Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SWUTC/97/467109-1		

4. Title and Subtitle	5. Report Date
A SYNTHESIS OF MODERN, PROFESSIONAL ECONOMIC WISDOM AND LITERATURE PERTAINING TO NAVIGATION PROJECTS	February 1997
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Ronald C. Griffin, Arthur P. James and John P. Basilotto	Research Report 467109-1
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. 10727
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Southwest Region University Transportation Center Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	14. Sponsoring Agency Code

15. Supplementary Notes

Supported by general revenues from the State of Texas.

16. Abstract

If large, complex, lengthy, multiple-use projects of interest to several groups are to be evaluated for their desirability, the criteria for the evaluation must first be agreed to. The setting for modern evaluation of government projects dates back to the River and Harbor Act of 1902, which, "required a board of engineers to report on the desirability of Army Corps of Engineers' river and harbor projects, taking into account the amount of commerce *benefited* and the *cost.*" Recently, however, environmental critics have charged that previous studies are of limited use because economic benefits present only one side of the ledger i.e., they do not analyze the potentially adverse impacts of maintenance dredging and disposal on natural resources. Industry on the other hand, believes that studies performed by the Army Corps of Engineers that only calculate benefit/cost ratios do not fully measure all of the benefits associated with inland waterway transportation and therefore the benefits are typically understated. Additionally, critics from all camps seem to agree that most studies neglect the "safety" or "risk" value aspects of inland waterway transportation compared to other transportation modes. Knowing how to evaluate and select projects to be approved, paid for, and operated by the government is important to all stakeholders, not just the government. This report examines the elements of cost-benefit analysis pertaining to navigation projects and synthesizes a sample of completed studies of waterway and other related public works projects over the last several years. The purpose of this undertaking is to provide a means of placing these studies into easily identifiable categories to aid future analysts in their task of selecting methodologies for studies they may undertake.

17. Key Words	18. Distribution Statement
Cost-Benefit Analysis, Economic Impact Studies, Gulf Intracoastal Waterway, Risk, Valuation Methodologies, Navigation, Input-Output Analysis, Principles and Guidelines, GIWW	No Restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	109	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

A SYNTHESIS OF MODERN, PROFESSIONAL ECONOMIC WISDOM AND LITERATURE PERTAINING TO NAVIGATION PROJECTS

by

Ronald C. Griffin, Ph.D.
Professor of Natural Resources Economics
Texas A&M University

Arthur P. James, Ph.D.
Assistant Professor, Department of Maritime Administration
Texas A&M University at Galveston

John P. Basilotto, Col. (R)
Assistant Research Scientist
Texas Transportation Institute

Research Report SWUTC/97/467109-1

February 1997

Southwest Region University Transportation Center
Texas Transportation Institute
Texas A&M University
College Station, Texas, 77843

ABSTRACT

If large, complex, lengthy, multiple-use projects of interest to several groups are to be evaluated for their desirability, the criteria for the evaluation must be first agreed upon. The setting for modern evaluation of government projects dates back to the River and Harbor Act of 1902, which "required a board of engineers to report on the desirability of Army Corps of Engineers' river and harbor projects, taking into account the amount of commerce *benefited* and the *cost*." Recently, however, environmental critics have charged that pervious studies are of limited use because economic benefits present only one side of the ledger, i.e., they do not analyze the potentially adverse impacts of maintenance dredging and disposal on natural resources. Industry on the other hand, believes that studies performed by the Army Corps of Engineers that only calculate benefit/cost ratios do not fully measure all of the benefits associated with inland waterway transportation; therefore, the benefits are typically understated. Additionally, critics from all camps seem to agree that most studies neglect the "safety" or "risk" value aspects of inland waterway transportation compared to other transportation modes. Knowing how to evaluate and select projects to be approved, paid for, and operated by the government is important to all stakeholders, not just the government. This report examines the elements of cost-benefit analysis pertaining to navigation projects and synthesizes a sample of completed studies of waterway and other related public works projects over the last several years. The purpose of this undertaking is to provide a means of placing these studies not easily identifiable categories to aid future analysts in their task of selecting methodologies for studies they may undertake.

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ACKNOWLEDGMENT

This report was developed as part of the University Transportation Centers Program which is funded 50% with general revenue funds from the State of Texas.

EXECUTIVE SUMMARY

Increased criticism from various stakeholders of the traditional methods of evaluation government navigation projects was the impetus for this project. This report examines the elements of cost-benefit analysis pertaining to navigation projects and synthesizes a sample of completed studies of waterway and other related public works projects over the last several years.

The first portion of the report emphasizes methodological responses to two question: (1) what counts in the *cost-benefit appraisal* (CBA) of water projects and (2) how are these things to be economically valued? To accomplish this task we begin with a review of cost-benefit methodology highlighting primary features and principles. The presentation presumes a basic understanding of economic concepts such as supply and demand functions. Subsequent sections then undertake answering the following primary questions:

1. How should the direct navigation benefits be assessed?
2. What is the legitimacy of considering employment impacts and secondary effects as navigation project benefits or costs, and what valuation methods are appropriate?
3. When navigation projects are accompanied by environmental benefits or cost, how should they be evaluated?
4. How might consideration of transportation-related risk bear upon the evaluation of navigation benefits?

The second portion of the report examines a sample of completed studies of waterway and other related public works projects over the last several years. It is an attempt to demonstrate what has actually been done under the umbrella of cost-benefit analysis. The categorization that results from this section is, in the end, a very simple one, separating studies that attempt to follow the tenets of cost-benefit analysis described in the previous section from other studies that, while they may measure certain economic benefits and/or costs, do so in a manner that is different from the general principles described in the first part of the report. This is not to say that all studies profess to be "cost-benefit" are clearly better than other studies attempting to evaluate waterway projects. In fact, alternative methodologies may be more appropriate when used to show the usefulness of some already existing facility.

The final portion of the report consists of brief summaries of actual waterway and waterway-related studies that have been written over the last thirty years. The summaries are separated into two general classes: Economic Impact Studies and Cost-Benefit Analysis.

In general, this report is about methodologies for calculating the benefits and costs of navigation projects. The first part of the report is a theoretical treatment of the subject, whereas the rest of the report deals with empirical samples.

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CHAPTER ONE

INTRODUCTION

Disparate attitudes among stakeholders in navigation projects have resulted in a confused array of perspectives regarding what counts in the cost-benefit appraisal of water projects and how these things are to be economically valued. This confusion expands the latitude available to juxtaposed stakeholders and widens the disciplinary breaches over which they contest. The result is wasted resources and expensive delays for project decisions.

Over the last seventy-five years numerous studies of the economic benefits of U.S. Intracoastal waterways projects have been conducted. The Gulf Intracoastal Waterway (GIWW) is one example of the use of several different methodologies to evaluate and eventually justify funding for the canal. The most frequently used methods for calculating the economic impact of operation on the GIWW were *benefit-cost* and *cost-effectiveness* analysis. Recently, however, environmental critics have charged that previous studies are of limited use because economic benefits present only one side of the ledger, i.e., they do not analyze the potentially adverse impacts of maintenance dredging and disposal on natural resources. Industry on the other hand, believes that studies performed by the US Army Corps of Engineers that only calculate benefit/cost ratios do not fully measure all of the benefits associated with inland waterway transportation; therefore, the economic benefits are typically understated.

Furthermore , industry believes that transportation should be viewed as one element of the manufacturing process: as a facilitator to unite raw materials with an intermediate goods process. Additionally, critics from all camps seem to agree that most studies, if not all, neglect the "safety" or "risk" value aspects of inland waterway transportation as compared to other transportation modes.

Knowing how to evaluate and select projects to be approved, paid for, and operated by the government is important to all stakeholders, not just the government. Part one of this study examines the elements of cost-benefit analysis pertaining to navigation projects. In part two, we examine a sample of completed studies of waterway and other related public works projects over the last several years. The purpose of such an undertaking is to provide a means of placing these studies into easily identifiable categories to aid future analysts in their task of selecting methodologies for studies they may undertake.

CHAPTER TWO

Elements of Cost-Benefit Analysis Pertaining to Navigation Projects

The purpose of this portion of the report is to synthesize modern, professional economic wisdom and literature into the narrowest possible perspective on what navigation-related impacts are to be counted and how each impact is to be valued. Because the motivating issue for this study is emergent interests in obtaining an accurate economic appraisal of the Gulf Intracoastal Waterway (GIWW), this study addresses the following primary questions:

1. How should the direct navigation benefits be assessed?

2. What is the legitimacy of considering employment impacts and secondary economics effects as navigation projects benefits or cost, and what valuation methods are appropriate?

3. When navigation projects are accompanied by environmental benefits or cost, how should they be evaluated?

4. How might consideration of transportation-related risk bear upon the evaluation of navigation benefits?

This section of the report emphasizes methodological responses to these questions. No empirical results for specific navigation projects are pursued. By setting aside the added complexities and distractions of empiricism, attention is focused on needed procedures for the economic evaluation of navigation projects. Because cost-benefit analysis, a well forged tool of economics, deals strongly with all four of the above questions, it is the guiding methodology here. No other method of evaluating public projects enjoys such widespread application or analytical power. Cost-benefit analysis has long served as an institutionalized component of federal decision-making for water projects. In the last 15 years, its application to federal policy has been expanded to include regulatory rule-making of many types, providing additional evidence of CBA's usefulness and power[1].

To accomplish the tasks of this section expeditiously, we begin with a review of cost-benefit methodology, highlighting primary features and principles. The presentation presumes a basic understanding of economic concepts such as supply and demand functions. Subsequent subsections then undertake the four investigation questions listed above.

The Foundations of CBA

Cost-benefit analysis, hereafter CBA, is founded on a branch of economics known as welfare economics. As differentiated from the economic theory of decision making by individual consumers and enterprise owners, welfare economics emphasizes public decisions that impact the economic interests of more than one person (Boadway and Bruce 1984; Graaff 1957). That is, what social choices are "best" when different choices will affect the welfare of different people differently - even oppositely? Welfare economics is a relatively young social science having made most of its advance during the past century. This advance has progressively established greater rigor for understanding the implications of social choice. Moreover, welfare economists have devoted significant effort to formulating and examining public decision criteria, such as CBA.

In the U.S. during the twentieth century, the relevance of welfare economics has been intimately tied to the desire for formal rules for deciding among alternative federal water projects. CBA was arguably pioneered in the pursuit of a better framework for resolving decisions about U.

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[1] The notion that public policy, like public projects, should offer benefits in excess of costs has been embraced by recent Presidential administrations. Executive Orders 12291 and 12866 require the formal consideration of benefits and costs for proposed regulations by federal agencies (1981; 1993).

S. water projects. Questions like "Which projects should be built?" and "How large should a particular project be?" have dominated debate and have captured the attention of economic theorists as well as decision makers. The current state of CBA, obtained primarily during the past 50 years, is built upon the contributions of these people.

As a subdiscipline within the growing science of economics, CBA continues to evolve. Difficult questions remain unanswered, and the methodological work continues. As a contemporary example, the valuation of environmental products and losses represents a major new thrust by economists to contribute more refined information to public decision-making processes. As this work matures and becomes "proven," the practice of CBA is being reformed to accommodate new procedures.

