actual	Proposed
Initiate			+	+	*	*		+		+
Plan Formulation		*		+	+	*		+		+
Evaluate Alternatives		*	*	+	+	*	*	+	*	+
Select Alternatives				+	+	*		+		+
Implement Plans					+	+				
Pay Costs	+			+				+		
Receive Benefits			+	+			+	+		

Bromley, Butcher and Smith, 1974.

Major role +

Minor role *

water projects financed by the general taxpayers would be greatly reduced.[5/]

Water Resources Council's Procedures for Project Planning and Analysis

The Water Resources Council's 1973 Principles and Standards has changed the methodology for evaluating federal water and related land projects. More information is now required concerning the possible environmental quality impacts of a project. Accounts for each alternative are required listing benefits and costs relating to the two objectives, national economic development and environmental quality. The benefits and costs relating to regional development and social well-being will be displayed where appropriate (U.S. Water Resources Council, 1973, p. 76). Finally, the new principles and standards call for a specific planning process.

Six major steps were specified by the WRC for planning and analyzing projects: (1) specify components of the objectives relevant to the project, (2) evaluate resource capabilities and expected conditions without any project, (3) formulate alternative plans to achieve varying levels of contributions to the objectives, (4) analyze the differences among alternative plans, (5) review and reconsider objective components and formulate additional alternatives if appropriate and, (6) select the best alternative based upon an evaluation of the trade-offs between objectives and considering where appropriate the two secondary concerns of regional development and social well-being.

General assumption and standards

The assumption made in the Principles and Standards are much the same as used in the traditional cost benefit analysis:

— Full employment is assumed except in regions of chronic unemployment and underemployment.

-- The relative price relationships and the general price level for outputs and inputs during or immediately preceding the period of planning are to be used to value project benefits and costs.

The period of analysis is the lesser of (1) the useful life of the project, or (2) the period beyond which further discounted

5/ Ciriacy-Wantrup has also recommended that beneficiaries from public resource development pay for the benefits received provided that benefits are practically assessable and that enough incentive is left for beneficiaries to participate in development. Ciriacy-Wantrup asserts that "Payments under these provisions are the best guarantee that the determination of economic feasibility will receive the most thorough scrutiny by state and local government and by private groups of beneficiaries." (Ciriacy-Wantrup, 1954) benefits and costs would not change the design results. One hundred years is the upper limit.

- In evaluating the federal and non-federal projects, taxes foregone or paid are excluded from the national economic development objective.

- Standard projections of national and regional growth rates in population, output, employment and the demand for goods and services are arranged for by WRC. These projections will be revised periodically and are to be used as a guide for project planning and analysis.

- The Water Resources Council will also publish data on prices of agricultural and other goods and services which are suggested for use in evaluation.

- Benefits and costs of a proposed project will be measured by comparing estimated conditions with and without the project.

- Projects should be analyzed under alternative implementation schedules to identify the schedule with the highest beneficial effects as compared to adverse effects.

- The net project returns should exclude all predictable risk, either by reducing benefits or increasing costs.

- Uncertainty is to be discussed in the report and specific strategies recommended to cope with it such as flexibility in project designs. Sensitivity analysis is also suggested as a means to test alternative assumptions on prices, discount rates, and economic, demographic and technological trends. Assumptions should be tested that would affect appreciably the project design or scheduling.

- Finally projects not implemented or initiated within 10 years after completion of the analysis should be reviewed.

Objectives

National economic development or national economic efficiency has always been considered a major objective of water projects. It involves increasing the output of the nation's goods and services or reducing the cost of a given output. The concept is broader than national product and national income accounts, Public goods, externalities or other effects of market imperfections which are not included in the national income accounts should be considered in project analysis. In other words, public goods and externalities should be counted as contributing to the national economic development objective where possible.

The components of national economic development can be measured in terms of increases in crop yields, recreational opportunities and

making capacity of power systems. Other measures of benefits include cost savings, increased productivity of inputs and reduced disruption of economic activity due to droughts, floods, and fluctuating water supplies.

The environmental quality objective involves the improvement, reservation, management, conservation, creation or restoration of the quality of certain natural and cultural resources. These resources include (1) areas of natural beauty and human enjoyment (open space, scenic rivers, lakes, beaches, shores, etc.) and (2) outstanding archedlogical, historical, biological and geological resources. Control of pollution and avoiding irreversible commitments of resources are also important components of this objective. In many cases these outputs must be measured in physical or qualitative terms rather than in dollar values.

In addition to the above two objectives the effects on regional development and social well-being will be displayed when appropriate. The regional development account can show benefits from higher regional income and employment, diversification of the regional economic base, and enhancement of the region's environment.

The social well-being account is primarily an attempt to measure the project impacts on the equitable distribution of real income and employment and other social opportunities. Specific components include effects on real incomes, security of life, health and safety; effects on educational, cultural, and recreational opportunities and effects on emergency preparedness.

The major problem with the latter two accounts is the possibility for double counting. Many of the effects listed under regional development and social well-being could easily be covered within the two major objectives. The main exception is the project impact on income distribution and employment which are not usually covered by the national economic development objective.

Measurement of Effects on Objectives

The general standard for measuring national economic development benefits is how much users are willing to pay for each increment of output. If demand curves can be estimated the benefits will be measured by the sum of market price (after the project) times increased quantity plus the increase in the consumer surplus (see Figure 6). The consumer surplus, ABC, is the amount over the market prices, P_1, that consumers would be willing to pay for the increased output Q_0Q_1. The total project benefits would be Q_0CABQ_1 or, with a linear demand function, $\frac{P_0+P_1}{2}(Q_1 - Q_0)$.[6/]

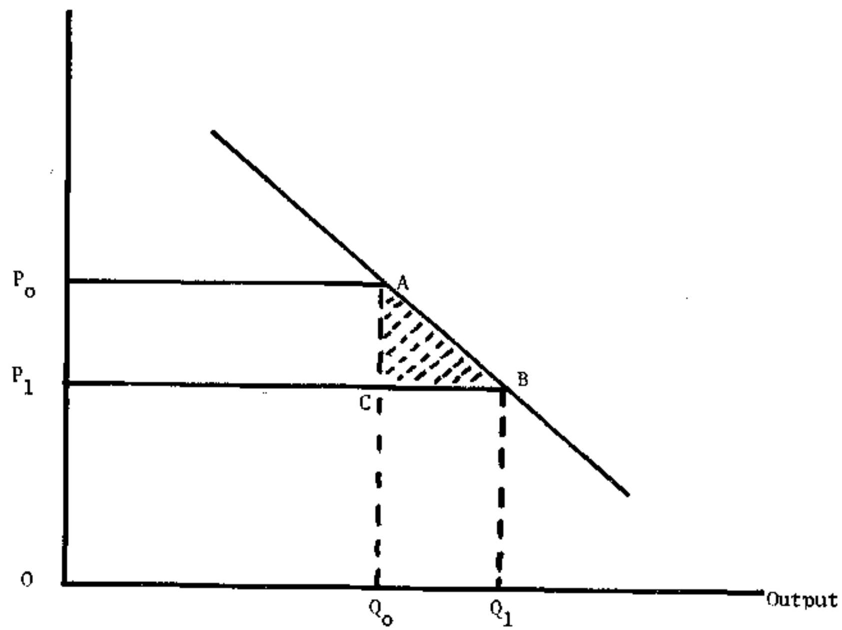
[6/] Estimate of area Q_0CABQ_1 in figure 1

$ABC = 1/2\ bh = 1/2\ (Q_1 - Q_0)(P_0 - P_1)$

$CBQ_1Q_o = P_1h = P_1\ (Q_1 - Q_o)$

(continued on page 24)

Figure 6. Consumer Surplus for an Increase in Output



6/ Continued

$$\text{Area} = 1/2\ (Q_1 - Q_0)\ (P_0 - P_1) + P_1\ (Q_1 - Q_0)$$

$$(Q_1 - Q_0)\ \left(\frac{P_0}{2} - \frac{P_1}{2} + P_1\right)$$

$$(Q_1 - Q_0)\ \left(\frac{P_0 + P_1}{2}\right)$$

b = base of triangle ABC

h = height of triangle ABC

The above example assumes the polar case of completely inelastic supply curves so that part of the consumer surplus, P_0ACP_1, is offset by the loss to producers. The other polar case is completely elastic supply curves in which the gain in surplus would be P_0ABP_1. There is only a gain in consumer surplus since perfectly elastic supply curves eliminate any possibility of producer surplus.7/ The intermediate case would be supply curves with some elasticity (see Figure 7). The gain in surplus is equal to the area between the supply curves and below the demand, S_0ABS_1. It is calculated from the new producer's surplus of P_1BS_1 minus the original producer surplus of P_0AS_0 plus the increase in consumers surplus of P_0ABP_1.

It is not always possible to estimate demand curves. Thus, two other techniques are suggested: (1) change in net income and (2) the cost of the most likely alternative. However, it should be remembered that in many cases the projects will not alter prices and market prices should be used for the evaluation.

Changes in net income are suggested as a means of measuring the output of intermediate goods or services. This requires a measurement of the net income change for all users both positive and negative. In addition, one must be careful that the increase in income does not include subsidies to users. For example, if farmers pay less than their full share of the irrigation project costs, part of their increase in net income is a result of the subsidy. The subsidy is just a transfer of income from the general public to the farmers and not an increase in net income.

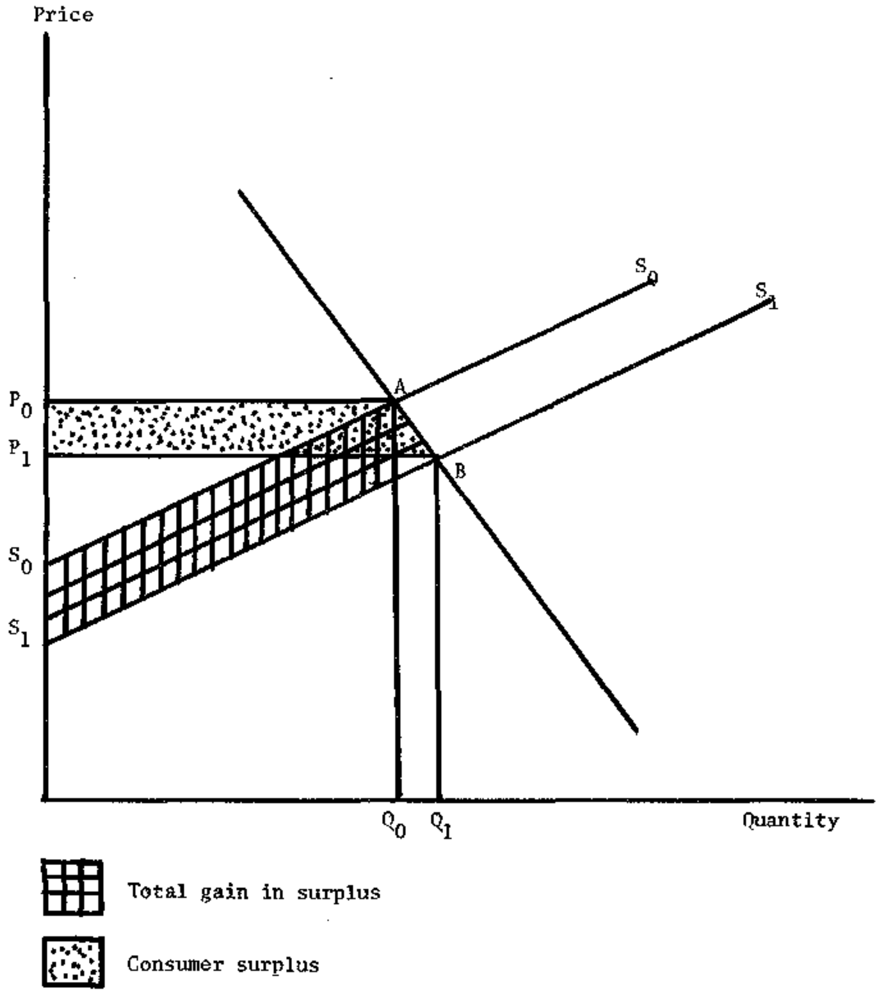
The cost of the most likely alternative is an opportunity cost approach. However, the most likely alternative could over-estimate the output value since there is no certainty that society would pay that much for the alternative. If the output is the same in the most likely alternative, it must have been rejected because costs were higher than the project being evaluated. Whatever the new project costs, the benefits would be higher since the next best alternative had higher costs and these costs are being used as a measure of benefits. Thus, the least cost project may be selected without any assurances that project benefits exceed the costs.

Environmental quality

The beneficial and adverse effects on environmental quality are to be displayed in physical and ecological terms. For example, the display would list for open space the total acreage, the pattern and distribution, the location relative to urban areas, the accessibility and the public amenities. Reasoned judgments by multidisciplinary teams will be required in situations where current standards or measures do not permit the evaluation of environmental effects. The material developed for this objective will be highly descriptive and difficult to interpret in a consistent manner.

7/ Producer surplus is the area above the short run supply curve and below the price line. This is in contrast to the consumer surplus which is the area above the price line and below the demand curve. An increase in consumer surplus is measured by the area between the two price lines and below the demand curve,

Figure 7. Total Surplus from Increased Output



Other beneficial and adverse effects

Because of the difficulties involved in measuring regional develop-

effects, they will be displayed only if requested by a Department Secretary or head of an independent agency. When regional development effects are evaluated they will be displayed by individual components. For the regional income impacts the change in net income will be shown. In the case of regional employment, estimates of changes in employment by skill level will be the basic display. The change in employment mix may also show age classes, sex, average wage, and labor force participation rates. What should be included under the population distribution component is rather ill-defined. Effects on population concentrations are supposed to be measured against some unknown population distribution objectives. The environmental conditions of special regional concern will be measured in physical terms and displayed like the environmental quality objective. Such an account would seem to be of limited use in light of the environmental quality objective which should already include any significant environmental concerns.

Finally, the impact on the regional economic base and stability is to be measured. When a region is too specialized, the following information is to be listed in the report: (a) current economic base, (b) projections of employment with and without the project, and (c) the percentage reduction in the areas expecting to be dependent on a specialized type of employment such as forestry or fishing. Beneficial effects include contributions to: (a) improving the balance of the region's economy, (b) stabilizing markets and employment, (c) reducing climatic variations and (d) reversing community declines.

Social well-being display is primarily concerned with the contributions to the equitable distribution of real income and employment and other social opportunities. The income distribution and employment impacts should be measured as net amounts of per capita income and employment accruing to designated persons or groups. Most of the other components such as security of life and health, emergency preparedness and educational and recreational opportunities can be measured through a combination of quantitative units and descriptive terms. However, these latter components would seem to have already been covered in the two primary objectives.

System of accounts

Two sets of accounts are constructed for the two primary objectives as well as for regional development and social well-being when requested. The first set of tables includes a listing of all the beneficial and adverse effects relating to each objective component (see Table 2). An attempt is made in these tables to provide a measure of these beneficial and adverse effects (benefits and costs). These tables are constructed for each alternative plan.

The second set of tables provides a summary and comparison between alternative plans (see Table 3). The emphasis is on the comparison and how the impacts of the alternative plans differ. This is supposed to be the table decision makers will use to decide among alternative plans. Plans should not include increments that physical or economically pre-

Table 2. Beneficial and Adverse Effects of a Plan

Social Well-being

Components	Measure of Effects
Income distribution	Create 1,000 low to medium income jobs for unskilled and semi-skilled workers
Life, health and safety	Provision of 100-year flood protection to city
	Production of 7 tons of fresh vegetables during winter
	Creates 10 small pools which increases mosquito population
Educational, cultural and recreation opportunities	Create 10,000 person days of boating, 5,000 person days of fishing and 20,000 person days of picnicking
	Influx of 500 construction workers will place burden on educational facilities for 4 years
Emergency preparedness	Provide 100 mw. hydroelectric power centrally located in region

Table 3. Summary Comparison of Two Alternative Plans

	Plan B	Recommended Plan	Difference
1. National Economic Development:			
Beneficial effects	$5,000,000	$8,000,000	+$3,000,000
Adverse effects (costs)	5,000,000	6,000,000	+1,000,000
Net beneficial effects	0	2,000,000	+ 2,000,000
2. Environmental Quality			
Open and green space and lakes	Create lake with 3,000 surface acres	Create lake with 3,500 surface acres	+500 surface acres of lake
Archeological resources	Inundate recognized historical feature	--	Does not inundate historical feature
3. Regional Development			
Employment constructure	300 semi-skilled jobs for 3 yrs.	200 semi-skilled jobs for 4 yrs.	-300 semi-skilled jobs for 3 yrs. +200 semi-skilled jobs for 4 yrs.
Operation and maintenance	850 permanent semi-skilled jobs	900 permanent semi-skilled jobs	+50 permanent semi-skilled jobs
4. Social Weil-Being			
Life, health & safety	Provides 100 yr. flood protection to city	Provides 50-yr. flood protection to city	-50 years of flood protection

clude non-Federal alternatives (i.e. state or local government projects and private projects) which would more effectively contribute to the objectives (U.S. Water Resources Council, 1973, p. 11).

Plan selection

The particular alternative selected for implementation is supposed to pass the test of economic efficiency. The national economic development benefits are to exceed the project costs (adverse effects). However, two exceptions can be made to this rule. First costs (adverse effects) can exceed benefits if the net deficit is due to the environmental quality objective and the net deficit is less than the net benefits foregone or additional costs required to obtain the increase in environmental quality. Second, a Department Secretary or a head of an independent agency can make an exception to the efficiency criterion.

In making the final selection the guidelines also require that a significant number of alternatives and trade-offs must be considered. Alternatives are to include both structural and non-structural approaches such as dams and flood plain zoning. One alternative will have the optimum contribution to national economic development. Another will have the optimum contribution to environmental quality. Major increments for additional or separable components to a plan will be included only if the benefits from their addition are greater than the costs.

Weakness of the Water Resources Council's approach

As might be expected the reimbursement and cost-sharing section is too general. It calls for the identifiable beneficiaries to bear an equitable share of cost commensurate with beneficial effects received. Even this rather weak statement was too strong for Congress and they asked for a review of the reimbursement and cost-sharing policy.

Reimbursement requirements are the most reliable test of the net benefit estimates and the most effective governor on additional capacity. If users must pay for the project then it is in their own private interest to see that benefits exceed costs by the largest amount possible. In contrast if they are not charged they will push for the largest possible project (Cicchetti and others, 1972).

Without the reimbursement requirement that beneficiaries pay the full cost of a project there will be a great deal of political pressure on the water resource agencies. The pressure will be to build uneconomic projects that are biased towards over-expansion as well as to allocate costs to non-reimbursable purposes such as flood control. Without full cost reimbursement policies the trend will continue in favor of supply management rather than demand management. We will continue to build large projects to adjust supply instead of using prices, zoning and flood insurance to affect the demand side.

Another basic weakness in the council approach involves the multiple objectives. Conceptually almost all the project effects are part of the

national economic efficiency objective. With the possible exception of income distribution any item listed in the other accounts could have been or already was included in the national efficiency objective. Thus, the WRC's approach leads to redundancy and double counting. In addition, there is wide professional agreement concerning the definition and measurement techniques for inputs and outputs under the national economic efficiency objective while this is not true for the other objectives.

The WRC's approach has not corrected the past tendency of water resource evaluation procedures to favor development and federal projects over preservation. This problem is highlighted in the planning process which begins with a project rather than the problem or restraint. The full opportunity cost of preservation must be considered over time. The value of the flow of services from undeveloped land must be included as a cost to the project. Questions concerning substitutes, irreversibilities of development and the nonreproducibility of the existing environment must be explicitly asked and evaluated. Irreversibilities of development are changes in resource use which cannot be reversed such as flooding a valley for water storage. The addition of the environmental quality objective does nothing to recognize explicitly or measure the preservation value of our existing natural resources. It has also not reduced the incentives for both the federal construction agencies and local groups to push for more federal construction.

As mentioned earlier the procedure for calculating the discount rate is an improvement but still leads to discount rates that are too low. Even this improvement was too much for Congress which continues to try to keep the discount rate low.

The methods for estimating benefits have a number of flaws. The three measures of economic development benefits do not assure that the least cost method of solving a problem is used. In addition, the net income measure would include the value of the subsidies on water unless the beneficiaries are required to pay the full cost of the water. Benefits calculated as the cost of most likely alternative approach does not require benefits to be greater than costs.

Finally, the suggestions for measuring recreation benefits are not adequate. Both the travel cost method and the bid or survey method can provide reasonable estimates of recreation benefits. However, the WRC clings to the outdated procedure of assigning fixed dollar values to recreation days. Thus, the guidelines need to be updated to include improved methods for measuring recreation benefits.

CHAPTER III

PROCEDURES FOR PROJECT PLANNING AND ANALYSIS

Most resource decisions are *or* should be made in some planning or budget framework. A project is not evaluated in isolation. A national or state planning or budget process provides one type of framework. In many developing countries this involves a five-year plan. In the U.S., it involves the President's three-year budget which is updated annually. The World Bank and AID use sector planning as a means of identifying viable projects which are then evaluated. Project analysis is just one stage in the decision making process.

Planning Framework

What follows is one possible planning framework that could be used in resource decision making. The planning framework includes eight steps, some of which are more important than others. Also the steps would not necessarily be done independently or in the order they are listed.

1. The first step is to identify objectives. National economic efficiency, regional development, improved income distribution, improved quality of life and environmental quality are the most commonly discussed objectives. If the objectives include some concern for income distribution, then one is faced with the question of what weights to attach *to* various benefits and costs. For example, if national economic efficiency and regional development were the objectives, one would have to identify which regions get special consideration. The project benefits in these special regions would be given extra weight or merit in the project evaluation. Possibly the benefits from the low income regions would be valued at 1.5 times the benefits elsewhere. However, this does not say anything about how the benefits are distributed among firms or households in the favored region.[1/]

2. The second step is to identify the relevant planning area or space. Resource immobilities and differences in resource endowments and income distribution make this step important particularly in developing countries. Examples of planning areas are agro-climatic regions, river basins and economic development regions. Most of the economic literature omits the question of space which probably derives from our simplifying assumption of perfect mobility. From a political viewpoint, the smaller the region, the better the opportunity for local input into project selection. The Corps of Engineers proposed the use of regions for their budget allocation in the late 1960's. The idea was rejected by the Bureau of the Budget (BOB) because they wanted to maintain project by project evaluation of Corps requests.

1/ To elimiate any bias towards public projects, high income regions would have to have demerits, i.e. their benefits would be worth only .5, to offset the merits given to favored regions. Otherwise, there would be an over-investment in the public projects relative to private projects since some of the public projects would have their benefits inflated. Only with offsetting demerits would the optimum distribution of investments between the private and public sectors be maintained.

3. Another important step is the selection of national parameters such as discount rate, value of foreign exchange, farm prices and wage rates for unemployed labor. To make valid comparisons between projects, consistent parameters must be used. Rules need to be established for calculating parameters such as discount rates. They may vary from year to year but at any point in time they would be the same. If the parameters change substantially, the question of re-evaluating projects must be raised. Ideally re-evaluation should continue right up to the time of construction. Even after construction has started, changing conditions may even warrant re-evaluation and stopping a project.

4. The fourth step is to identify the problems or restraints within each planning area or region and determine their order of priority. For example, is the limiting restraint a shortage of electric power or a lack of water in the dry season. This determination must involve local people and usually cannot be done from Washington or New Delhi. It should also not be restricted by what a federal government agency can do such as build water projects. In other words a problem should not be given high priority just because federal or state funds are available to address the problem.

The systematic process of problem identification usually requires information and inventory studies. Data is needed on natural resources, population growth and distribution, economic activity, and public services and facilities. As information is collected concerning a given area or region gaps in services and problems will become clearer. Projections of population growth and its distribution may indicate a sharp change in the number of school age children and suggest future gaps in education facilities. A growth in crop production may indicate a need for markets and improved transportation.

S. Once the restraints have been identified one should attempt to model the important relationships. Which problem should be dealt with first? Electric power may have to come before tube wells. Are there existing programs which might be useful in solving the problem? What are the important technical relationships? One should be clear about the uncertainty of given variables. Important interactions between key variables should be identified even if they are too complex to model completely. Also assumptions made in developing the model should be clearly stated. For example, are prices assumed constant and what is assumed about input availability?

6. The sixth and very critical step is to develop alternative solutions to deal with the restraint. Much of the information collected in step five would be useful in developing alternatives. What alternative programs, projects, or legal changes could be used to eliminate or at least modify the restraint. In the case of flood control one should consider levees, flood plain zoning and flood control or multiple purpose

dams. If one were concerned about crop pest problems the alternatives examined should include biological control, pesticides, insect resistant varieties, and changing crop rotations or planting dates.

As alternatives are considered the degree to which restraints are controlled or eliminated is important. In addition, there is the question of development time or the time required for the flow of benefits to become available, A combination of alternatives may also be better than one if the development time is long for the preferred alternative. For example, pesticides might be used until a new disease resistant variety is developed some five to ten years later.

7. Finally, the point is reached where alternatives can be evaluated. This is the stage where project analysis is applied. The question is which alternative or combination of alternatives is the most economically efficient means of solving the problem and meeting program objectives. If the best possible alternatives have not been identified the evaluation will be misleading. In some cases, the cost of eliminating the restraint is too high relative to the benefits and the decision will be to do nothing or at least live with the restraint for now. The costs should include any negative externalities created by the project.

8. If the evaluation has been done in the context of a budget or plan, additional criteria may be required in the final project selection. The following are some of the possible criteria: (a) the importance of the region and the particular problem to the nation or state as determined by the government, (b) the importance of the sector in which the problem occurs as determined by the government, (c) the project's benefit-cost ratio relative to other projects, (d) the project's nonmeasurable impacts both positive or negative and (e) the sequence of projects. (Is the alternative being evaluated necessary before another project can be implemented?)

Project Analysis

Project analysis is used by a private firm or a public agency to decide among alternative programs or investments. They generally have a budget constraint and cannot do everything desired or are interested in determining the most efficient means of doing a given task which at least minimizes costs. Project analysis brings in an economic efficiency criterion for selecting projects or programs.

The theoretical basis for project analysis has been the compensation welfare criteria. It was first suggested by Hicks and Kaldor and simply states that gainers should be able to compensate losers and still be better off. Pigou's broad welfare criteria that someone gains but no one loses or the slightly weaker criteria that losers are compensated by the gainers from the investment do not hold since there are almost always losers and they are not generally compensated. In other words all benefits and costs are counted no matter who pays or receives them. Of course, this leaves out the important question of the project's impact on income

distribution. Thus, all one can say is that society is better off from an economic efficiency standpoint (total benefits exceed total cost) but not necessarily in terms of social welfare. Only if losers are compensated can one argue that social welfare definitely has been improved.[2/]

Both public and private bodies use project analysis to help decide questions of resource use. This does not mean that the same benefits and costs would be counted by a private firm and public agency. Public agencies will even differ in what benefits and costs they consider, particularly if one compares federal and state agencies. Benefits to one state may be at the expense of another state.

Project analysis in this paper is approached from the national economic efficiency or public sector point of view. The private firm would use the same basic procedure but will likely use a different discount rate, not include the same costs and benefits, and use different values (prices).

Methods of project evaluation such as benefit-cost analysis have been misused enough by the various federal water agencies so that people have become properly skeptical of the results. The problem is not the methods of analysis but its misuse and the lack of good data. Do not expect too much particularly if there are data or measurement problems. However, this is no different than any other empirical analysis.

These methods of analysis provide a good screen to eliminate projects that should not be seriously considered. But when objectives go beyond economic efficiency, benefit-cost analysis is just one part of the decision making information. If one understands project analysis, the right questions can be asked about any particular study. Thus, it becomes more difficult for the advocate to misuse the various techniques.

Project analysis is a technical procedure involving economics and not politics. The weight to be given to project analysis in the final decision of whether or not to build the project is a political question.

There are three basic elements in project evaluation:

1. The time-wise description of the physical composition of the project. This basically involves engineering and design studies. The physical inputs and outputs are specified for each year of the project's expected life including the construction period. The decisions concerning optimum project design and life are generally made at this stage although it is not solely an engineering decision. Consequently the design selection generally

2/ This ignores problems associated with questions of the second best. In addition even when gainers compensate losers, the distribution of income may be made more unequal, as a result of the project unless compensation for equity losses is included in the damages for which compensation is required.

fails to consider marginal changes in benefits and costs. When projects are being evaluated in economic terms only one project design usually remains. At best cost information is used at the design stage to determine the relative costs of alternative designs.

2. The second step is to attach money values to the project inputs and outputs. Both demand analysis and cost studies are used if the project is large. The area under the demand curve for the quantity produced should be used to measure benefits while the opportunity cost or actual cost of inputs should be used to measure costs. For small projects that do not effect prices, benefits are measured by the increased output times market prices while costs are measured by input quantities times market prices. These are measures of what the consumers are willing to pay for the project output and the inputs used to build it. Use of market prices assumes there are no major market distortions such as farm commodity price supports.

This is usually the first stage where economics is involved. With values attached to one or more sets of inputs and outputs, the only important question that can be answered is whether or not benefits exceed costs for each set and by how much. Thus at best this becomes a method for screening out projects which do not meet the basic economic efficiency criterion. The question of size and design may have already been made without considering rates of return.

3. The final part of the project analysis is the calculation of a single measure of return based on the time path of costs and benefits. The costs and benefits are both discounted to obtain present values.[3] These values can be shown as ratios, net present values or rates of return. The discounting introduces a measure of the annual rate of substitution between present and future consumption. How much are we willing to pay for a dollar next year as compared to this year.

The four most commonly used measures of a single economic value of a project are: the benefit-cost ratio, internal rate of return, present value of net benefits (net present value] and present value of net benefits over capital investment. The formulas for calculating each of these methods are quite similar. The same costs and benefits enter each formula.

1. Probably the easiest to understand and the one from which all the others can be compared is the present value of net benefits (PV).

3/ As discussed in Chapter I costs and benefits are discounted over an appropriate time period to account for the time-value of money. A dollar received today is worth more to an individual or business than a dollar received sometime in the future. The dollar received today can be used to earn interest or put to other productive uses. In one year a dollar deposited at an interest rate of 6 percent will grow to $1.06. Similarly costs or expenses due at a future time are less costly to a business than expenses due today. An expense of one dollar today requires an expenditure of one dollar while the same expense a year from now requires an expenditure of $.943. The $.943 is deposited at 6 percent interest and after one year one dollar is available to pay the expense.

If no budget constraint exists and the project being considered is the best means of achieving the objectives, select it when PV is greater than zero. Reject projects with PV less than zero.

$$PV = -k_o + \frac{b_1 - c_1}{(1+i)} + \frac{b_2 - c_2}{(1+i)^2} + \dots + \frac{b_n - c_n}{(1+i)^n} = -k_o + \sum_{t=1}^{n} \frac{b_t - c_t}{(1+i)^t}$$ [4]

where t = years 1, 2, ... n

2. If capital is a restraint then present value of net benefits over capital investment (PV'/k) would be preferred in setting priorities where PV' is PV minus capital investment (k_o). The higher the value of PV'/k the higher the preference. Select the project when it is the best means of achieving the objectives and PV'/k is greater than 1. Reject projects with PV'/k less than 1.

$$PV'/k = \frac{\frac{b_1 - c_1}{(1+i)} + \frac{b_2 - c_2}{(1+i)^2} + \dots + \frac{b_n - c_n}{(1+i)^n}}{k_o} = \frac{\sum_{t=1}^{n} \frac{b_t - c_t}{(1+i)^t}}{k_o}$$

3. Frequently the internal rate of return (IRR) is used to rank projects. However, it might lead to an incorrect ranking of projects where the time paths of benefits and costs differ and/or the rate of return is much higher than the social rate of discount. If the social rate of discount is much lower than the IRR, a PV calculated using the

4/ If $b_i - c_i = a$, is constant over the project life then the formula for calculating the PV can be simplified as follows

$$PV = \frac{a}{(1+i)} + \frac{a}{(1+i)^2} + \dots + \frac{a}{(1+i)^n} =$$

$$\frac{a}{1+i}\left[1 + \frac{1}{(1+i)} + \dots + \frac{1}{(1+i)^{n-1}}\right] =$$

$$\frac{a}{1+i}\left[\frac{1 - \frac{1}{(1+i)^n}}{1 - \frac{1}{1+i}}\right] = \frac{a}{(1+i)^n}\left[\frac{(1+i)^n - 1}{1+i-1}\right] =$$

$$\frac{a}{i} - \frac{a}{i(1+i)^n} \quad \text{or} \quad \frac{a}{i}\left[1 - \frac{1}{(1+i)^n}\right]$$

As n becomes very large the second term approaches zero and the project's value is close to a/i.

social rate of discount may give a different ranking of projects than IRR. In other words IRR may be too high in some cases to provide the appropriate comparison of projects. Also, if the benefits minus cost changes sign more than once a unique solution may not exist. Projects would be selected that best achieved the objectives and where the IRR exceeded a chosen rate of return. For the World Bank this cutoff rate of return has been 12 to 15 percent. IRR equals r when

$$PV = -k_o + \frac{b_1 - c_1}{(1+r)} + \frac{b_2 - c_2}{(1+r)^2} + \ldots + \frac{b_n - c_n}{(1+r)^n} = -k_o + \sum_{t=1}^{n} \frac{b_t - c_t}{(1+i)^t} = 0$$

In other words, IRR is that r which makes the present value of net benefits equal to zero.

4. Finally, the benefit-cost ratio (B/C) is popular particularly in the U.S. because of its early application to U.S. water projects. However it cannot be relied upon as an indicator of priorities where capital is a restraint. This results from total costs rather than capital costs (investment) being included in the denominator. In addition if production costs are counted as negative benefits in the numerator rather than as costs in the denominator, the B/C ranking will differ from PV rankings. Projects would be selected that best meet objectives and where the B/C ratio exceeded 1 and rejected if the B/C ratio is less than 1.

$$B/C = \frac{\frac{b_1}{(1+i)} + \frac{b_2}{(1+i)^2} + \ldots + \frac{b_n}{(1+i)^n}}{k_o + \frac{c_1}{(1+i)} + \frac{c_2}{(1+i)^2} + \ldots + \frac{c_n}{(1+i)^n}} = \frac{\sum_{t=1}^{n} \frac{b_t}{(1+i)^t}}{k_o + \sum_{t=1}^{n} \frac{c_t}{(1+i)^t}}$$

$b_1, b_2, \ldots b_n$ equals a series of estimated benefits in years 1, 2, ... n and b_n includes the scrap value of the project at end of year n.

$c_1, c_2, \ldots c_n$ equals a series of estimated maintenance and operating costs in years 1, 2, ... n.

i equals the appropriate rate of discount for annual discounting (social time preference rate from national viewpoint or opportunity cost of capital.)

k_o equals project investment cost. For simplicity in calculations, the pre-operational period of only one year is often considered as being made in year "o" with discounting unnecessary. Where capital investments extend over a period longer than a year, those incurred after the first year are discounted to present value in the same manner as operating and maintenance costs. The investment costs include all costs of building the project.

Table 4 summarizes some of the important characteristics of each technique.[5/] These should be kept in mind when reviewing projects. The different strengths of the procedures for evaluating projects suggests that it is advisable to use more than one technique.

From the national viewpoint, input costs are valued at their opportunity costs in best alternative use. The costs are counted when real resources are withdrawn from the economy while benefits are counted when made available. Depreciation would involve double counting since the full value of a real resource is counted at the time it is available to the project and any scrap value is counted as last period benefits.

Criteria for Project Selection

In a planning and analysis of projects it is critical that all the relevant costs and benefits are included. The following criteria makes explicit the conditions a project must pass to meet the national economic efficiency standard:

(1) $DB + SB > DC + SC$

(2) $TC_A > TC$

DB = discounted direct benefits from project

SB = discounted secondary benefits from project

5/ The following are common discounting formulas for equal annual benefits or costs.

a. The discounted value (d) of an annual payment (p)

$$p\left[\frac{(1+i)^n - 1}{i\,(1+i)^n}\right] = d \quad \text{or} \quad p\left[\frac{1 - \frac{1}{(1+i)^n}}{i}\right] = d$$

b. Capital recovery factor is just the inverse of the above formula. In other words what annual payment is necessary to obtain a discounted value (d).

$$d\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] = p \quad \text{or} \quad d\left[\frac{i}{1 - \frac{1}{(1+i)^n}}\right] = p$$

i = rate of discount
n = number of years or periods

Table 4. Characteristics of Evaluation Procedures

Characteristics	PV	PV^1/k	IRR	B/C
discount rate determined	externally	externally	internally	externally
measure of volume	yes	no	no	no
difficult to calculate	no	no	yes	no
sensitive to changes in variables	yes	yes	yes	no
breakeven point	0	1	selected rate of return	1
usefulness in ranking projects	yes when k is about equal for all projects	yes	yes if time path of benefit and costs are same for all projects	has the most weaknesses

DC = discounted direct costs from project

SC = discounted secondary costs from project

TC = discounted total cost from project

TC_A = discounted total cost of best alternative to the project

The first condition states that the incremental addition to net incomes must exceed the cost of the project plus any loss in incomes in other regions where activities are displaced by the expansion of project related activities. All benefits and costs are discounted on the basis of a consistent time period. The second condition requires that the project cost must be less than the cost of the best alternative for supplying the same output. These conditions assume the optimum size of project has already been determined.

In analyzing U.S. public projects it is generally assumed that productive resources are fully employed, resources are highly mobile and there are no economies to large scale production. These assumptions imply that a new investment project yields no net benefits beyond its own net income. Any expansion of complementary activities (secondary benefits) is offset by a fall in activity elsewhere.

These assumptions may not hold in a number of real situations, particularly in Less Developed Countries. Thus, secondary benefits and costs should be considered on a project by project basis in situations where the above assumptions do not hold.

Secondary Benefits: increases in net incomes of factors of production engaged in activities related to the project through the market either as suppliers of inputs or as processors of project output. These increased incomes must be ones that would not have occurred without the project.

Secondary Costs: decreases in net incomes of factors of production engaged in activities which are displaced by the project through the market or are reduced because of the financing of the project. These income losses must be ones that would not have occurred without the project.

When factors of production cannot move quickly out of activities forced to contract by the project, then the decreases in their incomes over the period of their immobility constitutes secondary costs. If factors of production hired indirectly as a result of the project would otherwise have remained unemployed, the secondary benefits equal the net incomes earned by these factors. In the case of employing unemployed labor only structural unemployment should be counted as a secondary benefit. It is difficult to determine which factors employed directly or indirectly by a project will be drawn from the unemployed during the project's construction period and operating life. It is even more difficult to determine what would have happened to those factors in the absence of the project. Thus, most project evaluations should concentrate on direct benefits and costs particularly if the project is not large in relationship to the country's economy (Howe and Easter, 1971).

Uncertainty

Project analyses are generally done assuming that costs and benefits are reasonably certain. However, there is uncertainty involved with the quantities and values of both inputs and outputs from most proposed projects. Many textbooks conclude that uncertainty and risk are not relevant for public investment decisions. Since the government makes a large number of diverse investments, the risk is spread over so many projects that it is not important for any one project.

For private firms, small units of government and small countries, the above argument for excluding risk and uncertainty from project analysis does not hold. Private firms have used cutoff periods, payback periods for capital, risk premiums and conservative estimates of benefits to account for uncertainty. Sensitivity analysis and stimulation procedures have been used to measure the affect of uncertain variables on the results of project analysis. Chapter XI reviews these methods of considering risk and uncertainty and suggests an analytical approach to probability analysis that introduces uncertainty directly into the evaluation.

Financial Feasibility of Multi-Purpose Projects

The previous sections of this Chapter dealt with economic feasibility, that is, whether the project was justifiable to society in the return relative to the resources used in constructing and operating the project. In contrast to economic feasibility, financial feasibility refers to whether all reimbursable costs can be met by project revenues over the life of the project, as required by U.S. Federal law.

Reimbursable and Nonreimbursable Costs

According to law, some purposes of a multi-purpose project are reimbursable. This means that the beneficiaries of these projects must repay some portion of the costs allocated to these purposes. Reimbursable purposes include power, municipal and industrial water, and irrigation. Other purposes are nonreimbursable by the project beneficiaries. The costs for these purposes are borne by the general taxpayers. Examples are navigation, flood control, and fish and wildlife.

A project is financially feasible if the total of all reimbursable costs is covered by the project revenues. There is the important qualification that this requirement does not apply to each purpose separately, but to the sum of reimbursable purposes.6/

6/ Traditionally, electric power generation has aided other purposes. For example in the Act of 1937 authorizing the Central Valley Project of California, power is designated as "a means of financially aiding and assisting other functions." See (Ciriacy-Wantrup, 1954).

Cost Allocation

In order to determine the total costs which are reimbursable, project costs must be allocated to specific project purposes. However, before discussing this further we should note that in addition to repayment, there have been two other major reasons for interest in allocating costs. There are "ratemaking", and "yardstick" (Ciriacy-Wanthrup, 1954). Ratemaking refers to instances where the rates charged for items such as water and power are directly or indirectly tied to costs allocated for these purposes.

"Yardstick" refers to the notion that cost allocations leading to rates on, for example, power, provide a "yardstick" by which to judge whether rates set by private utilities are too high. As will soon become clear, allocated costs to a project purpose is not a valid yardstick by which to compare rates of private companies.7/ However, this connection has led to a lively interest on the part of private power companies in cost allocation of public projects.

At this point, it should be evident that because of the intimate connection between cost allocation and repayment, as well as the potential connection to "ratemaking" and "yardstick", there are vested interests in the final allocation of costs. While the political aspects of cost allocation, and the inevitable pressures present one difficult aspect of cost allocation, there is another, more technical problem, which adds complications. Let us examine this technical problem of allocating joint costs.

Joint costs

Typically, multipurpose water resource development projects entail a reservoir structure, the storage capacity of which is used to regulate stream flow for navigation, control floods, generate hydro-electric power, provide water for municipal and industrial use, and perhaps other purposes. The costs of items such as electric generating equipment and irrigation canals clearly can be unambiguously assigned to their respective purposes. However, the basic retaining structure cannot be so assigned to specific purposes. This is essentially a joint production situation.8/

7/ This is because public multipurpose projects are favored through economics of joint production and tax advantages (Ciriacy-Wantrup, 1954).

8/ For the private firm, the profit maximizing procedure would be to compute marginal revenues of alternative combinations of joint output and compare then to the marginal cost, and equalize them according to the conventional procedure (Ciriacy-Wantrup, 1954). While conceptually this could be done for a public water project, it generally is not done in practice. Even if it were, the final project selected still has joint costs to be allocated.

It is allocation of these joint costs that provides the technical problem. There is no theoretically sound basis for allocating these costs, and any procedure must necessarily be arbitrary. On an economic efficiency basis, it is necessary that the results of the final allocation do not lead to project purposes which are not economically justified, i.e., benefits for any individual purpose must exceed separable costs. On an equity basis, it may be argued that it is desirable to allocate joint costs in proportion to advantages reaped from the economics of joint production. This latter notion is embodied in the most commonly used procedure, the separable costs-remaining benefits method of cost allocation.

Separable Costs-Remaining Benefit (SCRB) Method

As an example of the separable costs-remaining benefits method of cost allocation, consider the example shown in Table 5. The project has a total cost of $10 million for three purposes: irrigation, power, and flood control. The project has associated with it features which are directly assigned to irrigation and to power. However, a major part of the project, such as the structure itself is not directly assignable to a particular purpose. The problem is to quantify these joint costs, and to assign them to specific project purposes.

The first step is to calculate the project costs without each of the separate purposes. This process yields the costs that are assignable to each purpose. In the example, total project cost is $10 million with all three purposes. Project costs without irrigation is $8 million. The $2 million difference is the separable cost assignable to irrigation. Without power, project costs drop to $6 million indicating $4 million in separable costs for power. As elimination of flood control does not reduce project costs, separable costs for flood control are zero. Column 3 shows the separable costs for all purposes. Subtracting the sum of the separable costs from total project costs ($10-$6) leaves $4 million as joint costs--those costs which cannot logically be assigned to any single purpose. The next step is to apportion these costs among the project purposes; irrigation, power, and flood control.

Under the SCRB method, the separable costs for each purpose are subtracted from the benefits from each purpose. The benefits have been estimated as a part of the project analysis phase discussed earlier. In this example, benefits are given in column (5).

Column (6) shows the benefits remaining after subtraction of separable costs. For example, after subtracting separable irrigation costs of $2 M from benefits of $4 M, there are $2 M in remaining benefits. Similarily, there are $4 M in remaining benefits for both power and flood control, making the total remaining benefits $10 M.

If the benefits remaining for a specific purpose, after subtracting separable costs, were negative that purpose would not be economically justified and should be dropped.

The joint costs are then apportioned according to the relative proportion of remaining benefits for each purpose. For irrigation, the proportion is 2/10, for power 4/10, and for flood control 4/10. These proportions are multiplied by the joint costs of $4 M, as shown in Column (7). In this example, the joint costs are allocated $.8 M to irrigation, $1.6 M to power, and $1.6 M to flood control. Column (8) shows the total cost allocated to each purpose (the separable costs for each purpose added to the joint costs allocated to each purpose). The sum of Column (8) must equal the total project cost in Column (1).

Alternative Cost Allocation Methods

Again cost allocation and project analysis are different, and are performed for different purposes. The economic test for a cost allocation procedure is whether it interferes with the derivation of economically correct investment and output decisions.

As total costs and benefits are unaffected by cost allocation, project justification cannot be affected. Under the SCRB method, if the benefits are so low that they barely exceed separable costs, no further allocation is made to this purpose. Thus the economic criterion will be preserved: if the benefits of a purpose exceed the separable costs, the B/C ratio for that purpose based on allocated costs will be favorable.

On the grounds of pure economic theory, another principle has been suggested: that of minimizing distortions which result from the requirement that total revenues equal or exceed total cost of reimbursable purposes rather than that price equals marginal cost (Eckstein, 1958, p. 268).[10] this calls for allocating costs in inverse proportion to the elasticity of demand for outputs of the various purposes. The rationale for this is that those outputs of least elasticity will experience greater flexibility in price (and least flexibility in terms of quantity demanded) associated with greater output. Repayment for reimbursable project purposes is made from project revenues. With a given price change to cover project costs, those outputs which have the least elastic demand will be purchased in the least diminished quantity relative to those with higher elasticity. This suggests that those outputs having low elasticity can be allocated a greater proportion of the costs and priced accordingly for repayment purposes.

This method is difficult to apply in practice since estimates of elasticities of demand would be needed for each purpose. Further, since non-reimbursable purposes are financed out of general taxation, "distortions" could occur through the impact of marginal tax rates (Eckstein, 1958, p. 268). The SCRB method is somewhat easier to compute although it requires that the project be reformulated without each of the purposes to determine the separable costs.

10/ The reader should keep in mind that output from water projects characteristically are subject to declining costs. Because marginal cost pricing may not cover total allocated costs, price may have to be greater than marginal costs if total allocated costs are to be recovered.

Table 5. Illustration of SCRB Method of Cost Allocation

1	2	3	4
Total Project Costs Including Irrigation, Power and Flood Control (1)	Total Project Cost Minus Cost of Each Purpose (Reformulated Project Costs) (2)	Total Cost of Project Minus Reformulated Project Costs Equals Separable Costs for Each Purpose (1)-(2)=(3)	Total Project Cost Minus Total Separable Costs Equal Total Joint Costs (Not Assignable to Individual Project Purposes) (1) - Σ(3) = (4)
10M	Without Irrigation 8M Without Power 6M Without Flood Control 10M	Irrigation 2M Power 4M Flood Control 0 6M Total Separable Costs	10M - 6M = 4M

M = millions of dollars

Table 5 (continued)

5	6	7	8
Project Benefits for Each Purpose (From Independent Calculation) (5)	Benefit for Each Purpose Minus Separable Cost Yields Remaining Benefits (5)-(3)=(6)	Allocation of Joint Costs $\frac{(6)}{\Sigma(6)}$ X (4)=(7)	Total Allocated Costs (3)+(7)=(8)
4	2	2/10 x 4 = .8M	2 + .8 = 2.8M
8	4	4/10 x 4 = 1.6M	4 + 1.6 = 5.6M
4	4	4/10 x 4 = 1.6M	0 + 1.6 = 1.6M
16M Total Project Benefits	10M Total Remaining Benefits	4.0M Total Joint Costs	10.0M Total Project Costs

There are also good arguments for completely abolishing cost allocation. If this were done, the marketable outputs from multi-purpose projects would be set at levels determined by market conditions (Ciriacy-Wantrup, 1954). However, cost allocation has to an extent been institutionalized, and it is not likely that major changes in these controversial procedures will occur in the near future.

CHAPTER IV

IRRIGATION

Irrigation is the first example of special problems associated with evaluating natural resource projects. The discussion is divided into four major sections. First is a section dealing with estimating the benefits from irrigation. The second section considers the problem of project costs and design. Third is a discussion of some issues relating to operating and maintaining irrigation projects. Finally, the chapter is concluded with an application of project analysis to a program for improving on-farm irrigation in India.

Benefit Measurement

The engineers can tell you on the average how much water will be available. In some systems they can even tell you when and where it will be delivered. However, water is just an intermediate or producer good and has value only if it is used to produce something else. In other words, the demand for water is derived from the production of some good or service.

The same measurement principle based on consumer willingness to pay still applies. The difference is that the project output, water, can be several stages of production removed from the final consumption. This can make the problem of measurement more complex (United Nations, 1972, p. 45). If the water is used to produce fresh vegetables which are directly sold to the consumer, the final output is vegetables. However, if the output is feed grains the final output may be eggs, milk, beef or chicken. Thus, the final consumption is removed several stages of production from where the water is used. When there are no government market restrictions or monopoly or monopsony elements at any stage of the market the demand for water is appropriately derived from the demand for feed grains.

There are at least four ways to obtain an estimate of the direct benefits for irrigation water: (1) the cost of pumping irrigation water in the area, (2) the market price for irrigation water if one existed in the area, (3) farm budget analysis, and (4) a derived demand function for some water using entity aggregated to the appropriate level.

Pumping Costs

To use pumping costs as an estimate of the value of new irrigation water there must be no restriction on pumping so that the farmer is equating private marginal pumping cost with the private marginal return from irrigation. The "common property" rationale ("If I don't pump it my neighbor will") leads pumpers to apply water up to the point where the marginal pumping costs equal the value marginal product. The marginal pumping cost is an upper bound on the value of additional irrigation water since the farmer would just pump more water rather than buy irrigation water at a higher price. To be of relevance the pumping must also be a viable alternative to farmers who will receive the new irrigation water (Howe and Easter, 1971, p. 37).

Groundwater in the United States and many other countries is a classic case of a common property resource. As mentioned in Chapter I when the subsurface ownership of resources such as groundwater is vested in a number of surface land owners the incentives are to over use the groundwater. Areas in Texas, California and Arizona have tried to adapt groundwater regulations to prevent excessive pumping which has caused the groundwater table to drop and land to subside.

Coimbatore District in India is another area faced with a rapidly dropping groundwater table due to excessive pumping. One can actually trace the Coimbatore problem to advances in technology and government subsidies. The development of cheap electric pumps along with government subsidized loans to buy the pumps and subsidized electricity rates has made over pumping possible. With the old technology, the depth of wells and the rate of pumping were naturally limited and the groundwater table was fairly stable. However, with more and more electric pumps and cheap electricity the groundwater table has been falling as much as six feet a year and wells are now reaching depths of 200 feet. Those who cannot obtain the capital to deepen their wells are going out of farming. The problem is also accentuated by the small sized land holdings. This means wells may be within a few feet of one another. In fact, in some situations half a well is owned by one farmer and the other half by another farmer.

Markets

A second method of estimating irrigation benefits is only available if irrigation already exists and the project is just bringing in additional water. If irrigation is available and is being sold in a free market situation, then the market price of the water can be used as an upper bound to the value of new irrigation. Again this must be a market free of monopoly elements. Where water is freely bought and sold, the price of the irrigation water should reflect its value marginal product. Thus the price of tube well water sold by farmers to their neighbors can be used as a starting point for valuing irrigation.

However delivery costs would limit the number of buyers and sellers in a given area. Buying and selling usually occurs only if some farmers have excess water and it can be delivered to the buyer. In public irrigation projects individual farmers may not be allowed to sell water even if it is in surplus. Thus a free market for water is not a common occurrence in many irrigation systems.

Farm Budgets

The third procedure involves using budget analysis to determine the residual return after all costs other than water costs have been subtracted from gross returns. The residual is the maximum a farmer can pay for the water and still stay in business. This again is an upper bound on the direct benefits from irrigation. Before the residual return or benefit can be derived, estimates must be made of cropping patterns, yields, product prices and production costs for the irrigated area.

If the area is already irrigated than the problem may be only of expanding crops already grown. A rice growing area will probably continue to grow rice while a dry land barley area will not continue

barley when irrigated. For a new area brought into production or dry land areas, estimating cropping patterns can pose a real problem. One have to synthesize cropping patterns based on soil types, weather and future demands. Estimating cropping patterns is not a very precise science and has resulted in some wild estimates of many acres of high value crops that are never grown or just displace production elsewhere. This is why demand projections are very important in synthesizing cropping patterns. Demand estimates should be a part of the analysis to indicate how much of each crop can realistically be marketed.

Once the cropping patterns have been estimated, yields have to be projected. These can come from test plots or possibly the experiment station. If irrigation is available in areas with similar agro-climatic characteristics, these farm yields can be used for the new area.

Market price should be used to value output when there is a free play of supply and demand with numerous buyers and sellers and the project is not large enough to alter prices. If on the other hand price is supported by the government, the existing market price would not be an appropriate measure of social value (Howe and Easter, 1971). Even if the market price is determined in a "free market" are there unusual conditions that are influencing the current prices? For example is the weather unusually good or is export demand unusually high due to crop failures in Russia or elsewhere? If unusual market conditions or government intervention do exist then market prices must be adjusted so that they represent what will likely prevail in the future without government involvement.

Production costs are constructed based on the cropping patterns and yield estimates. What inputs will be required to obtain the estimated crop yields? Farm or production records and information from areas with similar agro-climatic conditions should be used if available. Prices or values should be attached to these inputs that represent real resource costs or opportunity costs to society. Again market prices may have to be adjusted particularly if government action or unusual market conditions have distorted prices. Production costs, excluding water charges, are subtracted from gross projected returns to determine the farmer's maximum ability or willingness to pay for water.

Derived Demands

The final method is to derive the demand function for irrigation of some water using entity and then aggregate the demand to the desired level. The water using entity ranges from the typical farm to an entire irrigation district. Demand estimates are made from historical data or analysis of optimum water use patterns based on mathematical programming methods. In the latter case a schedule of increments of net income is generated by varying the quantity of water that is available (Hexem and Heady, 1978, Ch. 13). The value of the last unit of water available is the shadow price of water. Thus a schedule of shadow prices for irrigation water is obtained by constraining water at different levels in the programming model. Data on the technical input-output relationships necessary for the above estimates can come from experimental plots or from irrigated farms that exist in the area or in areas with similar agro-climatic conditions. However, there is generally a lack of technical data either from experimental plots or irrigated farms concerning the relationship between water and production responses (Hexem and Heady, 1978).

Schedules of the value marginal products of water can also be derived from production functions. One starting point is the producer's demand function for water derived from a production function.

$$Y = f(x_1, x_2 \ldots., w)$$

where Y is output, the x's are inputs and w the water input. Under competitive conditions the producer will select those amounts of inputs that simultaneously equates the value marginal products $P_y \cdot MP_{x_i}$ of each input with its price P_{x_i} where i refers to the inputs 1, 2 ... n.[1]

$$P_y \cdot MP_{x_1} = P_{x_1}$$
$$P_y \cdot MP_{x_2} = P_{x_2}$$
$$\vdots \quad \vdots \quad \vdots$$
$$P_y \cdot MP_w = P_w$$

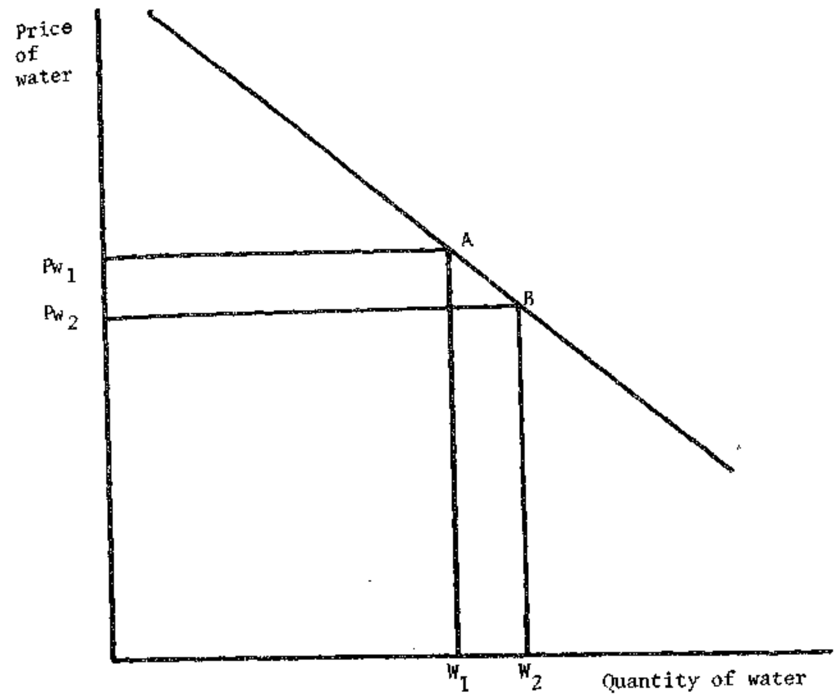
At the equilibrium point the cost of adding another small volume of an input is equal to the value of the additional output. The demand curve for water is derived from $P_y \cdot MP_w$ and can be plotted by varying the levels of water applied w (see figure 8) (Hexem and Heady, 1978, Ch. 11).

The area under the demand curve, ABW_2W_1, for an increment of water, W_1W_2, represents the maximum amount the producer would be willing to pay for the water. The prices indicated by the demand curve represent the value of output the producer can earn by using this water minus the costs of other inputs which are advantageous to adjust in conjunction with the increase in water use.

Obtaining the data necessary to estimate water demand functions can be a difficult task. Most water use studies apply irrigation so that yields are maximized. In other words, water is available and is applied at the right time and quantity so that water does not constrain yields. The problem is that we are interested in the range of water use that maximizes net returns and not yields. If water is scarce then maximum net returns will be achieved at some point where water restrains yields.

Both the timing of water applications during the growing season and the quantity applied will affect yields. Thus, both the quantity and timing of water may need to enter the production function. Such a produc-

Figure 8. Demand Function for Irrigation Water



tion function would be:

$$Y = f(x_1, x_2 \ldots, w, t)$$

with t representing the plant growth stage. A series of water demand curves would be derived from the production function, i.e. $P_y \cdot MP_{w_1}$, $P_y \cdot MP_{w_2}, \ldots, P_y \cdot MP_{w_n}$ where n refers to the stages in the plant's growth. This formulation allows water use to be optimized throughout the season depending on water supply and the plants' water requirements for production. Water at certain stages of growth may be very critical for production while in others it may not. In addition water may be more readily available and lower priced at certain times of the year. For example, in Colorado farmers have "free" water in spring that is available during high water periods from the river. The farmers only pay the cost of delivery or about $3 to $7 per acre foot. The optimum solution requires water to be applied at each growth stage up to the point where the cost of water equals its value marginal production or addition to the value of output.[1]

A related problem is the difficulty in separating the effect of other inputs such as fertilizer and high yielding varieties (HYV's) from the effect of irrigation. Fertilizer, HYV's and irrigation tend to be highly complementary which leads to high intercorrelation among the three variables. Several authors have used a composite input which includes irrigation as just one of the packages of practices (Mears, 1969). If this technique is used, the cost of the other inputs must be included as direct project costs. Another approach is to reduce the intercorrelation by estimating variety differences with a dummy variable to differentiate between local and high yielding varieties (Easter, 1977).[2]

The analysis becomes more difficult when the irrigation project just supplements rainfall. If rainfall is a significant source of water during the season, the benefits from irrigation become a function of the probability of rainfall. This adds a significant complication to estimating the value of irrigation water.

Special Measurement Problems

Even after the direct benefits from irrigation water have been estimated several problems still exist. First, what will be the adoption rate for the irrigation water? For farmers who have not previously irrigated there may be a three to six year lag between the water availability and its full utilization. A five year lag in benefits would reduce the benefit

[1] This assumes that return flows are not a source of irrigation water.

[2] An intercept dummy would be used if the HYV's just raised the level of production. When HYV's change the slope of the production function, a slope dummy should be used.

cost ratios to less than one for most large U.S. irrigation projects. On the other hand, if the project is just to increase irrigation water supplies for farmers short of water, there will generally be little or no lag.

Second, does the project create non-marginal changes? If the project is very large, it will affect market prices or the environment in ways that are difficult to predict. In the case of changes in the market prices for either inputs or outputs, these must be accounted for in the demand projections and in the cost of production studies (Howe and Easter, 1971). The environmental impacts may have to be measured in physical terms. For large interbasin water transfers amounting to millions of acre feet of water, non-marginal changes will be involved. To ignore them would be sheer folly.

Finally there is always the question of induced benefits. Wheat is produced but the wheat is used to produce bread. The production of wheat induces production of bread. Therefore, cannot the value added in the production of bread be counted? This will depend on the unemployment situation. If full employment exists, only the direct benefits can be counted. The net value of the increase in wheat production due to irrigation is the direct benefit. With full employment increased production of bread in the project area will only mean reduced production elsewhere.

If full employment does not exist then induced expansion in either the input supply industries or the products processing industry may be counted. If available for the area, an input-output model will provide estimates of the direct and indirect effects of the irrigation. The input-output coefficients include the value added to farm production and to the input suppliers to produce the increased output. Input-output tables can also be used to give a rough estimate of possible induced effects on the processing industries (Howe and Easter, 1971, p. 64-80). The critical assumption is the extent to which agricultural production has been a bottleneck to the expansion of the agricultural processing. If it has, then the impacts can be calculated from input-output coefficients for processing by assuming that processing expands to handle the increased output from irrigation.

Modifying the induced effects would be impacts on prices and the assumptions on mobility of resources. If outputs are increased substantially then prices should drop which will reduce net incomes from the project. Only if resources are immobile should unemployment be higher in a particular region than for the nation. Such immobilities will not last forever. Capital and labor will move to other areas where better employment opportunities exist. The project induced benefits should only include the losses in wages and interest for the period when labor and capital would be unemployed without the project.

Project Cost and Design

Cost Measurement

Irrigation costs involve construction costs, operation and maintenance costs as well as displacement costs which result from increased agricultural production. Direct project construction costs include storage facilities and all canals and ditches up to the farmer's headgates. Any increase in on-farm production costs including farm ditches and leveling must be counted. The present value of all anticipated drainage costs should be included even if they will not be necessary for a number of years (Howe, 1971).

The displacement effects include the loss in net income to agriculture and agricultural related business in non-project areas that are displaced by new irrigated production through lower prices or loss of markets. If prices are supported by the government then the increased costs of storage, support payments and the subsidy for overseas shipments to handle surpluses- are part of the project costs (Howe and Easter, 1971). Any increases in marketing costs associated with the increased irrigated production should be part of the cost. In new areas costs would include infrastructure investment such as roads.

The guiding principle to use in deciding on costs is the benefits given up in the most productive alternative use of the inputs. In other words what has to be given up to build the project? What is the opportunity cost? When markets are operating effectively, the market price of inputs will provide an efficient measure of opportunities foregone.

If wheat was produced before the irrigation project, which now with irrigation produces rice, the return or profit from wheat production is an opportunity cost of the project. The average land values before irrigation, assuming the market is operating properly, should reflect the average net return from wheat production. However, due to imperfection in the land market it is best to calculate directly the average net return before the project and include it as a project cost. The purpose of the analysis is to isolate the incremental increase in net returns from the project. This means that foregone returns must be included as an opportunity cost.

Again as mentioned in the last section prices should be adjusted for unusual market conditions. Prices vary seasonally and from area to area. If prices are stable over time except for seasonal variations quantity weighted average annual prices would be an appropriate measure (Howe, 1971).

Under certain conditions the market price may not be an appropriate measure of costs. In the case of a labor surplus economy, the opportunity cost of hiring another laborer may be close to zero. Yet, due to market restriction no employer can hire a person for wages near zero. A price near zero may be justified for any unemployed labor employed because of the project. However, if this increased employment just induces other unemployed people to migrate into the area, the cost to society of hiring the unemployed will be the actual wage paid (Meyers, 1974). One option for accounting for a zero opportunity cost of unemployed labor is to multiply each type of labor by one minus the probability that the labor will come from the unemployed ranks (Howe, 1971).

Market imperfections due to a few large operators or the existence of external cost may make market prices poor guides for the real social cost of inputs. In the case of a few operators distorting prices, shadow or accounting prices can be calculated for use in project evaluation. Estimating shadow prices usually turns out to be a difficult task with no assurances that the shadow prices will improve the evaluation (Warr, 1974). The most desirable approach for estimating shadow prices is an economy-wide programming model but this tends to be impractical because of large time and data requirements.

External cost should be included as project costs in value terms where possible. If values cannot be calculated for some of the external costs the physical magnitude should be recorded in the evaluation.

Design Considerations

In the design of irrigation projects the widest range of possible alternatives should be considered, including water conservation with no irrigation. Once the type of project has been selected the criterion for selecting the optimum design is to maximize the present value of net benefits.

One important consideration should also be kept in mind when selecting the optimum design particularly in countries where future conditions are uncertain. This is to build flexibility into the project. If it is a dry year and the reservoir is not full does the water still have to be delivered to all farmers or is the system flexible enough to provide some of the farmers with adequate water to grow a crop? For a multiple purpose hydro-power and irrigation project does the water used for power have to be used for irrigation right away or can it be stored in a lower dam for future use? These features will cost money but they will also produce benefits and add to the managers options for adjusting to future conditions.

Two general characteristics of irrigation projects are important in their design. First a major cost in water supply is the conveyance and distribution system. Dams make fine monuments but canals, ditches, pipes, siphons and use up the funds. Therefore, to keep costs down the service area must be compact and local water sources exploited before sources which require long canals for delivery. One of the key political problems in developing countries such as India is that "command areas" (service areas) are made too large in order to include more farmers. Over-sized service areas lead to high project costs and poor service for many farmers. Because of the large service area, the project designers skimp on the delivery system to lower costs which leads to inadequate water control and poor service. At times farmers are left to provide services which they are unable to perform and may even have to pay for water they do not receive.

Second, economies of size exist in building irrigation projects. This is particularly true of water storage both surface and underground. In addition, the larger and more varied the storage locations for irrigation the more stable and certain will be the water supply. Fluctuations in water supply in one part of the system can be offset by supplies in another part. Pooling of water supplies tends to firm up supplies for all Irrigators.

The standby capacity to serve demand will require a large storage capacity. This is one of the large fixed costs of storage type irrigation systems. It is also a very important requirement in areas of variable rainfall. Standby capacity may be as important as water itself. To make the necessary on farm investments, farmers need the assurance that their water supply will not run out (Gaffney, 1969).

Operation and Maintenance

One of the key questions that must be answered at the design stage is how will the system be operated? Will water pricing play a role in allocating the water or will allocation be completely administrative? If water pricing by volume is used then the system must be designed so that water delivered to each farm can be measured. This will usually require measurement devices at the farm level or at some level such as the village which will allow the charges to be allocated among the farmers based on quantity used.

The measurement devices for water pricing increase capital costs so that such systems are generally higher cost than an administratively operated system. Yet to efficiently allocate water in a purely administrative system requires certain water use controls so that water is not wasted. With a pricing system, price provides the farmer with an incentive to conserve the amount used. A purely administrative water delivery system can have a high operating cost just to maintain control over water use since there is no incentive for the farmer to conserve water.

With either method of allocating water, fees are generally collected from farmers to pay part of the costs. Therefore, the problems of collecting fees exist whether or not water pricing is used.

In many cases, the water supply for irrigation has all the characteristics of a natural monopoly which limits the scope for a free market. But it does not rule out the use of economic pricing and cost principles in planning, fixing the size, designing, maintaining and setting a price structure. It does mean that many of the economic decisions will be made in the public sector rather than in the market place.

In California the irrigation district has played a key role in developing irrigation. The district allowed small farmers to develop large scale irrigation projects that otherwise would have only been available to huge landowners. The taxing authority of the irrigation districts allowed them to cover fixed costs while using a marginal cost pricing system for allocating water (Gaffney, 1969).

The largest part of the cost of most systems is the fixed capital costs of storage and the canals, while the operation and maintenance costs are a small part of the total and are mostly variable. The operation of

the distribution system is generally a decreasing cost enterprise. If water supplies are adequate and capacity permits, another farmer in the service area can be irrigated with only minor increases in the operating and maintenance costs. To hold down costs all farmers in the service area should be induced to use and pay for the irrigation. A compact service area with all farmers using the irrigation water is one important aspect of a successful irrigation project. The authority to force land to be included in the service area, which California irrigation districts have, is one good method of insuring compact service areas.

Who has the responsibility for maintaining the irrigation is important for the continued operation of an irrigation project. In many developing countries maintenance is both an organizational and income problem. There tend to be no farmer associations or strong village organizations that can organize the farmers to do the annual maintenance. In addition, the small farmers with five acres or less have little income to spend on irrigation maintenance.

The division of responsibilities between farmers and the government for operating and maintaining irrigation projects must be clear. At what point is water under the farmers control and who is responsible for maintenance? Also is the water delivered to the farmer's field or does it have to flow through other farmers' fields? Delivery of water to each farmer's field and institutions to assure proper ditch maintenance can be critical to the effective operation of irrigation projections in many developing countries (Easter, 1975). In the western United States the irrigation district has been a key institution for the delivery of water to farmers. Farmers associations have played much the same role in Taiwan (Abel, 1975).

Analysis of a Small Irrigation Project

As an example of the application of project analysis, a small irrigation project in India is evaluated using all four methods of analysis. A number of key variables are tested to provide a simple case of sensitivity analysis as applied to an irrigation project. The idea is to determine if the project is profitable under a wide range of conditions. In addition, the analysis determines which variables are the most critical. This then allows the evaluator to study the critical variables in more detail and reduce the uncertainty concerning their values.

Sensitivity Analysis

In an effort to improve traditional irrigation systems in Eastern India, a small pilot project was installed during 1971-72 in Muretli Village. The basic idea was to install an improved water distribution system in a tank (small reservoir) irrigated village. The improved system included lining the main irrigation channel and construction of surface drainage ditches and field channels. If this pilot project, of only 26 acres, proved successful it would be applied in similar villages (Easter, 1975).

The actual project costs included 15,000 rupees for construction materials, 6,000 rupees for labor, and 3,000 rupees for technical assistance and other costs. The annual maintenance was estimated at 130 rupees. All inputs were actual resources used in the project valued at the actual market price or wage in the area.

Project benefits on the other hand, were estimated from successful water management projects in Sambalpar district. One of the critical questions was how often would water be available for a second crop? If a second crop was grown every year, the benefits would reach 200 rupees per acre. Without the second crop, benefits of 100 rupees per acre were more likely. These benefits are net of production costs and were valued at the government purchase price.

The investment costs of 24,000 rupees occurred in the first year and were not discounted. To provide a sensitivity analysis the maintenance costs and the project benefits were discounted at 10 and 15 percent. The former was near the rate used by the Indian government while the latter was closer to the opportunity cost of capital. Two lengths of project life were also tested; 10 years and 20 years. Based on the past maintenance record of irrigation projects in India, the shorter period is probably more realistic. Three benefit levels of 100, 150 and 200 rupees per acre, were tested to determine the breakeven point for the project.

Table 6 first shows the discounted benefits and costs which were used to calculate the net present values, the benefit/cost ratios, the present values over capital and the internal rates of return of the project. For example, 100 rupees per acre benefits times 26 acres equals gross benefits of 2,600 rupees. This is multiplied by the sum of the discount factors, 6.1446, to obtain the discounted benefits of 15,976 rupees for 10 percent and 10 years.[3/] The discount factors and benefits can be summed and multiplied because the benefits are the same for all years. If the benefits were different every year the appropriate discount factor would have to be multiplied times each year's benefit and then the benefits summed.[4/] Costs are obtained by adding the construction costs of 24,000 rupees to the discounted maintenance costs (130 x 6.1446 = 799). The net present value is then calculated by subtracting 24,799 rupees from 15,976 rupees to obtain -8,823 rupees. The benefit cost ratio is 15,976 / 24,799 = .644. For the

3/ The discount factor (d) for year n is $\frac{1}{(1+i)^n}$ where n is the year and i is the interest rate or discount rate. For a discount rate of 10 percent, the discount factor for year one, is $d = \frac{1}{1 + .10} = \frac{1}{1.1} = .909$. The sum of the discount factors (d) for 10 percent and 10 years is $D = \frac{1}{1.1} + \frac{1}{(1.1)^2} + \dots + \frac{1}{(1.1)^{10}} = .9091 + .8264 + \dots + .3855 = 6.1446$.

4/ An example would be benefits of 50, 100, 150, 200 and 150 for a five year project. With a 10 percent discount rate the discounted benefits are: 50 (.9091) + 100 (.8264) + 150 (.7513) + 200 (.6830) + 100 (.6209) = 45.46 + 82.64 + 112.70 + 136.60 + 62.09 = 439.49 rupees.