CBA on Paper: The "Principles and Guidelines"

For the past few decades, interest in the consistent and uniform application of CBA for water projects has resulted in the publication of mandatory rules for conducting CBA's concerning proposed federal water projects. The primary audience for these mandates is planning personnel of the water project agencies, chiefly the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation. These regulations specify what project impacts are to be evaluated and, in most cases, they suggest assessment methodologies.

The rules are revised from time to time. In addition to updating previous rules to take advantage of new methodological advances, motivation for a revision can sometimes come from changes in political preferences which can emphasize different priorities, For example, the current regulations, commonly called the "Principles and Guidelines" (P&G) were established in 1983 by the Reagan Administration. The 1983 P&G supplanted the rules set in place three years earlier by the Carter Administration. Relative to the Carter rules, the 1983 P&G acted to de-emphasize the standing of environmental costs and benefits that might be associated with a water project.

Today, the 1983 P&G are supported by a host of technical manuals which set forth agency interpretations of the P&G. The U.S. Army Corps of Engineers maintains comprehensive documentation of methods and data sources for conducting CBA according to the precepts established by the P&G. Much of this information is either contained in a publication entitled *Guidance for Conducting Civil Works Planning Studies* or in the many reports of the Institute of Water Resources (a branch of the Corps of Engineers) (U.S. Army Corps of Engineers 1990; Yoe 1995).

CBA's Central Objective

The P&G, together with supporting documents, specify the federal practice of CBA in considerable detail. Careful inspection of the P&G finds that these regulations represent good CBA methodology in most, but not all, areas. While the particulars of the P&G and its predecessors have changed over time, at the heart of each set of these regulations lies a very stable concept. Here, it is referred to as the *central objective*. The P&G share this concept with CBA. It is as follows: projects are deemed federally acceptable "... if the benefits to whomsoever they accrue are in excess of the estimated costs ..." (Flood Control Act of 1936). That is to say, all benefits are to be estimated in $ units and summed, and all costs are similarly estimated and summed. No attention to the distribution of these benefits and costs across different socioeconomic classes, regions, commercial or manufacturing classifications, or any other groupings of people or corporations are considered. If the total benefits exceed the total costs, then the proposed project is regarded as acceptable. This does not imply, however, that the project will be constructed. Financial resources for construction must still be found for the project in the political process, and there may be other acceptable projects which are politically preferred.

In the jargon of economics, the comparison of summed benefits to summed costs is referred to as a *compensation test*. This nomenclature derives from the following query: Could the beneficiaries of a project hypothetically compensate those people harmed by the project and still have some remaining benefits? A "yes" answer is regarded as necessary for project approval (Gittinger 1982; Mishan 1976; Sassone and Schaffer 1978; Schmid 1989).

In some ways this has been a worrisome criterion for welfare economists due to the hypothetical nature of the test. Some groups of people will inevitably experience losses as a result of a project's construction. For a single project this consequence may not be very troublesome for society. On the other hand, it may be contentious. More crucially, if there is a systematic bias across all water projects towards imposing losses on specific social groups, then the ethical palatability of CBA is weakened. In its present state, the P&G set aside this concern and focus heavily on total benefits vis-à-vis total costs. This emphasis is not without support. Consider the following statement by J. R. Hicks, one of welfare economics' strongest contributors:

> If the economic activities of a community were organized on the principle of making no alterations in the organization of production which were not improvements in this sense *[satisfying the compensation test]* and making all alterations which were improvements that it could possibly find, then, although we could not say that all the inhabitants of that community would be necessarily better off ..., nevertheless there would be a strong probability that almost all of them would be better off after the lapse of a sufficient length of time (Hicks 1941, p. 111, italicized note added).

Hicks is arguing that continued application of the CBA criterion to resolve every policy matter will, over time and on the whole, tend to benefit every person even though each person may be harmed by particular policy or project selections (Griffin 1995). This perspective has been implicitly embraced by the P&G's designers.

Some Basic Tenets of CBA

Welfare economics lays down certain tenets, in addition to the central objective noted previously, which are regarded as necessary for the conduct of CBA. Some of these principles are found to have noteworthy implications for the main pursuits of this section. The listing below discusses these principles. All of the included principles are derived from recommended practices for CBA. This does not imply that they have been completely built into the P&G, but the remainder of this section departs from the P&G to focus upon CBA. For each tenet, a statement of meaning is provided, and the underlying rationalization of the tenet is discussed. If necessary, additional details and examples are also included. These principles will be relied upon in later portions of this section. Readers who are less interested in the technical underpinnings of CBA methodology may wish to advance to the next major subsection commencing after the six tenets.

Tenet #1. Cost measurement will be founded on opportunity costs

In one sense, cost assessment is methodologically equivalent to benefit assessment except that goods are being used rather than produced. Hence, the procedures highlighted within discussions of the next two tenets are also applicable to cost evaluations. In another sense, cost evaluation is often simplified. Whereas public projects are usually focused upon the production of public goods which are only weakly provided by private enterprises, the inputs to these public projects are commonly offered in markets and used in a much broader array of economic activities. That is, the concrete, labor, energy, steel, etc. which goes into the construction and operation of a public project can be purchased in the marketplace. In many of these instances, market price serves as a good indicator of the value society places on these resources, so $P \cdot \Delta I$, where P is the price of any input and ΔI is the amount of the input used by a project, might do a good job of capturing the cost side of things.

While using price as the measure of a commodity's social value is practical in many instances, analysts must always be mindful that CBA requires social values because the essence of CBA is to gauge the attractiveness of a project to society. The operational requirement is that goods must be valued at their social *opportunity cost*. Price does not always coincide with opportunity cost. For example, in a region of high unemployment, the social opportunity cost of hiring certain workers may be small because they would be unemployed in the absence of the project. Here, the wages to be received by such workers overstates their opportunity cost. As an opposite example, the price of energy used during project construction excludes the environmental costs associated with energy production (acid deposition, carbon emissions). In this example, price may be too low for a use in a social evaluation tool such as CBA.

Tenet #2. Producer benefits are to be measured as producer surplus changes

In general, water projects can enhance the availability of water-dependent goods such as drinking water, transportation, and hydropower. In cases where these additional goods are used by firms in production activities, the net income of these firms can be increased. In these situations, the added income is attributable to the project and is therefore a benefit of the project. Moreover, other firms may have enhanced profitability if they utilize inputs provided by first-tier firms using water-project-generated goods. Such economic benefits are also to be counted as project benefits.

As an example widely applicable to the GIWW, a bigger canal can increase the profits of a tug operator who is a direct user of the canal. This increase in profits might be the result of lowered operation costs and/or an increase in the quantity of transported materials. In either case, we have a project benefit experienced by tug operators. Moreover, if the price of transportation services is subsequently lowered or transported tonnage increases due to the advantages incurred by tug operators, then users of tug services may also experience enhanced profits due to the water project. Both the added profitability of tug operators and the added profitability of the industries served by tugs are direct benefits assignable to the increase in canal size.

Figure 1 contains a common depiction of benefit assessment in a situation where the availability of a production input or service has been enhanced by a project. Prior to the project, Q_1 units of the input are available. After the project, Q_2 units are available. The curve D is total demand for the good, and this demand is illustrated as a function of the good's price which is measured on the vertical axis. The fact that this good may not be actually exchanged in the marketplace is irrelevant, theory wise, but market trading does assist application of this theory. This is true because market data can enable the statistical estimation of D which is pivotal in performing welfare analysis.

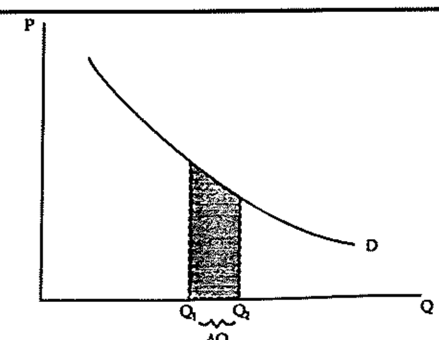

Figure 1. Willingness to Pay for a Quantity Increase

In valuing ΔQ, the increase in Q, it is noteworthy that demand for Q is *derived* from the demand producers face for the goods they produce. D is the mathematical product of two variables: the value of the goods produced with Q and the marginal product of Q in the production of these goods. The curve D is negatively sloped primarily due to the declining marginal productivity of Q in production. Due to the construction of D, which is predicated on the economically optimal use of Q, any single point on the demand curve tells us the incremental value of that level of Q. Using integral calculus, the shaded area of Figure 1 constitutes the total value of ΔQ to its immediate users. This shaded area is called the *willingness to pay* (Pearce 1983), and it is also the change in *producers' surplus* when the good Q is unpriced (free). When quantity changes such as ΔQ occur for price changes (as is typical), the change in producers' surplus is the appropriate measure of benefits experienced by Q users.

It can be highly useful that the trapezoidal change in producers surplus area depicted in Figure 1 can be approximated by the rectangular area $P \bullet \Delta Q$ where P is given by the height of the demand curve evaluated somewhere on the $[Q_1, Q_2]$ interval. The approximation is particularly good when ΔQ is small relative to the total production of Q. Unfortunately for many water projects, ΔQ is large relative to total Q, and in these instances $P \bullet \Delta Q$ overestimates the true change in producers surplus.

If a water project enhances the profitability of linked industries, then a similar approach can be used to illustrate the change in producers surplus measuring those benefits. In general, beneficiary industries may lie either forward or backward of the transportation industry. Forward industries use inputs provided or enhanced in some way by water transportation. Backward industries help to provide inputs for use in water transportation. The horizontal axis of Figure 2 measures the output of a *forwardly linked* industry. This output is denoted by the variable R. Demand for R is given by the demand schedule D_R. Prior to the construction of a water project (such as a bigger canal), the marginal cost of producing R is given by S_1. S_1 is then the supply curve for R, and its positive slope is the consequence of the generally increasing cost of producing progressively larger quantities of R. With project construction, the production costs of R may be lowered – either due to the relaxation of production constraints or lowered input prices (e.g. cheaper transportation or cheaper goods as a consequence of cheaper transportation). S_2 represents the new, postproject supply curve for R. Assuming that the good R is exchanged in markets, the lowered supply curve will have a price consequence. Price will be lowered from p_1 to p_2 and production/consumption will increase from R_1 to R_2. Generally, both consumers and producers of R may benefit from these changes, but producer benefits may be eliminated by the price fall in specific circumstances. Discussion of the measurement of consumer benefits is deferred to the next subsection. In the case of R producers, preproject producer surplus is indicated by area A_2. Postproject producer surplus is given by area $A_5 + A_6$, so the net gains of the project to R producers is

$$\Delta A = A_5 + A_6 - A_2.$$

Though the graphical depiction of this benefit measure is inconclusive about the sign of ΔA, it is positive in most circumstances where supply is increased[2].

Production-side benefits of a water project are obtained by summing all such changes in producer surplus[3]. As is apparent from the economic theory just summarized, actual computation of these benefits is greatly assisted by knowledge of specific supply and demand relationships. For market-exchanged goods and services, this information is often obtainable[4]. However, this is not the case for many of the goods and services provided by water projects. In such cases, sound economic theory and ingenuity is necessary to achieve a suitable "work-around." Much of the science and art of CBA has been engaged with the need to surmount the informational gaps caused by missing markets or missing data. Nevertheless, the above overview of producer surplus changes identifies the measures being ultimately sought. The suitability of all work-arounds rests on their ability to approximate producer surplus changes.