Table 6. Calculation of Project Returns.

a. Project Benefits Discounted at 10%

Project Life	Annual Benefits 2,600	3,900	5,200
10 years	15,976	23,964	31,952
20 years	22,135	33,203	44,271

b. Project Benefits Discounted at 15%

Project Life	Annual Benefits 2,600	3,900	5,200
10 years	13,049	19,573	26,098
20 years	16,274	24,411	32,549

c. Project Costs Discounted

Project Life	10%	15%
10 years	24,799	24,652
20 years	25,107	24,814

d. Present Value of Project at 10% Discount Rate

Project Life	Annual Benefits 2,600	3,900	5,200
10 years	-8,823	- 835	7,153
20 years	-2,972	8,096	19,164

e. Present Value of Project at 15% Discount Rate

Project Life	Annual Benefits 2,600	3,900	5,200
10 years	-11,603	-5,079	1,446
20 years	- 8,540	- 403	7,735

Table 6 (continued)

f. Project Benefit/Cost Ratios at 10% Discount Rate

Project Life	Annual Benefits 2,600	3,900	5,200
10 years	.644	.966	1.288
20 years	.882	1.322	1.763

g. Project Benefit/Cost Ratios at 15% Discount Rate

Project Life	Annual Benefits 2,600	3,900	5,200
10 years	.529	.794	1.059
20 years	.656	.984	1.312

h. Project PV'/k_o at 10% Discount Rate

Project Life	Annual Benefits 2,600	3,900	5,200
10 years	.632	.965	1.298
20 years	.876	1.337	1.799

i. Project PV'/k_o at 15% Discount Rate

Project Life	Annual Benefits 2,600	3,900	5,200
10 years	.517	.788	1.060
20 years	.644	.983	1.322

j. Project Internal Rates of Return[a/]

Project Life	Annual Benefits 2,600	3,900	5,200
10 years	1.0%	9.2%	16.6%
20 years	8.1%	14.7%	20.6%

Table 6 (continued)

a/ A rule for interpolating the value of the internal rate of return lying between two discount rates, one giving a negative present value and the other a positive present value, is:

$$\text{IRR} = \begin{array}{l}\text{lower}\\ \text{discount}\\ \text{rate}\end{array} + \begin{array}{l}\text{difference}\\ \text{between dis-}\\ \text{count rates}\end{array} \left(\frac{\begin{array}{l}\text{present value of project at}\\ \text{the lower discount rate}\end{array}}{\begin{array}{l}\text{absolute difference between}\\ \text{the present values at the}\\ \text{two discount rates}\end{array}} \right)$$

benefit-cost ratios, the increased production cost due to the irrigation improvement should also be included in the denominator as part of the project costs rather than being subtracted from the benefits as done here. Since the increase in production costs was very minor the end results of the evaluation are not altered. The PV'/k is 15,976 - 799 / 24,000 = .632.

Finally the internal rate of return was determined by finding discount rates that give a positive and a negative present value. Interpolation was then used to determine the internal rate of return (the discount rate that drives the present value to zero). From Table 6 we find that annual benefits of 3,900 rupees for 20 years and a 10 percent discount rate provides a positive present value while a 15 percent discount rate yields a negative one. Thus by using the interpolating formula from Table 6 we obtain:

$$IRR = 10\% + 5\% \left(\frac{8,096}{8,096 + 403}\right) = 10\% + 5\% \ (.95)$$

$$= 10\% + 4.7\% = 14.7\%$$

for annual benefits of 3,900 rupees for 20 years.

Each evaluation procedure is applied using the same basic information. With a simple project such as this small irrigation project, all four procedures show essentially the same results. At the 10 percent discount rate, and 10 year project life, 155 rupees per acre benefits are necessary to breakeven [(24,000 ÷ 6.1446) + 130] + 26 = 155.[5] The breakeven point is only 3 rupees less for the 15 percent discount rate and a 20 year project life. However, at the 15 percent discount rate and a 10 year project life the breakeven point occurs at about 189 rupees per acre benefits. With a 20 year project life and a 10 percent discount rate the lowest breakeven point occurs, 113 rupees per acre benefits.

The sensitivity analysis indicates that better estimates of benefits are needed. Since the project life of 10 years is the most likely, benefits would have to be in the 150-190 rupees range to just breakeven. Unless two crops can be grown and benefits are near 200 rupees per acre the pilot project is not profitable. On the other hand, if investment costs could be reduced by fifty percent without significantly reducing benefits, the project would be profitable. With costs cut in half, the benefit cost ratios would exceed one under all reasonable assumptions. Results from other water management projects indicate that lower investment costs are clearly possible. In Sambalpar where costs for much larger projects were only 34 rupees per acre, the benefit cost ratios exceeded 13 (Easter, 1975).

5/ Breakeven level of benefits per acre $= \dfrac{\dfrac{k\,i}{1-(1+i)^{-n}} + C}{\text{acres in project}}$ or $\dfrac{\dfrac{k}{\sum_{t=1}^{n} \frac{1}{(1+i)^t}} + C}{\text{acres in project}}$

k = investment or capital costs
C = annual operation and maintenance costs

The above formula can only be used when annual benefits and costs are equal.

CHAPTER V

FLOOD CONTROL

Introduction

Flooding is a result of natural forces, a part of the normal behavior of a river. A flood is usually defined as the state or height of water above some level, such as the banks of the "normal" river channel. The layman generally thinks of a flood occurring whenever a river overflows its banks.

Although streams have always periodically filled their channels and overflowed their banks, flooding has an ominous connotation. In short, floods cause damage to people and property. Historically, settlement centered in river valleys as streams provided water supply, power and transportation for growing villages and towns. River valleys provided good farmland as well as natural routes for roads and railroads. These areas, of course, are also those most susceptible to flood damage.

While reasons for settlement in flood prone areas today may not be as compelling as before, the earlier developments have by virtue of their very existence, attracted further development. People either seem to perceive that the benefits of residing or conducting business in the floodplain outweigh the costs, or they are unaware of the damage potential that may result from living or conducting business in the floodplain.

In attempting to reduce damages to people and property associated with flooding, there are two basic approaches, structural and non-structural. Non-structural measures are designed to keep people, personal property, and construction away from areas prone to flooding. This includes measures such as floodplain zoning, and ordinances regulating real estate development and land use.

Insofar as it is impractical to totally remove developments which have already occurred in the floodplain, non-structural measures are used in conjunction with structural measures designed to keep floodwaters away from people and property. These include dams, levees, stream channelization, and flood-proofing of buildings.

Sometimes, measures designed to reduce flood damages are mistakenly called "flood control" measures. Since floods cannot be totally controlled, one should bear in mind that the ultimate purpose of such measures is to reduce damages. This chapter is primarily concerned with specifying the appropriate measures of flood control benefits (amount damages are reduced) to compare to the costs.

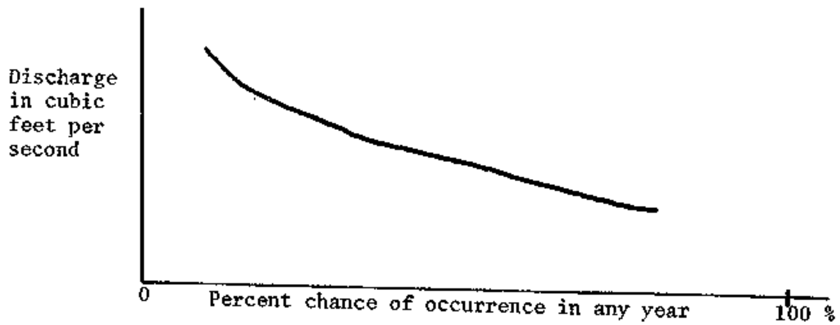
Estimating Flood Damages

As floods are an occurrence of nature, a basic problem is their non-predictible, random characteristic. In estimating flood damage reductions (benefits) of flood projects, this problem must first be addressed.

The probability of a flood is expressed in terms of flood frequency. For example, a flood occurring on the average every other year can be expressed as a 2 year flood, i.e., a flood having a 50 percent chance of occurrence in any year. A larger flood which is estimated to have a one percent chance of occurrence in any given year is called a 100 year flood. This does not mean that a flood of that size is expected to occur only once in a 100 year period. If a 100 year flood occurs in a region this year, there is still a one percent chance that a flood of that magnitude will occur next year. As the time period considered increases, say from 10 years to 25 years, the odds that a large flood may occur increase. A 10 year flood is smaller but more likely to occur than a 25 year flood.

Floods are measured by their maximum rate of discharge of water during the peak period, usually in cubic feet per second. A typical discharge-frequency curve is shown below in figure 9.

Figure 9. Frequency of Discharge (PEAK)

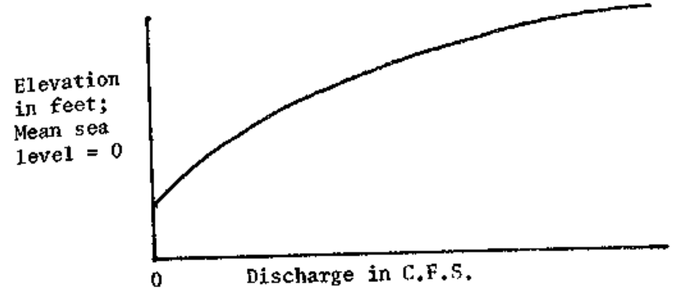


Most American rivers have relatively short records, which make the discharge-frequency curves statistically unrealiable. A large number of observations are needed on a number of points on a river for reliability. A further complicating factor is that the physical flood producing properties of a drainage basin may change over time because of channelization and urbanization. If this occurs, flood-frequency curves need to be corrected.

The various discharges of water at a given point are directly related to "flood stages" or water reaching various levels, as shown in figure 10.

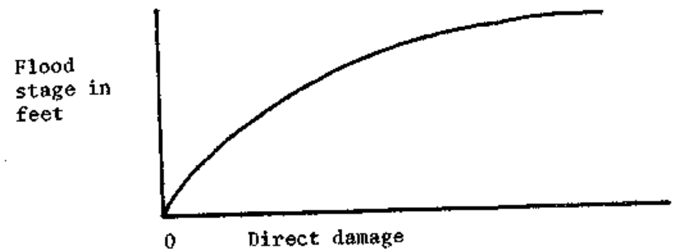
The next step is to estimate the damage that is associated with each stage. That is, the level of discharge is related to inundation at various levels. From contour maps, the specific areas can be designated that would be flooded at different water elevations (flood stages). Often, a survey technique is used to estimate the amount of damages that would occur at given flood stages. Questionnaires may be sent to major industrial firms, rainroads, governmental units, and public utilities after a flood. Residential areas may be surveyed completely or sampled. The firms and residents are asked to list the damages to their property caused by the flood

Figure 10. Flood Stages and Discharge Rates



A stage damage curve takes the form of that in figure 11. Direct damages increase as the flood stage increases.

Figure 11. Flood Stage and Damages



Flood losses are often expressed in terms of average annual damages. With sufficient data, the probability of each flood stage can be multiplied by the expected damage at that stage. The expected values are then summed. In the absence of sufficient data, annual flood losses can be estimated by averaging annual flood losses over some past time period.

A typical damage frequency curve is shown in figure 12.

Note that the area under the curve represents the average annual loss.[1/] The objective of a flood control project is to reduce damages. While no project can reduce to zero the probability of damages, a given project can

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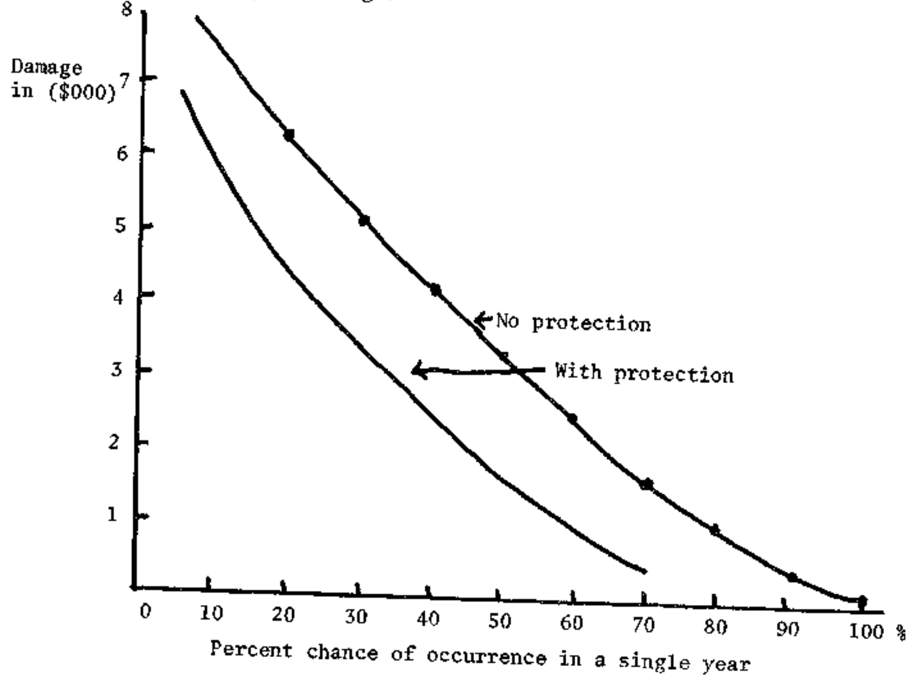
1/ The area under the curves in figure 12 represent the summation of damages multiplied by the probability of each level of damage, e.g., .1 x 7.2 + .1 x 6.1 + .1 x 5 + .1 x 4 + .1 x 3.1 + .1 x 2.3 + .1 x 1.6 + .1 x 1 + .1 x .5 + .1 x 1 = 3.09 thousand.

reduce the extent of damage of a given flood, all else equal.2/

The reduction in damages can be shown as in figure 12.

Figure 12. Frequency of Damages



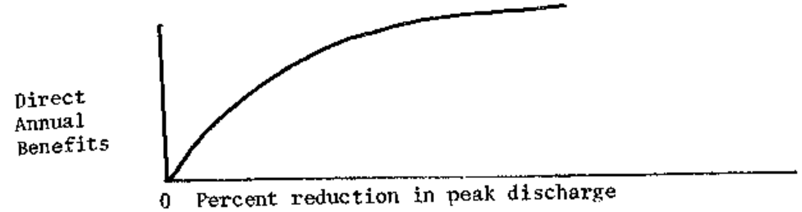
The upper curve relates direct recurring damages with no protection. The lower curve relates expected damages with a given level of flood protection. The difference represents the expected benefits (damages averted) from that project.3/

2/ This "all else equal" qualification is discussed in more detail in a succeeding section.

3/ As the damages are averted in the future, these need to be discounted to the present. The major portion of costs of the project are incurred early in the life of the project.

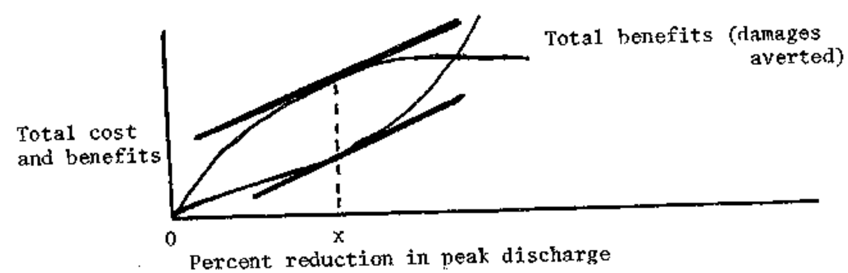
Figure 12 shows the expected reduction in damages for a given project. Although data requirements are larger, a more thorough analysis would include varying size of projects which would yield a curve represented in figure 13.

Figure 13. Direct Benefits from Reduced Discharges



Benefits increase as the size of the project and the amount of flood control is increased. Once a certain size of project is attained, projected benefits will level off and increase very little. The reason for this is that although the damages from an extremely large flood are high, the probability of it happening is small. A comparison of benefits and costs yields the usual shaped benefit and cost curves. The degree of protection is economically optimized at point x where marginal benefit equals marginal cost, (Figure 14).

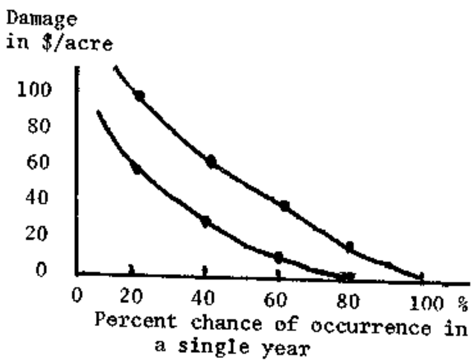
Figure 14. Benefits and Costs as Related to the Degree of Flood Protection



A Simple Example

Suppose, in the absence of protection, expected losses are as follows:

Figure 15. Frequency of Damages



Chance	Damage	Estimated Annual Damage w/o Protection
20%	$100/acre	$20/acre
20%	60	12
20%	30	6
20%	10	2
20%	0	0
		$40 Total/acre

Using 20 percent intervals gives an approximation of expected annual damages, in this case, $50,000 per year for 1,000 acres. Let us now assume that a project will reduce damages as shown in Table 7.

Table 7. Probability of Flood Damages in a Given Year (hypothetical data)

Chance	Damage with Project	Estimated Annual Damages With Project
20%	$60/acre	$12.0/acre
20%	30	6.0
20%	10	2.0
20%	5	1.0
20%	0	0.0
		$21.0/acre

The project reduced average annual damages by $40,000 - $21,000 = $19,000. The difference, $19,000 is the average annual benefit over the life of the project. This amount is discounted over the life of the project and the present value compared to the cost of the project.

Types of Flood Damages

The preceeding section described the general procedure for estimating flood control benefits. This section describes in more detail the types of benefits to be included.

Flood damages are conveniently classified as direct and indirect. Direct losses include those listed below.

~~Residential losses~~ include damage to grounds, trees, walks, houses, furnishings, and similar personal items.

Commercial losses include damage to land, buildings, equipment, in~~ventories~~, transportation facilities, etc.

Public losses include damage to public land, buildings, schools, playgrounds, roads, bridges, and other property of federal, state, municipal, and other public agencies.

Agricultural losses include losses of crops, livestock, stored crops, damages to buildings and equipment, damage to land, and costs of replanting.

These damages represent a real resource loss. Thus, although there are no markets for flood control services, there exists a conceptual willingness to pay to avert these damages, With rational behavior, consumers would purchase flood protection if it were offered in amounts and at costs that were less than the benefit in terms of damages averted.

Indirect flood losses include production losses associated with activities not experiencing direct physical damage from flooding. For example, with the destruction of an essential input (a direct loss), a firm may be forced to reduce production. There is a loss of output that the firm could have produced had it not been for the flood. The loss in output is a loss to society.

Similar indirect losses may occur because of flooding of facilities such as roads,or a flood-induced decrease in demand. These items, however, are only valid if the factors of production are unemployed because of the flood. For example, flooded roads prevent delivery of necessary inputs. If the firm has alternative outlets for its product, flood induced reduction of demand provides no basis for indirect loss.

The Growth Rate Assumption

Conceptually, damages averted on the average with a flood control project are compared to damages expected without the project. These damage reductions, projected into the future, are discounted and summed to give an estimate of present value.

In this calculation an important consideration is the assumption of the economic growth rate in the area affected by the project. The correct measure of flood protection benefits is the difference between the damage with and without the project. The growth rate to use in calculating benefits is the one expected to have occurred in the absence of the project.

Building a flood control project generally induces a more rapid rate of development in the floodplain than otherwise would have occurred. A given project preventing an anticipated level of flooding will thus prevent more damage by virtue of there being more property to be protected. However,this induced development should not be included as benefits since the objective is to estimate the value of future damages expected without flood protection. The rate of growth and development of property in the floodplain must be that which would, have been expected to occur without the project.

Flood Control Projects and Increased Land Values

Another potential benefit from flood control projects is the increase in productivity of land because of the reduced frequency of flooding. Farmers may shift from low return pasture to higher return crops such as corn or soybeans. The benefits from this increase in crop production is determined my summing the discounted average annual increase in net returns over the length of the project. These benefits are generally referred to as "land enhancement benefits" (Haveman, 1972).

By virtue of a flood control project improving the productivity of land, the question arises as to how do increased land values relate to benefits from a flood control project. Since this net increase in productivity is capitalized into the value of land, it is an obvious case of double counting to include both the benefits of increased net production _and_ increased land values as benefits of the flood control project. The second is a direct result of the first.

As an example, consider a project that permanently increases net output an average of $50 per acre. If this value were discounted at 5 percent and summed, the net benefits are .05 = $1000 per acre. However, this will also be the increase in land value at that discount rate assuming competitive markets,

The increased land values might be used as a measure of benefits to the project. However, under most circumstances, it is preferable to use net increased returns because increased land values may not accurately reflect increased benefits. To be an accurate measure of increased benefits, changes in land value would have to reflect the direct project benefits for crops and property damages averted, investment-induced productivity improvements on land in the floodplains, and the direct benefits associated with these. This can only occur if: (1) there are competitive markets for the products involved and buyers and sellers are rational and knowledgeable, (2) increased productivity is capitalized into value of the land, (3) the rate of interest used by purchasers equals rate of return appropriate for analyzing decisions in the public sector, and (4) rents observed prior to project construction include no anticipated returns from construction of flood structures.4/

Flood Control Measures as a Public Good

Flood control measures have attributes of a public good. Specifically, once a dam or levee is constructed, the "protection" afforded is available to all who live in the floodplain. That is, the marginal cost of an additional person using flood control is zero. My use of flood control does not reduce the benefits someone else gains.

The nature of flood control projects in the U.S. is that the federal government in general pays for flood protection, in effect, subsidizing residents of the floodplain. Costs for flood control are considered "non-reimbursible" and paid by all taxpayers.

4/ See Haveman, p. 22, for further elaboration of these points.

If the floodplain occupants paid for the flood costs incurred, the residents would simply decide on their own whether the possibility of enduring flood losses would be worth the advantage of locating or residing in the floodplain. This assumes they have perfect knowledge concerning the frequency of floods and the level of damage. However, since floodplain dwellers do not pay the major portion of costs attributable to flood control, the real cost of that decision is much greater than the private cost.

A 1973 study concluded that of the $35.5 million in 1972 Minnesota Flood Damages, 92 percent was paid by the federal government (Hopeman, 1972). For just the Minnesota River Basin, the costs were borne as follows: Federal Government, 33 percent, state and local government 15 percent and the remainder, 52 percent, by the private sector.

Because of the incidence of these costs, individuals have less incentive to take into account costs of residing in the floodplain than if all the costs were incident upon private decision makers.

CHAPTER VI

NAVIGATION

Early Perspectives[1/]

Improvements in navigation are among the potential benefits of public investment projects in water resources. Prior to 1860 water transportation was crucial in the development of cities. However traffic was mostly downstream, due to lack of mechanical power. The Mississippi River, for example, was shallow, swift, and obstructed with rocks and other debris. Early traffic consisted of flat boats and log rafts moving timber downstream with less than 10 percent of the traffic going upstream.

Two major developments in water transportation occurred in the early 1800's to greatly improve inland waterway transportation. The first of these was the successful application of steam power to boats., made by Robert Fulton in 1807. As the steamboat could travel upstream as well as downstream, it could carry produce to market, and could bring back luxuries and necessities from outside the region by return trip.

The second factor in the growth of inland waterways was the extensive construction of canals to connect major bodies of water. Examples were the Erie Canal connecting Lake Erie and the Hudson River and the Illinois-Michigan Canal connecting the Great Lakes and the Mississippi River System. During this period of inland waterway growth (prior to 1860) the water transportation systems were developed with the aid of the States and the Federal Government. The first Rivers and Harbors Act was passed in 1923. A year later, Congress authorized the Corps of Engineers to remove snags, sandbars and debris from the Mississippi River.

The early era of waterway transportation was supplanted by the dominance of the railroads after 1860. Railroads were able to overcome limitations of topography and climate imposed on inland waterways.

A revival of interest in inland waterways began around the turn of the century resulting from a number of factors. First, inland waterway development was part of a program for the conservation of natural resources which was strong under Theodore Roosevelt. Second, there was some belief that waterways provided a cheaper mode of transportation than railroads. Third, there was the belief, or at least the hope, that development of waterways would put downward pressure on railroad rates and help to relieve periodic traffic congestion on the railroads. (Herbert Hoover, while president, openly advocated development of the Mississippi River to obtain a measure of the reasonableness of railroad rates). Fourth, waterway projects were actively pushed by local communities and interests. And fifth, elements of romanticism of the steamboat era reinforced the renewal of interest in inland waterway development.

[1/] This section draws heavily from: Rodney W. Christianson, Commercial Navigation On the Upper Mississippi River: An Economic Review of its Development and Public Policy Issues Affecting Minnesota, WRRC Bulletin 75, 1974.

This revival was shortly translated into governmental action with the passage of the 1902 Rivers and Harbors Act. In 1903 the state of New York voted to develop the old Erie Canal into the New York State Barge Canal. President Theodore Roosevelt appointed the Inland Waterways Commission in 1907 to prepare a national plan for improving inland waterways. It was succeeded by the National Waterways Commission in 1909 which recommended specific legislation to develop water transportation and bring about greater cooperation between railroads and water carriers. The Commission's 1912 report severely criticized isolated projects built without regard for their place in a national system and waterway projects resulting from "logrolling" and "the porkbarrel" (National Water Commission, 1973, p. x).

During this period of renewed interest in inland waterways, the Upper Mississippi River System was extensively developed for navigation. A channel depth of 4.5 feet was authorized prior to 1900, bypassing some of the more severe rapids with short lateral canals with locks. In 1907 a 6-foot channel was authorized. Its increased depth was to be achieved mainly by construction of large numbers of rock and brush "wing dams" - low structures extending radially from the shore into the river to constrict low-flow waters.

The post WWI traffic congestion on inland waterways was especially acute on the Upper Mississippi River System where there was high demand for movement of bulk commodities such as grain, coal, lumber, chemicals, ore, and petroleum. The Federal Barge Line was created by Congress to help relieve congestion. It was operated by the Federal Agency which ran the railroads during and after WWI. In 1924, the Inland Waterways Corporation, completely government owned, was set up to run the Federal Barge Line. Its purpose was to demonstrate the practicability of barge operations and develop a barge service that could later be sold to private operators (which occurred in 1953).

Congress approved the 9-foot channel depth in the Upper Mississippi in 1930 and completed construction in 1940. This was accomplished largely by a system of locks and dams which regulate and maintain the desired water level and by canalization. The locks and dams create a series of slackwater pools which have adequate depth for river transportation.

Water transport has several advantages relative to the other modes of transporation. First, water carriers have little resistance to traction at moderate speeds which allows great carrying capacity for the vehicle. For example, the 8500 horsepower towboat, the United States can handle 40,000 tons of freight at one time. Thus bulk commodities such as petroleum, coal, iron and steel, and cement, sand and gravel are well-suited for water transport. Second, the ton-mile cost of water transportation is low. The average 3.0 mills per ton-mile for water carriers represents a savings to shippers (although not necessarily to society as a whole) of 4.0 to 5.4 mills per ton-mile over the various least cost alternatives to water shipment (National Water Commission, 1973, p. 114). The lower cost is due to the large carrying capacity and the absence of maintenance and capital charges for the use of waterways by water carriers. Waterways improved and maintained by government are free of toll (with exception of the Panama Canal and the St. Lawrence Seaway).

However, whether water transport is cheaper than land movements depends upon all costs incurred to make it possible. The real cost would be much greater than that actually charged by water carriers when the waterway is largely artificial, like the New York State Barge Canal. Here large public expenditures were required to make navigation possible. When these costs borne by the taxpayer are considered, water transportation often proves more expensive than rail transportation. On the other hand, there are natural waterways, such as the Great Lakes, which need little or no improvement and maintenance. But most inland waterways fall between these two extremes so it's not possible to generalize about the cost of water transportation. Each proposed waterway project must be carefully examined individually to determine its full real cost to society.

Aside from purely cost considerations, there are other economic advantages to waterway development. It may be needed to relieve traffic congestion on the railroads. The recent boxcar shortage for grain shipment is an example. During the first six months of 1973 the United States experienced its greatest freight car shortage in history. The shortage reached 30,000 to 40,000 cars daily in some of these months (Locklin, 1966, p. 724).

Finally, waterway development benefits not only the communities situated on the waterways but also many others. For example, grain is trucked all the way from North and South Dakota to Mississippi River ports in the Twin Cities area to be barged down the river. Common carrier barge shipments on the Mississippi River come from nearly every state in the United States. The public gains since cheaper transportation of raw materials lowers production costs. This assumes, of course, that lower costs are reflected in lower prices to consumers. Furthermore, most waterway development is multi-purpose serving flood control, power, and recreational needs as well as promoting navigation.

In addition to these benefits to private shippers and consumers there is also a public policy advantage. Since waterways are public transportation, facilities improved with public funds, use of canals, locks, and harbor facilities can be directed towards government policy more easily than other modes of transportation. Consequently, user charges could be levied which could result in shippers paying the full economic cost of water transportation if the public so desires.[2/]

There are disadvantages of navigation and waterway development. The obvious shortcoming of water movement is the time involved. Water transportation is slower than rail in most cases, and is seasonal in the northern parts of the country. Service can be easily interrupted by flood or drought. But the most serious disadvantage for shippers is the locational factor. Unless both the origin and destination of the shipment is on or near a waterway, water transportation can be very costly or impossible. For example the transfer of freight between modes of transportation often absorbs the savings made possible from the lower costs of navigation.

Railroads have opposed development of waterways and limited their expansion by their refusal to establish through routes and joint rates, and provide

[2/] This is seen by some as a negative element.

the necessary interchange facilities. Some of their reasons for opposing further development of waterways are as follows. First, railroads spokespersons argue that unfair competition is created since waterways are subsidized by government while railraods construct and maintain their own roads. As a result, the railroads have a high level of fixed costs relative to variable costs. The water carriers have high variable costs and low fixed costs since the government is bearing most of the fixed costs by constructing and maintaining the waterway. Waterway carriers are thus able to charge less than the full real costs of water transportation. This may result in a misallocation of traffic between the two modes of transport.

Secondly, railroad interests assert that waterway development results in private benefits for only a few at public expenses. However, this is only true to a limited extent, since as previously noted, many others will also benefit through lower transportation costs. These are not arguments against developing them at public expense. The railroads and others maintain that user charges should be levied on water carriers using publicly provided waterways. Water carriers would then pay some or all the costs involved in constructing, operating, and maintaining waterways thus shifting the cost of supplying such facilities from the taxpayer to the user of the waterways.[3/]

Real Resource Costs and Transfer Payments

The public benefits from a transportation improvement stem from two sources: (1) cost savings in terms of real resources on existing traffic, and (2) willingness to pay for additional traffic. The first item, cost savings on existing traffic would at first seem to be straightforward. However, there is a crucial, sometimes confusing source of error in measuring cost savings, since savings in real resources are not necessarily the same as savings to shippers, as reflected in rate structures.

In order to better visualize the sources of benefits arising from a navigation improvement, let us look at a simple example related to bridge construction. This example will serve to separate cost savings on existing traffic from willingness to pay for new traffic. It will also enable us to distinguish transfer payments as reflected in rates from real resource cost savings.

Consider a river that can be crossed in that proximity only by a ferry. This ferry is a privately owned monopoly, charging $1.00 per crossing. The costs to the ferry owner are 75¢ per crossing. It currently is used for 5,000 crossings per year.

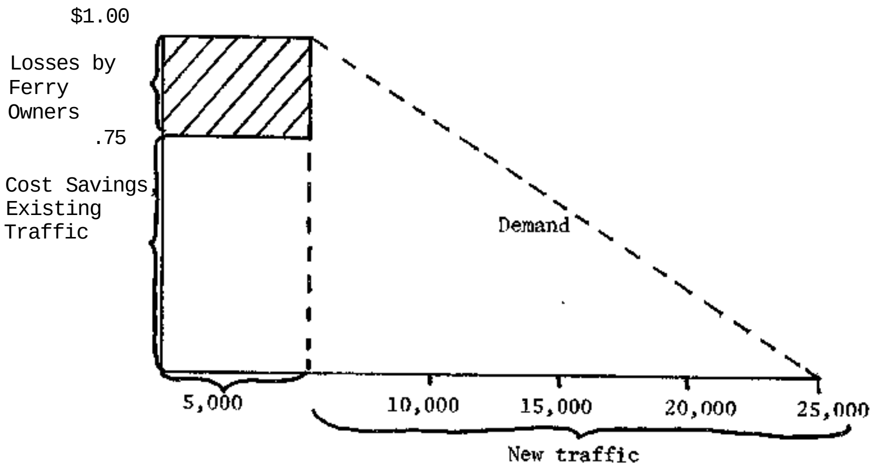
The government is considering building a bridge which would have a capital cost of $100,000 and would be used at no charge to the public. A total of 25,000 crossings per year are expected, and the ferry would no longer operate.

[3/] At the time of this writing, legislation has been passed (P.L. 95-502) establishing user charges starting at 4 cents per gallon of fuel, increasing to 10 cents per gallon in 1985.

In deciding whether to build the project, one needs to compute the present value of benefits and costs through the life of the project. Costs and benefits to society in general must be considered, whether or not they are represented by a monetary outlay.

It is helpful to construct a diagram to show the concepts and the amounts involved in the bridge project.

Figure 16. Reductions in Cost for Existing Traffic and Willingness to pay for Additional Traffic.



There are 4 separate groups involved.

1. The taxpayers spend (lose) $100,000 now to finance the bridge.
2. The ferry owners lose profits of $1,250 or 5,000 x (1.00 - .75).
3. The existing travelers gain $5,000. Where the 5,000 crossings per year previously cost $1.00 each, the crossings are now made at no cost to the travelers.
4. New travelers now use the bridge. The demand for bridge crossings is measured by the area under the demand curve for the 5,000th traveler through the 25,000th traveler.

On an annual basis, what are the costs and benefits?

Clearly, the new traffic generates a consumers surplus. In this example it is 20,000 x $1.00 x 1/2 = $10,000. The analysis of existing traffic is slightly more complex. The annual benefits to existing traffic would first appear to be $5,000 x $1.00. However, a portion of the fees formerly paid for crossing, the $.25 x 5,000, is actually a transfer payment or monopoly rent, rather than a payment for real goods and services. Previously, trav-

lers paid this rent, but now they do not. This does not represent cost saving in terms of real resources. The cost savings are the reduction in resources used by the ferry owners of $.75 x 5,000. This assumes that these resources can be transferred to other uses.

The total benefits of the bridge are the cost savings for existing traffic plus the value of new traffic.

Annual benefits

Existing travelers cost savings: $.75 x $5,000 =	$3,750
New traffic: 20,000 x $1 x 1/2 =	10,000
	$13,750

The existence of transfer payments is a possible source of confusion. While they are real to the party losing them, they should not be counted as losses to society. On an equity basis, the gainers could compensate the losers if society deems this to be desirable.[4]

The Nature of Navigation Benefits

Improvements in inland waterways, ports, and harbors yield outputs or products having a value to society. The basic nature of national benefits regarding navigation are reductions in costs incurred to satisfy the demand for transportation services. More specifically, the cost savings generated by navigation improvements are represented by the reduction in the value of real resources that the nation devotes to transportation. While conceptually, this appears straightforward, in practice there are a number of difficulties and points of confusion. To estimate the value of benefits of waterway improvement, one must isolate the reductions in real cost for existing transportation, and the willingness to pay for increases in transportation services which occur because of the improved navigation facility. The components of the real value of national benefits from an investment in navigation facilities include the following:[5]

1. Reduction in real transportation costs on those units of existing traffic that already use the waterway.

2. Reduction in real transportation costs on those units of existing traffic that shift from alternative transportation modes to the waterway.

4/ To complete the analysis, the present value of $13,750 annually, at a discount rate of 6%, for 50 years (assuming a 50 year life and no O + M costs) is $216,727, yielding a B/C ratio of 2.17, indicating that the bridge is economically justified. If annual operation and maintenance costs were $2,000 for 50 years the B/C ratio would be 216,727 ÷ (100,000 + 31,524) = 1.65.

5/ This discussion draws from Robert H. Haveman, The Economic Performance of Public Investments: An Ex-Post Evaluation of Water Resources Investments, Johns Hopkins Press, Baltimore, 1972.

3. The net reduction, if any, in real transportation costs on those units of existing traffic that remain on alternative transportation modes.

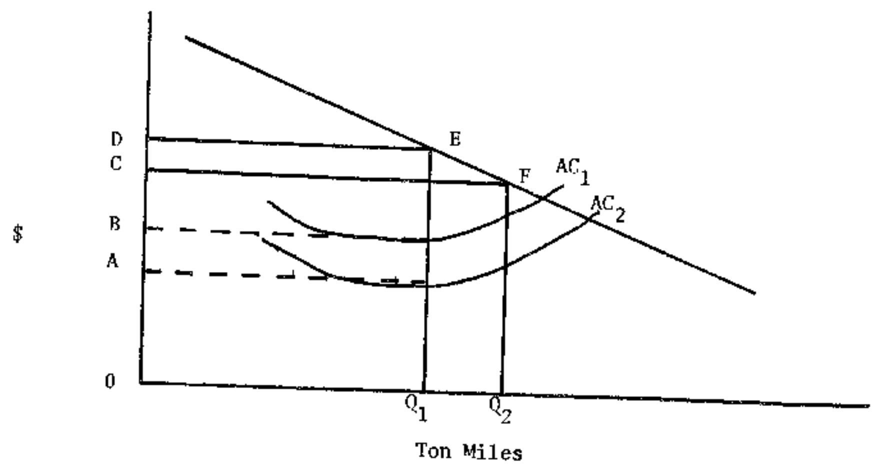
4. The willingness to pay for additional transportation services by purchasers entering the transport market (including other modes) because of the reduced average effective rate resulting from the waterway improvement, less the marginal cost of supplying these additional services.

The first three elements involve reduced costs of existing traffic while the fourth element involves the value of additional transportation services.

These two sources of benefits can be shown graphically. Assume that a navigation project lowers the costs of shipping from AC_1 to AC_2. If Q units of traffic are moved, average cost will be OB. The navigation improvement resulted in a reduction of costs to 0A, the cost savings in terms of real resources to shippers would be AB times Q_1. The lowered cost curve is a direct result of the navigation improvement.

Suppose the rate (as opposed to cost) of shipping was originally OD. Suppose that because of the improvement, the rate was lowered to OC. The increase in traffic generated is $Q_2 - Q_1$. The total willingness to pay for additional traffic is $Q.EFQ_2$. The net willingness to pay for additional traffice would be (LEFQ, minus the incremental costs of moving that traffic (not shown on the diagram),

Figure 17. Reduction in Cost for Transportation.



6/ The cost curve AC_1 reflects the average costs when each shipper has chosen the least expensive mode as reflected in rates. This is not necessarily least cost to society because of the possible disparity between rates and costs.

Benefit Estimation for Existing Traffic

In practice, the process of estimating navigation benefits through cost savings to existing traffic continuing to move on the waterways involves estimating future traffic on the unimproved waterway and estimating the difference in marginal costs on improved waterway vs. the unimproved waterway. This gives the cost savings (reflecting real resource costs) attributable to the improvement. These values, appropriately discounted, give the present value of future benefits through cost savings to traffic continuing on the waterway (i.e., which would have moved on the waterway in the absence of its improvement) .

Estimating the benefits resulting from traffic shifting to barge from alternative modes is more complex. It involves estimating future rate differences and time-in-transit between improved waterway and alternative modes, and the accompanying increased waterway traffic (which would have moved on alternative modes in the absence of the project), and estimating the marginal cost differential between future barge transportation on improved waterway and transportation on alternative modes for traffic estimated. The difference in marginal cost times the increase in traffic, summed over future years, appropriately discounted, gives an estimate of future national cost savings (benefits) from traffic shifting to the improved waterway. Let us consider each of these in turn.

For traffic continuing to use the waterway, in practice a "factor of increase" of x percent times existing traffic is generally used for the relevant trade area to estimate the increased traffic that would have used the unimproved waterway. This estimated traffic flow is then multiplied times the cost savings to obtain the benefits to existing traffic.

For traffic shifting from alternative modes, the roles must be consistent. Suppose, for example, that in response to projected rate differentials between rail and barge, that an additional 10,000 tons of wheat will move by barge beginning in 1971, and every year thereafter. The basis for benefit (cost-savings) on this component is the marginal cost differential between shipping that amount of wheat by barge as opposed to rail. If that savings were $1.00 per ton, one would sum the discounted amounts of $10,000 per year over the life of the project. Note that if the marginal cost of shipping by barge were higher than shipping by rail, the benefit (cost-savings) would be negative for this component.

Benefit Estimation on New Traffic Generated

New traffic generated includes (1) the future value of increased transportation services on the improved waterway (that would not have occured without the improvement) and (2) waterway-induced rate reductions on alternative modes which increases their traffic. The first of these components involves estimation of the additional traffic that would not have existed in the absence of the waterway. A shorthand way of doing this would be to use a "factor of increase" of Y percent times existing traffic flows although care must be taken to exclude traffic shifting from alternative modes as discussed above. The "willingness to pay" less the marginal costs of providing the barge service discounted over time measure the benefits from additional traffic generated on the improved waterway.

The remaining component, future value of additional traffic generated by waterway for alternative modes, is rather difficult to estimate in practice. Conceptually, it is necessary to estimate the rate decreases likely on alternative modes, such as rail, due to the improved waterway, and the likely rate response. The estimated additional traffic times the willingness to pay for additional transportation on alternative modes minus marginal cost of the barge is the benefit from this component.

Real Resource Savings vs. Savings to Shippers

A possible source of confusion in estimating benefits to navigation projects is the confusion of rates with real resource costs. As stated above, the benefits from a national point of view are the savings in real resources.

Savings in real resources are very likely not accurately measured by rates. For example, suppose a navigation improvement enables an additional ton of wheat to be shipped by barge from St. Paul to New Orleans. The shipper makes the choice on the basis of the difference in rate of the railroad and the barge. To the shipper, the savings of the barge over rail is a benefit. However, from the viewpoint of society, the benefits are the savings in real resources involved in moving that ton of wheat. The reduced use of energy and labor on the barge as compared to the railroad would be a saving to society.

It is unlikely that real resource savings would be accurately reflected by a comparison of rates. Rail rates are highly regulated by Government. Furthermore, railroads,are characterized by high fixed costs, which are reflected in rates. Thus, by shipping one less ton of wheat by rail, the savings in real resources is negligible--certainly less than is reflected in the rate. Because of this phenomenon, the estimation of benefits to navigation projects tend to be overstated if based on rates, rather than savings in terms of real resources.

An Example

Empirical studies suggest that usual railway rates exceed marginal costs of a specific haul by 15 to 40 percent (Eckstein, 1958, p. 174). Suppose that a commodity can be shipped by rail for $4.80 per ton. If the rail rate exceeds marginal cost by 20 percent, the marginal costs of shipping by rail are $4.00 per ton. Now, suppose the barge costs are accurately reflected in the rate of $3.00 per ton charged on the waterway. The savings to shippers are $4.80 minus $3.00 or $1.80 per ton. The savings in real resource costs are only $1.00 ($4.00 minus $3.00) per ton. Thus, while the railway rate exceeds marginal cost by 20 percent, the overstatement of benefit is 80 percent, giving a substantial upward bias to the estimate of benefits attributable to the navigation project.

Actually, the overstatement may be even larger if the rate savings to shippers are counted as benefits rather than the savings in real resource costs. This would occur because the cost of waterway improvements are subsidized by the Federal Government. Thus, to the extent that the barge lines are not required to meet the overhead of keeping shipping channels open, this cost will not be reflected in rates of the barge lines. Barge rates would be lower than real resource cost of providing the service.[7]

Past Practice in Benefit Estimation

In practice, benefit estimation has not been conceptually sound (Havemen, 1972, Ch. 3). In particular, prior to 1960, expected traffic growth in a region was often incorrectly attributed to the waterway, whereas, a significant portion of this traffic would have occurred anyway. Furthermore, for the commodities that were expected to shift to the waterway from alternative modes, the change was based on a comparison of freight charges on and off the waterway. In other words, the change was based on current alternative-mode freight charges and barge rates expected to prevail after the waterway improvement. By assuming these rates do not change over the life of the project, the switch from rail to barge was overestimated since competition should cause railroads to request permission from the Government to lower rail rates.

However, even after 1960, rail rates have been used as an estimate of real costs. As discussed earlier, rates are not an accurate indicator of costs. When measuring national benefits (benefits to society) from transportation services, estimates of costs savings and willingness to pay for new service should be used. Although there are difficulties in forming empirical estimates of cost savings and willingness to pay, these difficulties do not justify using a faulty conceptual approach. The use of rate differences as benefits is only justified if the analysis is done from the shippers point of view as done in the next Chapter.

[7] P.L. 95-502, the Inland Waterways Authorization Act of 1978 provides for a user charge based on fuel use. This would tend to reduce the amount of the Federal subsidy.

CHAPTER VII

BENEFIT-COST ANALYSIS OF RAIL LINE IMPROVEMENT FROM THE SHIPPERS VIEWPOINT*

The Minnesota Rail Service Improvement Program provides for financial assistance from the state to rehabilitate eligible rail lines. One of the requirements for participation is that rail users provide a minimum of one-third of the total capital. This capital contribution by the rail users will be repaid in full by the railroad according to a schedule in the contract, based on the volume of shipments.[1/]

The decision of whether to participate in such a program either as an individual shipper, a group of shippers, a railroad, or as a state agency is a major financial decision. Railroad branches eligible for such aid are generally financially weak and consequently investments in them entail capital risk both for the shipper and the state. For its part, the railroad must agree to provide a minimum level of service during the contract period. The railroad may not receive enough revenue to cover service costs and be obligated to accept operating losses for the contract period. The state has a limited amount of funds for rehabilitation, hence, one of the criteria for allocating funds is the economic potential of the branch line.

The objective of this chapter is to present a methodology for evaluating the economic feasibility for shippers of participating in the Minnesota Rail Service Improvement. In contrast to the chapter on navigation, the focus is on the private profitability of the program to shippers (users).

Methodology

Benefits

The benefits from participating in the Rail Service Improvement program are the same as those of having rail service. This is because rail lines eligible for rehabilitation funds under the Minnesota Rail Service Improvement Program are in general "marginal" lines, i.e., they either do not meet Class II Federal Safety Standards or cannot support railcars with a gross weight of 263,000 lbs. Inability to support such a weight excludes the use of 100 ton grain hopper cars. These rail lines are generally in poor physical condition and usually do not generate sufficient revenue traffic for the railroad to consider major rehabilitation expense (or investment). Consequently, although not necessarily in imminent danger of abandonment, they will not survive without help.

* This chapter is based on the Staff Paper; Cost-Benefit Analysis for the Minnesota Rail Service Improvement Program: Methodology and a Case Study, 1977 by Jerry Fruin, Gordon Garry, K. William Easter and Harald Jensen.

1/ For a full description see "Rules Implementing the Minnesota Rail Service Improvement Program".

The benefits of rail service can be grouped into three relatively distinct classes. First, are the "tangible" benefits to individual shippers that can be measured in dollars and cents. Second are the "intangible" benefits to individual shippers, firms or small groups which although very real, cannot be measured in dollars and cents. Third are those benefits which do not accrue to individuals or firms but rather to the community as a whole. These "community" benefits are also, in most cases, intangible since it is difficult to put a dollar and cents value on them.

Individual shippers when deciding whether to participate in the Minnesota Rail Service Improvement Program are primarily interested in the tangible benefits and costs but will also consider the intangible benefits accruing to them. The state and other governmental bodies are interested in the benefits to all groups.

A. The possible tangible benefits of rail service to shippers include:

1. Cost savings due to lower rates for rail than for other modes of transportation.
2. Cost savings from loading or unloading cargo for rail instead of for other modes.
3. Cost savings in handling oversize shipments by rail because railroads can carry larger and heavier loads than trucks.
4. Cost savings due to less loss or damage in handling or transit.
5. Cost savings from avoiding the capital expenses of adding facilities, such as truck docks or materials handling equipment to replace rail facilities.
6. Premiums (or avoided discounts) from buyers who prefer rail shipments because of rail services such as diversion or transit privileges, inspection, security, equipment characteristics, etc.
7. Reduced rates for multiple hopper shipments that were not possible before rehabilitation because of weight limitations.

These benefits are, of course, shipper specific and affect shippers differently. There is no guarantee that rail service will provide benefits. In some cases rail service may involve an additional cost. For instance, rate differences between rail and truck vary widely depending on both origin and destination and the specific commodity. In some cases, the rail rate is higher than the truck rate, and the rail users incur a net cost over truck rates when they elect to use rail service. Similar examples of net costs, such as higher damage in rail shipments, can be demonstrated for other potential savings. The shipper must deduct such costs from benefits when attempting to determine the total tangible benefits.

B. The possible intangible benefits of rail service to shippers include:

1. The existence of intermodal competition for hauling goods and commodities. Effective competition holds down rates and provides an incentive for improving service and increasing efficiency. Many people view this as the most important benefit of rail service.

2. Railroads may provide better service in terms of operating schedules, type of equipment, transit or diversion privileges, etc.

3. Rail facilities may be necessary for businesses that need oversized cargo shipments.

4. Lack of rail service may limit or restrict the growth of the businesses of the rail user's customers as well as other related businesses in the area.

C. The possible community benefits of rail service include:

1. Reduced future investment in alternative transportation facilities, such as roads and highways. The number of heavy truck loads, which increase road and highway deterioration, are reduced by the presence of rail service. Maintenance requirements for competitive transportation modes are decreased, that is, highway life may be extended or maintenance costs reduced. This may decrease total transportation costs to the community.

2. There may be decreased fuel consumption and/or decreased air pollution.

3. Businesses in the community, such as grocery stores and automobile dealers, may realize increased business due to tangible and intangible benefits received by the shippers with rail service. This results in larger payrolls and an increased tax base in the community.

4. Communities having rail service may have a competitive advantage in attracting new industry which may lead to a more diversified local economy.

Several of these community benefits are not limited solely to communities having rail service but have an impact on a wider geographical area. For example, reduced highway construction or maintenance costs have a benefit for the entire State of Minnesota while reduced fuel consumption will benefit the nation.

<u>Costs to Shippers</u>

Under the Rail Service Improvement Program, a Shippers Association provides funds to be used by the railroad for rehabilitation. These funds are then repaid to the Shippers Association according to the volume of shipments originated at or received by participating shippers. Since the shipper's

contribution is returned before the state's, there is very little risk of their capital not being returned if projections of future shipments are at all realistic. Consequently, the shipper is in effect making a low risk interest free loan to the railroad for a set period of years. The primary cost to the shipper then, is the cost of money during the time it is tied up in the rehabilitation project. This cost of money will be the highest of:

1. The interest rate on existing loans or new loans required to furnish the rehabilitation funds.

2. The interest rate on savings or the rate of return on alternative investments outside the firm.

3. The rate of return on alternative investments within the firm.

This cost will vary over the life of the contract being highest at the beginning of the contract when the railroad has use of the entire loan and decreasing as repayments are made and the amount of the loan is reduced. Other costs to the shipper are the expenses associated with additional investments required to obtain cheaper rates, such as investments in equipment to handle hopper cars. In such a case, these costs must be included as part of the cost to shippers for upgrading the rail line.

<u>Steps of Analysis</u>

The analysis can be broken down into the following steps:

1. Determine the total funds required for rehabilitation. Determine the probably requirement for funds from shippers, state, and the railroad. The shippers will generally pay one-third of the cost.

2. Determine the current (or typical) annual volume of shipments, the maximum potential annual volume of shipments if the line is upgraded, and the probably volume of shipments after rehabilitation.

3. Select one or more payback rates per car (or ton) that the railroad must pay shippers. The required payback rate will vary depending on the length of the contract, the volume of shipments, and the proportion of shippers who participate. A range of payback rates should be investigated to get an idea of the "worst" and "best" and "most likely" situations under different volume and participation assumptions.[2]

4. Determine the cost of money or interest rate to be used and discount the investment cost. Rates of 5, 8, 12, and 18 percent are used in the case study. The 5 percent rate was the cost of money available from subsidized federal economic development loans while the 8, 12, and 18 percent rates provide a good range of possible cost of funds on the private market or returns on alternative investments.

[2] The payback is the amount per car the railroads must pay the shippers for loan repayment. As the contract period is shortened, the payback per car has to increase. As the number of cars increases through volume or participation, payback per car can be decreased.

5. Determine the value of discounted net tangible benefits over the appropriate time frame.

6. Determine what intangible benefits should be considered.

7. After considering the benefit/cost ratio and the various intangible benefits, make the investment decision.

Case Study

Rail user information for the year 1975 was obtained from the "1976 Minnesota Rail Line User Questionnaire" responses of the 41 Minnesota rail users on the Chicago and Northwestern Railroad (CNW) from Tracy, Minnesota to Gary, South Dakota. Additional information was obtained from the "Record of Shipping" provided by 10 of these shippers. Of the 41 rail users, 20 sent rail shipments in 1975. Ten of these were grain elevators. Thirty-five rail users received goods by rail in 1975 including 14 firms that also shipped goods out by rail. Five of the grain elevators received rail shipments.

Commodities and goods received by rail include farm implements (11 users), fertilizer (7 users), buildings supplies, salt, tires, plywood and similar merchandise (7 users), lumber and poles (5 users), and foodstuffs and similar merchandise (7 users). Some shippers received more than one category of merchandise.

1975 Actual Rail Cars

The principal commodities shipped out were grains and soybeans which accounted for over 95 percent of the outbound volume in 1975 (see Table 8). Over half of the 393 inbound cars were fertilizer. The next largest categories of inbound cars were lumber and poles and farm implements. These categories combined with fertilizer accounted for over 80 percent of the inbound cars. A total of 1,223 cars originated on or were delivered to destinations on the line.

The Burlington Northern Railroad (BN) also provides rail service to Marshall, Minnesota which is between Tracy and Gary. Sixteen of the 41 surveyed shippers have Marshall locations. Since some of these 16 have BN rail service, they would not be significantly affected by the loss of rail service on the CNW. Consequently, their participation in a rail rehabilitation program is very questionable compared to shippers who depend entirely on CNW service. This potential lack of participation is reflected in the third column of Table 8, which shows the total cars shipped to and from locations other than Marshall. A total of 1,003 cars originated at or were delivered to locations other than Marshall. Of these, 95 percent of the inbound traffic was accounted for by fertilizer, lumber and farm implements.

Potential Volume

The fourth column of table 8 provides an estimate of the potential volume of boxcars. This was obtained by converting the total tonnage of truck shipments shipped or received by the 41 rail users into the number of

Table 8. Volume in Railroad Carloads - Actual and Potential

Commodity	Cars Shipped 1975	Cars Shipped without Marshall	Total Potential cars	Total potential cars without Marshall	Maximum probable cars	Maximum probable cars without Marshall
			OUTBOUND			
Corn	377	321	596	524	486	422
Oats	246	225	246	225	246	225
Wheat	137	137	322	308	230	223
Soybeans	34	29	594	465	34	29
Other Outbound	36	12	52	20	50	16
Total outbound	830	724	1,810	1,542	1,036	915
			INBOUND			
All commodities	393	279	1,089	828	413	299
Total cars 1975	1,223	1,003	2,899	2,370	1,449	1,214

SOURCE: 1976 Minnesota Rail Line User Survey (41 users).

rail cars required to haul that tonnage. This number was then added to the number of 1975 actual rail cars shipped. The fifth column is obtained in the same manner and contains the potential volume of boxcars without Marshall shipping locations.

Because of the truck competition all of this "potential" volume would not move by rail even if the line were upgraded and rail service were improved. The last two columns are an estimate of the "maximum probable" volume of rail shipments after rehabilitation.

Oat shipments virtually all go by rail so no increase is possible for oats unless production increases. Large increases in outbound rail shipments of corn, wheat, and soybeans are possible. However, it is unlikely that any additional rail shipments of soybeans will be made. Existing truck rates to Dawson and Mankato, the destinations for the soybeans, are well below minimum rail rates and there is no reason to expect this situation to change.

On the other hand, more corn and wheat might go by rail if hopper car service were available. An arbitrary estimate of one-half of the corn and wheat shipped by truck in 1975 was added to 1975 rail shipments to provide an estimate of the "maximum probable" rail shipments of corn and wheat.

"Potential" and "maximum probable" receipts of inbound commodities were also estimated. Currently over 80 percent of the dry fertilizer and lumber and poles come by rail. Hopper cars and better service will increase this percentage but not many more carloads will be required to raise rail shipments to 90 percent. These are the only categories of inbound shipments estimated to increase for the "maximum probable" after rehabilitation. The large increase in "potential" inbound cars is due to the large quantities of trucked in feed. This was the equivalent of about 450 boxcars. However, for the "maximum probable" it was assumed that the feed was not being shipped long distances and that trucks would retain a rate advantage over rail.

In summary a total of 1,223 rail cars originated at or were delivered to locations on the line of which 1,003 were for locations other than Marshall. If all movement of commodities to and from the 41 users went by rail, volume would increase by over 120 percent to 2,899 cars with Marshall and 2,370 cars without Marshall. However, due to the nature of the commodities and their origins and destinations, a total of 1,449 cars including Marshall and 1,214 cars without Marshall is more likely. This means that under stable business conditions rail volume is not likely to increase more than 20 percent due to improved facilities and service.

Analysis (All shippers except Marshall)

The methodology described in the previous section is now applied to various combinations of payback amounts, volumes and benefits:

1. Shippers investment $1,000,000

   a. Payback amounts $100/car
      $200/car

   b. Discount (interest) rates 5%
      8%
      12%
      18%

2. Shipping Volume:[3/]

   a. 1,000 cars per year consisting of:

   b. Outbound: 225 oats
      487 corn and wheat

   c. Inbound: 288 fertilizer, lumber and merchandise

3. Benefits:

   a. Freight rate differences:
      - corn, wheat, oats (truck rate lower than rail) -5.5¢/cwt.
      - fertilizer, lumber, merchandise +$6/ton

   b. Price advantages:
      - corn, wheat +3¢/bu.
      - oats +9¢/bu.

The $100 per car payback will return the shipper investment in 10 years. The $200 per car payback will return the shipper investment in 5 years. The benefits are based on current rate differences and price differentials as reported by shippers. Only rate differences and price differentials were included in the benefits.[4/] For corn, wheat and oats shippers are paid a premium for grain shipped by rail.

3/ This level of shipment is almost the same as the 1975 volume without Marshall and represents 100 percent shipper participation. Any shift from truck to rail probably will be more than offset by those shippers choosing not to participate. Thus the 1,000 car volume is probably a high estimate of potential users.

4/ If the analysis was done from the point of view of society, then the rate and price differences would not be the measure of benefits. Instead the measure should be the difference in cost of transportation. Therefore, any savings in real cost of transportation by using rail vs. truck would be the benefit. Since shipping rates are regulated they are not likely to be representative of actual costs of transportation. Thus, the private cost savings estimates would be different from the cost savings to society.

The benefits from rail service to the 25 non-Marshall rail shippers is approximately $172,000 per year when benefits are reduced by the favorable rate differences of truck over rail for grain (see Table 9). At current truck and rail rates, rail shippers of corn and wheat have a net loss of $3.00 per car ($66-$63). It was assumed that shippers will ship by rail despite this cost to take advantage of intangible benefits, such as the availability of transit and diversion privileges. The benefits would be nearly $219,000 per year if there were no difference between truck and rail rates.

Table 9. Annual Benefits with One Thousand Cars per Year.

Commodity	Number Cars	Rate* Difference	Rail price advantage	Total	Total with rail grain rates equal to truck rates
Corn, wheat	487	-$66/car (-5.5/cwt)	$63/car	$-1,461	$30,681
Oats	225	-66/car (-5.5¢/cwt	$337.50/car 9¢/bu.	$61,088	$75,938
Fertilizer, lumber, merchandise	288	$390/car $6/ton	-- --	$112,320	$112,320
			TOTAL	$171,947	$218,939

* Rate charge for rail shipment per cwt. minus rate for trucking.

The cumulative discounted benefits for the $172,000 and $219,000 benefit levels were computed for both 5 and 10 year periods (tables 10 and 11). Discount rates of 5, 8, 12 and 18 percent were used. Cumulative discounted benefits range from $392,038 at 18 percent and a 5 year payback period to $1,164,250 at 5 percent and a 10 year payback period.[5/] Total discounted costs range from $134,150 at 5 percent and a 5 year payback period to $550,494 at 18 percent and a 10 year payback period. (See Appendix for example)

With a 5 percent discount rate and a 5 year payback period, the shippers' discounted benefits in the second year of the program are larger than the total discounted costs, regardless of whether rail and truck rates for shipping grain equal, or rail rates exceed truck rates (see Table 10). As the discount rate increases, the breakeven year increases until it is the 5th year at 18 percent. Since costs start out higher but increase at a lower rate than benefits, cumulated benefits do not exceed cumulative costs until year 5 (see Figure 18). If money were to cost just a little more than 18 percent then

5/ It should be noted that no benefits accrue in the first year because it is assumed that rehabilitation will take one year.

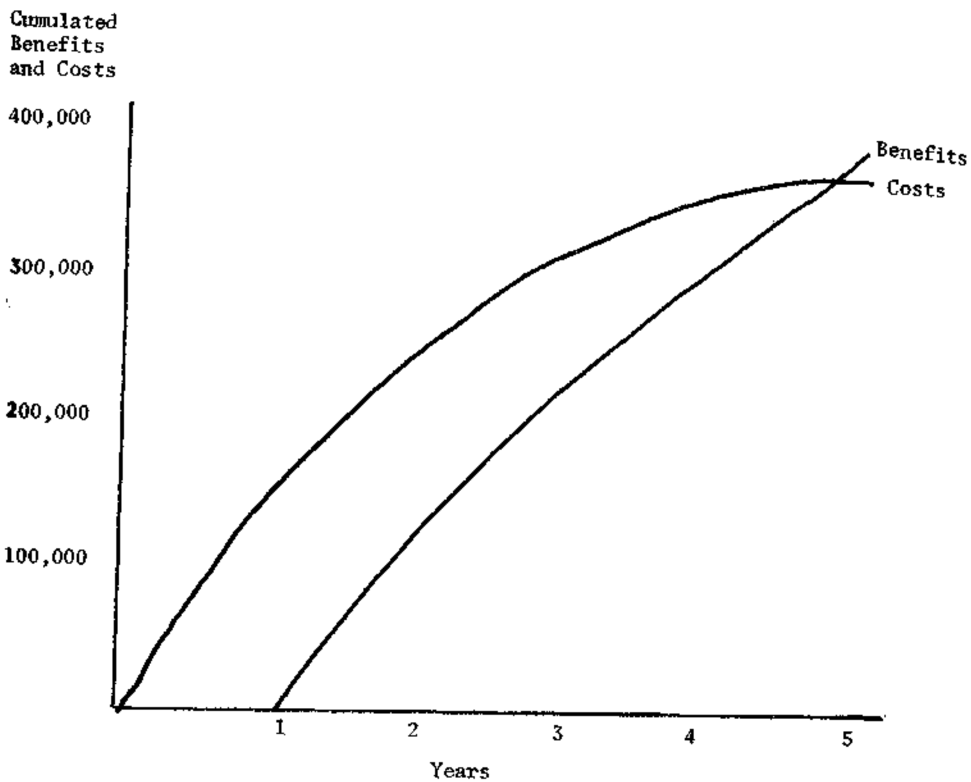
Table 10. Discounted Costs and Benefits with $1 Million Shipper Investment and One Thousand Cars per Year (payback $200 per car - payback and benefit period 5 years)

Interest/ Discount Rate	Total Discounted Costs	Total Discounted Benefits Rail Grain Rates Exceed Truck Rates	Year Discounted Benefits Equal Discounted Costs	Total Discounted Benefits Rail Grain Rates Equal Truck Rates	Year Discounted Benefits Equal Discounted Costs
5%	$134,150	$580,835	2	$739,574	2
8%	$201,456	$527,360	3	$671,485	3
12%	$279,072	$466,319	4	$593,761	3
18%	$374,508	$392,038	5	$499,180	4

Table 11. Discounted Costs and Benefits with $1 Million Shipper Investment and One Thousand Cars per Year (payback $100 per car - payback and benefit period 10 years)

Interest/ Discount Rate	Total Discounted Costs	Total Discounted Benefits Rail Grain Rates Exceed Truck Rates	Year Discounted Benefits Equal Discounted Costs	Total Discounted Benefits Rail Grain Rates Equal Truck Rates	Year Discounted Benefits Equal Discounted Costs
5%	$227,895	$1,164,250	3	$1,482,432	3
8%	$328,968	$994,367	4	$1,266,121	3
12%	$435,024	$818,121	5	$1,042,709	4
18%	$550,494	$626,917	8	$798,250	6

Figure 18. Year Discounted Benefits Equal Discounted Costs.



th cumulative discounted benefits over the 5-year payback period would be less than the total discounted costs when rail rates exceed truck rates. In that case, a shipper could not justify investing in rail rehabilitation on the basis of the tangible benefits.

If the payback period is extended to 10 years, the discounted benefits are increased as are the costs (see Table 11). The results are still favorable although the number of years required until discounted benefits equal costs has increased. The discounted costs have increased substantially even though the shippers' initial investment is the same as in the 5-year payback example. This is due to the longer period of time that interest is paid on the loan or foregone on alternative investments by the shippers who have loaned the funds to the railroads at zero interest.

Analysis (Major User Participation Only)

The previous analysis assumed that all shippers participated in the rail rehabilitation program. The number of cars for which a payback was based was approximately equal to the total 1975 car volume. This section assumes that only the major shippers who had expressed interest in rehabilitation would participate. All costs, rates and interest rates remain the same. The only difference is that the payback and benefits are based on 670 cars per year instead of 1,000. Annual benefits total $75,134 for these major shippers when rail rates for shipping grain exceed truck rates and $112,622 if rail rates equal truck rates (see Table 12). Because of the smaller number of cars and the constant investment, the required payback period for the railroads increases to 8 years at $200/car (670 x 200 x 8 = $1,072,000) and to 15 yrs. at $100/car (670 x $100 x 15 = $1,005,000). In other words it takes 8 and 15 years to pay off the million dollar loan at repayment rates of $200 and $100 per car. Discounted benefits are cumulated for 8 and 15 year periods at discount rates of 5, 8, 12, and 18 percent (see Tables 13 and 14).

Table 12. Annual Benefits with 670 Cars per Year.

Commodity	Number Cars	Rate Difference	Rail Price Advantage	Total	Total With Rail Grain Rates Equal to Truck Rates
Corn, Wheat	433	$-66/cars (-5.5¢/cwt)	$63/car (3¢/bu.)	$-1,299	$27,279
Oats	135	$-66/car (-5.5¢/cwt)	$337.50/car (9¢/bu.)	$+36,653	$45,563
Fertilizer, Lumber, and Merchandise	102	$+390/car (+6¢/ton)	-- --	$+39,780	$39,780
			TOTAL	$75,134	$112,622

Table 13. Discounted Costs and Benefits with $1 Million Shipper Investment and 670 Cars per Year (payback $200 per car - payback and benefit period 8 years).

Interest/ Discount Rate	Total Discounted Costs	Total Discounted Benefits Rail Grain Rates Exceed Truck Rates	Year Discounted Benefits Equal Discounted Costs	Total Discounted Benefits Rail Grain Rates Equal Truck Rates	Year Discounted Equal Discounted Costs
5%	$182,718	$414,136	4	$620,770	3
8%	$268,255	$362,143	6	$542,836	4
12%	$363,450	$306,169	11	$458,933	6
18%	$472,689	$242,681	never	$363,767	15

Table 14. Discounted Costs and Benefits with $1 Million Shipper Investment and 670 Cars per Year (payback $100 per car - payback and benefit period 15 years).

Interest/ Discount Rate	Total Discounted Costs	Total Discounted Benefits Rail Grain Rates Exceed Truck Rates	Year Discounted Benefits Equal Discounted Costs	Total Discounted Benefits Rail Grain Rates Equal Truck Rates	Year Discounted Equal Discounted Costs
5%	$307,055	$708,434	6	$1,061,908	5
8%	$428,046	$573,419	10	$859,527	7
12%	$544,643	$444,715	35	$666,607	11
18%	$659,151	$318,866	never	$477,966	never

With the longer payback period, discounted costs are higher. Discounted benefits to participating shippers are less because there are fewer shipper benefiting. The railroad would be better off at either payback level than under the previous case because they would have an interest free loan for a longer period of time. The railroad's cash flow or profit is then increased in the first years of the period because it does not have to make a $100 or $200 per car payback for 330 of the cars hauled on the line.

The time required for cumulative discounted benefits to equal total discounted costs for the shipper has increased substantially from the 1,000 car payback situation. Relatively good benefit/cost ratios of over 2 and 3 to 1 are still obtained at either payback level for a 5 percent discount rate. The ratios are based on a 15 year investment period for the $100/car payback level with benefits accruing for 15 years and on an 8 year investment and benefit period with a payback level of $200/car.

For a 12 percent discount rate with rail grain rates higher than truck rates, cumulative benefits do not equal costs until the 10th year with the $200/car payback level. When the payback is only $100/car and the discount rate is 12 percent, it takes 35 years for discounted benefits to equal total discounted costs. At an 18 percent discount rate, discounted <u>tangible</u> benefits will <u>never</u> equal total discounted costs for either payback rate.

Distribution of Benefits Among Shippers

The preceding sections demonstrate that with shipper participation rates of two-thirds or more from locations other than Marshall, the discounted tangible benefits exceed discounted costs for all but the higher discount rates and longer payback period. However, benefits will not be the same for all shippers. Benefits vary depending on the product or commodity being shipped or received, the distance moved, handling characteristics, alternative markets, etc.

To illustrate these differences, five examples are analyzed, each with a different mix of commodities: (1) 100 cars of fertilizer, (2) 100 cars of corn and wheat with truck rates equaling rail rates, (3) 100 cars of corn and wheat with truck rates less than rail rates, (4) 100 cars of oats with truck rates equaling rail rates, and (5) 100 cars of oats with truck rates less than rail rates.

Cost and benefits are computed for 5 and 12 percent discount rates. Each shipper is assumed to invest $100,000 with payback periods of 5 and 10 years.

The profitability of the investment in rail rehabilitation is greatest for the fertilizer and oats shippers (see Tables 15 and 16). A fertilizer shipper with a rail rate advantage of $6/ton clearly has a favorable benefit/cost situation in all cases as does the elevator with shipments of oats at a 9¢ per bushel price premium. In contrast, an elevator with corn and wheat to ship cannot justify an investment based on tangible benefits. These differences demonstrate the importance to individual shippers of evaluating their proposed investment in terms of their expected future commodity mix

Table 15. Distribution of Discounted Costs and Benefits Over a 10 Year Payback Period ($100,000 investment - 100 cars per year - $100 per car payback per year).

		100 cars fertilizer		100 cars oats		100 cars corn & wheat	
Discount Rate	Total Discounted Costs	Cumulative Discounted Benefits	Year Benefits Equal Costs	Cumulative Discounted Benefits	Year Benefits Equal Costs	Cumulative Discounted Benefits	Year Benefits Equal Costs
5% - Rail grain rates equal truck rates	$22,790	$264,069	2	$228,521	2	$42,657	6
5% - Truck grain rates less than rail rates	$22,790	$264,069	2	$183,833	2	Rail shipping increases costs	never
12% - Rail grain rates equal truck rates	$43,502	$185,562	3	$160,582	3	$29,975	25
12% - Truck grain rates less than rail rates	$43,502	$185,562	3	$129,130	4	Rail shipping increases costs	never

Table 16. Distribution of Discounted Costs and Benefits Over a 5 Year Payback Period ($100,000 investment - 100 cars per year - $200 per car payback per year).

		100 cars fertilizer		100 cars oats		100 cars corn & wheat	
Discount Rate	Total Discounted Costs	Cumulative Discounted Benefits	Year Benefits Equal Costs	Cumulative Discounted Benefits	Year Benefits Equal Costs	Cumulative Discounted Benefits	Year Benefits Equal Costs
5% - Rail grain rates equal truck rates	$13,415	$131,742	2	$114,007	2	$21,281	4
5% - Truck grain rates less than rail rates	$13,415	$131,742	2	$ 91,712	2	Rail shipping increases costs	never
12% - Rail grain rates equal truck rates	$27,908	$105,768	2	$ 91,530	3	$17,086	9
12% - Truck grain rates less than rail rates	$27,908	$105,768	2	$73,631	3	Rail shipping increases costs	never

and their cost of money, It also highlights the problem of obtaining participation by all shippers.

Conclusion

For the shippers as a group, the Minnesota rail program appears to make rail line improvement look like a good investment. However, within this group there is a great deal of difference. To fertilizer and oats shippers the investment is a good one but for corn and wheat shippers it is not. Thus the level of participation becomes a critical question.

From society's standpoint, the investment is questionable since the analysis includes only the investment costs to the shippers as the project costs and includes rate and price differences as the benefit measure rather than the real transportation cost savings. Even if rate and price differences are assumed to be close to the real cost savings to society, the investment costs to the state and railroads must be included for a complete evaluation.

In contrast the improvement will probably benefit society longer than assumed in the analysis. Short payback and benefit periods were selected for the evaluated because of the private firms requirement for a rapid return on their investment. The shorter period also reduced the uncertainty involved in assuming that current benefit levels would continue into the future. Society would take a longer run viewpoint which would add to the benefit stream and make the investment more profitable.