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[2] Producers are experiencing two opposing effects on profit: a decline in their production costs and a decline in the price of their product. If product demand is such that a small change in quantity causes a large price change, producers can experience an overall loss in producer surplus.

[3] Contemporary theory observes the realistic opportunity of capturing the producer surplus of forwardly linked industries using a *general equilibrium* demand curve in Figure 1 (Just, Hueth and Schmitz 1982). If the procedures and data used to estimate the demand curve D in Figure 1 are consistent with general equilibrium welfare measurement, then measurement of ancillary benefits such as DA would be redundant and improper.

[4] The customary procedure for identifying supply or demand relationships is to collect price and quantity data from actual market activity and apply suitable regression methods to estimate supply and/or demand functions.

Tenet #3. Consumer benefits are to be measured as consumer surplus changes

In addition to the heightened profitability of economic production activities which has been considered above, final consumers of water project-enhanced goods may experience benefits which are not part of some industry's profit. That is, consumers may gain additional satisfaction or *utility* from the additional services and goods made available by a water project. These commodities may include those project products directly usable by consumers (e.g. water, recreation) or derived final consumer products (transported goods, goods manufactured using hydropower or water). For example, a new waterway may contribute to water recreation (e.g. the number of fishing days) and thereby improve consumer welfare. Or, a water project may increase the supply of some final commodity (e.g. gasoline containing an additive that was transported by barge) and thereby lower its price or alleviate a shortage; either of which is a benefit to consumers.

Assessment of such benefits requires that consumers' enhanced utility be *monetarized* into $ units. A great aid to this requirement is the consumers' total demand curve for the good being increased by the water project. Referring again to Figure 1, if D represents consumer demand for a direct output of a water project, then the shaded area is the change in *consumer surplus*. This depiction is enabled because the demand curve possesses the useful feature of indicating the marginal value of the commodity Q to consumers. Consequently, the shaded area is an appropriate measure[5] of consumer benefits for ΔQ. In situations where ΔQ is small, this area can be approximated using $P \bullet \Delta Q$.

In the case of a water project's forward linkages to final consumers, the change in consumer surplus can be illustrated using Figure 2. Again, the project is presumed to have a favorable impact on the supply of a produced and marketed good. Price is reduced, and production/consumption is increased. Integration is sufficient to obtain net consumer value after consumers pay for the good. Area A_1 is consumer surplus prior to the project, and area $A_1 + A_2 + A_3 + A_4$ is consumer surplus following the project. The difference, $A_2 + A_3 + A_4$, is the correct measure of this aspect of the water

[5] A more complete discussion of this matter would include attention to the distinctions between Marshallian and Hicksian measures of consumer welfare change. In most cases these distinctions are empirically small and are subsequently set aside. Here, they are set aside at the onset for purposes of expediency.

project.

As in the case of producer-side benefits, all consumer benefits are to be summed, and market-derived information greatly aids application of these methods. Where market exchange of the relevant goods or services is not the norm, other procedures can be employed with the following caveat. Any such procedures require theoretical rationales for why they estimate the consumer surplus changes discussed here.

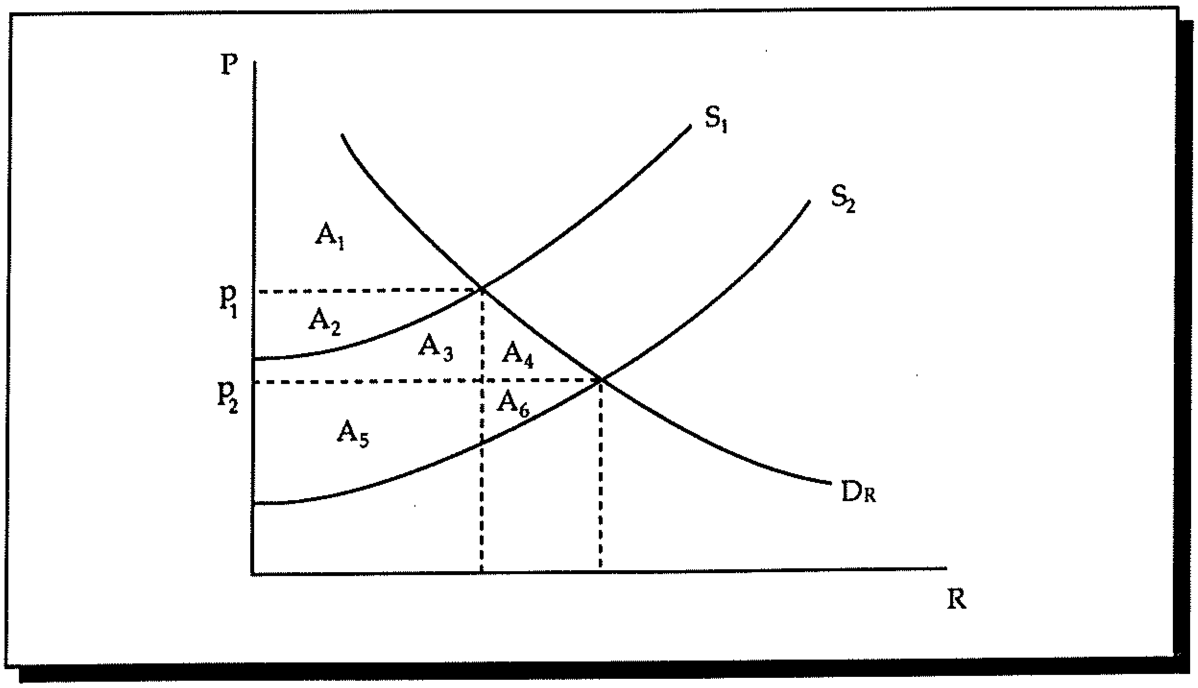

Figure 2. Willingness to Pay in a Linked Industry

Tenet #4. Zero-sum transfers of benefits or costs are to be ignored

As a consequence of CBA's central objective; comparing summed benefits to summed costs, we must ignore any economic aspect of a project which results in the mere one-for-one transfer of a benefit or cost. As a basic example, if a project results in a $10 million profit for firms using project-enhanced port facilities, but firms at other ports consequently lose $10 million in profits (possibly because of a one-for-one relocation of traffic), then the two economic effects would appear to cancel one another. If the *accounting stance* of the decision-making authority spans both gaining and losing ports, then the economic effects do cancel and there is no net benefit in this particular example. If the decision-making authority is only concerned for the gaining port, then there is a $10 million benefit to be counted, because the accounting stance does not extend to the losing ports. However, most water projects constructed in the U.S. are largely developed and funded by federal agencies, thereby establishing a national accounting stance. In these circumstances, the $10 million benefit would be negated by the $10 million loss unless a portion of these losses occur at ports outside the U.S. This perspective, though well founded, is a source of contention for regionally oriented project participants, such as local governments and regional consumer or industry organizations.

This tenet surfaces in many other ways in CBA. A more subtle appearance of this principle was implicit to the producer benefits illustrated in Figure 2. When project-supplied goods lower the supply curve for a forwardly linked industry, price falls and quantity produced increases. However, some members of this industry will be too far away from the project to experience the cost reduction which led to the industry's lower supply curve. These members only experience a reduction in price for their output, and they are therefore negatively impacted by the project. What occurs is that the extra profit of some industry members is greater than the losses of other members. The benefit measure illustrated with Figure 2 is, in actuality, a net benefit – in keeping with the tenet of ignoring zero-sum transfers.

Tenet #5. Temporal aggregation will employ discounting

Most public projects involve long time scales in which the timing of benefits is unmatched by the timing of costs. This feature begets something of an apples and oranges problem for economic assessments. Individuals and social communities of individuals are not indifferent between a unit of value today and a unit of value in some future period. Other things being the same, they prefer the unit of value today. In economic jargon, individuals and corporations have *private rates of time preference* indicating their tradeoffs between $1 today and $1 "tomorrow."

Details about rates of time preference emerge in financial markets where borrowing and lending take place, and these details can be used to address the apples and oranges problem of temporally separated costs and benefits. If auction interest rates for relatively riskless, governmentally backed treasury bonds is 5% after inflation has been removed, the market participants are suggesting that they equivalently view \$100 today and \$105 a year from now.

The only remaining matter is the question of whether a private rate of time preference, such as 5% in the above example, is usable for the social rate of time preference needed for CBA. Hotly debated during CBA's evolution, the matter remains theoretically unsettled except for the general recognition that the social rate of time preference is "somewhat" less than private ones (e.g., if private rates are identified as 5%, then the social rate should be less than 5%). The crux of the matter is as follows: Financial markets are composed of present-day agents disclosing personal tradeoffs regarding *their* todays and tomorrows. But government, as taker of today's people and people yet to be born, must exhibit concern for the welfare of future people, and it must make tradeoffs regarding today's people and tomorrow's people. Many theorists regard CBA decision criteria as harsh in accounting for the welfare of future people (Ferejohn and Page 1978; Howe 1990; Lind 1982). For example, if the rate of time preference is 5%, a \$1,000 cost to be experienced in 100 years, is only costed at \$7.60 today which is easily outweighed by slight present-day benefits. Other theorists observe that 5% is the opportunity cost of project funds, and it is therefore the appropriate rate. Federal policy has acted to extinguish debate over rate of time preference selection by legislating either a fixed rate or a process for the annual revision of the rate. The latter approach is used for federal water project studies.

The selected rate, called the *discount rate* in CBA, can be used to calculate either a *benefit-cost ratio* or a *net present value* for a proposed project. Formulae are as follows:

$$\text{BCR} = \frac{\sum_{t=0}^{T} \frac{B_t}{(1+d)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+d)^t}} \qquad \text{NPV} = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+d)^t}$$

where the planning period begins in the current year, $t = 0$, and extends to some future planning horizon, T. B_t and C_t are total benefits and costs in the subscripted year; these are estimated using the methods of cost and benefit estimation over viewed above. d is the discount rate. Once one of these summary economic indices has been computed, the decision criteria is as follows. If the benefit-cost ratio exceeds 1.0, then the project is judged to be beneficial. If the net present value exceeds 0, then the project is beneficial. While there are clear circumstances in which one of these criteria may be preferred to the other, here they can be regarded as equivalent insofar as they provide the same recommendations regarding project acceptability. They do not rank alternative projects identically, however (Sassone and Schaffer 1978, p. 28). Finally, analysts and decision makers must be mindful that neither of these criteria tells us whether a project is scaled (sized) most efficiently.

Tenet #6. Intangibles and incommensurables should not be ignored

The general procedures outlined above seek to condense all the consequences of a project into a single index, either a benefit-cost ratio or a net present value. This index is then used by CBA to resolve a recommendation – either the project is deemed to have benefits in excess of costs or it is not. This procedure works very well in many circumstances as long as all project consequences are commensurable. A *commensurable* impact is an effect upon human welfare that can be valued using reasonable economic techniques. However, in the present state of economic science, not all project impacts may be commensurable.