The total investment costs for upgrading the Tracy to Gary line are about three times the cost to the shippers since the shippers only pay one-third of the investment costs. If costs are three times higher, the Tracy to Gary improvement is profitable only at the low discount rate of 5 percent and at 8 percent when benefits are based on a thousand cars. Thus, for society, the measurement of tangible costs and benefits indicates that it is a very marginal investment. Unless intangible benefits are substantial or benefits accrue to users of more than a thousand cars or for a longer period, the investment should not be made.

CHAPTER VIII

VALUING RECREATION AND ENVIRONMENTAL RESOURCES[1/]

The key question in this chapter is how to place values on recreation and environmental resources. Values are needed so that recreation and environmental resources can be. compared with timber production, alternative recreational uses, electric power production, mining and irrigation. Ideally, one would like to estimate demand curves for recreation or environmental resources. The area under the demand curve could then be used to measure project benefits and willingness to pay.[2/]

Traditional markets generally cannot be used since markets do not exist for most recreational and amenity uses of the environment. One can think of the possibilities for using market values as a continuum starting with commercial recreation sites and going to unique natural environments owned by the federal government, such as Hells Canyon or the Boundary Waters Area. If congestion does not occur, the price that a commercial recreation site charges will be a reasonable measure of benefits as long as the decision whether or not to maintain the site is not in question. This assumes that the costs of travel to the site is small relative to the charge. The fees provide a willingness to pay test for the site but exclude any travel cost or option value.[3/] In contrast most state and federally owned recreational sites charge a zero or nominal fee that do not provide a conventional market test.

Finally, the difference between "equivalent variation" and "compensating variation" makes it difficult to judge the market solution. The minimum compensation acceptable for the right to use an environmental resource (no income constraint) and the maximum willingness to pay for the right to use the resource provide different estimates of demand curves. This can also be thought of as the willingness to pay as compared to the willingness to sell.

1/ Environmental resources are defined as the amenity uses of natural environments.

2/ One concern about using the consumer surplus as a measure of public investment is that it will overvalue public investments relative to private investments. This would be inappropriate if it caused a shift of private investment funds to the public sector. However, it is not clear that the approval of a public project will divert funds from private projects. The overall public expenditure levels tend to be decided independently of any one project. Thus, when it is possible,consumer surplus should be used to measure public benefits even though the same measure is not used in the private sector.

3/ Option value or demand is the amount people would be willing to pay for the option of using the site sometime in the future. It is only important for unique resources that are infrequently used and may be converted into other uses.

The area under demand curve with no income constraint (willingness to sell) would clearly be the larger of the two. Which is the proper measure is an unanswered question although from a practical standpoint willingness to pay is much easier to measure (see Freeman, 1979, Ch. 3 and Mishan, 1971a for more details).

Environmental Resources

The amenity uses of environmental resources have some important characteristics which distinguish them from the extractive uses. The differences become quite clear when estimating the supply and demand for amenities.

On the supply side certain environments may be non-producible or at least have a very inelastic supply. In addition, amenity services enter directly into the utility function of the consumer rather than being used to produce any consumer goods. Substitution possibilities are, therefore, quite limited. Substitution can only take place in consumption and many amenity uses of the environment have few good substitutes. All these characteristics mean that advances in production techniques will have very limited positive impacts on the supplies of environmental resources. The major opportunity for expanding the supply is through improved management of environmental resources. Improved management could reduce congestion and expand the resource area available to the public.

On the demand side technology is likely to have a significant impact on environmental resources in contrast to the supply side. Amenity uses of resources are income elastic. Advances in technology have increased the demand for amenity uses of resources such as outdoor recreation, sightseeing and bird watching. As more material goods are produced the relative importance of amenities increases (Krutilla and Fisher, 1975).

Learning by doing also is an important characteristic of amenity uses of the environment such as white water canoeing and wilderness orienteering. Many who have never used the amenities of the environment will learn to use them in the future but currently they do not evince any demand. These potential values may never be realized if amenity uses are not preserved since individuals will never have the opportunity to learn how to use them. The learning opportunity would be foreclosed because of the nonreproductible nature of environments.

There also seems to be something of a shift in the U.S. tastes towards environmental resources such as wilderness areas. This may be partly due to the young age distribution of the U.S. population. If this is the case, the shift may soon stop as our population ages. The increased demand for environmental resources also could be due to higher incomes and a saturation with material goods. Another reason for an increased quantity demanded may be the low relative prices of many of the environmental resources rather than any basic changes in tastes. Many of our state and national parks still charge only very nominal fees. Finally, these apparent changes in tastes may be just a fad that will soon pass particularly as congestion increases in our wilderness areas.

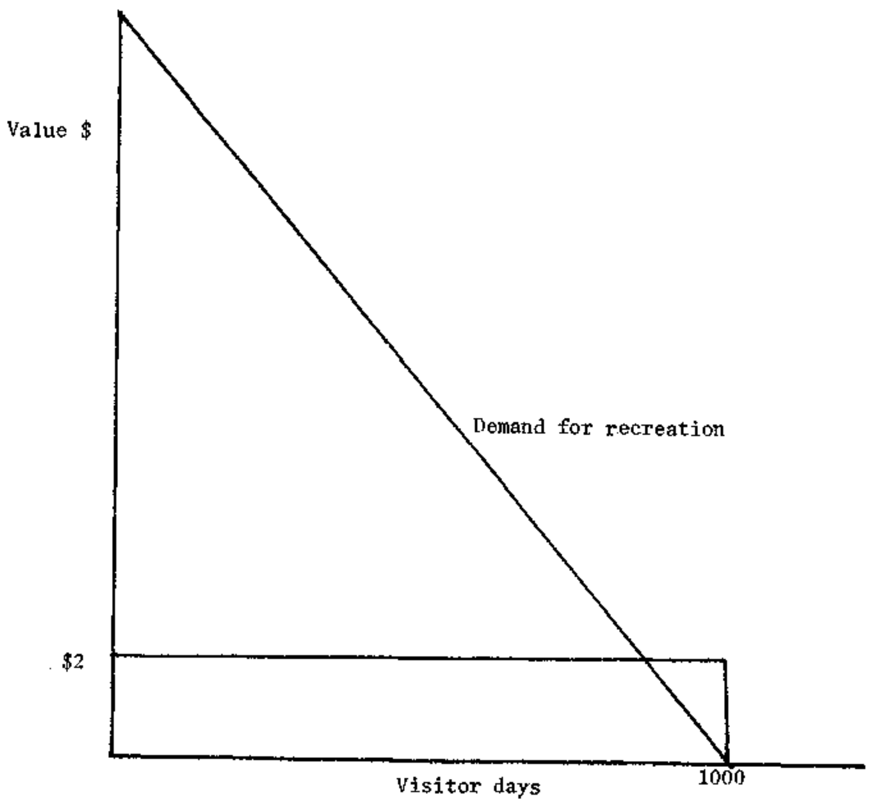
The alternative uses of a wild river for electric power generation or as a natural environment illustrates the differences between amenity uses and extractive uses. The supply of electricity can be provided by a number of sources besides hydro-generation. There are also other types of energy that are good substitutes such as natural gas or coal. In contrast, wild rivers are fixed in supply although their services might be expanded by improved management. Technology can have an impact on increasing the supply of electricity by improving production and transmission methods. The natural services of wild rivers will not be increased by technology except through new management techniques. The demand for wild rivers has increased more rapidly than for electricity. The combination of these supply and demand conditions suggests that the value of the amenity uses of water will increase more rapidly in the future than the value of water used for hydro-power (Krutilla and Fisher, 1975).

Valuation Methods

Three procedures have been used in the past to value recreation benefits: (1) interim unit day values, (2) surveys of potential users, and (3) cost of travel.[4/] All three have weaknesses but the interim unit day approach is by far the weakest and is of little use in valuing other environmental resources (Dwyer, Kelly, and Bowers, 1977). The interim unit day procedure relies on a fixed value per unit recreation day selected from a range of values provided in the WRC's Principles and Standards. Unit values are provided for both general recreation and specialized recreation with the latter having values over three times larger. The interim unit day approach is at best based on the average willingness to pay as judged by the planners who pick the value. This will only approximate the total willingness to pay under unusual conditions. If the interim unit day value selected was $2.00 and the total visitor days were 1,000 the value of the recreation site would be $2,000. However, as shown in Figure 19, this would be a major underestimation of the area under the demand curve. One could also draw a situation where the interim day approach would provide an overestimate. Only with a great deal of luck will this approach even approximate the appropriate estimate of recreation benefits.

4/ A fourth possibility, which is similar to but less practical than the survey approach, is the voting procedure. Alternative proposals consisting of different environmental quality or recreation opportunities and associated tax increases would be placed on referendum vote. The elections would have to be conducted in a large number of jurisdictions each of which would have a different proposal for environmental quality improvement and tax increase. Each jurisdiction would vote yes or no on a proposal and provide one sample point. The data on environmental quality, taxes and socio-economic characteristics would be analyzed to determine the demand for environmental quality at various prices as measured by taxes. Voting can provide unbiased demand information when all costs are financed through the jurisdiction's taxes and all benefits accrue to voting residents and their families (Freeman, 1979, Ch. 5).

Figure 19. Recreation Interim Unit Day Value Compared to Area Under Demand Curve.



Travel Cost Method

The travel cost procedure for estimating outdoor recreation demand was popularized by Clawsen and Knetsch and has improved the estimates of recreation benefits. In essence the procedure uses the actual travel cost to a site plus time cost (leisure foregone and work opportunity costs) incurred during the travel as a proxy for the price of the recreation service.[5/] To do this they classified outdoor recreation into three major groups mostly based on two characteristics: (1) location and type of recreation involved and (2) pattern of use (day outings or vacations). The three groups identified are user-oriented areas (close to users), resource-based areas (where outstanding resources occur) and intermediate areas (day or weekend outings) [Clawson and Knetsch, 1966].

Clawson and Knetsch consider outdoor recreation as total experience. In other words, outdoor recreation involves more than the on-site experience. It includes time, expenses and satisfactions from (1) planning, (2) travel to, (3) experiences on site, (4) travel back, and (5) reflection. Usually some or all are involved in recreation activities. Planning and travel will be much more important in resources-based recreation as compared to user-based recreation.

The total recreation experience was the unit of analysis first used by Clawson and Knetsch. The demand analysis is done in terms of dollar costs per visit. To obtain a range of observations, differences in the number of visits and travel cost are calculated for zones of different distances from the recreation site. The effect of population distribution within each zone is removed by placing the recreation visits on a per capita or a per 1,000 population basis.

Persons close to the recreation site would have a lower cost (price) of using the site and, therefore, a higher use than those more distant. Figure 20 shows this relationship with a curve sloping downward to the right. Point "f" on the curve would represent people in an area close to the recreation site while point "a" is derived from an area far from the site. The value of the recreation (measured by the consumer surplus) to

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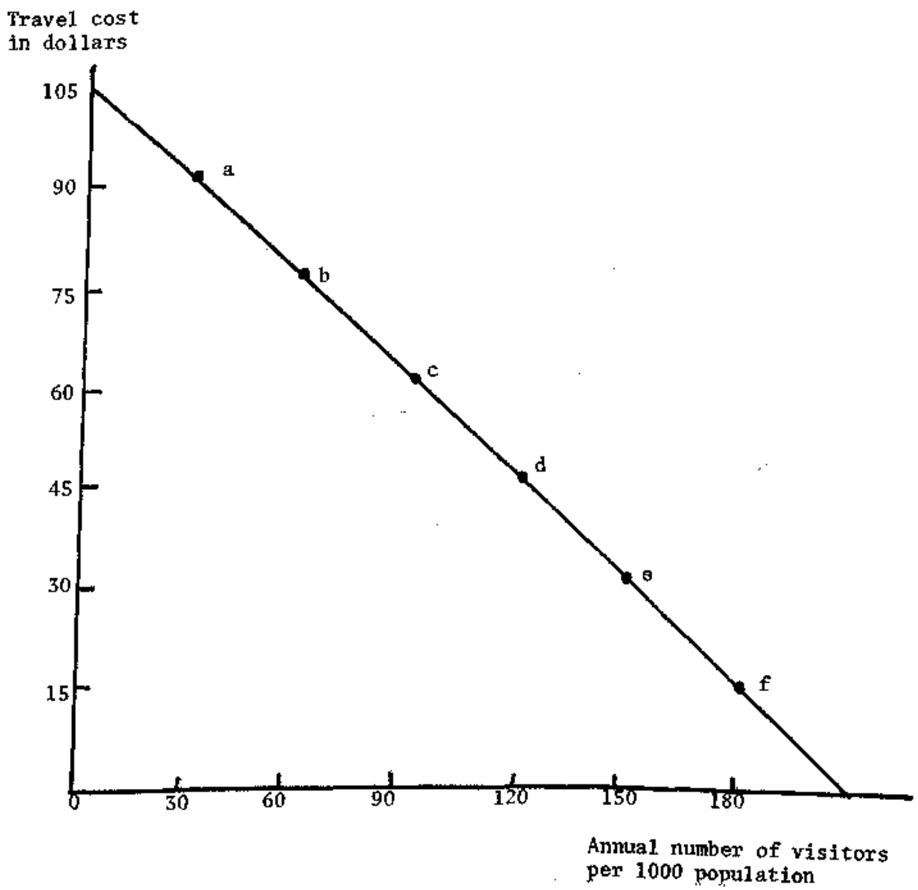
5/ As pointed out above placing a value on environmental resources such as recreation is complicated by the fact that these services are not exchanged in the market and are provided at zero or nominal prices. However, Becker, 1965, suggests a model that can be used to analyze recreation demand. Consumers are visualized as producing their own recreation because they must travel to the site before they use the service. He views consumption activity as the outcome of individual or household production processes combining market goods and time to produce the desired service. What makes recreation special is that a very large portion of the total cost of production is accounted for by travel cost (money and time). The nonexistences of market determined fees does not imply that the individual does not pay for using a recreation site. Rather, the price can be measured by travel costs (Cicchetti, Fisher, and Smith, 1976).

Figure 20. Total Recreation Experience Demand Based on Travel Cost.



people at location "f" is equal to the area, 15, f, 105 or 1/2 [(105 - 15) 180] 10 = \$81,000.[6/] This is the area under the demand curve and above the travel cost for location "f". The total value of the recreation experience is the summation of the consumer surpluses at each of the locations "a" through "f" times the number of 1,000 people at each location. The demand curve in Figure 20 is for 1,000 people and must be aggregated across the numbers of 1,000 people to obtain the total demand.

A demand curve for the specific site can be constructed assuming that rising travel costs associated with the increased distance from the site will influence the number of recreation visits in the same manner as any increased recreation cost such as admission charges. The demand for the specific recreation site is obtained by varying the admission charge. The first point on the demand curve, using the data from Table 17, is a summation of visits from zones "a" through "f" or 6,330 visits. This gives the point for a zero admission charge. The next point is derived by assuming a \$15 admission charge which raises the amount those in each zone must pay by \$15. One can infer from the demand curve in Figure 20 that the rate of visits would be 150 visits per 1000 at a travel cost of \$15, 120 visits per 1000 at \$30, etc. In other words, what rate of use is shown on the demand curve for a value equal to the travel cost plus the \$15 admission charge. Multiplying these visit rates times the population in each zone and adding, provides the number of visitors at a \$15 admission charge. Those in zone "a" would make zero visits, zone "b" 450 visits, zone "c" 300 visits, zone "d" 540 visits, zone "e" 1,680 visits and zone "f" 1,500 visits for total of 4,470 visits.[7/] The admission charge is raised another \$15 to obtain the next point on the derived demand curve and so on until the admissions charge of \$90 drives visits to zero as shown on Figure 21 and Table 18.

When other places are visited on a trip to the recreation site one should allocate part of the travel costs to these other places. The allo-

6/ The consumer surplus under the demand curve is based on 1,000 population per location. The actual population at location "f" is 10,000, therefore, the area under the demand and above the cost is multiplied by 10.

7/

$$\left(\frac{0}{1000} \times 12{,}000\right) + \left(\frac{30}{1000} \times 15{,}000\right) + \left(\frac{60}{1000} \times 5{,}000\right)$$
$$+ \left(\frac{90}{1000} \times 6{,}000\right) + \left(\frac{120}{1000} \times 14{,}000\right) + \left(\frac{150}{1000} \times 10{,}000\right)$$
$$= 0 + 450 + 300 + 540 + 1680 + 1500$$
$$= 4{,}470$$

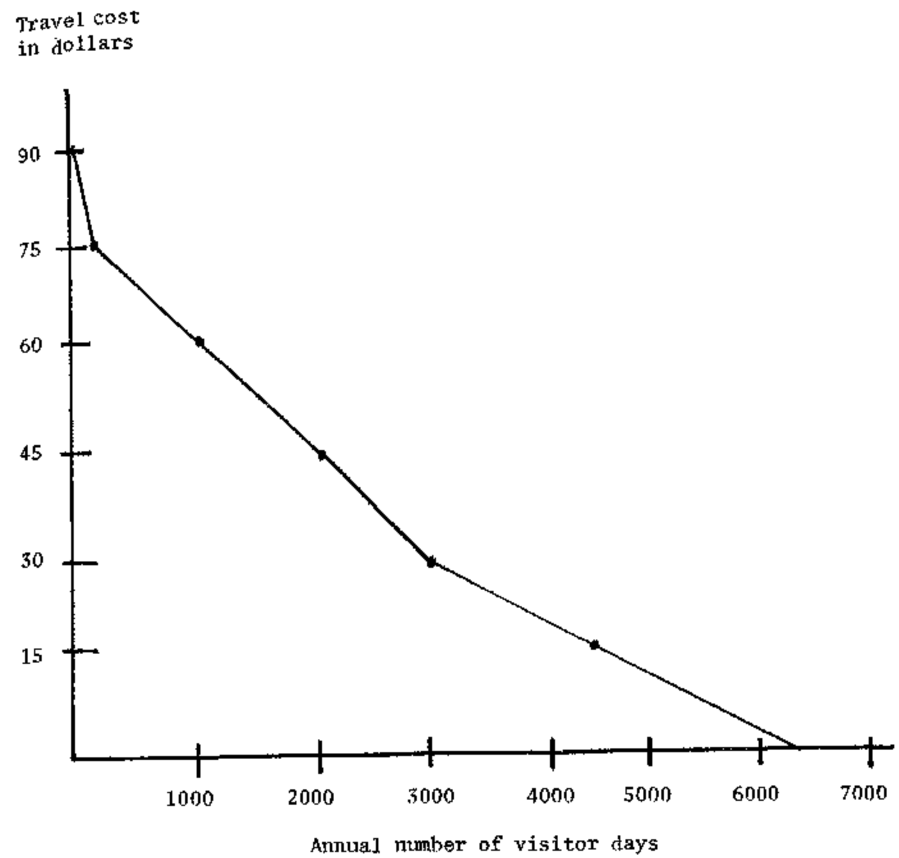
Table 17. Total Travel Cost and Visits to Recreation Site.

Zone	Population	Travel Cost	Total Annual Visits	Visits/1000 Population
a	12,000	$ 90	360	30
b	15,000	75	900	60
c	5,000	60	450	90
d	6,000	45	720	120
e	14,000	30	2,100	150
f	10,000	15	1,800	180
			6,330	

Table 18. Derived Demand for Recreation Site.

Administration Charge	Number of Visits
90	0
75	300
60	1,020
45	1,920
30	2,970
15	4,470
0	6,330

Figure 21. Derived Demand for the Recreation Resource.



cation is rather arbitrary but is better than ignoring the problem. However, for many intermediate recreation areas only one site is visited and the problem does not arise.

Intermediate recreation sites have another characteristic which make them easier to value. People tend to stay approximately the same length of time at this class of recreation. If the length of stay varies significantly among users, the travel cost method is difficult to apply. Different lengths of stay at a site imply either different quantities of recreation consumed or different classes of recreation services. Longer stays may even be substituting for additional visits. It seems unlikely that the length of visits would be evenly distributed among the various distance groups.

The alternative of measuring recreation by days of usage faces another problem. The travel costs are not variable with the number of days spent at a recreation site. The cost is the same whether the visit is for a day, a week or a month.

The travel cost method will underestimate the demand if visitors travel only relatively short distances to a site. Travel cost may represent only a small portion of their demand. McConnell, 1975, suggests that most visitors must travel at least 50 miles for the travel cost approach to be applicable.

The above procedure for estimating the derived demand also does not account for a number of shifters such as income and taste. Estimating the benefits from recreation depends on the ability to identify and quantify the relationships between the levels of observed use and the various factors influencing use. This is necessary before one can isolate the relationship between travel cost and use.

The factors influencing the use of a given recreation site include: (1) alternative sites or opportunities available, (2) characteristics of the site and locations, such as size and attractiveness of site, (3) the socio-economic characteristics of the population of potential users such as income, leisure time, age and education, and (4) the distance or travel cost of the potential users from the recreation site. Alternative sites are likely to reduce the demand for the site under consideration, although some alternative sites may be complements. The larger and more attractive the site the higher will be the demand. The larger the population of potential users and the younger, the higher is their demand likely to be for the site.

With more leisure time and higher incomes, people will tend to engage in recreation at greater distances. The timing and amount of leisure influences the use of recreation. The shortened work day gives people more time to spend at user-oriented local parks and recreation clubs. Annual paid vacations have increased the use of resource-based recreation. Thus, future projections of recreation demand will be dependent on how leisure time is made available--three or four day work weeks or two month annual vacations.

These above factors can be combined into a model depicting their relationship to recreation. The model can then be estimated based either on time series or cross-sectional data. One fairly complete model can be written as follows: $V_{ij} = f(C_{ij}, P_i, Y_i, A_j, S_j, T_j, B_i)$.

Where:

V_{ij} = number of trips from population source i to recreation site j,

P_i = size of population at origin i,

B_i = size of population age 18-25 at origin i,

S_j = size of park j,

C_{ij} = cost of travel between origin i and park j,

A_j = alternative sites j,

T_j = an index of the attractiveness of each site j, and

Y_i = average income of population at origin i.

Recreation visits are primarily affected by size of population, age of population, size of park, travel cost, alternative sites, attractiveness of sites and incomes.

The relation between visits and travel costs provides an estimate of the recreation demand curve. Changes in the other variables will cause the demand curve to shift. The area under the demand curve can be used to estimate the benefits from having the recreation site. The same procedure can be used to value other environmental resources. In this case the question is how much are people willing to pay to travel to see or use these environmental resources?[8/]

There are several problems with this specification of recreation demand. First the time and money costs are not considered separately. However, when these two variables are both included in a model a high intercorrelation occurs which prevents an accurate estimate of individual effects. The alternative approach is to assume a particular tradeoff between the money and time constraints (Dwyer, Kelly and Bowers, 1977). This assumes that travel time is a disutility. However there may be cases where travel time through a scenic area provides a benefit to the traveler.

A second problem involves the impact of congestion which is not explicitly included in the model. Congestion can significantly reduce the benefits enjoyed by users at a given site. "If congestion is not taken

8/ A similar approach would be to estimate the demand for market goods and services which have substitute or complementary relationships with environmental quality. These might include household cleaning expenditures, additional repairs due to pollution and property value differences caused by environmental differences.

into account when a demand function derived from an existing site is applied to a new site, it must be assumed that congestion affects both sites in a similar manner and also that populations of both market areas have similar dislikes for congestion. Estimating the impact of congestion on willingness to pay for a proposed site is particularly difficult because the cost of congestion at an existing site may not be a useful guide. The survey method appears to be the most useful approach to evaluating the impact of congestion on willingness to pay." (Dwyer, Kelly and Bowers, 1977)[9/]

Finally as with the conventional goods, estimating the demand for recreation involves an identification problem. It arises because observations of price and quantity are likely to be points of intersection between the demand and supply functions. When data is collected on prices and quantities, one is not sure whether changes in the points reflect supply or demand responses. If the supply is changing fairly rapidly while demand is stable, time series data will trace out the demand curve. However, if the reverse is true, then the supply curve is traced out. Knowledge about the particular market can provide a good indication of which function is being estimated.

During the late 1960's and the 1970's, demand appears to have changed more rapidly than supply indicating that one is likely to be tracing the supply curve rather than the demand curve. The use of cross-sectional data from areas with different supply conditions is one way around this problem. Data can be collected from available recreation areas that are good substitutes for the proposed site. The travel cost method works best for site specific recreation such as skiing which is already available in other areas.

If there are no available sites that closely resemble the proposed site, a survey of potential users can be conducted. With the data from actual operating sites one can construct a demand curve based on what people actually have paid. In contrast the survey of potential users has the same basic problem as the bid method. The demand curve is based on what people say they will pay rather than what they actually pay.

Survey or Bid Method

If information concerning travel cost is limited or felt to be an inaccurate measure of willingness to pay, the survey or bid technique can be used to estimate willingness to pay. The bid technique has been used primarily in evaluating the benefits from recreation and pollution abatement. The basic idea is to obtain from a sample of potential beneficiaries their willingness to pay for improving the environment. The key assumption is that the sampled individuals will do what they say they will do. The technique can be used to ask either how much is one willing to pay for an improved environment (compensating variation) or how much one will have to be paid to give up a clean environment (equivalent variation).

9/ Congestion will cause an underestimation of the demand for recreation. Higher fees will reduce use and congestion. Therefore the demand for the site will increase for the remaining users due to the decreased congestion. As long as congestion exists each point on the demand curve must relate to the level of congestion that will exist at that price.

The bid methods generally used involves asking the respondents to answer "yes" or "no" to the question "Would you continue to use this recreation site if an additional user fee of X dollars was levied?" The user fee or admissions charge is varied up and down until the highest positive response is obtained. This same procedure has been adapted to estimate benefits from the provision of an improved environmental quality. For the environmental improvement the question generally asked is "Would you pay X dollars to obtain the level of environmental quality shown in this picture?" An alternative question is "How much would you take to allow the level of pollution shown in this picture?" The latter question eliminates the income constraint and should provide a higher estimate of benefits.

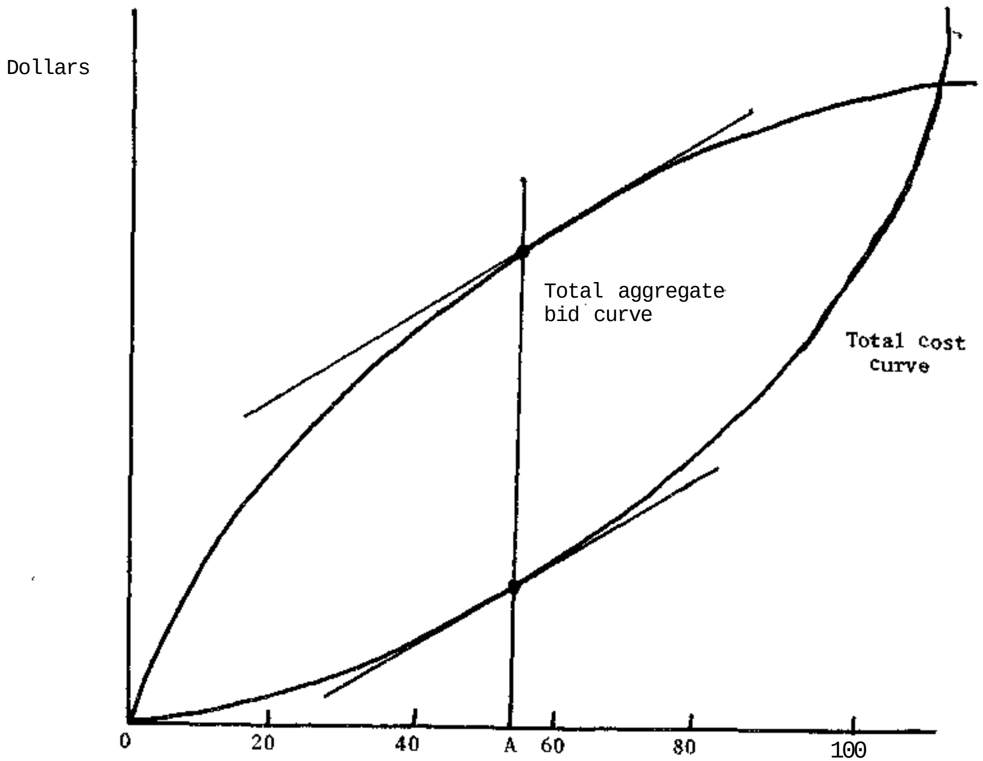
Several problems exist with the bid procedure. One is the possibilities of free riders. These would be people who assume the service will be paid for by others. They, therefore, indicate a zero or low willingness to pay for the service even though they would use the service and think it is valuable. Second, when individuals are asked how much they must be paid to allow pollution of their environment a number respond by saying infinity. Too many infinite responses make demand estimates difficult and raise some serious questions about the accuracy of the responses. Third, the situation posed for the people being interviewed must be realistic. For example, the method of payment for the services must be familiar to those being interviewed such as a sales tax or a user fee. Recreationists would be asked how high a user fee they would be willing to pay for clean air while consumers of electric power generated by coal would be asked how high a sales tax they would be willing to pay for clean air. If the situation is not realistic the response is not likely to be realistic.

The responses collected from a survey of people's willingness to pay for different levels of environmental improvement are used to construct benefit or bid curves (see Figure 22). these curves are simply the combinations of dollars and environment about which the consumers are indifferent. The curves pass through the initial environmental state, zero in Figure 22, with dollars on the vertical axis and environmental quality on the horizontal axis.[10/] It must pass through the origin since a rational person would bid zero for zero environmental improvement. These individual benefit curves are aggregated over the appropriate population to determine the total benefits or social value of the environmental improvement. This is a vertical summation since most environmental improvements are public goods and nonmarket goods (see Ch. 1 for definition of public goods).

An example would be a program to provide cleaner air. One could not exclude others from the use of the clean air and the added cost of another person seeing the landscape and breathing the air would be zero. In addition, the decision to have cleaner air is a group decision involving a community or a group of communities in a region.

10/ Individual bid curves are indifference curves with the numeraire good, the measure of value which can be in dollars, on the vertical axis and the public good (environmental quality) on the horizontal axis.

Figure 22. Optimum Level of Environmental Quality.



Environmental improvement in tons of pollution removed per year

Any environmental cleanup, air or water, will involve decisions concerning quality rather than quantity. This can lead to questions concerning the measurement of the quality improvement. For example, if the quantity of particulate air pollutants is used as a measure of air quality the conventional negative slope of the demand curve may not occur. This is because of the inverse relationships between visibility and concentration or particulate pollutants. Visibility increases at an increasing rate as particulate pollution is reduced. Thus, although diminishing marginal utility of visibility may exist, the increasing visibility resulting from reduced particulate influences the slope in the opposite direction (Randall, Ives, Eastman, 1974).

Once the survey data has been collected, the individual benefit or bid curves are aggregated across the population using the air. The aggregate bid curve represents the benefits from cleaner air. These benefits can then be compared with the cost of cleaning up the air. The optimum point would be where the marginal cost of additional cleanup is equal to the marginal benefits (first derivative of the aggregate bid curve) from the improvement in air quality (point A in Figure 22). This is the point where the difference between the aggregate bid curve and total costs are maximized.

Conclusion

Although both the travel cost method and the bid method have weaknesses both can provide reasonable estimates of demand or benefit curves. The methodology has now progressed far enough where both of these procedures should be preferred over the interim unit day approach. The only advantage of the latter is the low cost involved in obtaining the benefit values. If surveys are required to develop site specific travel costs or bid curves the cost of estimating benefit values can be significant. Thus, some general travel cost data or bid curves need to be constructed for use on proposed small recreation sites. However, for large sites the extra cost of generating site specific demand curves is probably warranted.

CHAPTER IX

FROM U.S. AGRICULTURAL RESEARCH*

Investment in U.S. agricultural research is substantial and continues to grow. Past studies have shown that agricultural research expenditures have had high rates of return. However, private investment in agricultural research is restricted since many of the research benefits cannot be captured by a private firm. Thus, the public sector must do much of the basic agricultural research.

This chapter briefly reviews approaches used to assess returns to U.S. agricultural research and explains the usefulness of project analysis in such evaluations. The analysis is then applied to the Land Grant University's 1978 federal budget requests for additional corn and soybean research funds.

A Review of Past Evaluations of Research

The first major attempt at quantitative evaluation of agricultural research investments was conducted by T.W. Schultz, 1953. He calculated the value of inputs saved in agriculture due to improved production techniques and compared this with the costs of research and development. His effort was followed by Griliches, 1958, who calculated the loss in consumer surplus that would occur if hybrid corn were to disappear. His analysis assumed that the adoption of hybrid corn shifted the supply curve of the product downward to the right. He estimated the returns in the two polar cases of perfectly elastic and perfectly inelastic supplies. In each case the area below the demand curve and between the original and the shifted supply curves constitutes the estimated amount of the returns.(see pages 25-6)

Peterson, 1967, generalized Griliches' formula for estimating consumer surplus and applied it to poultry research. He calculated the case where supply is neither perfectly,elastic nor perfectly inelastic and did not require a demand elasticity of minus one as Griliches' formulae did. Peterson, 1971, says that the biggest problem with the method that he and Griliches use (which he refers to as the index number approach) is to obtain a measure of productivity gain that reflects only the output of research.

In another study, Griliches, 1964, was perhaps the first to use an aggregate production function approach to estimate a marginal product of research. A marginal return provides more information about potential future returns than an average return for those studying the merits of

* This chapter is based on an article published in Agricultural Economics Research, October 1977, Vol. 29, No. 4, by K. William Easter and George" Norton.

new research projects. Evanson, 1967, also calculated a marginal product of aggregate agricultural research expenditures. In addition, he estimated that the returns over time first increased and then decreased with the high point occurring after about six years.

Fishel, 1971, describes a computerized model for collecting and processing information needed to evaluate research activities and to select an efficient allocation of resources. He stresses the importance of recognizing that there is a probability distribution around likely benefits from research. To obtain the information needed to arrive at a subjective probability distribution, scientists were asked to predict (1) the most likely outcome as well as high and low outcomes that would be exceeded only one-third of the time and (2) high and low outcomes that would be exceeded only in very exceptional circumstances. Application of the model required a fairly extensive set of surveys.

Bredahl and Peterson, 1976, look at the differences in rates of return to various kinds of agricultural research (cash crops, dairy, poultry, livestock) to determine if the overall rate of return could be increased by reallocating some research resources from the low to the relatively high return activities. They utilize aggregate agricultural production functions with research as a separate independent variable to estimate the marginal products of research.

Another type of research evaluation procedure has been used involving various types of scoring models. These models do not provide quantitative estimates of benefits and costs but rank the research alternatives. The National Association of State Universities and Land Grant Colleges and the USDA published in 1966 the results of a study of agricultural and forestry research programs in the U.S. The study evaluated the strengths and weaknesses in the research program, identified future research problems, and recommended a level of public research for the next 10 years. A major result of the study was the systematic classification of research areas. A simple scoring model was used to determine the extent to which each research priority area met certain criteria. Each specified criterion was then given a weight in terms of importance. This system was used to bring out facets of a problem that otherwise might have been overlooked but it was not employed as the basis for a mathematical allocation of resources.

Another study which used a simple scoring scheme to rank research problem areas was done in Iowa to aid in the allocation of resources at the Iowa Experiment Station (Mahlstede, 1971 and Paulsen and Kaldor, 1968). This study was one of the first to give explicit consideration to the importance of the probabilities of success of a research project.

The majority of agricultural research evaluation studies have fallen into three basic classes: (1) the study of returns to aggregate agricultural research; (2) the study of returns to research on individual commodities; and (3) the use of models which are designed to provide a ranking of alternative research projects or problem areas within an individual agricultural experiment station or nationally. Most of those studies in the first two categories are oriented toward the past while the third is oriented toward evaluating research for the present or future.

As a practical matter the Federal Government must evaluate budget requests for additional research funds annually. Can any of the techniques mentioned above play an important role in this evaluation process? The classification scheme developed in the USDA-SAES study aids in delineating where the funds might be used. Evaluations of returns to past research provide valuable insights into the benefits of future research. However, there has been little quantitative ex ante estimation of returns to research.

This chapter addresses two important questions confronting ex ante research. (1) What information is required to estimate benefit cost ratios for future research expenditures? and (2) How can this information be analyzed in a manner that is not misleading and yet is simple enough not to require excessive time and resources?

Corn and Soybean Research

The analysis is for the North Central region where the largest increase in corn and soybean research funds occurs. The analysis is concerned only with the new research requests in the following research program areas (RPAs):

(1) RPAs 207-209 - Crop protection from insects, diseases and weeds for corn and soybeans

(2) RPA 307 - Improvement of biological efficiency of crop production for corn and soybeans

Scientists from the Land Grant Universities provided estimates of yield and cost effects and adoption rates for technology developed with the new research funds. The low end of their range of estimates is used in the analysis (see Table 19). To calculate the benefit-cost ratios for each RPA the following assumptions were made: (1) a discount rate of 10 percent, (2) harvested acreage held constant at the 1975 level, (3) corn and soybean quality will remain constant or the increase in quality will not lower livestock feeding costs, (4) a corn price of $2.00/bu. and soybean price of $4.75/bu., (5) a probability of success of .8 for corn and .5 for soybeans, (6) research impacts limited to only the North Central region, (7) the lag and time of adoption as specified in table 19, and (8) all research benefits end in the year 2000.