It is informative to distinguish between two types of goods which are not commensurable: incommensurables and intangibles. An *incommensurable* is a project result that cannot be valued using reasonable techniques, but it can be physically measured. For example, barge traffic on an inland canal might be expected to stir silt and reduce water clarity in a measurable amount. But how might this impact be valued? Similarly, a dredging operation's off-channel deposit of silt might create x acres of predator-free nesting area resulting in y new hatchlings each breeding season, but, again, what might be the value of this impact?

An *intangible* is a project impact that can neither be counted nor economically valued. For example, a large hydroelectric project may enhance the country's national security through enhanced self-sufficiency in energy production and decreased exposure to political influence exerted by energy-exporting countries. But how can we measure or value the increment to national security? Either task represents a considerable challenge. Similarly, this same hydroelectric project might conflict with an indigenous people's traditional activity, such as harvesting fish during migratory spawning runs, with some consequential loss of cultural integrity for the group. Again, both physical and economic measurement of this impact are problematic.

The existence of both incommensurables and intangibles means that some project impacts will not be monetarized. Such impacts cannot then be included in any CBA economic metrics such as the BCR or NPV. But, at a conceptual level, this does not infer that such impacts are irrelevant. They are project consequences distinguished only in our ability to monetarize them.

In these circumstances benefit-cost ratios and net present values are incomplete metrics. The advice of CBA theorists in these situations is to avoid full reliance on a benefit-cost or net present value criterion. Regardless of which economic measure is computed and reported in the decision-making process, it should be accompanied by the reasonable disclosure of unmonetarized project impacts. This task can only be achieved by describing unmonetarized impacts using available information and data. In the case of incommensurables, physical measures of impacts should be reported. Intangible impacts should also be described even though physical measurement is infeasible. This body of impact information is often very extensive, and it may be advisable to present impacts using a large, many-page tableau whose cells contain descriptive text and physical impact measures (Sassone and Schaffer 1978).

Valuation Methodologies

Having over viewed governing principles for CBA, it is now possible to examine the conduct of CBA for the four primary thrusts of this study: navigation benefits, secondary economic effects, environmental benefits and costs, and risk. The following subsections take up each of these matters individually, drawing upon contemporary economic theory as well as the structure provided by the CBA tenets.

Direct Navigation Benefits

Tenet #2 serves as the point of departure for the evaluation of navigation projects to direct beneficiaries. Direct benefits will be exclusively examined here; deferring to the report's next subsection discussion of secondary benefits resulting from economic linkages. Revisiting Figure

1 momentarily, the typical navigation project will enable an increment of ΔQ to transported tonnage. As discussed earlier, mathematically integrating under transportation demand identifies the appropriate economic measure of direct navigation benefits. But this simple model does not disclose the origin of transportation demand. Nor does it adequately portray some peculiarities of transportation economics. A more detailed examination is required to elucidate these matters.

A four-paneled graphical model of transportation supply and demand is shown in Figure 3. The lowest panel is essentially equivalent to Figure 1. The upper three panels illustrate the construction and interpretation of Figure 1 for transportation studies. The leftmost panel incorporates all aspects of supply and demand for any single commodity (e.g. grain, oil, gravel, or any manufactured good) in a specific area/region. The rightmost panel contains supply and demand curves for the same commodity in a different area/region.

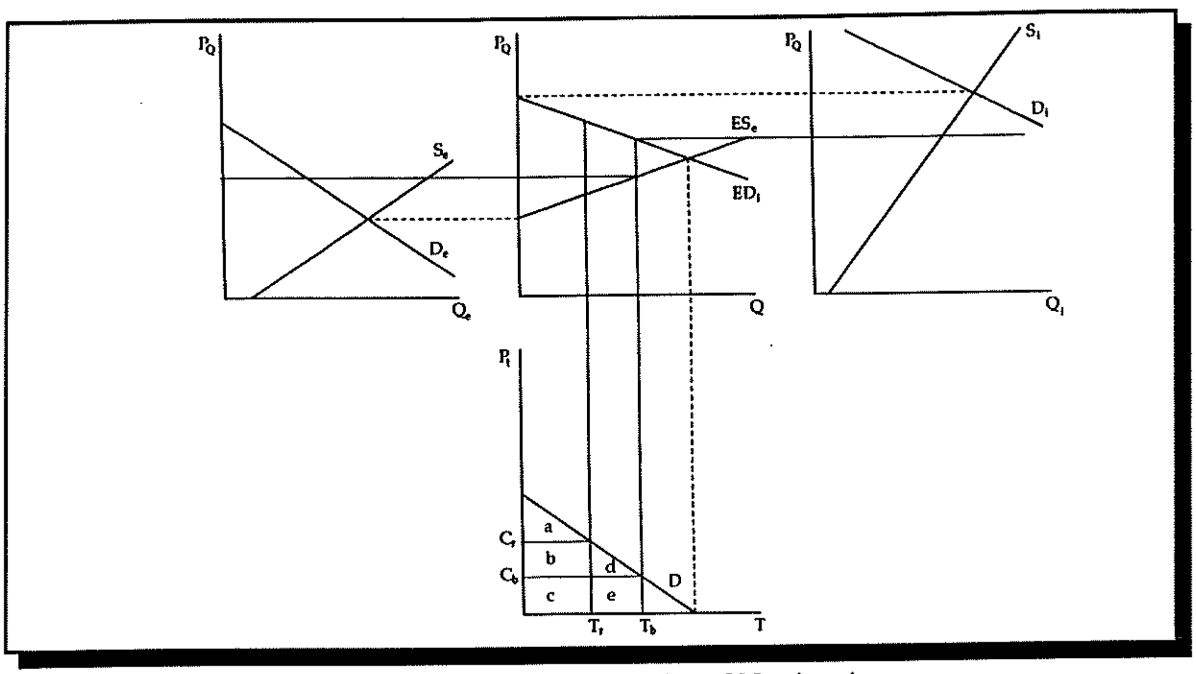

Figure 3. The Direct Benefits of Navigation

In the absence of any commodity movement between the two areas, it is apparent that the commodity is more valuable for the rightmost area than in the leftmost area thus motivating transportation of the commodity from the leftmost region (the exporting area) to the rightmost region (the importing area). Realizing this, we construct an *excess supply* curve for the exporting area by horizontally subtracting D_e from S_e. The result, ES_e, is drawn in the upper center panel. For every possible price level, ES_e indicates how much of the commodity Q is available for efficient export after satisfying local demand in the exporting area. By similar construction, an *excess demand* function, $ED_i = D_i - S_i$, is obtained for the importing area and placed in the upper center panel. Consulting the upper center panel now, the intersection of ES_e and ED_i would identify the quantity of Q to be traded if transportation were costless. This intersection also indicates the commodity price which would prevail in both regions if transportation was costless.

To extend the model to the more realistic case of costly transportation, the demand for the *transportation of Q*, denoted here as commodity T, is obtained as the vertical subtraction of ES_e from ED_i. The result, D, has been placed in the lower panel. Hence, the origin of transportation demand has been demonstrated. Observe that the area beneath demand curve D, which was earlier shown to be crucial in evaluating project benefits, is equivalent to the triangular area between ES_e and ED_i. In turn, this area can be shown to be summed consumer and producer welfare impacts attributable to Q's direct producers and direct consumers in the exporting and importing regions.

At this stage of our model development, several different scenarios might be considered depending on the presence of alternative modes of transportation and their relative capacities and operating costs. The scenarios are too numerous for exhaustive consideration here, but the flavor of a more complete economic model can be appreciated by exploring one or two situations.

Suppose that a proposed navigation project will enable barge transportation of a commodity which has been previously transported by rail[6]. Once the navigation project is in place, suppose that the per unit cost of transport by barge will be less than that for rail, and barge transport will therefore become the mode of choice. In the lower panel of Figure 3, this situation is depicted by presuming a constant marginal cost of C_r for rail and a constant marginal cost of C_b for barge.

In this scenario T_r units of commodity Q will be transported by rail between the two areas prior to the project. The total direct benefits of rail transport is given by the area under the demand curve, that is area a+b+c. The cost of this transport is area b+c which can be equivalently stated as

[6] This scenario also applies to the estimation of benefits for a canal dredging project if, in the absence of dredging, a more expensive mode of transportation would be used.

$C_r \bullet T_r$. Thus, the net benefit (total benefit minus cost) of transportation is area "a" when rail is the only available mode.

After project completion, the direct benefits of transport are a+b+c+d+e, and these are achieved while incurring operating costs of c+e. The net benefit of barge transport is then a+b+d. Most importantly, the project increases transportation net benefits by b+d. Observe that, due to the additional traffic caused by lowered transportation costs, multiplying the cost savings (C_r–C_b) by initial traffic quantity (T_r) would understate true navigation benefits. The correct measure of economic benefit (b+d) should be assigned to the navigation project and compared to project construction costs and other project-derived costs and benefits to decide whether the project is economically justifiable[7].

With a basic understanding of the meaning and goals of this model, many different navigation scenarios can be theoretically analyzed. For example, barge and/or rail transportation may be limited by capacity constraints resulting from installed infrastructure. Or, in the absence of water-based transportation, no transportation may occur. These and other situations can be modeled by making suitable modifications to Figure 3.

As is customarily true, the economic theory is sufficiently pliant to be adapted to many particularized settings. As an example pertinent to some GIWW situations, the exporting area may simply be company X's plant A and the importing area may be the company's plant B which uses A's output as a feedstock. If company organization is such that all of A's output goes to B, then D_e is absent and $ES_e = S_e$. If plant B receives this feedstock only from plant A, then S_i is also absent, and $ED_i = D_i$. The economic benefit of barge transportation over rail transportation, area b+d in Figure 3, is still correct in this scenario, and it is precisely the same as the increment to company X's profitability resulting from the cost reduction attributable to the navigation project.

Empirical application is the real challenge of the general theory illustrated with Figure 3. Important problems can arise in application, and these problems usually stem from incomplete

[7] This measure depicts navigation benefits during the period for which the demand curve D pertains. Parallel calculations for every period within the planning horizon are required. These benefit calculations must then be inputed to the BCR or NPV formula.

information and data. In practice, three primary issues perplex the estimation of navigation benefits:

1. When can prices in nonnavigation transportation modes serve as per unit measures for the social value of water-borne transportation?

2. What techniques are available to estimate how the amount of transportation services will increase due to the lowering of transportation costs and prices?

3. How much of the increased traffic might be accompanied by a reduction elsewhere?

These three questions are interrelated. With respect to issue 1, the lower panel of Figure 3 has suggested that nonnavigation prices might well estimate the gross per-unit benefit of all transportation up to T_r. The same is not true of increased transportation (issue 2) above T_r which clearly has gross per-unit values below C_r. Estimation of the amount of increased traffic and the net benefit of this increased traffic appears to require estimation of the D curve. Often, however, transportation transactions do not take place under competitive conditions, because regulation of interstate transportation rates by governments, and rate stipulation by government are not conducive to generating good data for the statistical estimation of D. Moreover, the occurrence of increased traffic at the project site may be matched by reduced traffic elsewhere which would partially or fully offset any direct benefits attributed to increased traffic (applying tenet 4 and presuming a national accounting stance). Thus, it would appear difficult to conduct CBA at a navigation project site without considering repercussions for transportation elsewhere, both for navigation and other modes.