Several of the above assumptions are probably conservative. The scientists estimated that production costs would decline as a result of the increased research. Yet, for simplicity in the analysis only increases in yields are counted as benefits even though cost reductions would afford the same benefits. In addition the prices assumed for corn and soybeans were based on projections which assume no increase in exports over the period.

Benefit Cost Estimates

The increase in research costs and in the future value of production are incorporated in a simple framework to arrive at the benefit cost ratios. Using corn for RPA 307 as an example, benefits can be calculated for the North Central region as shown in Table 20. Yields are expected to begin

Table 19. Information Required for Estimating Returns for Public Research to Increase Corn and Soybean Production.

	Crop	RPA	SY a/	$/SY (000)	Costs end	1975 Yield bu/acre	1975 area (1000 acres)	% change in yield by the yr.2000	Year avail.	Adoption Pattern (percent of total area) 1st	2nd	3rd	4th	5th
I	Corn	207-9	2.5	77.1	1996	88.9	54,722	2	1982	30	50	75	75	75
II	Corn	307	3.0	72.3	1993	88.9	54,722	2.25	1985	30	60	80	80	80
III	Soybeans	207-9	1.5	69.6	1996	31.1	33,557	1	1982	30	50	70	85	85
IV	Soybeans	307	3.0	74.4	1993	31.1	33,557	2	1985	40	70	90	95	95

a/ SY stands for scientist year which includes the cost of the scientist's salary as well as supporting facilities.

Table 20. Example of How Information was Used to Obtain the Benefits for North Central Region, Corn, RPA 307[a/]

Year	Bu/acre Increase	X	Probability of Success	X	Increase in Production Taking Into Account the Adoption Rate	X	Price/bu	Nondiscounted Benefits	X $\frac{1}{(1+i)^n}$	Discounted Benefits
								(1000 dollars)		(1000 dollars)
1978	0				0					
.	0				0					
.	0				0					
.	0				0					
.	0				0					
1985	.125	X	.8 = .1		(5472 x .3)	X	2 =	3283	X .4665 =	1,532
1986	.25	X	.8 = .2		(5472 x .3) + (5472 x .6)	X	2 =	9850	X .4240 =	4,177
.	.		.		4925 + (.8 x 5472)	X	2 =	18606	X .3855 =	7,173
.	.		.		4925 + (.8 x 10944)	X	2 =	27360	X .3505 =	9,590
.	.		.		.		.	.	.	.
2000	2.00	X	.8 = 1.6		66,201.5		.	132,421	X .1117 =	14,791
										$ 200,476

a/ NOTE: One could wait and not multiply by the probability of success and/or the price/bu until after calculating the discounted increase in production. The result would be the same and would facilitate sensitivity analysis.

to increase in 1985, rising to a level 2.25 percent above that of 1975 by the year 2000. That is a rise of two bushels per acre (88.9 times 2.25) or 0.125 bushels per year for 16 years. If the probability of success is 0.8 the expected gain is only 1.6 bushels by 2000.

The number of acres affected is based on the adoption pattern. In 1985, only 30 percent of the 54,722,000 acres will realize the expected increase of .10 bushels per acres. In 1986, 60 percent will have adopted the 1985 methods and 30 percent, the 1986 methods. The annual increase in production is multiplied by $2 per bushel to estimate the total receipts or undiscounted benefits for each year. These benefits range from about $3 million per year in 1985 to over $133 million in the year 2000. Using a discount rate of 10 percent and discounting back to the beginning of 1978, this future stream of income would have a present value of $200,476,000.

Costs are $216,900 per year for three SY's at $72,300 per SY starting in 1978 and ending in 1993. The present value of the stream of expenditures at the beginning of 1978 is $1,696,961.[1/] The benefit-cost ratio for corn from RPA 307 is: $200,476,000 divided by $1,696,961 equals 118.14. That is, one dollar of costs is expected to return $118, as viewed from the starting year of 1978. These benefits from corn research in the North-Central region are especially high because the yield increases occur over a large acreage.

The importance of the acreage affected can be illustrated by considering the Southern region. The Southern corn acreage in 1975 was 8.8 million acres, compared to 54.7 million in the North Central region. If the same yield increases are assumed for the Southern region, the benefit-cost ratio drops to 26 for corn in RPA 307. This is for the same research expenditure as in the North Central region and it assumes that the research affects only in the Southern region.

Sensitivity Analysis

The benefit-cost ratios should be tested to see how sensitive they are to changes in assumptions concerning the length of lags, probability of success, prices, and yields. If, for example, scientists were overly optimistic in their estimates of future yield increases the yield estimates may have been high. Past research productivity estimates made by Bredahl and Peterson, 1976, indicate that the yield increases are high. To adjust for this possible optimistic tendency, benefit-cost ratios were calculated with the yield increases reduced by 50 percent (see table 21).

1/ $\sum_{t=1}^{16} = \frac{C_t}{(1+i)^t}$ = $216,900 x 7.8237 = $1,696,961.

Table 21. Sensitivity Analysis of the Benefits and Costs of New Production Research on Soybeans and Corn.

	Corn		Soybeans	
	RPA 207-9	RPA 307	RPA 207-9	RPA 307
1. Under initial assumptions	137	118	45	40
2. With longer lags	117	102	38	30
3. With lower probabilities of success	86	74	27	24
4. With both longer lags and lower probabilities	73	64	24	19
5. With $2.50 corn and $5 soybeans	172	148	47	42
6. With 50 percent lower yield increase	69	59	22	20
7. With both lower yield increase and lower probabilities	43	37	13	12
8. With lags, probabilities, and yield changed	37	32	12	9

As a check to see if the reduced yield increases are reasonable, all scientists from the North-Central region working on corn in RPA's 207-209 and 307 were assumed to be just as productive as the new scientists. With yield increases reduced 50 percent and the lower probability of success, corn yields in 2000 would be 16 bushels higher because of the research. In other words, corn research in the land grant universities in the North-Central region would increase corn yields in the region by 18 percent in 25 years. Assuming only the 50 percent reduction in yield increases for soybeans, scientists from the North-Central region in RPA's 207-209 and 307 would increase yields three bushels, or 10 percent, in 25 years. Both outcomes seem quite reasonable in light of the past productivity of agricultural research expenditures in cash grains. The outcomes also indicate that the reduced yield increases are more realistic, particularly for corn.

Additional sensitivity analysis was done for changes in assumptions, concerning length of lags, probability of success and prices. First, the lag between the research expenditures and the availability of the results for adoption is extended from 7 to 10 years for RPA 307 and from 4 to 6 years for RPA's 207-209, which lowers the ratios (row 2, Table 21). Second, the probability of success assumption is reduced from 0.8 to 0.5 for corn and from 0.5 to 0.3 for soybeans. Again, the ratios are lowered (row 3). Third, we increase the length of lag and reduce the probabilities of success, both of which lower the benefit-cost ratios. Fourth, the prices of com and soybeans are increased to $2.50 and $5, respectively. These prices are closer to 1976 prices and raise the ratios substantially, as shown in row 5. Fifth, the yield increases are reduced by 50 percent, and the ratios are lowered (row 6).[2/] Sixth, the yield increases and the probabilities of success are both reduced, which further lowers the benefit-cost ratios. Finally, the length of lag is increased, the probability of success reduced, and the yield increases lowered by 50 percent. These changes lower the ratios substantially but, as indicated above, the reduced yield assumptions are more consistent with past trends. Yet the ratios remain high indicating research has a high payoff over a wide range of assumptions.

Distribution of Benefits

The benefit-cost ratios say nothing about the distribution of those benefits between farmers and consumers. Benefits and costs of increased production are passed along to society in many ways. The additional corn and soybeans will move through markets and generate employment as well as other economic activity. Increased supplies will create downward pressure on prices which reduces the value of the increased production to farmers and raises the benefits to consumers.

2/ A 50 percent reduction in the acreage affected by the new research would have the same impact as the yield reduction. However, the adjustment implied by such a large reduction in acreage would mean an increased rate of farmers moving out of agriculture and more declining rural communities.

Lower corn prices cause downward pressure on livestock prices as feed becomes cheaper. The impact of lower livestock prices spreads to the wholesale and retail sector and benefits consumers. Lower soybean prices have a similar effect on livestock prices and also affect the markets for margarine, shortening, and salad oil. The effects spread through a wide portion of the agricultural sector and to a certain extent the foreign trade sector as well.

To help measure the distribution of the research impact, estimates published in a report by the National Academy of Sciences, 1975, are used. For that study, several econometric models were combined to obtain empirical estimates of the effects of pest control on soybeans and corn. Estimates are made, based on this report, of the effects on prices in the feed/livestock/meat economy of a 3 percent increase in corn and soybean production (see table 22). These figures are not intended to be precise calculations, but rather approximations to show the types of changes that would result from an increase in corn and soybean production due to additional research. The biggest impact is on prices farmers receive, wholesale soybean oil prices and retail prices of oil products.

Because the increase in production generally causes a corresponding decline in price, consumers are the major beneficiaries. To illustrate, assume the initial price of corn is $2 per bushel and production is 5 billion bushels (see figure 23). If production increases 3 percent, the price of corn drops approximately 3 percent to $1.94. The research effort increases production as shown by the shift in the supply curve from S to S'. Consumers gain A + B in consumer surplus from the increased production and lower price. The change in gross returns to producers is represented by the gain of C minus the loss of A. Note that we are comparing the change in consumer surplus with the change in gross returns to producers and not with "producers surplus." Quantitatively, the following effects have occurred: (1) the 3 percent increase in production means a gain of 0.15 billion bushels of corn, (2) the price drop of 3 percent means a decline from $2 to $1.94, (3) the gain in consumer surplus equals A + B ~ 0.06 x 5 billion bushels + (0.5) (0.06) x 0.15 billion bushels = $304.5 million, (4) the change in gross returns to producers equals C-A which equals $1.94 x 0.15 billion bushels ($291 million) - $300 million = -$9 million. In summary, consumers gain $304.5 million in consumer surplus while producers lose $9 million in gross returns.

As with corn, the price effect of the increased production of soybeans almost offsets the production effect, leaving gross farm income from soybeans virtually unchanged. The price effect is especially strong for soybean oil and this spreads into the fats and oils sector (see table 22). The long run effects on livestock is half of 1 percent or less.

The analysis of corn and soybean research shows that there will likely be a high return with effects spreading throughout the feed/livestock/oils sectors. In the end, the consumers will likely be the major beneficiaries. However, to the extent that exports are price responsive, the price effects will be smaller, and the farmers will benefit more. There will also be an increase in foreign exchange earnings if export demand is elastic.

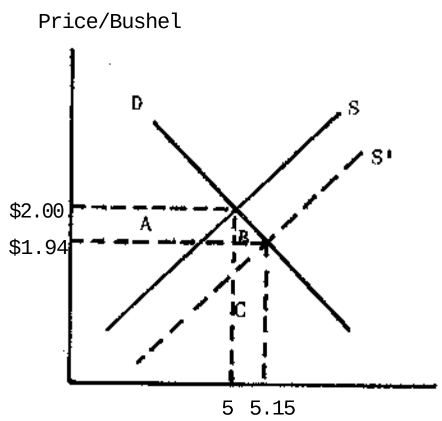
Table 22. Estimated Changes in prices due to a Three Percent Increase in Corn and Soybean Production for the U.S. [a]

Item	Corn	Soybeans
	% change	
Prices received by farmers	-3.1	-2.9
Soybean meal prices at wholesale	—	-1.5
Soybean oil prices at wholesale	—	-4.5
Price of feed cattle	-1.1	---
Retail price of beef	- .93	- .06
Farm price of pork	-1.3	- .24
Retail price of pork	- .72	- .15
Wholesale price of broiler chickens	-1.6	- .54
Retail price of chickens	-1.2	- .39
Retail price of eggs	-1.1	- .21
Retail price of margarine	—	-3.7
Retail price of shortening	—	-6.3
Retail price of salad oils	—	-4.3

[a] Source: Based on estimates in National Academy of Science Report, 1975.

— not applicable.

Figure 23. Impact of Research on U.S. Corn Production



Livestock

The benefit cost framework applied to corn and soybeans can be generalized to many cash grain and other crops. It can also be useful for analyzing livestock research although the types of benefits may be more difficult to quantify.

The benefits from beef cattle research might be measured in terms of increased reproductive efficiency, reduced cow maintenance costs, lower costs per pound of gain or improved meat quality. A good starting point would be to focus on the costs per pound of gain. Swine research benefits would be quite similar with increased reproductive efficiency and lower costs per pound of gain being important measures of benefits.

For dairy cattle the measurement problems will be a little different. The most important output is milk rather than meat. Thus milk production per cow would be the primary measure. Reproductive efficiency and percent butterfat should also be considered.

Research to improve animal health will likely be important for all classes of livestock and will be reflected in several of the benefit measures. For example, improved animal health could improve reproductive efficiency and reduce the cost per pound of meat or milk.

Rural Development

Still more difficult to evaluate is the rural development research and extension efforts. Title V of the Rural Development Act of 1972 provides special funding for research and extension programs for rural

development. The primary objectives of the Rural Development Act are to: increase employment and income opportunities, improve essential community services and facilities, improve quality of life, improve housing and enhance those social processes necessary to achieve these objectives.

To evaluate impacts of the Rural Development Act, cost effectiveness analysis is probably more feasible than benefit-cost analysis. For example, it is much more difficult to put a dollar value on improved land-use regulations than on an additional bushel of corn. On the other hand, if an improved regional transportation system leads to a measurable increase in jobs and incomes, benefits could be valued in dollar terms. Still measuring benefits on a regional basis is a risky proposition because of the possible loss of jobs and incomes in other regions. In general, then, it is more realistic to expect cost-effective analysis to be the primary means of evaluating rural development research and extension.

To apply cost-effectiveness analysis to future budget requests for rural development research and extension will involve three kinds of information: (1) a listing of specific research and extension objectives, [2) a cost breakdown by objectives (how much will be spent to meet each objective), and (3) a display of projected outcomes in dollar terms, if possible, or in physical terms. Finally an attempt should be made to compare the cost of these projected outcomes with alternative methods of obtaining the same results.

The objectives and cost information should come from the budget proposals. The possible outcomes could be obtained from social scientists working on similar problems. Alternative methods might also be obtained from social scientists. However, in many cases, this information will be location specific and the evaluation may involve numerous potential outcomes.

Conclusion

The application of benefit cost analysis to future Land Grant Universities' budget requests for agricultural research and extension will be a major task. Yet the task seems feasible particularly for crop and livestock research. Policymakers can be presented with a range of possible returns under varying assumptions. One of the keys to this type of analysis is the cooperation of the scientists and social scientists in providing estimates of potential outcomes. Still rural development research results are going to be difficult to quantify and are a much more heterogeneous product than crops and livestock research.

CHAPTER X

EXTERNALITIES: THE DIVERSION OF THE CHICAGO RIVER*

This chapter diverges from the main approach of the bulletin, ex ante project planning and analysis, by reviewing a project from the ex-post side. It is not intended to determine whether planning expectations and estimations were born out. Rather it is a look at a broad sweeping and complex externality issue. The external costs incurred and benefits conferred by the project will be discussed. This will allow the reader to get a general view of externality issues which was first discussed in Chapter I.

The Chicago Diversion

The city of Chicago occupies an area of flat terrain at the south-west corner of Lake Michigan in the Great Lakes Drainage Basin. Prior to the 1900's, Chicago, unlike many other populous cities, lacked a major waterway from which to draw its water supply and flush its wastes downstream, thus protecting its water supply. From its inception, Chicago drew its water from Lake Michigan and dumped its wastes into the Chicago River running through the heart of Chicago and, prior to 1900, into the lake. The problem was obvious: Chicago was polluting its own water supply. The problem intensified as the city grew, and in 1885 a typhoid and cholera epidemic claimed 12 percent of the city's population. An immediate and lasting solution was paramount.

The Mississippi Drainage Basin is separated from the Great Lakes Drainage Basin by an eight foot ridge located 12 miles to the west of Chicago. Engineers reasoned that a canal could be constructed which would link the Chicago River to the Illinois River, which flowed westward to the Mississippi, at Lockport, Illinois some 30 miles southwest of Chicago. The canal would be cut deep enough to reverse the flow of the Chicago River, made possible by Chicago's higher elevation relative to the area west of the divide. Thus, the Chicago River would flow away from Lake Michigan into the Illinois River. The city's water supply would be rendered safe. The mammoth and costly project was completed in 1900 and the flow reversed.

It is important to note that in the late 1800's project planning and analysis was not as it is today. Project analysis was not employed as a measure of the project's worthiness and as a result external impacts were not incorporated into the decision making process. While benefiting Chicago to an egregious extent, the project had significant impacts upon the region stretching west to the confluence of the Illinois and Mississippi Rivers, and east as far as Montreal.

* This chapter was written by Richard J. Magnani based on a Plan B paper done for Agricultural Economics 8-264 and 8-364.

The Chicago Project Externalities

Chicago can be considered a large public industry producing a public good (diverted water) indigenous to the city. Chicago pimps water out of Lake Michigan and discharges water down the Illinois River affecting institutions and residents in both regions. Since residents in these regions are outside Chicago's jurisdiction Chicago has no incentive to adjust its diversion by incorporating the external impacts in its diversion decisions. Doing so would internalize the effects. Since expanding Chicago's jurisdiction is not a feasible alternative one of the other mentioned alternatives would be outright prohibition of the diversion. This has been attempted by the Great Lakes States many times in legal actions since 1900 but has been unsuccessful in each case.

The solutions (partial solutions) presently employed are regulation of the diversion (as stipulated by a U.S. Supreme Court decision) and preventative devices in the form of waste water treatment facilities in Chicago which work to cleanse the water reaching the Illinois River. Voluntary agreements have not been successful and tax/subsidy solutions have not been attempted.

Models of Individual Externalities

A simplified economic model provides the theoretical basis to depict the divergence (if any) between the present diversion and the optimal diversion accounting for the externalities. This is accomplished in graphical form in stepwise fashion exercising supply and demand curves which incorporate total costs and total demand (willingness to pay) of and for diverted water. No attempt is made to quantify the demand and supply curves into functional forms, rather the relative positions of the various schedules are examined. Where appropriate, data is presented to illuminate the breadth of the external costs and benefits.

Chicago is limited, by a decree of the U.S. Supreme Court, to a diversion of 3,200 cubic feet/second or 2,070 million gallons/day. The major perceived variable costs to Chicago of producing the diversion include pumping the water from the lake, operating the canal locks, dredging the channels, maintenance costs, the sizeable water treatment costs (required in order to treat the used water before it is discharged as effluent into the Chicago River), localized flooding costs due to the diversion and localized pollution cost.[1/]

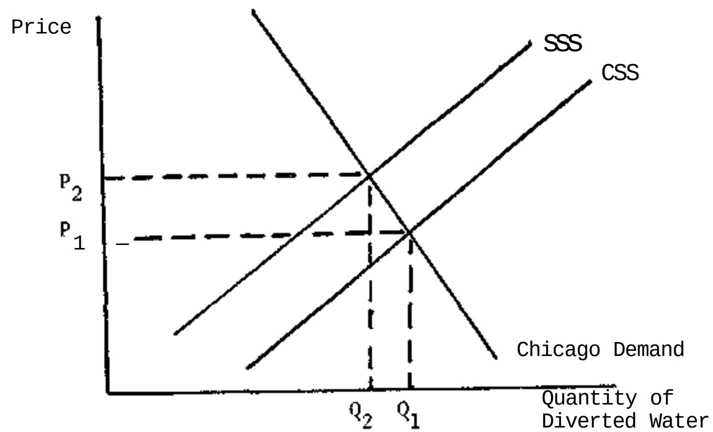
Chicago's variable diversion costs are depicted in the Chicago Supply Schedule (CSS) in figure 24.[2/] Chicago's demand for diverted water demonstrates the city's demand for an unpolluted water supply and the concomi-

1/ Pollution in Lake Michigan was the primary reason for building the canal. Presently pollution is a major problem in the Chicago River. Huge sewer and storm overflow interceptors built along with the river project to prevent wastes from reaching the lake instead allow vast amounts of pollution to reach the Chicago River system.

2/ The fixed costs of the original project are considered sunk costs and excluded.

tant absence from disease. Implicit in this demand is the complex dollar evaluation of human life and health. Also included is the demand for domestic, municipal, and industrial water uses. At least a portion of the demand curve is likely to be inelastic due to the water's function as a basic necessity.

Figure 24. Diverted Water Supply and Chicago Demand.



The supply curve SSS includes the external costs to the Great Lakes States in addition to Chicago's variable diversion costs. The external costs accrue to commercial shipping and hydroelectric power generating enterprises.

Chicago's diversion of 3200 cfs causes a lowering of the Great Lakes as much as 2.76 inches, depending upon general seasonal or cyclical lake levels (Maris, 1966, p. 68). Lake Superior is unaffected since it is situated upstream from the other lakes.

The Great Lakes States represent one of the largest industrial concentrations in the world highly dependent on raw materials and the low water transportation cost of these materials. There are 275 U.S. Ports on the Lakes (other than Superior) to accommodate the transport vessels. Few of the ports are natural harbors, therefore, the Army Corps must dredge the harbors regularly. However, not all harbors (particularly the smaller ones) are dredged regularly and then some are only partially dredged. Complete dredging allows a fully loaded vessel ample draft clearance even at seasonally or cyclically low water levels.

The problem is lack of clearance for a fully loaded vessel. If the diversion causes a lowering of lake levels, situations arise where, in

combination with incomplete dredging, a vessel cannot carry a full load into some harbors. Additional costs are incurred by shippers who must make extra trips to haul "leftover" tonnage. Also, there are added costs to the Army Corps to increase dredging operations for harbor maintenance.

In the mid-sixties when the Supreme Court was hearing a case brought by the Lakes States against Chicago to reduce the diversion, the lake levels were at cyclically low levels. The shipping clearance problem was, therefore, aggravated at that time. The estimated costs to Great Lakes shippers was between $84 and $106 thousand annually.[3/] This estimate can be taken as conservative because the present fleet size composition has been changing from smaller to larger ships. Larger vessels require more draft which would result in even greater losses in the shallow harbors. Also, as shipped tonnage increases the extra hauling costs from partially loaded vessels increase.

A complicating factor in recent years has been the cyclically high lake levels which have resulted in a reduction in the external costs to shipping. The Great Lakes states have actually encouraged more diversion in order to reduce lake shore erosion. The external costs to shipping, then, are quite variable depending on cyclical lake levels, fleet size, ship numbers, value of cargo and the extent of dredging.

In addition to navigation costs, New York and Canada have claimed that the lowering of lake levels has caused a loss of electric power generated by large hydroelectric power facilities on the Niagara and St. Lawrence Rivers. Low lake levels lessen the flow through the plants and the full capacity of the facility is not used causing a loss of electrical energy production.

The measure of the loss of energy from a hydro facility is the cost of capacity and energy supplied at an alternative steam plant powered either by fossil or nuclear fuels. The most economical alternative source of power is from coal fired steam plants. An estimate of the cost of the lost power for the New York plants was made in 1966 and pegged at $3 million (Maris, 1966, pp. 293-330). No estimate was available for the Canadian facilities. Recent high lake levels, of course, result in a reduction or elimination of the cost of lost power since the plants have available the necessary flow for full or near full capacity generation.

Consulting Figure 24 again, the external navigation and power costs are added to the Chicago supply (CSS) to obtain the Social Supply Schedule (SSS) which lies above and to the left of the CSS. If the lakes are at extremely high cyclical levels the external costs will approach zero, or if the lakes are at moderate to high levels the SSS curve will be positioned only slightly above the CSS.

Chicago perceives only the CSS or internal diversion costs and, therefore, would use Q_1 quantity of water. If Chicago included the external

[3/] No figure for additional dredging costs was available.

costs to Great Lakes shippers and power producers the SSS would become the relevant supply schedule, and the quantity of diverted water demanded would fall to Q_2.

External benefits have an opposite effect on the quantity of water diverted. Shorefront properties on the Great Lakes are subject to erosion from wind driven waves and localized flooding which result in millions of dollars of damage each year to the 10,000 miles of lake shoreline in both Canada and the U.S. The diversion provides a benefit in reduced costs to shore properties by lowering lake levels, particularly in periods of high lake levels.

In addition to the erosion benefits, an external benefit is conferred upon downstream Illinois River residents, when the quantity of diverted water works to purify the pollution that Chicago discharges into the river system.[4] The diverted flow provides the media that carries the pollution downstream, but the flow (added to the Illinois River) increases the natural cleansing properties of the river and moves the pollution at a faster rate downstream. The extra flow increases the water speed which adds oxygen to the water allowing the water to more easily breakdown certain pollutants into less harmful substances. The added flow which moves the pollution downstream at a greater speed does not allow for a high degree of sludge buildup along the banks and bottom.

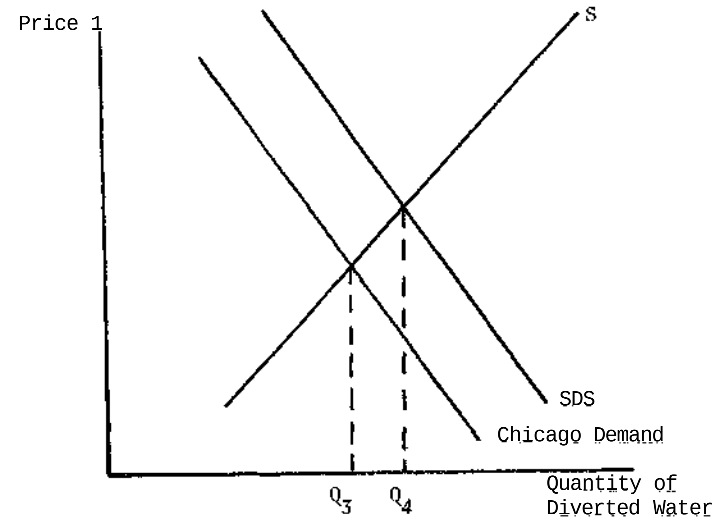
The benefits attributable to a reduction in the pollution are aesthetic, recreational and economic. The economic benefits are twofold. One, lower pollution levels reduce the water treatment costs for the major city on the river, Peoria, that relies on the river for its potable water supply. Secondly, pollution abatement is beneficial to the area's fishermen. Before the diversion the Illinois River supported one of the nation's richest fishing grounds. Commercial fishing is constrained substantially by pollution levels.

Recreation benefits would be in the form of increased sport fishing, which on the upper Illinois River has been largely eliminated, boating, picnicking, hunting, and swimming.

Chicago's willingness to pay to maintain an unpolluted interior waterway is represented by the demand curve for diverted water (see Figure 25). The social demand schedule (SDS) is to the right and above the Chicago demand by an amount roughly equal to the external erosion and downstream pollution abatement benefits. The SDS shows the willingness to pay for diverted water on the part of Chicago, Great Lakes property owners, and downstream residents.

4/ Granted, the Illinois River did not have Chicago's waterborne pollution to contend with prior to the diversion. In this sense the pollution costs incurred by downstream residents and establishments are an external cost attributable to the diversion. However, the project's completion is not a variable amenable to examination here. It is a fact of the past. The only variable under consideration is the amount of the diversion, not abandonment of the project.

Figure 25. Social Demand for Diverted Water.



Chicago failing to account for the external benefits would produce at Q_3, resulting in underdiversion. Accounting for the external benefits yields a diversion of Q_4. At extremely high lake levels the external erosion benefit would be high resulting in an SDS further out to the right. Lower lake levels would move the SDS closer to the Chicago demands Varying lake levels would not affect the downstream pollution benefit.[5]

An external cost in the form of downstream flooding fits into the framework shown in Figure 24. The increased flow in the Illinois River has significantly added to the flooding costs on the river. Unfortunately, a hydrologic engineering study would be required to determine how much less frequently levees and river banks would be topped if less water was diverted. Cropland along the mainstream and some tributary streams would be affected along with property damage to residences, municipal, commercial and industrial structures, transportation delays, lost profits due to shutdowns, etc. If this externality was accounted for the (SSS) supply curve would shift to the left and the diversion would be reduced.

5/ Downstream pollution should be lessened in the future as Chicago attempts to purify the water in the Chicago system. Advanced waste water treatment, instream aeration units and underground sewage overflow reservoirs all have the potential to dramatically reduce pollution throughout the entire Chicago and Illinois River system.

The final major external effects are benefits to navigation on the Illinois River and power generation. The construction of the canal system connecting the Chicago and Illinois Rivers allowed for a navigable throughway linking the Great Lakes with the Mississippi River.[6] The diverted water is necessary to provide the required nine foot deep channel throughout the entire range of the Illinois River and the canal system. Any reductions in the 3200 cfs flow would cause losses in barge traffic. Six locks and dams built before 1939 are also necessary to maintain the nine foot channel throughout the river due to intermittant dry seasons which could reduce the water depth in some areas and prevent water commerce even with the 3200 cfs flow. So both the locks and dams and the diverted flow are critical to water commerce. The navigation benefits accrue to many states in the midwest as well as to Chicago. Thus benefits are partially external to Chicago due to the impacts on transportation costs throughout the area.

The navigation benefits are measured by comparing the cost of transportation presently employed, barge, with the next best alternative. Since the majority of commodities shipped in this area is bulk, low value to weight, materials such as coal, limestone, gravel, metal scrap, etc. rail shipment would be the next best alternative. Truck shipping is uneconomical for long distance hauling so it is not a reasonable alternative. The value of this navigation benefit was estimated to be $151 million in 1980, growing to $168 million by 1985 (Magnani, 1977, p. 31].

If the navigation benefits were included in a social demand schedule an increase in diversion would be required since the new curve would be above and to the right of the old schedule. However, the Illinois River is presently maintained at a nine foot depth and an additional flow of water will not allow for greater shipping capacity or greater benefits. The present flow fully satisfies the depth requirement necessary to provide the external economy. This is shown in Figure 26 by the use of kinked demand curves. The added willingness to pay on the part of out-of-region shippers, for a navigable waterway will not require an increase in diversion.

If the quantity of diverted water was less than Q_5, such as Q_6 in Figure 27, the added willingness to pay for the diversion by the shippers outside the Chicago area would result in an increase to Q_7 if these benefits are heeded by diversion decision makers.

A hydroelectric facility on the Illinois River downstream from Chicago receives an external benefit from the diversion since the facility uses water flow not available prior to the diversion. Chicago also has a hydroelectric facility located on the Chicago River that uses the added flow. The two facilities have different generating capacities with the plant internal to Chicago, the larger of the two, underutilizing its generating

6/ Prior to the canal project an old narrow canal did connect Chicago to the Illinois River, but the size of the canal prohibited the use of motor driven barges.

Figure 26. Navigation Demand.

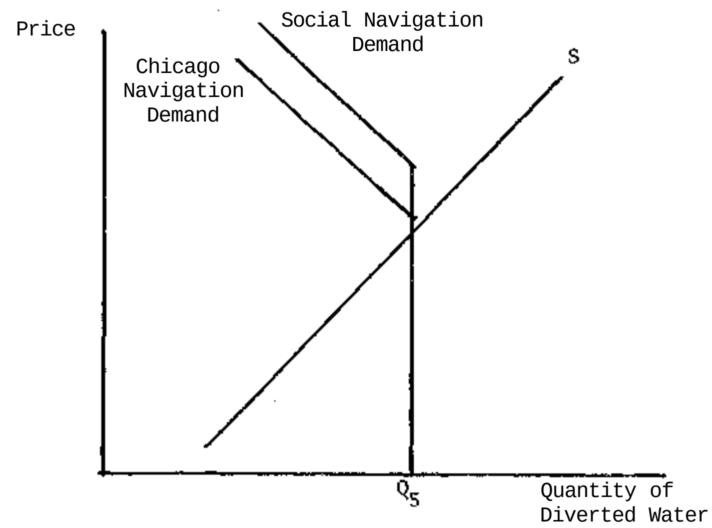
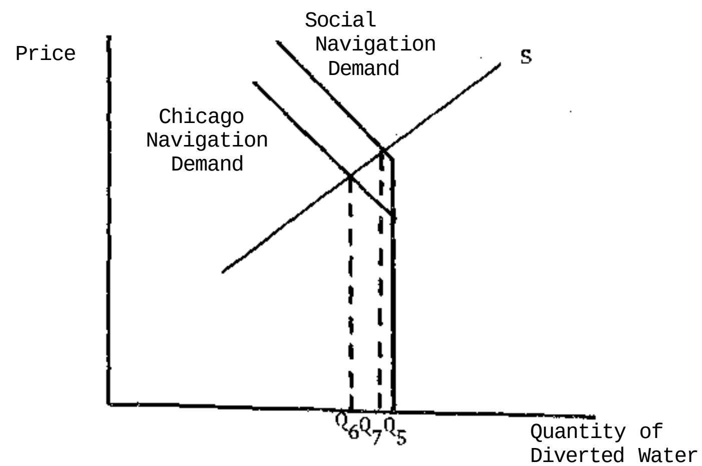
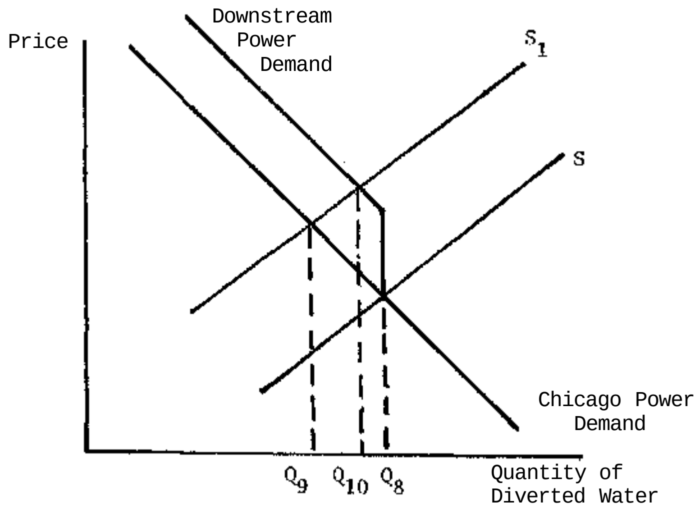


Figure 27. Optimum Diversion for Navigation.



capacity at the present 3200 cfs diversion. The downstream facility with just over one-tenth the generating capacity of the Chicago plant is used at full capacity at the present diversion level. The Chicago facility can use additional flow whereas the downstream facility cannot. The Chicago power demand schedule is not kinked due to the excess capacity of the Chicago plant enabling it to use quantities of water greater than Q_8, the present diversion (see Figure 28). At quantities diverted less than Q_8. the downstream power demand schedule lies above and to the right of the Chicago demand by an amount equal to the external power benefit. Therefore at quantities less than Q_8, say at Q_9, the willingness to pay for power generated downstream is great enough to require an increase in diversion to Q_{10}. At Q_8 the downstream demand is perfectly inelastic since to the right of Q_8 the downstream demand is fully satisfied.

Figure 28. Electric Power Demand.



The external power benefits from the small downstream plant have been estimated at between $15 and $92 thousand per year (Magnani, 1977, p. 48). This is small in comparison to the $140 to $263 thousand per year benefits from the Chicago plant (Magnani, 1977, p. 49). These estimates are based on the next best alternative method for producing the power, a fossil fuel plant.

Combined Externalities

Now that the individual externalities have been examined, the external benefits and costs can be combined and a picture of the divergence, if one exists, between the present diversion and the optimal diversion can be obtained. Unfortunately, the complexities and the sheer enormity of the

externalities make it difficult if not impossible to estimate all the costs and benefits. A unique solution is probably impossible leaving a range of possible solutions which, though imperfect, lend insight to the problem.

Figure 29 illustrates the combined external effects. First, the total Chicago demand schedule for water must be determined so that the external benefits can be added vertically to the basic demand curve. To obtain Chicago's total demand, TDC_1 in Figure 29, the following demands must be combined: the city's demand for unpolluted domestic water supply from Figure 24, the city's demand for a clean interior river system from Figure 25, the city's kinked demand for navigation water from Figure 26, and the city's demand for electrical power from Figure 28. These demand curves are summed vertically since the diverted water is a public good.