The following subsection moves to the general matter of welfare estimation for sectors having economic dependencies with a project-influenced industry.

Economically Linked Industry and Employment

Having considered the evaluation of direct navigation benefits experienced by navigation-using industry, we now examine the possibility that consumers or navigation-linked industries may experience commensurable welfare changes as a result of navigation projects. It is well acknowledged that economically linked industries and households encounter *secondary* or, synonymously, *indirect economic effects* when any industry changes its production level. *Induced economic effects* are a class of indirect effects that may also warrant attention. But do any of these impacts translate into welfare effects that should be incorporated in cost benefit analyses? This question is the heart of considerable confusion and misinterpretation in economic analysis. The importance of allaying this confusion is readily underscored with the few following observations.

It has become common to approach the analysis of secondary economic effects by applying *input-output analysis* to develop *economic multipliers* which convert direct economic changes into the sum of direct plus indirect economic impacts. Obtained multipliers are commonly on the order of 2.0 to 3.5 indicating that secondary effects easily surmount and dominate direct impacts. Hence, the issue of whether or not secondary impacts count is of some consequence in decision making for public projects.

Moreover, a growing number of economic impact studies, using input-output analysis and concentrating on secondary effects, have been conducted for port and waterway transportation facilities in recent years. Example studies include those performed by Garrett and Burke (1989), Mercer (1995), and Ryan (1996). Interest in the results of such studies continues to increase as industries, firms, and public facilities strive to "prove their worth" in a political climate that is increasingly conscious of economic growth and employment. The media has become quick to report employment and economic impacts of these organizations when such information is available, thus contributing to the general politicization of economic impact analysis. But is it truly proper to consider such impacts? Other groups have begun to use similar approaches in railing against public support of particular activities. For example, a recent study by Diaz and Kelly presents economic evidence purporting to demonstrate the economic unattractiveness of a particular segment of the GIWW (Diaz and Kelly 1994). Yet the study considers expenditures and secondary effects without analyzing direct benefits. While the omission of direct welfare effects is clearly improper in project analysis, the unanswered question is again: Is it proper to consider secondary effects in CBA? This question is investigated in the following two subsections.

General Equilibrium Welfare Analysis

Having noted the relevance of our topic, what is the nature of the secondary welfare impacts that may be properly considered? The theory of general equilibrium welfare analysis observes that there may be emergent welfare effects both forward and backward of the directly impacted industry (Just, Hueth, and Schmitz 1982). Let us denote the navigation-using industry as industry number N in an ordering scheme that begins with basic raw materials (industry number 1). In the case of forward linkages for navigation, the reduced cost of transportation translates into lower costs of production for navigation-using industry thereby lowering its marginal costs of production. If the fall of marginal production costs is significant, and if the affected firms are significant to their industry, the lowered marginal costs (equivalent to the supply function) lowers product price which (a) negates some portion of the direct benefits to the N^{th} industry and (b) produces indirect benefits for the product's purchasers (either final consumers or industry N+1). In turn, the reduced product price in the forward industry conceivably generates another round of welfare effects for industry N+2 and so on. If the change in transportation costs is insufficient to produce a price fall in the immediately forward market, then there can be no forward welfare effects.

In the case of backward linkages, a similar situation holds. The reduction in transportation costs for industry N potentially raises its demand for other (nontransportation) inputs. If the demand increase is sufficient to generate an increase in the price of industry N-1's output, additional net welfare benefits will be created in the industry and possibly, through additional linkages, in industries N-2, N-3, etc.

As distinguished from the measurement of direct benefits discussed earlier, forward/backward industry welfare effects result from transmitted price changes. These price changes admit the feasibility of beneficial secondary welfare effects while simultaneously lowering direct welfare effects. As such, secondary welfare measurement is double-edged.

Having noted the existence of validly incorporated benefits in backward and forward industries, how are they to be estimated? Various literature on this topic discusses three general methods.

Method 1 involves *sequential partial equilibrium analysis* in each individual industry proceeding forward and backward of the primarily affected industry (industry n). This method requires knowledge or estimation of the individual supply and demand functions for each analyzed industry. Employed supply and demand functions must be sufficiently detailed to observe the price interdependencies of linked industries. When completed, the various welfare effects, computed as changes in producer and consumer surplus measures, are to be summed.

Method 2 requires the availability of *general equilibrium supply and demand functions* for the primary (n^{th}) industry only. General equilibrium functions endogenize price reactions in linked industries, effectively treating all forward industries as merged and all backward industries as likewise merged (Just, Hueth and Schmitz 1982). Welfare analysis for this single, equilibrium market then captures the direct and indirect welfare impacts. Estimation of general equilibrium functions via econometric analysis presumes that general price-quantity data observed from market operations demonstrates a general equilibrium character. That is, it is strongly presumed that <u>all</u> prices simultaneously adjust to a perturbation anywhere in the economy without lag.

Method 3 is similar to method 1 in that all affected industries are separately modeled. Here, however, supply and demand functions for all industries are incorporated in a single *computable general equilibrium (CGE) model*. Simultaneous solution of the model's market-clearing identities identifies all prices. Applied to the analysis of a prospective navigation project, an appropriate CGE model could be constructed and solved with and without a change in transportation price due to a potential navigation project. Economic welfare measures can be internally computed for each of the two model solutions, and the difference between the two constitutes the direct and indirect welfare impact of the project.

All three methods are feasible, yet the second method has a demanding assumptive base which is unlikely to be fulfilled, at least for navigation-related situations. Methods 1 and 3 are therefore more practical, but they too present demanding analytical tasks. An important question at this juncture concerns whether input-output analysis represents a suitable CGE model. Input-output analysis has been characterized by some authors as a CGE model (Dixon et al. 1992), but it is noteworthy that price determination is not endogenous to input-output models. Because changing prices forward and backward of the directly affected industry play a key role in the secondary welfare effects noted above, input-output analysis may not possess the robustness needed to estimate secondary welfare effects. The appropriateness of employing input-output methods in welfare analysis is examined below.

The Role of Input-Output Analysis

Input-output (I-O) analysis is a method of exhibiting and examining the interdependence of economic activities within a given region. In truth these interdependencies are very complex, and it is a formidable task to model the many relationships. Input-output makes modeling more feasible through linearization of an economy's internal workings. Using recent business data, the I-O analyst organizes a region's total economy into comprehensive industry groupings and other categories as necessary to capture all flows of goods, services, and money in the regional economy. Other categories include such things as government, exports, imports, and households.

The I-O analyst uses data on the expenditure and income patterns of each of these sectors to obtain a snapshot of financial flows within and among the sectors. This information enables a tabular representation of the total value of every sector's output along with the sector's purchases from each other sector. Simple division produces a matrix, denoted by A, of direct coefficients where each matrix element, a_{ij}, is sector I's direct purchases from sector j per dollar of sector j's output. A's dimensions are n′n where n is the number of industry sectors in the model. The key element of I-O is to then assume that the fixed proportions represented in A will be preserved in any contractions or expansions that may take place in the economy. This is a strong assumption, but it succeeds in linearizing all economic relationships, thereby making further modeling quite simple. With knowledge of the matrix of direct coefficients, various multipliers can be computed. These include *output multipliers* and *income multipliers*. With additional information *employment multipliers* can also be computed. All of these multiplier concepts require calculation of the matrix of <u>direct plus indirect</u> coefficients. Letting I denote the n′n identity matrix, which has 1's along its diagonal and 0's elsewhere, direct and indirect coefficients are given by the n′n matrix $(I - A)^{-1}$

where -1 denotes matrix inversion. $(I - A)^{-1}$ is called the Leontief inverse (Miller and Blair 1985).

Output multipliers are obtained by summing the columns of $(I - A)^{-1}$. If N is a 1′n row vector of 1's, then the vector of output multipliers is given by O where

$$O = N(I - A)^{-1} .$$

Notice that the matrix of direct coefficients, A, is the only information needed to complete this calculation. Each of the n elements of vector O is the output multiplier corresponding to a specific sector. Thus, the i^{th} element of O is the combined increase is output value, required from <u>all</u> industries, that must accompany an increase of \$1 in deliveries to final demand by industry I. Because each multiplier includes the final demand deliveries, output multipliers are necessarily greater than 1.0.

Miller and Blair refer to the output multiplier defined above as a *simple* output multiplier, because it does not incorporate the *induced* effects of respending by households (Miller and Blair 1985, p. 102). The *total* output multiplier is an expansion of the multiplier concept to include induced effects. Computationally, a formula equivalent to the previous one applies once the A matrix is expanded to include a household row and column, thereby having its dimension increased to (n+1)′(n+1). The matrix I and vector N must be similarly expanded.

Output multipliers are the predominant multipliers emerging from I-O analysis, and it is especially important to consider their proper interpretation. Suppose that a sector called Agriculture in a Texas I-O model is expected to increase its exports to areas external to Texas by \$1 million due to an exogenous change in policy. If the output multiplier for this sector is 2.1, then this means that the \$1 million in added sales will be accompanied by another \$1.1 million in sales in the Texas economy. The addition to the value of output for the Texas economy is therefore estimated to be \$2.1 million rather than \$1 million.

The next crucial question is: Can this \$2.1 million increase can be interpreted as a rise in economic welfare for the state or for the nation? This question embeds multiple issues. If this question is motivated by a cost-benefit appraisal of the original, export-inducing policy, then the direct benefits of the \$1 million have been addressed separately by willingness-to-pay measures as discussed in preceding subsections. The earlier discussion suggested that the true direct benefit of the \$1 million in output is measured by the addition to net returns in the industry experiencing the increased output. To employ a corporate analogy, a $1 million increase in sales does not generate $1 million in benefits for a firm, because the firm must purchase many things to produce the additional goods or services. The increase might cause, say, a $50,000 increase in profits which is an enhancement of the firm's welfare. Not surprising, the same is true for valid forms of social economic accounting. Because the inputs used to create the added output have opportunity costs and these opportunity costs are usually well represented by market prices, the net increase in direct benefits is substantially below the change in total direct output.

This underlines the essential difference between an *economic impact* and a *change in economic welfare* – two different, although correlated things. One million dollars is the direct economic impact of the studied policy, but the welfare change is limited to the amount by which the impact exceeds its opportunity costs. The direct economic welfare change can only equal the direct economic impact when opportunity costs are zero. In a market-oriented economy it is rare to see inputs having zero opportunity costs. An input will only have zero opportunity costs if it would otherwise be unemployed.

But what of the secondary effects, that is, the $1.1 million in accompanying output for the above example? Might there be welfare gains of a general equilibrium nature in these secondary effects? The abbreviated answer is "yes," but ordinarily the welfare gains will be substantially less than the secondary economic impacts. Again, a large portion of any impact will be accounted for in the opportunity costs of consumed inputs. Once these opportunity costs are subtracted from the $1.1 million, the result will be a true welfare gain. Thus, in the case of both direct and indirect impacts, the existence of opportunity costs for employed inputs serves to substantially limit welfare increases.

Do *income multipliers* more closely approach the requirements posed by welfare analysis? They at least sound as though they might. Income multipliers can be readily calculated if households are separately represented by a Household row and column in the I-O model. Let H be the $1 \times n$ vector where H's i^{th} element is payments made by sector I per dollar of I's output. Hence, it is defined similarly to all other elements of matrix A. *Simple income multipliers* are then given by the elements of M where

$$M = H(I - A)^{-1} .$$

The i^{th} element of M is then the impact of a \$1 increase in sector I's deliveries to final demand on direct plus indirect household income. *Total income multipliers*, which also embed induced effects (resulting from household respending), can be obtained by the same calculation once the H vector and A matrix are expanded to endogenize households.

Therefore, simple and total income multipliers represent the impact of changes in final demand deliveries upon regional household income. Unfortunately, this is not the same as a welfare effect for regional households because labor, like other production inputs, has opportunity costs. If, by applying I-O analysis, a \$1 million prospective increase in the output of a specific industry is projected to expand direct household income by \$150,000 and indirect household income by another \$50,000, then the I-O model has assumed that this additional labor will be diverted from its previous pursuits. The internal structure of an I-O model does not allow wage rates to be bid up by economic expansions. The increased household income is therefore the result of things such as (i) longer working time (and less leisure time[8]) among existing workers, (ii) immigration of new wage-earners who were working in other regions, and (iii) work performed by people who were previously unemployed. Only in case (iii) can social opportunity costs be argued to be low. Thus, income multipliers would tend to well overstate regional welfare changes unless regional unemployment is running very high. Due to friction in the operation of labor markets, economists believe that a full employment economy is obtained when unemployment is as low as 6%, not 0% (Ottosen and Thompson 1996). Because of the cost of matching available workers with available jobs as well as relative immobility of people (as compared to other production inputs), it is neither realistic nor efficient to achieve near-zero rates of labor unemployment.

In case (ii) where new workers are acquired from other regions, it can be argued that there is a substantial <u>regional</u> enhancement of household income even though the <u>national</u> enhancement may be small and overstated by a regional income multiplier. This argument represents the use of a regional accounting stance rather than a national one. While regional accounting stances are valid rationales for judging regional projects and policies, federal agencies would normally use national

[8] Even leisure time possesses opportunity costs, both privately and socially. Economic analyses sometime employ wage rates as the marginal value of leisure time in full employment situations.

accounting stances in their decision-making processes (as noted under tenet #4). Moreover, even from a regional perspective, it may be sensible to distinguish between welfare changes made available to a region's existing residents and those made available to its future residents. To the extent that the constituency for today's decision-making processes is composed of today's residents, then estimating welfare changes only for existing residents is preferable.

For completeness, we define *employment multipliers* at this point even though their role in welfare analysis is limited. Let L denote a 1′n vector of employment coefficients where the i^{th} coefficient is the number of workers employed per dollar of sector I's output. A 1′n vector of employment multipliers is then given by E where

$$E = L(I - A)^{-1} .$$

E_i, the i^{th} element of E, is the number of direct and indirect employees accompanying a $1 change in sector I's deliveries to final demand. Note that the units estimated by the employment multiplier are the number of employees rather than their income. As for previously discussed multipliers, induced employment effects can also be incorporated if households are endogenized as a distinct sector of matrix A and vector L. Moreover, regional employment multipliers are not appropriate for national accounting stances for the reasons noted in the income multiplier discussion.

The above discussion generally indicates that I-O based multipliers are ill suited for illuminating direct and indirect welfare effects in most circumstances. In the case of direct welfare effects, I-O analysis is not applicable as the methods discussed in previous subsections admit no role for I-O. In the case of indirect (secondary) welfare effects, the discussion of multipliers does not conclude that indirect welfare effects are nonexistent. The primary points emerging from the discussion are as follows:

- Secondary welfare effects are distinct from economic impacts – which is the emphasis of I-O analysis;

- I-O multipliers (all types) help to estimate economic impacts, not secondary welfare effects appropriate for CBA; and

- I-O multipliers would seem to substantially overestimate secondary welfare effects due to their inclusion of opportunity costs (which should be subtracted).

Given that I-O multipliers do not indicate secondary welfare effects, does I-O analysis have the capability of contributing to the estimation of secondary welfare effects in some other way? Repeated debate and inquiry over this issue as it relates to water projects has generally forwarded a negative response (Cooke 1991; Hamilton et al. 1991; 1993; Hughes and Holland 1993; Young and Gray 1985). However, even the most critical literature suggests that cautious and purposeful extensions of I-O models can be successful in estimating secondary welfare effects. Accomplishing this requires that opportunity costs be subtracted from the so-called *value-added* components of the I-O model so that remaining portions of value-added correspond with true welfare changes (Hamilton et al. 1991). It is improper to include the entirety of value added, because it is largely attributable to other inputs (such as labor, capital/depreciation, and land) which possess opportunity costs of their own (Young and Gray 1985). Literature of this matter consistently underlines the importance of not attributing all value added to a public project when there are other important inputs which are jointly responsible for increments in produced goods.

<u>Environmental Benefits and Costs</u>

The issue of how to evaluate environmental impacts accompanying navigation projects can be readily resolved by reviewing CBA tenets #3 and #6. These principles apply to both positive and negative environmental effects. Because most environmental impacts tend to be experienced by households rather than by producers, it is generally appropriate to economically assess environmental impacts for their influence on consumer surplus (tenet #3). The fundamental element for conducting such an evaluation is consumer demand for the good being affected (e.g. concentration of a given water contaminant, number of a specific species). But because environmental goods tend to be allocated by nonmarket institutions (policies), consumer demand estimation can be problematic.

Nonmarket valuation methodologies for "working around" the absence of direct market data for estimating demand include hedonics, the travel cost method, and contingent valuation (Feenberg and Mills 1980; Freeman 1979; Johansson 1993; 1987; Moss, McCann and Feldman 1994).

Depending on actual circumstances for the specific environmental impacts under consideration, one or more of these methods may be applicable. But application of these methods can also be expensive. If economic evaluation of environmental impacts is infeasible due to a lack of data and the high cost of performing nonmarket valuation, then tenet #6 applies directly. That is, some impacts will have unmonetarized effects on social welfare and will not be incorporated in the benefit-cost ratio or net present value economic metrics relied upon by CBA. This does not infer that such effects are irrelevant. In this case the economic metrics must be accompanied by the reasonable disclosure of unmonetarized project impacts.

It bears mentioning that consumer expenditures on environmental goods, such as sport fishing (expenses for equipment, bait, lodging, charters, etc.), are <u>not</u> directly usable for measuring the welfare effects of a prospective change in the quality of sport fishing[9]. To continue with this illustrative example, nor is expenditure information a valid estimate for the net benefit of the sport fishery prior to any changes. Expenditures are presumably a lower bound for <u>gross</u> benefits, because rational people would not engage in such expenditures otherwise. However, such expenditures are both a private and a social cost and are necessarily excluded from net benefits. Net benefits may be less than, the same as, or more than expenditures; there is no way to tell based on mere expenditure information. The net benefit of a sport fishery is its gross value to consumers <u>minus</u> expenditures. That is, it is the consumer surplus. In CBA, the welfare effect of an action which will improve or degrade a sport fishery is its change in consumer surplus.

<u>Risk Impacts</u>

The issue of risk for project analysis is a broad topic, as there are risk-related dimensions to many aspects of public projects. Risk considerations arise from all the uncertain aspects of a water project as well as the analytical work that accompanies project evaluation. What will the completed project cost? What will future demand be for project products? Will future technologies and preferences enhance project demand or provide important substitutes? Will the productive life span of the project be long or will it depreciate quickly due to natural forces or unforeseen events? All

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[9] Such information may, however, be usable by an indirect estimation procedure such as the travel cost method.

such questions bear upon project analysis. Here, however, concern is limited to the risk of accidents in alternative transportation modes. The cost of accidents with which we are concerned include both environmental and life hazards.

To the extent that navigation projects offer an alternative mode of transportation in which the costs of accidents differ from accident costs for alternative modes, it will be useful to capture these differences in social costs and enter them in a CBA index (BCR or NPV). Theoretical examinations on the matter of accomodating uncertainty in CBA show that the central objective of CBA is not entirely definitive in stating how social risk preferences are to be measured. Here, we will observe two alternative measures, either of which can be validly included in CBA indices (Graham 1981). The two are option price and expected surplus value.

In general, the costliness of any single accident will depend on a variety of factors, and some of these factors will vary over time. Suppose that the chance of accidents is greater for transport mode B than it is for mode A. In the case of differing accident risk between modes, an individual person's *option price* for mode A over B is the maximum constant payment the person is willing to make in every period (regardless of whether an accident occurs during the period and regardless of the character and circumstances of an actual accident) to ensure that mode A is being used rather than mode B. Obtaining these evaluations requires the careful survey of a representative sample of people. In keeping with CBA's central objective, the sum of option price across all people would constitute an acceptable measure for the value of risk reduction in employing A rather than B.

The alternative welfare measure, *expected surplus value*, can be obtained as follows for the above example. Let T_A and T_B represent ton-miles or some similarly dimensioned measure of the amount of transportation undertaken with mode A and B, respectively. This notation permits reduced or induced transportation resulting from differing transportation costs. Denote alternative accident classes by the index j which enumerates accidents of differing severities and costs. j extends from 1, the class of low-level accidents, to the integer J which represents the most costly accidents. The number of different accident classes is arbitrary and can be selected by the analyst.

The cost of a single j-class accident is C_j which includes all costs associated with a j-class accident including monetarized environmental and human health losses. In general, the probability of j-class accident will differ between modes, and it will be a function of traffic volume. Thus, we write these probabilities as ${}_AP_j(T_A)$ and ${}_BP_j(T_B)$ where ${}_iP_j(T_i)$ is the probability of a j-class accident for mode I (I = A or B). Using expected surplus value, the social risk benefit of changing from mode B to mode A is the expected accident damages occurring with B minus the expected accident damages occurring with A. Thus, the expected surplus value is

$$\sum_{j=1}^{J} {}_BP_j(T_B) \bullet C_j - \sum_{j=1}^{J} {}_AP_j(T_A) \bullet C_j = \sum_{j=1}^{J} \{{}_BP_j(T_B) - {}_AP_j(T_A)\} \bullet C_j \ .$$

In general, the expected surplus value approach appears to be a preferable technique for project analysis, although both approaches have demanding informational burdens. Theoretically, it cannot be said whether option price or expected surplus value will be greater. Because of the presence of environmental costs in accident-related damages, it may be true that not all environmental consequences will become monetarized by these measures, again necessitating nonmonetarized disclosure via descriptive accounts which must now incorporate available probabilistic information.

Summary

Reviewing this research in relation to the four primary questions highlighted at the outset, most of the attention has been garnered by the pivotal issues of direct benefit and cost measurement. CBA's central objective and the majority of CBA's tenets dictate economic techniques for estimating the direct economic effects of navigation projects. It has been noted that navigation projects may generally contribute to producer and/or consumer welfare in manners necessitating economic assessment of changes to producer and consumer surpluses. When the appropriate surplus measures are incorporated in the net present value or benefit-cost ratio metrics, discounting is employed to adjust for the social rate of time preference. Earlier, surplus measurement in a generic navigation situation was illustrated using arbitrary supply and demand relationships for exporting and importing areas. Therefore, the central technique for evaluating transportation benefits is predicated on information regarding to the supply and demand for transportation.