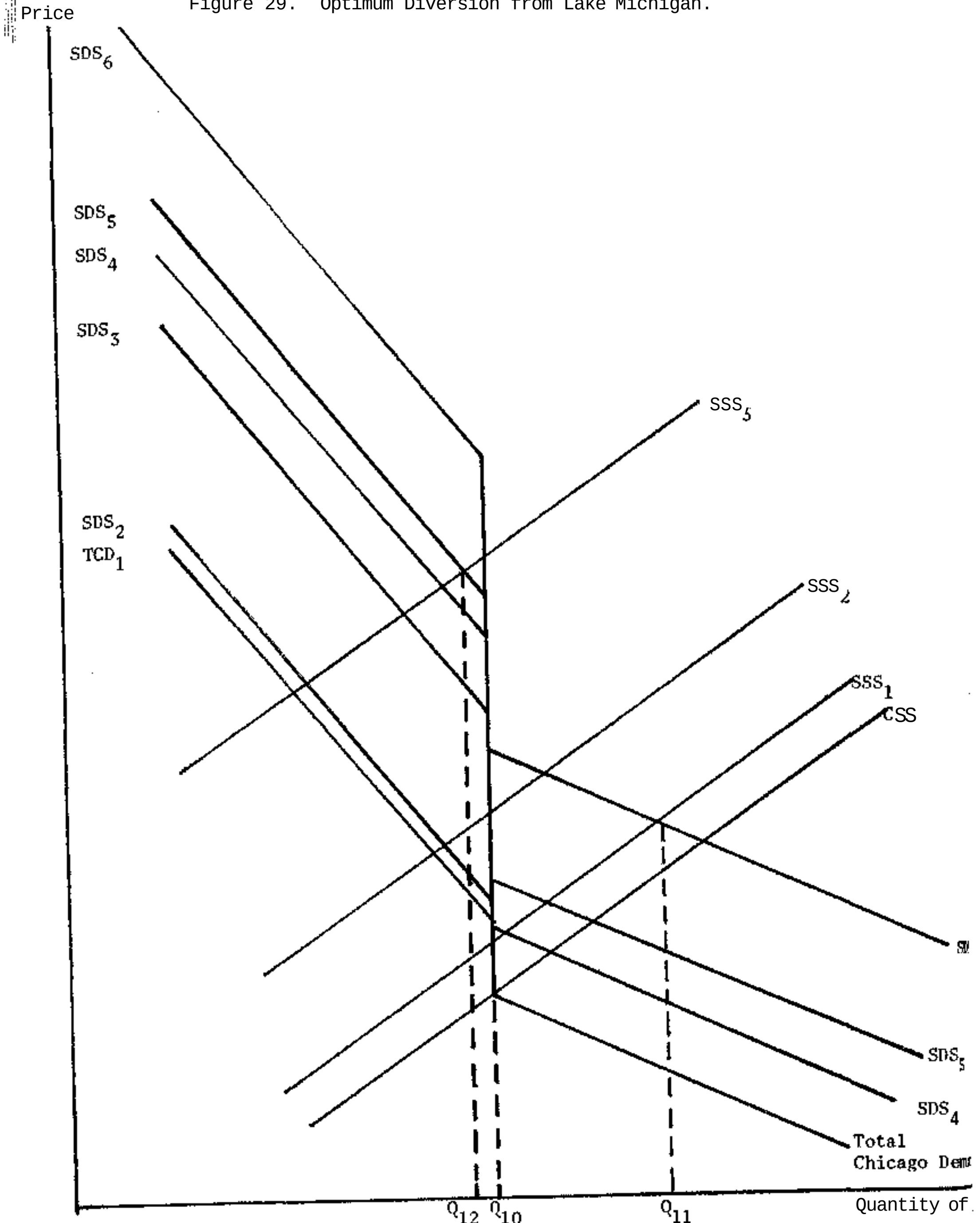
The external benefit from downstream power generation increases demand to SDS 2 which terminates at the present diversion, Q_{10}. The non-Chicago navigation benefit which also terminated at Q_{10} increases demand to SDS 3. As discussed above, these two external benefits are not increased by diversions of more than Q_{10}. The much larger vertical distance between SDS 2 and 3 vs. SDS 2 and TCD 1 is explained by the greater navigation benefit relative to the power generation benefit. External erosion benefits to Great Lakes property owners are included in SDS 4 which is shifted up on both sides of the kink since there are erosion benefits to an increase in diversion. Since these benefits were not quantified the difference between SDS 3 and 4 is arbitrary.[7]

The benefit in the form of downstream pollution abatement is shown by the difference between SDS 4 and SDS 5. SDS 5 represents the total demand for diverted water. Since the exact level of demand is not known let SDS 5 be the lower bound of diversion demand and SDS 6 be the upper bound.

On the supply side, we begin with the Chicago Supply Schedule (CSS), Chicago's variable diversion costs shown in Figure 24. To the CSS are added the external costs of: (1) flooding for downstream Illinois River residents and institutions, and (2) lower lake levels for shippers on the Great Lakes and for hydroelectric facilities in Canada and New York. As stated previously the costs to shipping and power are greatly dependent upon cyclical Great Lakes water levels. When lake levels are low, the costs to shipping are higher, while the external erosion benefits are lower. Downstream flooding costs are not correlated with lake levels. A lower bound estimate of the external costs is shown in the Social Supply $Schedule_1$ (SSS_1). The position of the SSS_1 is arbitrary but it represents

[7] It's certain that the erosion benefits do not outweigh the river navigation benefits. An Army Corps report stated that erosion benefits of nearly nine million dollars annually would accrue from an increase of 10,000 cfs in the diversion over present levels. (Correspondence with R.D. Slife, Detroit District Engineer, Corps of Engineers, January 1977.)

Figure 29. Optimum Diversion from Lake Michigan.



the lower bound when lake levels are high and costs low. An upper bound estimate reflecting low lake levels is represented by SSS_2.

Figure 29 depicts the range of optimum diversion as the demand schedules SDS 5 to SDS 6 and social supply schedules SSS_1 to SSS_2. Interpreting the more liberal estimate of the benefits and the more conservative cost estimates, SDS 6 and the SSS_1, the optimum quantity of diverted water becomes Q_{11}, a substantial increase over the present diversion, Q_{10}. In contrast, the more conservative benefits and liberal costs, SDS 5 and the SSS_2, results in an intersection of the two curves in the kinked region at Q_{10}. Thus, no change in diversion would enhance the allocation of the water resource. The reason for no decrease is simply due to the greater external benefits particularly transportation benefits compared to the external costs.

In order to obtain a quantity less than Q_{10} the external costs would have to be as high as SSS_3 which intersects the lower bound benefit curve SDS 5 at a lower diversion, Q_{12} This great a leap in external costs is not a likely event at present. The range of the optimum solution is likely to fall somewhere between Q_{10} and Q_{11}.

The range of results may not hold in the future as the positions of the social demand and social supply curves shift. For example, as the volume and value of materials shipped on the Great Lakes increases and ship size increases the external navigation costs will increase. The benefits to navigation on the Chicago and Illinois Rivers will also increase as shipped tonnage rises. As the number of residences and structures on the shores of the Great Lakes increase with development and population growth erosion benefits will assume larger proportions. External pollution costs may subside as more preventative measures are taken.

The reader must remember that the relative positions of the curves in Figure 29 may not correspond to reality. Assumptions and simplifications were necessary to render a view of the externalities affecting the optimal diversion. However, it does appear, based on the benefits and costs that can be estimated, that an increase in the diversion may be justified.

Estimated costs of $84 to $106 thousand annually for Great Lakes shipping, $3 million for Great Lakes power generation, and the unestimated downstream flooding costs are offset by the sizeable annual benefits for downstream navigation of $123 million, the $15 to $92 thousand for downstream generation power and the unevaluated Great Lakes erosion benefits and downstream pollution abatement.[8/]

8/ Some final benefit estimates comes from the Army Corps of Engineers. One study in 1973 estimated that an increase in the diversion of 10,000 cfs would yield a net benefit to Great Lakes power, navigation and shore properties of $3 million per year (Correspondence with R.D. Slife, Detroit District Engineer, Corps of Engineers, January 1977), The very large erosion control benefits during this period of high lake levels outweighed the costs to power and shipping. On the downstream side costs would result from flooding. Another Corps study estimated downstream flooding costs of approximately $100 thousand per year for an increase of 3,000 cfs (U.S. Army Corps of Engineers, 1975). Flooding costs would probably increase at a greater rate with diversion levels in excess of the additional 3,000 cfs.

Conclusion

This chapter highlights the wide range of impacts, both positive and negative, that a project can have beyond its main purpose. Although not all of the impacts are measured, their direction is clearly determined. By systematically trying to measure each external cost and benefit, the range of possible outcomes is narrowed. At the very least, one can conclude that the diversion should not be reduced.

Thus no matter how complex the natural resource investment issue, systematic economic analysis can provide important information to decision makers. To argue that one should not analyze the economic impacts of public decisions is to argue that decision makers should not make informed decisions. The only limitation would be the time and funds one can allocate to the analysis. The allocation for analysis should probably be closely related to the size of the investment and its potential impact.

CHAPTER XI

RISK AND UNCERTAINTY IN PROJECT ANALYSIS*

Earlier chapters have examined problems encountered in the identification measurement, and valuation of costs and benefits. This Chapter deals with the evaluation of investment projects in which there is a significant degree of uncertainty regarding future costs and benefits. What is meant by uncertainty and its importance in project evaluation is discussed first. Next is the major part of the Chapter which describes some practical methods for including uncertainties in project analysis. Finally, probability analysis is used to evaluate a small irrigation project in India.

Risk and Uncertainty

Most project analyses are done under the assumption that all costs and benefits can be estimated, though there is sure to be at least some degree of uncertainty about their future values. Of all the difficulties encountered in the application of project analysis those relating to uncertainty are common to most projects. In the literature on project evaluation risk and uncertainty receive relatively little attention. No consensus has emerged on the "correct" treatment of risk and uncertainty in either the theoretical or practical sense.

A useful distinction is often made between the concepts of risk and uncertainty. Risk may be defined as characterizing situations in which the outcome is not known in advance but the range of possible outcomes is known and the probabilities associated with these outcomes are either known or can be accurately estimated. The riskiness of an investment, then, can be thought of as the probability that the profitability of the investment will fall below some critical level. Risk situations are those which can be protected against by some form of insurance or pooling of the risks over a large number of people.

Uncertainty, on the other hand, refers to situations where the range of possible outcomes is known but the probabilities of the various outcomes occurring cannot be reliably estimated.

The risk-uncertainty distinction, though theoretically convenient, represents two extremes. The literature in investment evaluation usually recognizes the distinction but, ignores it in practice. Generally, the actual degree of knowledge about the probability distributions of the costs and benefits will fall somewhere between these extremes. Seldom

* This chapter is based on a paper done by Donald R. Genedek for Agricultural Economics 8-264 and 8-364, titled "Risk and Uncertainty in Project Appraisal," Winter 1975.

will the probability distributions be completely known, but generally one can expect to have some notions of their dimensions. Thus, the usefulness of the risk-uncertainty distinction in practical applications is limited. Consequently, this Chapter makes no strict distinction between risk and uncertainty and assumes there is some knowledge of the relevant probabilities.

Many of the practical texts take the position that, in general, risk is not a relevant factor for public investments.[1/] The argument is that the government should be indifferent to risk and evaluate investments based on the present value computed using the expected value of net benefits. The rationale for this position is that, typically, governments make a large number of diverse investments. The benefits from any given investment are, in general, small relative to the total output of the economy. Because of the large number and diverse nature of its investment, the government can be confident that every unexpected loss will be matched by an unexpected gain.

The above argument, though widely held, admits to some exceptions. Governments may not undertake enough investments to pool the risks adequately. Small developing countries are a case in point. Lack of a sufficiently large number of projects to balance out the risks may also be a characteristic of subcentral levels of government; states, countries, and municipalities. Another exception to the expected present value criteria is when the project involved is large enough to affect social welfare significantly, e.g. large inter-basin water transfers. It is enough to note here that in at least some instances risk is taken into account in project evaluation.

Uncertainties are reflected in the streams of costs and benefits, the prices at which these streams should be valued, the life of the project, and the value of alternative investments. Some of the major sources of uncertainty in investments are the following:

1) Technological change and development may alter the profitability of an investment substantially. New techniques or products may make the output of an investment obsolete.

2) Government actions or policy can have great effects on an investment's net return. Even government officials evaluating government projects cannot regard future policy as a certainty.

3) Natural factors, such as rainfall, are often very crucial to the costs and benefits of particular projects.

1/ Little and Mirrlees, 1975, and Unido, 1972, for example, both take this position.

4) Future supply and demand conditions of the inputs to and outputs of projects.

5) The future operation and maintenance of the project under consideration itself is subject to varying degrees of uncertainty.

6) Social and economic response to the project in the local area.

Methods of Adjusting for Uncertainty

A number of methods have been used in dealing with uncertainty in project evaluation. Some are practical in nature while others are mainly of theoretical interest.[2/]

The simplest way of making an allowance for uncertainty is to adopt a cutoff period. The expected life of the project is simply shortened for the project analysis. In the later years of an investment the net benefits are normally positive, so dropping off these benefits lowers the present value or internal rate of return. The rationale for this is that the later years are naturally the ones about which uncertainty is greatest. A related method called the payback period gives the project a certain number of years to recover the initial capital investment. If the capital is not recovered within the payback period, the investment is rejected.

These approaches are an attempt to eliminate uncertainty about the later years of an investment. However, the discounting process itself does this by attaching lower weights to the benefits accruing in later years. A second criticism of these and other ad hoc adjustments is that the amount of adjustment is arbitrary; there is no way to determine the appropriate adjustment systematically.

Another method of adjusting for uncertainty is the inclusion of a risk premium in the discount rate used. If the investment criteria is the internal rate of return, the risk premium is subtracted from the calculated rate of return.

Uncertainty is also included in project analysis by making conservative estimates of the net benefit flows expected to accrue to the project. Finally, uncertainty may be expressed as a lack of confidence in the results of or in the form of qualifying remarks about the estimated value of the project.

Sensitivity Analysis

Probably the most common approach to uncertainty in project evaluation is sensitivity analysis. The idea behind sensitivity analysis is to determine how sensitive a project's present value is to changes in the values of variables entering into the project analysis as shown at the end of Chapter IV.

2/ For a brief treatment of the more theoretical approaches, such as certainty equivalence, see Mishan, 1971.

To conduct a sensitivity analysis one isolates the key variables in the analysis. Then the value of each variable is ranged over its possible values and a separate calculation of the project value is made for each value. All other variables are held constant. The results may be expressed as absolute or percentage changes in present value for a given change. A graphical display can be constructed from sensitivity analysis of a variable such as rice yield (Figure 30). The switching value, the rice yield at which the present value of the project becomes zero, occurs at $\overline{X}$.

The probability that the rice yield falls below $\overline{X}$ gives an indication of the probability that the project's present value will be less than 0. Of course, this will be true only if the rice yield is the only sensitive variable.

The problem with sensitivity analysis is that generally there will be more than one variable to which the present value is sensitive. In this case interpretation of the results becomes much more complicated. However, sensitivity analysis is a very useful method for determining which variables require more study.

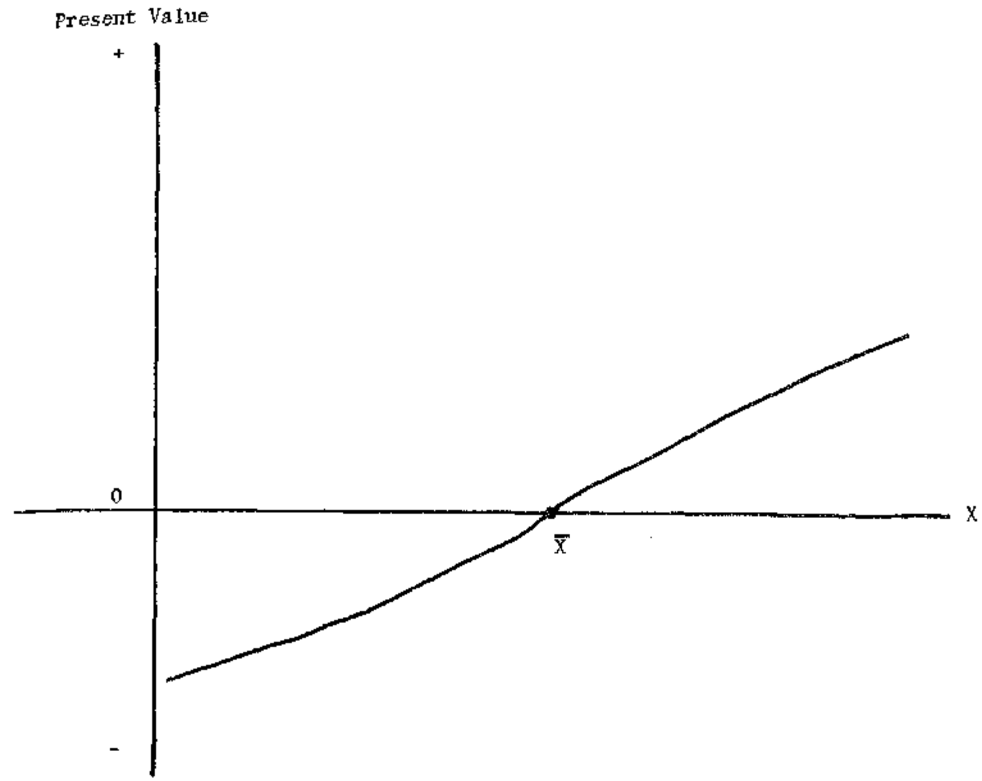
Probability Analysis

Another approach to the problem of uncertainty in project evaluation is the technique of risk analysis or probability analysis. Probability analysis is not a solution to the uncertainty problem, it is only useful as an aid to the investment decision. Unlike project analysis, it does not imply any particular decision criteria. In project analysis the decision criteria is simple: undertake any project whose present value is greater than zero (in the absence of capital constraints). Probability analysis essentially rejects the idea of a single estimate of a project value. Rather, it provides an estimate of project value over a range of probabilities. Judgments are made on the range of possible values and likelihood of their occurence for each of the uncertain variables in the analysis. These judgments, based on either objective or subjective information, take the form of probability distributions. These probability statements about the input variables are then combined, enabling one to make probability statements about the profitability of the project.

Two approaches to probability analysis have been developed: (1) a simulation approach which uses Monte Carlo methods, and (2) an analytical approach which derives the probability distribution directly.

Not all projects are suitable for probability analysis while for many it may be unnecessary. Before a probability analysis is conducted, a conventional project analysis should be done. On the basis of this many projects will be clearly acceptable or immediately rejected. Two situations in which probability analysis techniques may be particularly useful are: (1) When a project is marginal, that is, when the conventional project analysis is inconclusive, and (2) when there is a great deal of uncertainty about project costs and benefits. Even if a satisfactory value is obtained, these uncertainties may mean that the analyst has no confidence in the results.

Figure 30. Graphical Display of the Results of a Sensitivity Analysis.



1. The Simulation Approach

The simulation approach to probability analysis was originally developed by Hess and Quigley, 1973. The simulation method involves estimating the probability distribution of the present value or internal rate of return using Monte Carlo methods.

The Monte Carlo technique is a sampling procedure by which complex expressions involving one or more probability distributions can be evaluated. As with all sampling procedures, it is subject to some degree of error. Random values from these distributions are drawn and substituted into a model to derive a sample value of the desired distribution. This procedure is then repeated enough times to generate a statistically significant estimate of the probability distribution. Because of the large number of computations required, the use of a computer is generally necessary.

In principle, there is no reason why all of the variables in the analysis could not be included in a simulation analysis. In practice including all variables in the analysis may be unrealistic and in any case unnecessary. There will be little uncertainty about some variables and these can be treated as constants whose value is known. Other variables though uncertain, may have an insignificant effect on a project's present value. The first step in the analysis, then, is to identify the uncertain variables, that is, those with significant uncertainties. The logical way to identify the uncertain variables is through a sensitivity analysis. Each uncertain variable in the analysis then can be examined to determine if the project is sensitive to changes in its value.

Any variables that are strongly correlated should be considered together in the sensitivity analysis. For example, if the price of materials and their availability are correlated, then one would expect that if price is high there should also be a delay in obtaining the materials. Examining the sensitivity of a project to high price and low availability together may lead to different results than their consideration as separate variables.

The problem is aggravated by the fact that correlations are often difficult to detect and quantify. One solution is to limit the disaggregation in the analysis. Estimating the distribution of total construction costs, rather than separately estimating labor and equipment costs, implicitly includes the correlation between them. However, the more we aggregate, the more difficult the estimation becomes. This implies a tradeoff between the advantages of disaggregation in estimating probabilities and the elimination of correlation through more aggregation.

Another solution to the problem of correlation is contained in the concept of conditional probability distributions. The probability distribution of one of two correlated factors can be expressed as a function of the level of the other factor. For example the number of sunny days might be expressed as a function of rainfall. The computer would be programmed to choose a random value for annual rainfall and then use this value to determine the particular distribution used to generate the random value for annual sunny days.

Once the uncertain variables have been identified, no further analysis .. be necessary. If the only uncertain variable is construction costs, then estimation of the probability that this cost will exceed the critical level also estimates the probability that the project will be unprofitable.

With several uncertain variables the next step is to assign probab-ility distributions to the uncertain variables. These distributions can be based on either objective or subjective information or a combination of both.

The probability distributions chosen are not limited to any particular form. They may be classical distributions, normal, chi-squared, etc., or non-continuous forms such as the uniform or step-rectangular distributions. The choice is limited only by the characteristics of the variable under consideration. Some of the methods which have been used to estimate such probability distributions will be discussed later in the chapter.

The final step is the actual simulation. The simulation amounts to conducting a project analysis on the project for a large number of values for the variables. It may be thought of as a gigantic sensitivity analysis in which sets of values of the uncertain variables are combined with the constant variables in the project analysis. The particular sets of values used are chosen randomly from the estimated probability distributions.

The computer is programmed to generate a set of random values of the uncertain variables from their estimated distributions. Next, this set of values is substituted, along with any constant variable, into the project analysis model and the present value or internal rate of return is computed. This process is repeated a large number of times, as many as 200 or more. The results amount to a random sample of possible values of the present value or internal rate of return. From this sample an estimate can be made of the probability distribution of the project's value.

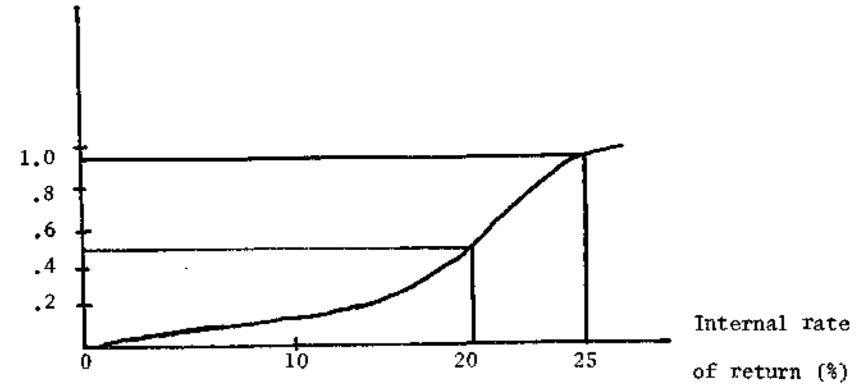
The sample size of the simulation is the number of times the above process is repeated. Determination of the appropriate sample size for any particular problem is a complicated statistical problem. A sample as small as 50 may adequately illustrate the distribution, though in practice samples of up to 1,000 are used.

The results of the simulation analysis can be displayed in the form of either a simple or a cumulative distribution (see Figure 31). A cumulative distribution shows the probability that the measure of project worth will be less than (or exceed) any given value. Both the present value and internal rate of return can be used in either of the distributions. The cumulative distribution is the more easily interpreted of the two.

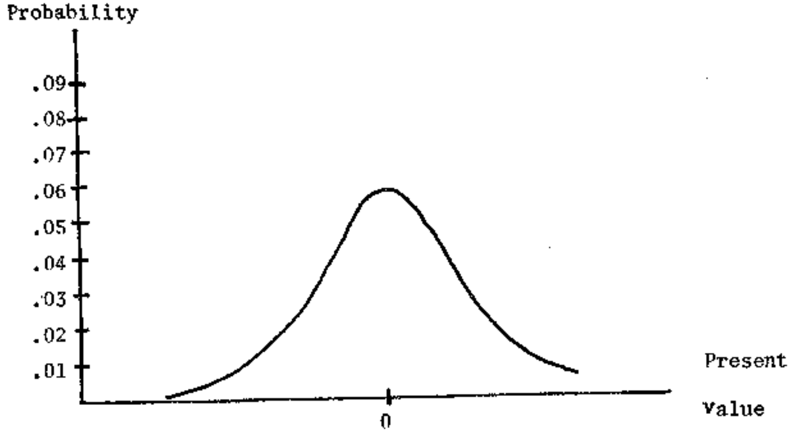
How these results will be used depends upon the relevant decision criteria. The interpretation of the information contained in the results is straightforward. For example, in part a of Figure 31, the probability

Figure 31. Graphical Display of the Results of a Simulation Analysis.

a: cumulative probability distribution of rate of return



b: Simple distribution of present value



of obtaining a rate of return less than 20 percent is 55 percent. If the cost of capital is equal to 20 percent, the project has a 55 percent chance of being unprofitable. On the other hand, the distribution indicates that the probability of obtaining a high rate of return, say 25 percent or greater, is only 5 percent. The probability of the internal rate of return falling within the range of 20 to 25 percent is 40 percent.

The simulation approach described above can be a powerful tool in evaluating investments under conditions of uncertainty. It enables the analyst to handle a wide range of probability distributions of the uncertain variables crucial to the profitability of the investment. Since its development, the simulation approach has been used in a number of applications. However, it is by nature an imprecise technique, providing only an approximation of the true probability distribution of the measure of a project's net return. The simulation method is also inadequate for describing the tails of the distribution though in practice the tails of the distribution are often not of interest.

2. The Analytical Approach

An alternative to the simulation techniques, that uses probability analysis of an investment is the analytic approach. First developed by Hillier, 1965a, 1965b, and 1969, and Wagle, 1967, the analytic approach provides an estimate of the mean and variance of the project's net return and is easier to calculate without the use of a computer. In applying the analytical method the initial stages of the analysis proceed along the same lines as in the simulation method. Once it has been determined that a probability analysis is to be done, the uncertain variables must be identified. Then the means, variances, and the nature of the relationships between the net benefit flows in each year must be estimated. From these a measure of the probability distribution of the present value or internal rate of return can be obtained.

The analytical approach to probability analysis is essentially an application of probability theory to investment analysis. An investment project can be thought of as being characterized by streams of costs and benefits. In each year the net benefits of the investment are the sum of the benefits and the costs. These costs and benefits can be thought of as components of the total net benefits in each year.

a. The Analytical Model

Let B_t be the total net benefits of an investment in year t. Then the present value PV_n of an investment with a life of n years is:

$$PV_n = \sum_{t=1}^{n} B_t/(1+i)^t \qquad (1)$$

where i denotes the discount rate.

If there is uncertainty about any of the components involved in B_t, then B_t can be thought of as a random variable. Assume that B_t is a random variable with finite mean B_t and variance B^*_t. Under this assumption the present value is also a random variable whose mean $\overline{PV}_n$ and variance PV^*_n can be derived.

First consider an investment with a life of n years. The expected value and variance of the present value of this project are derived as follows:

$$E\,[PV_n] = \sum_{t=1}^{n} \overline{B}_t/(1+i)^t = \overline{PV}_n \qquad (2)$$

$$Var[PV_n] = \sum_{t=1}^{n} B_t^*/(1+i)^{2t} + 2 \sum_{t \neq 1} \frac{cov\ (B_t, B_1)}{(1+i)^{(t+1)}} = PV_n^* \qquad (3)$$

where t and 1 are used for indexing the years of the investment 1, 2, ... n.

Thus, given the means of the net benefit flows, the expected present value of the investment can be derived from equation 2. This is exactly the same as computing the present value of the expected net benefits. Given the variances of the yearly net benefit flows and the covariance between each pair of years, equation 3 derives the variance of the present value.

Once the mean and variance of the present value of the project have been derived, an evaluation of the risk involved in the project can be made without further assumptions. The additional information provided by the variance enables one to evaluate the riskiness of the project.

Most of the classical probability distributions are completely specified by the mean and variance. Thus, if the form of the distribution of present value can be assumed to be of a particular form, say normal, then the mean and variance of present value specify the entire distribution. However, such an assumption is not necessary to continue the analysis.[3/]

Although evaluation of risk can be made without the assumption of a particular form for the distribution of present value, it is desirable if a distributional form can be specified. The normal distribution is

[3/] The mean and variance by themselves provide a basis for evaluating risk. Several types of calculations can be made to aid this evaluation. One of these, Tchebycheff's inequality, concerns the upper bounds on risk. This inequality states that if k is any positive number, then

$$prob[\,|(PV - E(PV)| \geq k \sqrt{Var(PV)}] \leq 1/k^2$$

for all k regardless of the form of the probability distribution of present value. For example, for k equal to three, the probability of the present value lying outside the range plus or minus three standard deviations is less than $1/3^2$ or less than .11. Alternatively, we can state that the probability of the present value lying within three standard deviations of the mean is greater than 89 percent. A weakness of the Tschebycheff inequality is that it is generally very conservative. If the distribution of present value is normal, then the actual probability of an observation deviating from the mean by more than three standard deviations is .0014.

widely applicable and is generally used when the analytic method of probability analysis is applied.[4/]

Even when conditions necessary to justify normality are not present, the distribution of present value can be expected to approximate normality reasonably well. Applications of the simulation approach to probability analysis often lead to results very close to normality. Pouliquen found that in most of the risk analyses conducted by the World Bank the distributions obtained were very close to being normal. He compared the distributions generated by simulation with normal distributions having the same mean and variance. In most instances the differences were not *large*. Pouliquen concluded that even though normality cannot be proved by the Central Limit Theorem, it may be a good assumption.

One disadvantage of the analytical method is that the probability distribution of the internal rate of return cannot be derived directly. If the internal rate of return R is the desired measure of project worth, its probability distribution can only be derived indirectly. The distribution is derived by seeing what values of the discount rate i make the present value zero.[5/]

b. Level of Estimation

The analytical model described above in equations 2 and 3 provides expressions for the mean and variance of the present value of an investment. These expressions depend on the means and variances of the net

[4/] Two of the more important conditions under which the distribution of present value can be shown to be normal are:
1) if the yearly flows of net benefits $B_1, B_2, \ldots B_n$ have a multivariate normal distribution, then the present value is normally distributed since it is a linear function of the B_t.
2) if one of the forms of the Central Limit Theorem applies. The Central Limit Theorem basically states that, under certain conditions, the sum of a number of random variables will be asymptotically normally distributed. The most familiar set of conditions is that the net benefit flows $B_1, B_2, \ldots {}_n$ be independent, identically distributed random variables with finite mean and variance. See Hillier, 1969, pages 24-29 and also Wagle, 1967, pages 17-18 for additional conditions under which the assumption of normality holds.

[5/] The internal rate of return R is less than a given discount rate i* if and only if the present value computed with given i* is less than 0. Using the relation:

$$prob[R<i^*] = prob\ [PV< 0|i^*]$$

one point on the cumulative distribtion function for R can be obtained. (This relation may not always hold, see Hillier, 1965a). By repeating this calculation for as many values of i* as desired, the entire cumulative distribution of R may be obtained.

benefits in each year and the covariances between them. In order to apply the model, estimates must be made of these parameters. Depending upon the particular investment being analyzed, estimation of the means, variances and covariances can take place at a number of different levels. Estimates of the mean and variance of the net benefits can be done for each year directly. Projects, in which there are only a small number of component costs and benefits associated with the net benefits, are the most likely candidates for direct estimation of means and variances.

For more complex projects, the various components (costs and benefits) of the yearly net benefits is the best starting point. Since net benefits in year t (B_t) is a sum of its components in much the same way that the present value is a sum of all yearly net benefits, derivation of the means and variances of B_t proceeds in much the same fashion as that outlined above.

Assume that there are m components of the total net benefits in each year, some of which are random variables and the others are constants. Those components which are random variables reflect the sources of uncertainty in the evaluation. Let Z_{tk} denote the benefits (costs) from the component k in the time period t. Assume Z_{tk} has a finite mean $\overline{Z}_{tk}$ and variance Z^*_{tk}.

The net benefits in year t are then:

$$B_t = \sum_{k=1}^{m} Z_{tk} \tag{4}$$

and the expected value and variance of the net benefits in year t are:

$$E(B_t) = \sum_{k=1}^{m} \overline{Z}_{tk} = \overline{B}_t \tag{5}$$

$$Var(B_t) = \sum_{k=1}^{m} Z^*_{tk} + 2 \sum_{k \neq j} cov(Z_{tk}, Z_{tj}) = B^*_t \tag{6}$$

If equation 4 and 5 are used to derive the mean and variance of B_t, these in turn require estimates of the means, variances, and covariances of the component costs and benefits. Again, these estimates may be made directly or the problem may be further broken down. To illustrate this, suppose that one of the costs is labor, L. Labor costs are equal to the wage rate w times the quantity of labor used Q. Assume that both w and Q are uncertain variables in the analysis, then if w and Q are independent with means $\overline{w}$, $\overline{Q}$ and variances w*, Q* the expected value and variance of labor costs are:

$$E(L) = E(w \cdot Q) = \overline{w}\,\overline{Q} \tag{7}$$

$$Var(L) = \overline{w}^2 x^* + \overline{Q}^2 Q^* + w^* Q^* \tag{8}$$

If w and Q are not independent, similar though more complicated expressions can be derived.[6/]

Computation of the variance of the present value also requires estimates of the covariances between the net benefit flows for different years. Estimation of all covariances can be a prohibitively large task. For example, with a project life of only ten years, 45 covariances are needed, with 20 years, 190 covariances. In order to simplify the problem, some form of pattern which is both reasonable and simple must be imposed on the correlations between net benefits in different years.

Three possible patterns of correlation are: (1) Complete independence between net benefit flows; (2) Complete dependence, all net benefit flows are perfectly correlated, and (3) Partial dependence. The first pattern, that of independence, is the easiest to analyze. If all net benefit flows are independent, than all of the covariances are zero. The partially dependent cases are much more complicated. However, it is possible to formulate models of correlational patterns between costs and benefits both within and among years. Once a model is developed regression techniques can be used to estimate correlation coefficients from which the covariances can be derived. (Hillier, 1969; Bussey, 1971; and Wagle, 1967).

3. Estimation of Probability Distributions

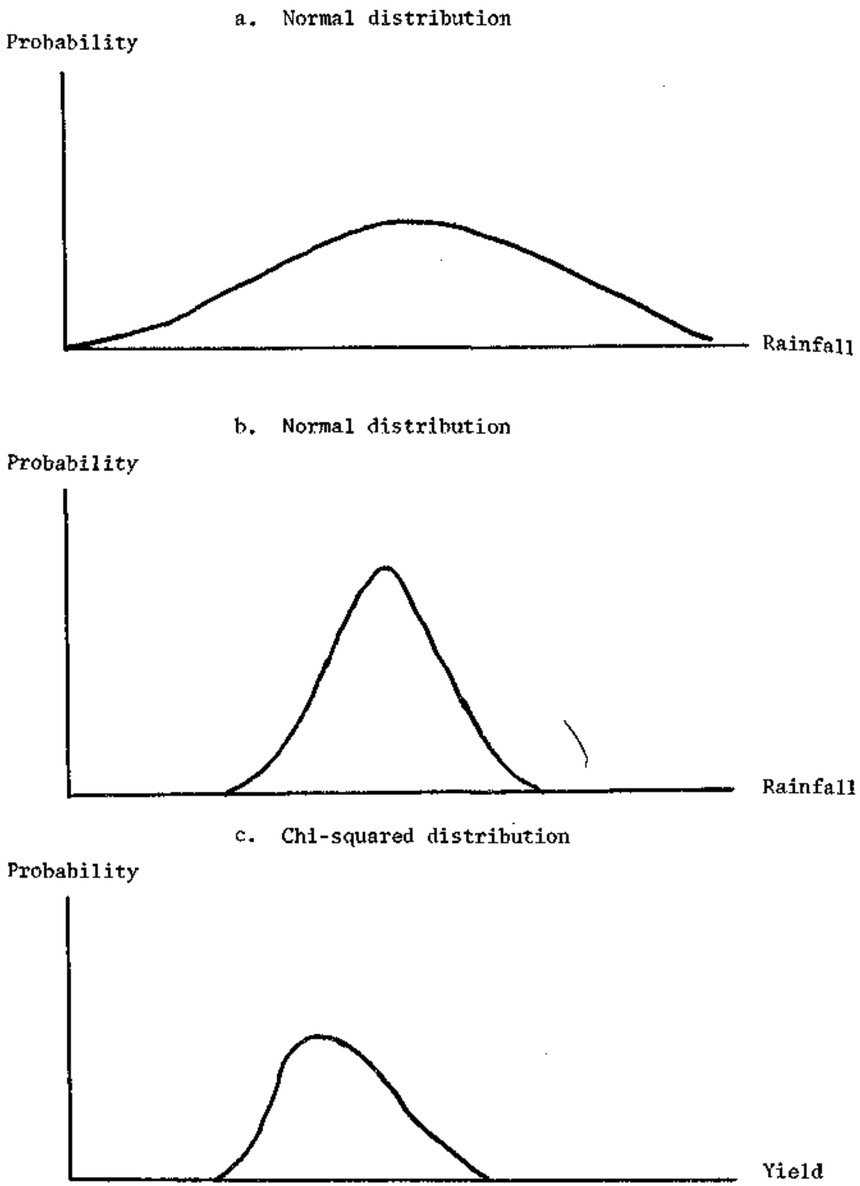
Estimating the probability distributions of the uncertain variables, is the stage of probability analysis that is most often questioned. Critics contend that for many variables all that can be made are "guesstimates." However, it is easier to estimate the results of the analysis. In addition, conventional project analysis itself depends upon many of the same judgments. Estimates of the expected values of the variables in the analysis must incorporate, at least implicitly, some judgments about the underlying probability distributions. Probability analysis makes these judgments explicit.