Concerning the matter of secondary economic effects, it is observed that welfare measurement also applies to industries and consumers who may be economically linked to navigation, and valid welfare effects in these sectors are generally a consequence of commodity price changes originating from the navigation project. Some form of general equilibrium welfare analysis is most appropriate for performing welfare change estimation for linked industries, but the informational/analytical burden is high for such techniques. Input-output analysis stands as a ready alternative, but due to its nontreatment of price repercussions, input-output analysis is in need of crucial adjustments if its results are to assist in welfare analysis. The input-output-derived multipliers, which estimate direct plus secondary and possibly induced economic effects, cannot be interpreted as welfare consequences unless the social opportunity costs of committed resources and production inputs are first debited. This adjustment is not commonly pursued in input-output work. Thus, input-output results generally represent economic impacts rather than welfare effects – the distinction being crucial in policy/project study. Economic impact and welfare effect will generally coincide only for local accounting stances in which all resource/input costs accrue externally.

The final motivating issues for this research involve the economic measurement of the environmental and risk consequences of prospective navigation projects. Risk analysis (for transportation-associated risk) is shown to be achievable by extending the economic tools to capture probabilistically dependent accident costs. In the case of environmental evaluation, important, evolving techniques are available for the monetarization of project-caused, environmental enhancements or harms. While sometimes justifiable, these techniques can be expensive to deploy, and it is therefore unlikely that all environmental influences will be evaluated. In such situations, we must be mindful that environmental impacts are project consequences distinguished only in our ability to monetarize them. Their omission from net present value or benefit-cost ratio metrics does not demonstrate irrelevance, but it does underscore the incompleteness of the economic metrics. Meritorious decision making must now contemplate more than a single economic index.

CHAPTER THREE

Methodologies and Empirical Examples of Cost/Benefit Analysis in Practice

This section examines a sample of completed studies of waterway and other related public works projects over the last several years. It is an attempt to demonstrate what has actually been done under the umbrella of cost-benefit analysis (CBA). The purpose of such an undertaking is to provide a means of placing these studies into easily identifiable categories to aid future analysts in their task of selecting methodologies for studies they may undertake. The categorization that results from this section is, in the end, a very simple one, separating studies that attempt to follow the tenets of cost-benefit analysis described in the previous section from other studies that, while they may measure certain economic benefits and/or costs, do so in a manner that is not consistent with the general principles described earlier. Even though these differences should, in theory, be easy to discern, our survey of the existing literature demonstrates that some analysts are not aware of the distinction set forth here, evidenced by the fact that they often mislead their audience by using the terms "cost" and "benefit" in the titles of their studies without embracing the principles of cost-benefit analysis. This is not to say that all studies that profess to be "cost-benefit analysis" are clearly better than other studies attempting to evaluate waterway projects. Nor do we wish to imply that all of the cost-benefit studies that, indeed, do profess to the principles of CBA as suggested by this study's previous section do indeed follow the accepted principles of CBA. Much to the contrary! This section is an attempt to show that, often, so-called "cost-benefit analysis" studies are at a considerable variance from the standards set forth earlier in this study. Only through a clear understanding of the differences among such so-called CBA studies will analysts be apprised of the reasons why they must be both critical and, at the same time, open in their choice of methodology when they are evaluating waterway projects.

In the practice of evaluating benefits and costs of actual projects involving the expenditures of public funds, there is a huge number of projects comprising a myriad of approaches and methodologies. There is no easy way to categorize the studies that have been used to evaluate the benefits and costs that have given existing projects their lives. In fact, there are several ways--none of which can be said to be the ideal way--of grouping these studies. Further, because a large number of these studies have been conducted by private consulting firms whose modeling to derive benefits and costs can be considered proprietary, it is not always possible to determine the origins of some of the values of benefits or costs, or both, in a particular study. Some of them, unfortunately, must be taken at face value based on the long-term reputations of the consulting firms who have conducted such studies.

Therefore, this section will not attempt to catalog every study involving cost-benefit analysis that has ever been done. Such a task would prove formidable, if not impossible, due to the sheer volume of literature that would need to be gathered and assimilated from the past sixty years or so of completed studies related to publicly funded projects of various types in every country where such studies have been written. Further, because of the difficulties mentioned above, even if it were possible, it probably would not add much to our understanding of the actual practice of CBA. In fact, in the early years of CBA, many analysts typically made up numbers that demonstrated the desired result, or at least failed to document or explain the methodologies by which their numbers were derived--a common complaint about the practice of CBA that has not, even to this day, been completely resolved, either in the minds of those proposing projects or of the critics of public project approval. Prospects of solving this problem become even more remote given the fact that private consultants developing proprietary models and data still play large roles in the production of cost-benefit studies. Therefore, this study cannot presume to solve all of the problems that surround the use of cost-benefit analysis or any other methodology in evaluating public waterway projects. Still, since it is essential that we consider port and waterway rehabilitation and expansion, it is beneficial to examine some of the ways that studies of waterway projects might be categorized, and then select from these an arrangement that is simple enough to be useful to future analysts of projects related to waterways.

Categories of Studies

Port vs. General Navigation

Most studies of public water resource projects can be separated into those associated with a particular **port** and those of a more general nature, usually associated with more systemic projects concerning **general navigation** on an inland waterway or system of waterways.

If the project is port related, the objectives of its construction are generally related to costs directly incurred by that port, costs such as those caused by 1) vessel delays between entering and leaving the port; 2) physical deterioration or obsolescence of existing infrastructure; 3) need for additional berths or other facilities to cover increased or potentially increasing shipping demand at the port; or 4) needed channel dredging to widen, straighten, and/or deepen the channel. Also, the changes in technology and transportation priorities in recent years (such as containerization and the passage of ISTEA) have demanded improvements to take into consideration improvements in the port's linkages to other transportation modes through construction of rail linkages, container facilities, or other intermodal linkages, with such a project providing benefits to the overall transportation system as well as the port in question.

Benefits related to port-specific projects may be thought of primarily as those which accrue locally. Such benefits, first and foremost, involve Pareto-improvements in a number of the situations above.[10] These include 1) decreases in delay time for vessels while in port; 2) a reduction in accidents in the port's ship channel; 3) reductions in the cost to shippers of using water transportation at that port so that shippers use it rather than some alternative mode or port; and 4) increases in the port's profitability.[11]

In practice, a large number of such port development projects tend to be primarily concerned with berth improvements or repair, or replacement of some other existing equipment or facility, or

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[10] A Pareto-improvement is measured as a reduction in opportunity cost. That is, it means that there is a gain because of the project that is not fully compensated by a loss or losses elsewhere in the system, so that net societal benefits exceed societal costs.

[11] Technically, an improvement in a port's profits does not necessarily constitute a Pareto-improvement, since losses might occur elsewhere. The fundamental principles of CBA may be violated if such a measure is included in a project's benefits without also measuring the losses. Nevertheless, a project's profitability is often an important consideration to a port given that it should not create too much of a drain on the community coffers.

with the widening, straightening, or deepening of the ship channel.

If the project concerns general navigation on inland waterways, the primary objectives of its construction usually involve the costs of 1) traffic delays caused by congestion on certain portions of the waterway; 2) rehabilitation or replacement of lock and dam structures that are old or obsolete; and 3) dredging to improve traffic flow and safety of existing waterways or to extend the waterway to areas not presently served.

This last project type has, historically, been considered one of the most cost-efficient methods of improving an inland waterway because the labor and capital costs of dredging are generally low relative to the safety and traffic-flow return on such projects. In the last few years, however, critics of dredging projects have often raised environmental concerns regarding detrimental effects of dredge spoil removal and disposal on nearby riparian and riverine habitats that depend on the waterway for life support. Critics claim that if a waterway's construction disrupts these habitats, yet is subject to low use, there is argument that the good provided is not very close to the definition of a "pure" public good, so users of the waterway should be charged to cover the costs of the waterway's existence.[12]

If environmental costs are deemed high and are, at the same time paid only by direct users, the expected transportation-cost-reduction benefits to potential users would, of course, be reduced or eliminated, as would be spillover benefits to others in the economy. Therefore, potential users would tend to consider alternative transportation modes so that the improved waterway might, indeed, be subject to low use, validating the criticism of the project.[13]

On the other hand, when the waterway promotes high use, the "users-should-pay" argument loses some of its strength. Nevertheless, the contention by some critics that users should bear a larger part of the project costs, coupled with the subjective nature of--but genuine need for--measuring the true environmental costs of dredging projects, has often made it difficult to maintain or increase channel width or depth, or to improve goods transport speed and safety through channel

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[12] A pure public good creates spillover benefits that are shared by everyone in the economy, whether or not they are "direct" users of the good, and whether or not they actually pay for the good, either through taxes or user fees. Because there are many benefits accruing to "nonusers," taxpayers should be expected to cover much of the cost of a pure-public-good project.

[13] See Constance E. Hunt, "Reducing Environmental and Economic Costs of Inland Waterway Operation and Maintenance."

straightening. In fact, many projects that have been delayed by litigation procedures in the last few years have faced the problem of the subjective nature of environmental cost measurement.

As they pertain to inland waterways, the benefits of waterway improvement projects are usually exemplified by measurable 1) reductions in traffic delays along the waterway; 2) improvements in safety along the waterway; 3) reductions in shipping costs for the transport of goods from origins to destinations served by the waterway and alternative modes; and 4) increases in the flow of goods that encourages domestic and international trade. If an inland waterway project is to be constructed, the reasoning behind its acceptance should manifest itself in the gains to the overall waterway system or subsystem rather than merely the creation of a benefit at one point on the waterway, say the Port of Decatur, Alabama, at the expense of a port elsewhere on the waterway, such as the Port of Chattanooga, Tennessee. Similarly, benefits provided by the Tennessee-Tombigbee Waterway should not accrue at the expense of equal losses on the Mississippi River system. After all, if gains at one point are canceled by losses elsewhere, there is no Pareto-improvement, so that the project violates Tenet #4 of CBA principles and guidelines, as described in the previous section of this study.

Because waterway systems encompass a much broader spectrum of problems than might occur for the typical individual port, waterway development projects take on a wider variety of objectives than do port-specific projects. Still, a large portion of such projects involve dredging or lock and dam improvement. Of course there are some notable exceptions, such as the construction of the Tennessee-Tombigbee Waterway and proposed extensions of the intracoastal waterway system, including the Gulf Intracoastal Waterway (GIWW).

Economic Impact Studies, Categorized by Type

Many studies are constructed under the general category known as **economic impact studies (EIS)**. If such a study is conducted for a particular port project, it is often called a **port impact study (PIS)**, a subset of the EIS methodology. There is a vast literature studying an enormous variety of projects and facilities under the guise of EIS/PIS. For many years, such studies were the most common way of evaluating public facilities. However, if this category is taken broadly, as it often is, it can include a wide number of methodologies used for many purposes. In the parlance of many local port studies and, to a lesser extent, a number of other waterway studies, we might see in the titles of these studies the term "economic impact," "feasibility," "input-output," "cost-benefit," or some other description as to the purpose or methodology of the study. Historically, analysts have often taken these terms to be synonymous in meaning. If we choose to categorize waterway studies in this manner, cost-benefit analysis can then be considered one of several types of economic impact study. Project evaluation conducted under the title of "economic impact study" has, in fact, included, but has not been limited to, the following methodologies: 1) the income-expenditure method; 2) economic base analysis; 3) input-output analysis; and 4) cost-benefit analysis.