A number of approaches to the estimation of subjective probability distributions are possible. Two of the most common are the portrait and step rectangular methods.

In the portrait approach a choice is made from the standard statistical distributions (normal, chi-squared, etc.) and imposed on the variable in question. The available information is then used to choose a standard deviation that results in a good "fit" between distribution and the variable. This approach is useful when information about the variable is limited. A potential problem is that there is a tendency for evaluators to accept any smooth distribution. Figure 32 illustrates some of the distributions which might be used in the portrait approach. The normal distribution is widely used and reasonable for many variables. Chi-squared distributions have the property of being skewed and are also used in probability analysis.

6/ w*Q* will generally be quite small and can be disregarded, see Goodman, 1960. See Wagle, 1967, for more details and appropriate statistical references.

Figure 32. Examples of Distributions Used in the Portrait Approach.



The step rectangular approach is widely applicable and has been found highly reliable (see Figure 33). Intervals are chosen and probabilities assigned to them. The intervals can then be combined or further subdivided until the resulting distribution is satisfactory. This method enables the evaluator to use all of the information available but does not require more. The resulting step rectangular distributions may approximate one of the standard distributions. If the analysis is to be made via simulation, there is little to gain by smoothing out the distributions. In analytical probability analyses, smoothing may better reveal the variance.

Two useful forms of the step rectangular distribution are the uniform and the discrete distributions (see Figure 33). Discrete distributions must be used for variables which are noncontinuous, such as the project life in years. Here probabilities must be assigned to single values rather than intervals. In the uniform distribution each possible value is equally likely to occur. If the range of possible values can be specified but reliable estimates of the probabilities are not possible, the uniform distribution can be used.

Another possible distribution is the Beta distribution. The Beta distribution is entirely defined by the minimum and maximum values and the mode. The standard deviation is set at 1/6 of the range. The mode is equivalent to the most likely value, which may or may not be equal to the mean. If the mode is set equal to the mean, then the Beta distribution approximates the normal except for its tails. Otherwise the distribution will be skewed right or left according to whether the mode is less than or greater than the mean. The procedure for estimating the mean is to make three estimates: optimistic, pessimistic, and most likely. The optimistic estimate should reflect the highest reasonable value, the pessimistic the lowest, and the most likely estimate the modal value for benefit flows. Assume that these three estimates represent the upper and lower bounds and the mode, denoted by U, L, and M, respectively. Then the expected value and variance of the Beta distribution are computed as follows:

$$\text{Expected Value} = [(U + L + 4M)/6] \tag{9}$$

$$\text{Variance} = [(U - L)/6]^2 \tag{10}$$

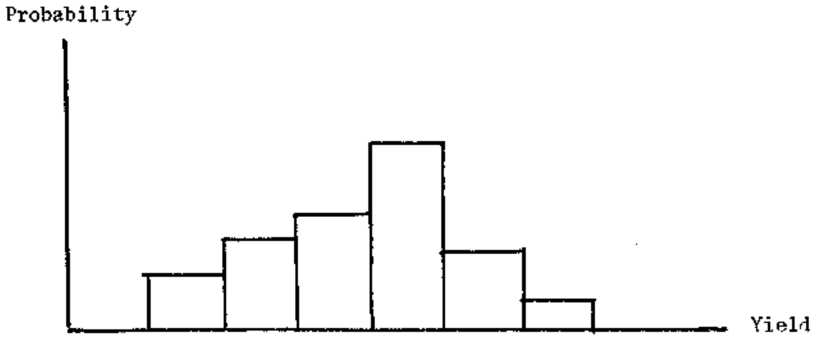
The estimates of U and L should ideally reflect plus and minus 3 standard deviations. Extremely unlikely values should be ignored.

4. Comparison of the Two Methods of Probability Analysis

Both the simulation and analytical methods of probability analysis are potentially useful techniques in evaluating risk and uncertainty. There is no clear choice as to the best method, each has advantages over the other. The analytical method is exact. It does not require the use of a computer and would be expected to be less costly to implement. Its major disadvantage is in the difficulty in estimating correlation patterns. Not only are correlations hard to quantify, but they may go unnoticed.

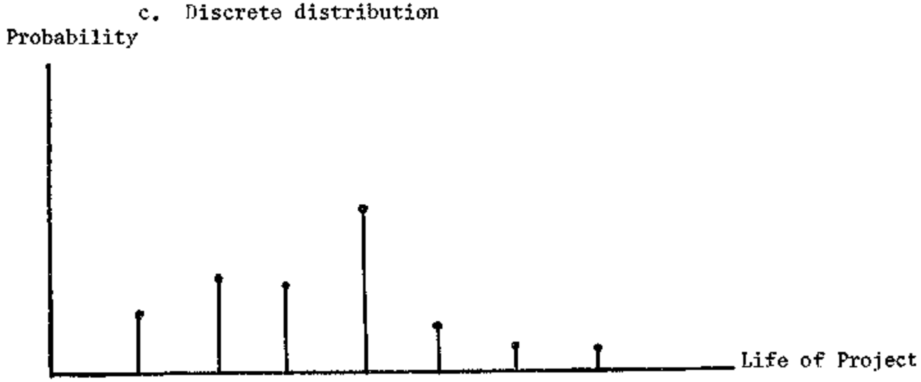
Figure 33. Examples of Step Rectangular Distributions.

a. Step rectangular distribution



b. Uniform distribution

c. Discrete distribution



Situations where the pattern of correlation may be reasonably simplified by assumption, such as assuming complete dependence or independence, are the most likely candidates for the analytical approach.

The simulation model also has its advantages. One of these is that the range of probability distributions which can be easily handled is larger than in the analytical method. Also, once the underlying probability distributions have been estimated, no further simplifying assumptions are necessary. The simulation approach is also attractive in that it requires little statistical or mathematical sophistication. Since both approaches have their advantages, which one is used depends upon the particular problem at hand.

Example of Probability Analysis

As an example, probability analysis is applied to a pilot project to improve irrigation water management in a east Indian village (Easter, 1973). The goal of the project was to allow farmers to use available water more efficiently during the wet season (May-September) and hence increase their yields. There is also a possibility that the project would enable a dry season crop to be grown. There are thus two sources of potential benefits; increased yields through more efficient water use, and the possibility of a dry season crop. The benefits in any year are dependent upon the amount and distribution of rainfall in the area. If rainfall is good, there will be few wet season benefits in that year. In a poor rainfall year wet season benefits may be substantial. In years of heavy rainfall the potential for dry season benefits also exists.

The major crop in the project area is rice. Generally, 40 inches of rain are necessary for an average wet season crop and 50 or more inches for a good crop. The distribution of the rainfall over the growing season is also important. A general rule of thumb is that at least four inches are necessary for seedbed preparation. In the case of transplanting, which increases yields, an additional three inches is considered necessary (Colyar, 1967).

Rainfall in the area is highly variable from year to year. One cannot say with certainty that there will be adequate rainfall for the wet season crop, though in most years at least an average crop can be grown. If there are seven or more inches of rain in May and June and a total of 50 or more inches throughout the growing season, wet season benefits from irrigation improvement will be negligible. However, if these totals are not reached, benefits will accrue to the project in varying amounts. Finally, in high rainfall years water may be available for a dry season crop. Because of the uncertainty about rainfall, the benefits in each year also are highly uncertain. The initial project analysis discussed in Chapter IV found internal rates of return ranging from 1 to 16.6 percent depending on whether total net benefits were estimated to be 2,600, 3,900, or 5,200 rupees per year. These rates of return were calculated assuming a 10 year life for the project.

Construction costs were known to be 24,000 rupees. There was little uncertainty about maintenance costs which were assumed to be five rupees per year. Thus the only variables in the analysis about which uncertainty was significant were the benefits which would accrue to the project in each year. For this example rainfall and its impact on yield was assumed to be the only uncertain factor influencing benefits.

Using the analytical model the probability distribution of the internal rate of return was estimated. The distribution of net benefits was estimated from historical rainfall data. The rainfall data covered 21 years, 1944-65, and was reported by month. Each year was examined to determine what the net benefits would have been if the irrigation system had been in operation. Both wet and dry season benefits were counted. Since there is little reason to expect that rainfall in successive years is correlated, it is assumed that net benefits in each year are independent of net benefits in all other project years. This assumption would have to be modified in a project which had significant storage capacity to allow water to be carried from year to year. The independence among years greatly simplified the analysis by eliminating the covariance terms in the analytical model.

Dry season benefits are possible only if there is adequate rainfall during the year and the irrigation authorities release this water to the project area for a dry season crop. It cannot be determined in advance whether or not water will be given to the project area even if it is available. Because of this, the above estimation of benefits was done under three assumptions:

1) No water will be provided for a dry season crop if it is available.

2) Dry season water will be potentially available every other year.

3) Dry season water will be released to the project area every year in which it is available.

The rainfall amounts and the estimated net benefits under the three alternative assumptions are shown in Table 23. Three step rectangular distributions were made from the three sets of 21 observations. Beta distributions were then fitted, choosing maximum, minimum, and most likely values. The mean and standard deviations of the total net benefits were then commuted using equations 9 and 10 (see Table 24). The mean and variances of the present value are computed using equations 2 and 3. By repeating this calculation for different interest rates the cumulative distribution of the internal rate of return was obtained.

Under assumption 1, no dry season benefits, the project is clearly not profitable. Even at a zero discount rate the present value is a negative -7,800 rupees. Since the analysis deals with a pilot project, it is plausible that construction costs could be much smaller in the future. Even if construction costs are halved to 12,000 rupees, the present value

Table 23. Rainfall Distribution and Annual Benefit Estimates, 1944-65.

Year	May-June Rainfall (inches)	Total Growing Season Rainfall (Inches)	Total net benefit estimates (Rupees) Assumption 1	2	3
1944-45	3.7	42.6	2,340	2,340	11,440
45-46	6.9	52.9	780	5,330	5,330
46-47	7.6	40.2	1,170	1,170	1,170
47-48	4.5	80.8	1,690	1,690	4,290
48-49	10.3	48.8	520	9,620	9,620
49-50	11.4	50.7	- 130	- 130	4,420
50-51	9.3	38.6	2,860	2,860	2,860
51-52	6.0	39.7	2,080	11,180	11,180
52-53	2.6	38.7	4,420	4,420	4,420
53-54	4.9	49.0	2,340	2,340	6,890
54-55	4.4	45.4	2,340	11,440	11,440
55-56	12.7	53.7	- 130	- 130	4,420
56-57	16.3	61.3	- 130	4,420	4,420
57-58	5.4	41.7	2,080	2,080	11,180
58-59	4.4	59.5	1,690	4,290	4,290
59-60	3.8	46.6	2,340	2,340	11,440
60-61	9.1	41.6	1,170	10,270	10,270
61-62	15.1	65.8	- 130	- 130	2,470
62-63	7.3	32.1	2,860	2,860	2,860
63-64	5.0	41.6	1,170	1,170	1,170
64-65	15.2	58.0 (est.)	- 130	2,470	2,470

Table 24. Expected Net Annual Benefits and Standard Deviations.

Assumption	Dry Season Benefits	Expected Value[a/] of Total Net Benefits	Standard[b/] Deviation
		- - - - - - Rupees- - - - - -	
1	None	1,625	758.3
2	Every Other Year	3,618	1,928.3
3	Every Year	5,568	1,711.7

a/ Expected Value = $(U+L+4M)/6 = \frac{4,420 - 130 + 4(1,365)}{6} = 1,625$

b/ Standard deviation = $(U-L)/6 = \frac{4,420 + 130}{6} = 758.3$

computed at 10 percent is -2,045 rupees.[7/] The probability that the rate of return will be less than 10 percent is about 75 percent.

If the dry season benefits are potentially available every other year, as in assumption 2, the project fares better. At a 10 percent discount rate the present value is -1,798 rupees, at 15 percent it falls to -5,866 rupees. The cumulative distribution derived under assumption 2 shows the probability of the rate of return being less than or equal to 10 percent is about 62 percent (see Figure 34). The probability that it will be less than 15 percent is 96 percent. If construction costs can be reduced to 12,000 rupees, the project shows a positive present value for both 10 and 15 percent discount rates. With this cost reduction the uncertainty about the profitability of the project is almost eliminated. There is only a 3 percent chance that the project will not earn a rate of return better than 10 percent.

Under assumption 3, when dry season benefits are assumed to accrue in every year in which water is available, the project appears quite profitable even with the 24,000 rupees construction costs. The present values are 10,185 rupees and 3,920 rupees at 10 and 15 percent discount rates respectively. A graph of the resulting distribution for the internal rate of return is shown in Figure 35. The probability of obtaining a rate of return less than 15 percent is only 9 percent.

The initial sensitivity analysis in Chapter IV was enough to show that the profitability of the project was dependent upon dry season or second crop benefits. The probability analysis quantifies and clarifies this uncertainty regarding the dry season benefits. The critical uncertainty about the dry season crop benefits is not the rainfall but the decisions of the irrigation authorities whether or not to provide water to the pilot area.

Conclusions

The treatment of risk and uncertainty in project appraisal is a difficult and unsettled issue. Given the existence of significant uncertainties about a project, some adjustment to conventional project analysis will likely improve decisionmaking. If there is at least some information about the likelihood of various uncertain values occurring, this information should be included in the evaluation. The techniques of probability analysis are one means of including all of the available information in a formal, reproducible way.

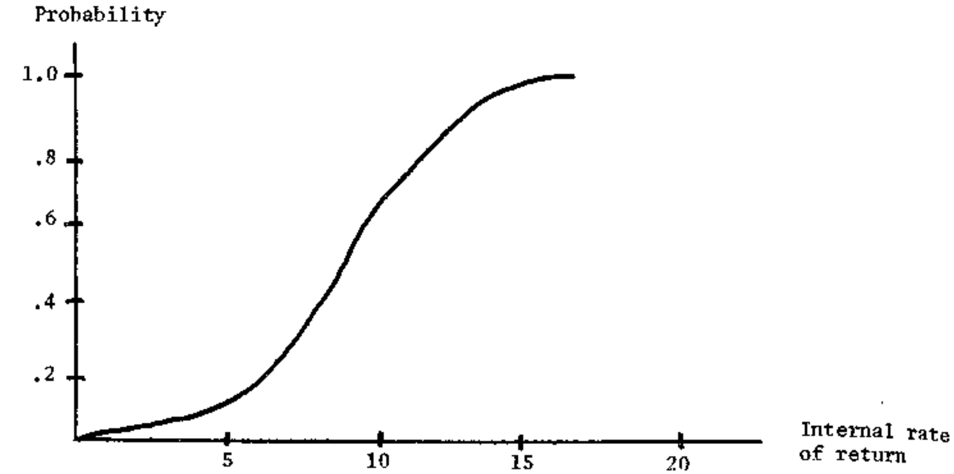
7/

$$E[PV_n] = -\text{Capital cost} + \sum_{t=1}^{n} \frac{E(V) - \text{annual maintenance costs}}{(1+i)^t} = \sum_{t=1}^{10} \frac{1,625-5}{(1+.10)^t} - 12,000$$

$$= 9,955 - 12,000 = -2,045$$

Figure 34. Cumulative Probability Distribution of Internal Rate of Return Under Assumption 2.

a. Construction costs of 24,000 rupees



b. Construction costs of 12,000 rupees

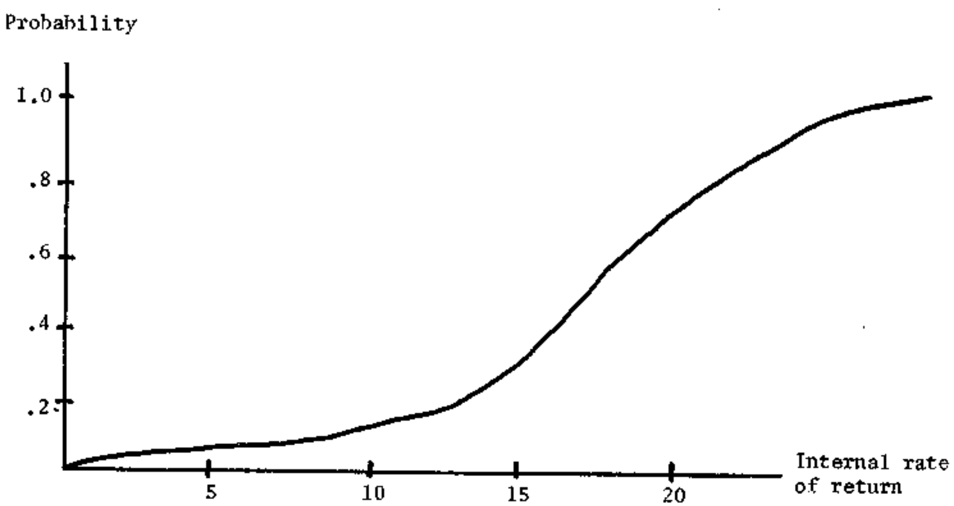
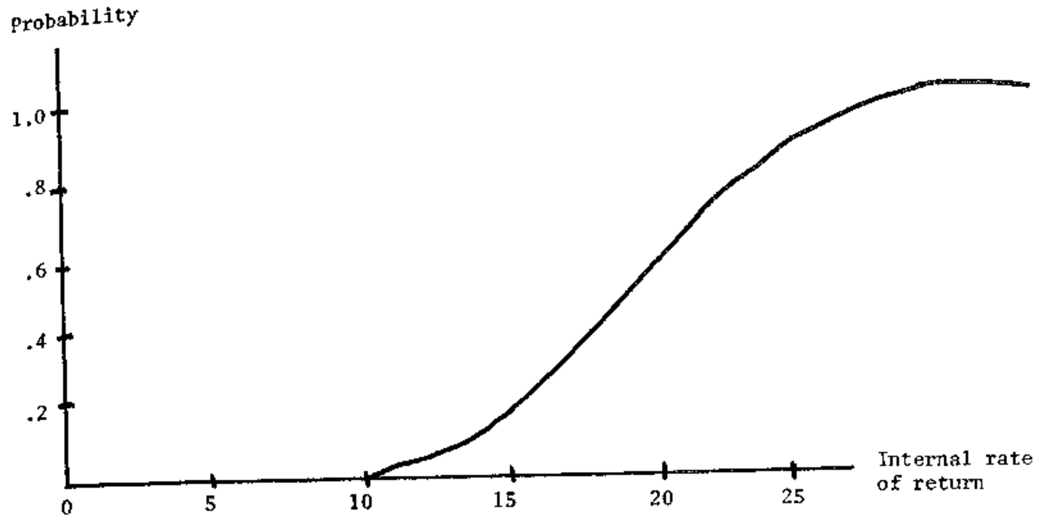


Figure 35. Cumulative Probability Distribution of Internal Rate of Return Under Assumption 3 and Full Construction Costs.



Probability analysis can be done in a simplified manner, as in the above example, or can become a very complex analysis. In either case it can be a valuable aid in investment decisions. Its value lies not only in the indication given of the riskiness of a project, but also in the additional information a more detailed analysis can provide.

CHAPTER XII

OTHER APPLICATIONS AND ISSUES IN PROJECT ANALYSIS

The central premise of project analysis is that economic efficiency is a desirable objective. Project analysis attempts to measure the degree to which a given project is economically efficient. With a given project, a favorable evaluation involves a present value greater than zero, which cannot be further improved, a determination that no superior alternatives exist and a decision that public funds should he expended to deal with the problem.

However, there may be other objectives which can alter the decision. These include environmental quality, improved income distribution, and regional development. One of the major efforts in the 1970's has been to introduce additional objectives into the formal evaluation process. The decision making process has always included other objectives but various groups wanted more explicit attention given to these new objectives. The prime addition has been environmental quality. Environmental impact statements are intended to aid in the inclusion of this objective. Unfortunately, environmental impact statements (EIS) have added too little information relevant to decision making relative to their cost. The idea that a project may have many impacts, such as the water diversion from Lake Michigan discussed in Chapter IX, is a sound concept. What is needed is a careful consideration of what is important for the decision. One should not be forced to study and record everything that might be somehow related to the project. Collecting stacks of little used information can make the cost of preparing EIS prohibitive and of minor consequence in decision making.

The real danger with environmental impact statements is that so much information is collected that it obscures the important facts such as the assumed life of project, the discount rate used, the projected growth in demand and the alternative solutions considered. However, it is quite clear that environmental restraints have forced decision makers to consider the impacts of decisions on important environmental resources. For example, the impact on endangered species has forced decision makers to reconsider their approval of projects which have failed the economic efficiency test. In the reevaluation the low benefit-cost ratios were important in stopping the projects. Thus environmental requirements can complement economic analysis or at least require decision makers to seriously use the analysis.

The important task for the future is to better integrate the information on environmental quality with the more traditional economic project analysis. This must be done without inundating the decision maker with pages and volumes of little used information. Economists should have an important role in any such exercise since their training is designed to help isolate the important decision variables.

A Broad Prospective

Public decision makers should take a broad prospective in assessing public projects. For example, water decisions are best considered as part of the total river basin or watershed. The action taken on a dam project will affect the water availability and flow patterns throughout the basin. Recreation development should be considered in the context of the regional demand and supply for the given recreation activities. The development of another artificial lake may be totally inappropriate because of lakes already available in neighboring states or counties.

State decision makers should be encouraged to rise above the temptation to ignore the part of project costs funded by federal agencies. This has been a key problem with the Bureau of Reclamation projects in the West. They obtain strong state and local support because the states pay little of the costs and receive most of the benefits. From the national point of view the projects generally have benefit-cost ratios less than one. However, if the states can ignore most of the costs, the benefit-cost ratios appear larger than one. Hopefully, in the future, more state decision makers will begin to ask what is best for the nation rather than "what is the best for me." Short of that, a planning unit charged with taking a broad regional or national viewpoint needs to be involved in the decision making process.

Ex-post Analysis

The emphasis of this bulletin has been on ex-ante analysis where one is concerned with future costs and benefits. Project analysis can also be applied on an ex-post basis to determine the past performance of a program or project. As noted in the chapter on analysis of agricultural research, evaluation of the past performance has been the thrust of most studies of agricultural research. Such ex-post analysis can help program managers and suggest ways for improving ex-ante analysis.

In ex-post analysis the big problem arises from the difficulties in determining what the situation would have been without the project. One can do a before and after study,but what is desired is a with and without project comparison. "The basic economic efficiency criterion requires the observed values of relevant output-related variables be compared with the values that would have existed if the project had not been undertaken" (Haveman, 1972).

An additional problem arises from the fact that many resource projects are long-lived investments. An ex-post analysis a decade after the project is built may only capture a fifth or less of the benefits. Thus although the analysis has ten years of output data, estimates still must be made of future outputs.

In addition, if the project's performance is dependent on random events such as rainfall,the analyst must decide if the years of data represents normal conditions. To do this one must use historical data in much the same way as in ex-ante analysis. The only difference is that there is ten years more data.

A final problem arises from the fact that many times complete records, of project or program outputs or costs have not been kept or have been lost or destroyed. Ideally the decision to do ex-post analysis should be made before a project is built or the program started. Information needed for the evaluation should be decided on and procedures for collection established. Otherwise the information collected will meet certain accounting requirements but will fail to accurately depict performance and real resource costs.

Problems for Developing Countries

The emphasis in this bulletin has been on project analysis as applied in the U.S. context. However, it is important to point out some of the added difficulties that project analysts face in developing countries. The lack of markets, data, and trained personnel all serve to make their evaluation task very difficult.

The lack of markets along with fixed exchange rates has made the use of shadow prices much more important in developing countries than it has been in the U.S. Besides trying to determine a social rate of discount, the three most frequently estimated shadow prices have been foreign exchange, the wage rate in economies faced with substantial unemployed workers and the value of investment.

The problem in the case of foreign exchange has been fixed exchange rates which lead to overvalued local currency. Two approaches are generally used to account for this problem. First, contributions to the balance of payments is considered as a distinct objective to which a project can contribute. Second, foreign exchange is given a shadow price so that imported goods have a higher value than world market prices (United Nations, 1972),

In the case of wage rates in a labor surplus economy, the question is what value to place on unemployed or underemployed labor. It is clear that the answer is not a zero wage rate because of the migration and resettlement costs associated with the increase in employment, particularly in urban areas (Meyers, 1974). The appropriate wage is more likely to be close to the actual wage rate on urban project even if it is above the wages paid elsewhere in the economy.

The shadow price for investment is introduced because many developing countries make the judgment that the rates of savings and investments should be valued more highly than current consumption. The shadow price of investment is, generally, the net present value of future consumption resulting directly or indirectly from a unit of marginal investment (United Nations, 1972).

We have chosen not to address these shadow price questions in the Bulletin since, in the U.S. context, they have not been important issues. This situation may change in the future, particularly the question of the level of savings and investment which more economists are saying are below what they should be in the U.S. In contrast, the selection of an appropriate discount rate has been an important issue in the U.S. and is discussed in the bulletin.

The lack of current information about prices and quantities of various inputs and outputs also hinders the analysis of projects in many developing countries. In some cases the data is not collected because of the cost in money and manpower involved. In others it is just the government's ineptitude or the fear that someone will find out the production levels. In addition, the lack of formal markets makes it difficult to collect price data.

Shortages of trained manpower limits evaluation work in some developing countries. The situation is improving, but if a country has only a few trained agriculturalists, should they be evaluating a proposed irrigation project? More likely they will be running the Department of Agriculture or the Agricultural Universities. Thus the evaluation is done by inadequately trained personnel, or people from outside the country.

Developing countries are confronted by many constraints that are not present in the U.S. For example, in making the projected level of yields for an irrigation project, one must account for a whole range of possible constraints. There may well be a lack of credit to buy seed for high yielding varieties and fertilizer. If production is increased, are the roads and market facilities adequate to move the surplus? Finally, with these constraints and the fact that irrigation may be new to the farmers, a lag in the full use of the irrigation water and in the yield response must be expected. In a number of cases, a six year lag has been experienced between project completion and when the water is fully utilized (Abel and Gulliver). Such lags must be built into the project analysis otherwise an overevaluation of the project is certain.

Summary

Chapter I points out that natural resources such as air and water which have been considered by many as being free resources are, in reality, scarce goods. Consequently, economics has an important role in helping decision makers allocate these scarce natural resources. The problems of externalities, common property goods, and public goods are also highlighted. Many of our natural resources have one or more of these characteristics which creates problems for valuing and allocating these resources.

Chapter II on project planning and analysis highlights the historical development of project analysis and discusses the Water Resource Council's Procedures for Planning and Analysis. The chapter stresses that no matter how good your evaluation procedures are, the evaluation is no better than those doing the analysis. If the agency that wants to build the project also does the analysis, one should not be surprised to find the results biased in favor of construction. Chapter III presents one possible framework for planning and analyzing project investments. The first section on planning is followed by the procedures for calculating benefit-cost ratio's, internal rates of return, net present values and the ratio's of net present value over capital. The final section discusses the financial feasibility of projects and methods of cost allocation.

In the early development of Western U.S. agriculture, public irrigation investments were important. Today most of the remaining feasible irrigation investments involve use of ground water by individual farmers. Chapter IV suggests four methods for evaluating irrigation benefits: (1) the cost of pumping irrigation water, (2) the market price for irrigation water, (3) farm budget analysis, and (4) a derived demand for some water using entity aggregated to the appropriate level. All four procedures have been used and can be adapted to a particular evaluation need. Project cost, design, operation and maintenance questions are also discussed. The chapter concludes with an example of project analysis applied to a small irrigation project in India.

Although structural engineering works are rarely, by themselves, complete solutions to the elimination of flood hazards, flood control investments are still made. Chapter V discusses the measurement of benefits (damages foregone) based on the difference in damages between the situation with and without the project. In doing this, one must be careful to not count as benefits reduced damages that occur because development is higher due to the project. Benefits are calculated on the basis of growth which would have occurred in the region without the project.

Navigation, like irrigation, was one of the first public investments to require a type of economic evaluation. Chapter VI shows that the savings in real resources is the appropriate measure of navigation benefits. Transportation cost reductions measured in terms of the saving in real resources are the primary benefit from navigation. Maintaining competition can also be a benefit from navigation, particularly on inland waterways.

The rail line improvement chapter VII provides estimates of the potential return to investments for upgrading a rail line from the shipper's point of view. The major benefits to shippers are lower rail rates and higher commodity prices (premiums). The cost to the shipper is the loss in interest on capital made available for upgrading the rail line. One of the key issues is the distribution of benefits from the rail line improvement. Shippers of fertilizer and oats are the big gainers while shippers of corn and wheat gain very little from the improved service. Thus it seems likely that not enough of the shippers will participate in the state program of upgrading rail lines to make it viable.

Recreation and environmental resource investments have become increasingly important to public decision makers. This trend is likely to continue because of the very inelastic supply of environmental resources and the rapid growth in demand. Three general methods of valuing benefits are discussed in Chapter VIII: (1) interim unit day values, (2) travel cost and (3) surveys of potential beneficiaries. The latter two procedures with various modifications are the best suited for valuing recreation and environmental resources. Even though the survey approach is based on the assumption that people will do what they say they will do, this is far superior to selecting some arbitrary unit day values.

Past evaluations of agricultural research have been based primarily on ex-post studies. Chapter IX presents an ex-ante analysis of proposed new research on soybeans and corn in the North Central Region. The analysis depends heavily on scientists' estimates of likely increases in production created by the new research. A sensitivity analysis is done on the assumptions concerning the yield increases, the probability of success, the lags between development and adoption, and the commodity prices. Under all the assumptions research investments exhibited high potential returns. Finally, an analysis of the distribution of research benefits shows that the consumers are likely to be the major beneficiary.

Chapter X highlights the large number of externalities that can be created by one natural resource decision. The reversal of the Chicago River to flow westward and protect Chicago's Lake Michigan Water supply have had impacts as far east as New York state. The reversal affects navigation and power production on both the Great Lakes and the Illinois River. The Mississippi River traffic, flooding and pollution on the Illinois River, and erosion along the Great Lakes are all influenced by the diversion of water down the Chicago River.

Risk and uncertainty are always involved in project analysis to some degree. Thus one must ask whether or not uncertainty should be included as part of a project's analysis and whether or not it is relevant for public decisions. Chapter XI provides alternative approaches that can be used to account for uncertainty. The major emphasis is on probability analysis with an example given of how it is applied to a small irrigation project in India.

In conclusion, one must realize that project analysis and planning is only one input into the decision making process. Clearly, non-quantifiable benefits and costs have to be included. Furthermore one would expect the decision maker to have certain information based on experience that would influence the decision. Our primary hope is that project analysis will be part of the decision making process and that the analysis is done as well as possible,given limits on time and funding.

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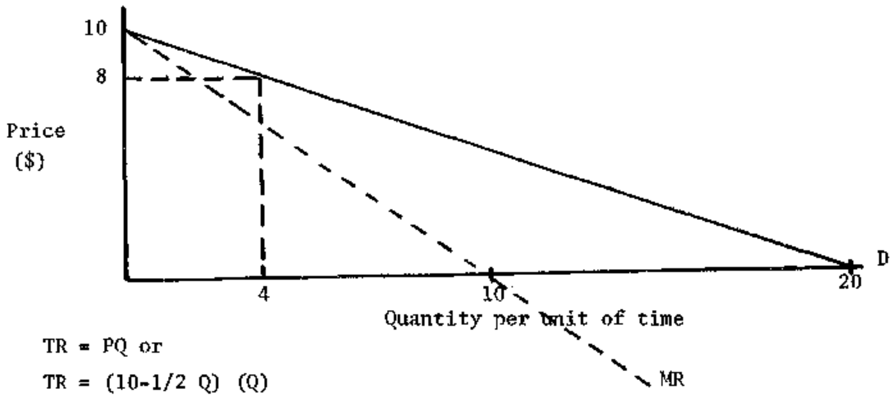
APPENDIX TO CHAPTER I

In natural resource decisions, consumers' willingness to pay for the net output of a project is the appropriate measure of benefits. Where an increase in output is sufficient to cause a price decrease, using the reduced price to place a value on output would result in an understatement of benefits. "Willingness to pay" provides a complete measure of benefits since it includes the addition to both consumer surplus and total revenue. For an individual the willingness to pay is the area under his or her demand curve. The area under a market demand curve shows the willingness to pay of the consumers in that market.

It is instructive to view the geometry of "willingness to pay". Consider as a simple example, the demand curve, P = 10 - 1/2 Q. Most students are familiar with the total revenue curve associated with such a demand curve.



TR = PQ or

TR = (10-1/2 Q) (Q)

$= 10\,Q - 1/2\,Q^2$

The marginal revenue curve is $\frac{dTR}{dQ} = 10 - Q$. The slope of the MR curve is twice that of the linear demand curve.

The TWP curve, by contrast, is the area under the demand curve up to any given point, or the integral of the demand curve. In this case, TWP is $\int_0^{20} Q\,dq$ or TWP = $10Q - 1/4\,Q^2$. Hence to find TWP at Q = 4, TWP = (10·4) - 1/4 (16) = 40 - 4 = 36. Note that consumers surplus (the difference between what consumers would be willing to pay and what they actually pay) is TWP - TR. Algebraically, this is $(10\,Q - 1/4\,Q^2) - (10\,Q - 1/2\,Q^2) = 1/4\,Q^2$. At Q = 4, consumer surplus equals 4. A check by inspection reaffirms that TR is 4 x 8 or 32 (what consumers pay) and since TWP was 36 at Q = 4, this leaves a consumers surplus of 4.

Note also, that since TWP is the integral of the demand curve, if we plot the TWP curve, the slope of TWP, $\frac{\Delta TWP}{\Delta Q}$, at any point must equal price. In other words, the slope of TWP gives us an approximation of the value which society places on another unit of that product.

APPENDIX TO CHAPTER VII

TABLE 1

Cost Calculation for Investment of $30,000 and Annual Payback of $6,000 (100 cars with payback of $60 per car)

Year	Capital Investment	Discount Rate	Interest Cost	Discount Factor a/	Discounted Costs
1	$ 30,000	5 %	$ 1,500	.953	$ 1,430
2	24,000	5	1,200	.907	1,088
3	18,000	5	900	.864	778
4	12,000	5	600	.823	494
5	6,000	5	300	.784	235
					$ 4,025

a/ See Chapter IV, page 19, for a definition of discount factor.

TABLE 2

Benefit Calculations for Firm Shipping 50 Cars of Oats and Receiving 50 Cars of Fertilizer Annually

Year	Commodity	Rate Difference Per Car a/	Total Rate Saving or Loss	Savings From Loading Per Car	Total Loading Savings	Price Advantage Per Car	Total Price Savings	Total Benefits (3)+(5) + (7)	Discount Factor For 5%	Discounted Benefits
	(1)	(2)	(3)	(4)	(5)	(6)	(7)			
1	Fertilizer	$390	$19,500	$10	$500	---	---	$20,000	.953	$19.060
	Oats	-66	$-3,300	---	---	$337.50	$16,875	$13,575	.953	$12,937
2	Fertilizer	$390	$19,500	$10	$500	---	---	$20,000	.907	$18,140
	Oats	-66	$-3,300	---	---	$337.50	$16,875	$13,575	.907	$12,313
3	Fertilizer	$390	$19,500	$10	$500	---	---	$20,000	.864	$17,280
	Oats	-66	$-3,300	---	---	$337.50	$16,875	$13,575	.864	$11,729
4	Fertilizer	$390	$19,500	$10	$500	---	---	$20,000	.823	$16,460
	Oats	-66	$-3,300	---	---	$337.50	$16,875	$13,575	.823	$11,172
5	Fertilizer	$390	$19,500	$10	$500	---	---	$20,000	.784	$15,680
	Oats	-66	$-3,300	---	---	$337.50	$16,875	$13,575	.784	$10,643
										$145,414

a/ Car holds 65 tons of fertilizer, 3,750 bushels of oats, and 2,100 bushels of corn.