The **income-expenditure method**, when used in port and waterway studies, is a regional macroeconomic model that examines the relationship between gross regional product (GRP) and regional consumption, investment, government purchases of goods and services, and net regional foreign trade.[14] Employment of this model usually requires the use of a variety of U.S. census data for the region under study in order to develop a single multiplier relating autonomous regional expenditures to total regional output (equivalently, income or GRP). Once the region's multiplier is calculated, any local waterway expenditures can be multiplied by that single multiplier to estimate output and employment benefits of the facility on the studied region.

Economic base analysis separates the local economy under study into two parts: 1) the economic base--the sector that produces goods and services that are exported from the local economy; and 2) the local sector (or service sector) consisting of firms and resources that merely serve the local economy. This methodology relies on the evaluation of export sector demand to determine employment and output levels in the region under study. Given the fact that waterway facilities are generally considered contributors to an area's economic base because they provide export facilities, analysts can estimate the relative value of the port or waterway under study based on the way it enhances the area's exports, and can calculate the contribution of such a facility to the area's economic base.[15]

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[14] Net regional foreign trade is trade in goods and services between states or areas in the geographic region under study and all foreign trading partners.

[15] For a thorough statement of the use of economic base methodology in waterway studies, see W. Cris Lewis and Terrence F. Glover, *Linear Programming/Economic Base-Evaluation Model for Estimating the Regional Development Impacts of Water Resource Projects: User Manual.*

Input-output analysis (IO) is a methodology used to describe the interdependence of resources and goods and services among the sectors of the economy. IO analysis is a fairly complex modeling procedure, in that the collection of primary data required to build such a model for a region or local area is generally beyond the budgets of most studies. However, surveys of local establishments coupled with secondary data from the U.S. Department of Commerce The Input-Output Structure of the U.S. Economy can be used to calculate a number of regional relationships between inputs and outputs, and several regional multipliers. Because the IO method breaks the economy into separate industries, the method is widely used in a variety of port and waterway studies, and some of the results of IO studies are used to augment other kinds of studies. However, the aforementioned data problems usually render IO analysis suitable only for large studies with large budgets.[16]

Cost-benefit analysis (CBA), in this context, as a subcategory of EIS, is merely another methodology for determining the "economic impacts" of some port or waterway facility. The theory of CBA models was discussed in the previous section of this study. But, as we will see in a moment, there can be some distinct differences between cost-benefit analysis and economic impact studies.

Economic Impact Studies vs. Cost-Benefit Analysis

In contrast to the previous grouping, another way to differentiate between types of port and waterway studies--and the grouping that we select for this study--is to separate them into two distinct categories, **economic impact studies (EIS)** and studies involving **cost-benefit analysis (CBA)**. This dichotomy can be used for separating the time frame of the study into long- versus short-run, as well as defining the study's purpose as to either the evaluation of an existing facility or the determination of the feasibility of constructing some new project.

Taken in this context, economic impact studies differ from CBA and some other methodologies in that 1) EIS are generally used to show the usefulness of some already existing facility to a particular geographic area; that is, they are ex post models of facilities; 2) they tend to

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[16] For a thorough statement of the use of input-output analysis in waterway studies, see U.S. Department of Transportation, *The Regional Port Impact Model Handbook, Volume 1: Guide for Preparing Economic Impact Assessments Using Input-Output Analysis*.

describe only the benefits of the studied facility, ignoring costs (which are already sunk, except for operations and maintenance); 3) these benefits do not necessarily comply with the principles and guidelines of CBA in that they measure gross monetary values that are greater than overall improvements in consumer or producer surpluses; and 4) their time frame is almost always a single year.[17]

The complexity of economic impact studies varies from study to study, depending on the scope of the facility being evaluated, the size of the geographic area under the facility's impact, and the methodology involved in the study. A few merely examine direct effects on output, employment, and wages resulting from the existence of a given facility. Most gather such information by surveying firms and other persons whose existence in the geographic area seems to relate directly to the existence of the port or waterway facility being studied. However, most impact studies also examine indirect and induced impacts, usually using multipliers derived at the national or regional level from some secondary source, such as the *Input-Output Structure of the U.S. Economy*. One problem that analysts should (and often do) recognize when using multiplier values taken from the national tables is that the multipliers for a nation or a large region may be inappropriate for the (usually smaller) region under study. Critics argue that if these multipliers are wrong, they are generally too high, meaning that their use without any adjustments exaggerates the economic impacts of the facility being examined if the hinterland affected is smaller than the nation or some very large region.[18] Of course, any reduction in the multipliers for the locality at hand is dependent on local (usually survey) data and will always be somewhat subjective. There is, therefore, always a built-in potential for criticism of the multiplier values being used.[19]

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[17] These studies may discuss the annual impact on the economic area under study as a result of the facility, but that annual impact is usually based on a single year's data collection and multipliers. Therefore, while many such studies assume some continuation of these impacts for some time into the future, the static nature of the measurements calls for adjustments to these impacts on a regular basis as variables important to the facility's operation change over time.

[18] The multipliers always include the direct effects, plus either indirect or both indirect and induced effects. Therefore, they must be larger than one. The size of the multiplier in input-output analysis is directly related to the degree of interrelationships among the various firms and households in the area. Naturally, the more comprehensive the area studied, the larger the multipliers. So, those for the U.S. will generally be larger than those for a given state or region for any given industry. Using U.S. numbers without sharing down to the region causes an overstatement of secondary effects. See, for example, Ronald E. Miller and Peter D. Blair, *Input-Output Analysis: Foundations and Extensions*.

[19] A way out of this problem has been demonstrated through the use of a multi regional model using national IO data. See Arthur P. James, *A Three-to-get-Two-Region Nonsurvey Input-Output Model with Complementary Feedback Effects*.

Another problem often associated with EIS is that these studies rarely make any effort to show that gains caused by a particular facility have come at the expense of some losses to other facilities, to competing modes, or to other regions of the country. While most analysts who construct these studies argue that they make every effort to show "conservative" results, the very nature of accounting for benefits (often with double counting) while ignoring costs tends to exaggerate the net impacts caused by the facility.

The short-run, static nature of such studies also limits their usefulness, relegating them primarily to public relations tools used to justify the continuing existence of some facility. While it is impossible to say with certainty without a complete catalog of waterway studies, it is likely that the majority of the studies now in existence that have been done by port authorities and other water transportation agencies are of this type. Thus, while EIS analysis can have its place, it is not a generally recommended tool for evaluating the economic efficacy of new project construction.

Cost-benefit analysis, as described earlier in this study, 1) is generally used to evaluate the feasibility of a yet-to-be-constructed project; that is, it is usually an *ex ante* model evaluating the economic efficiency of some future facility; 2) should present as accurately as possible both the benefits and costs of the project; 3) should measure benefits based on Pareto-improvements shown as reductions in opportunity costs through improvements in consumer and producer surpluses; and 4) should estimate the timing of these benefits and costs as they will occur over some extended period and discount them to present value by use of an acceptable social rate of discount.

In practice, in order to evaluate expected benefits from some new-project construction over the current facility, some benchmark for performance of the existing facility must be established. Performance models are often used for such evaluations. Such models fall into three general classes: 1) ship distribution in ports (SDP) models, 2) queuing theory (QT), and 3) simulation models.[20] These models can be used to analyze the costs of vessel delays due to traffic congestion at a port or on a waterway.

Because it analyzes berth occupancy, the SDP approach, as its name implies, is particularly

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This study shows that interregional trade multipliers gleaned from disaggregating the national tables produce regional coefficients that are only slightly different from those estimated from survey data.

[20] This model review is described more fully by Jose Holguin-Veras and C. Michael Walton in their study, *A Categorized and Annotated Bibliography to the Performance Analysis of Port Operations*.

useful when the project under consideration involves improvements to port facilities and proposed berth construction, say, at the Port of Houston, rather than construction of some more complex waterway project, such as channel widening along the Gulf Intracoastal Waterway. The SDP methodology uses a Poisson distribution to measure the number of days per year that some number of ships occupies a particular port. By use of this model, the analyst can calculate the amount of time that the port's berths are vacant versus the amount of time that they are occupied. From that information, the analyst can determine the waiting costs for ships that use the port and project the optimum number of berths to minimize these vessel delays. Benefits accruing to shippers through vessel delay reductions can then be compared to costs of constructing, maintaining, and operating any new berths to meet the optimal number at the port. If the benefits exceed the costs, the berth construction project is acceptable.

A problem associated with the use of the SDP approach to benchmark the existing performance of a port concerns the assumption of a Poisson distribution to represent the average number of ships that occupy the port per day. The problem lies in the lack of independence of ship occupancy data. That is, the number of ships present on a given day is to some extent dependent on the number of ships that occupied the port the previous day, and so on. So, critics of the SDP approach find some of the required statistical rigor that comes from independence of variables lacking in this methodology.

The queuing theory approach has been used for port and waterway performance analysis since the early 1960s. While, like the SDP approach, QT seems to be most applicable to berth improvements, it can be, and has been, used to measure performance of other types of port facilities and to evaluate more general navigation problems, such as lock and dam construction. QT provides an accurate measurement of vessel delay costs if and only if three assumptions hold. First, ship arrivals must be random; second, service times for vessels must be independent both of each other and of the number of vessels waiting for berths; and third, the population of vessels must be homogeneous. Unfortunately, while we can often reasonably make the second assumption, the first and third are generally not valid because of the wide variety of ship sizes and the large number of ships traveling on fixed schedules. When these assumptions are violated, QT underestimates waiting times and therefore underestimates current vessel delay costs at the facility. Such a mismeasurement biases any consideration of additional berths against new construction because cost savings would be underestimated. This problem with QT is most evident when the facility being studied is a port with a complex set of facilities and a wide variety of traffic.[21]

One might think that queuing theory is a suitable approach for some particular inland waterway construction projects, like the GIWW, given that there is a smaller array of vessel types traveling along inland waterways than typically enter a given port. A large portion of commercial inland waterway traffic is likely to consist of convoys of barges under tow. For waterways that have wide, straight, and deep channels, relatively little altitude variations, and few locks, and for those that see only a few "standard" types of traffic, the QT model may be an appropriate methodology for project evaluation. But when there are several locks or narrow channels creating numerous places for potential bottlenecks, the QT model becomes less useful. Further, even if barges are themselves somewhat standardized vessels, if the convoys containing them vary greatly in type or size, the model loses some of its statistical validity. If there is a large population of other traffic using the locks or other facilities, the QT model becomes still less relevant for the project's evaluation. Further still, vessel arrivals can hardly be described as random along a congested waterway, because bottlenecks at one point influence arrival times of traffic at another. This fact again causes statistical problems with the independence of variables.

Appropriateness of the QT model, then, depends on the problem at hand. While the methodology works best for projects at a small port visited by homogeneous traffic, it still might be more appropriate for some project on the GIWW, that sees fairly homogeneous convoys of towed barges than for evaluating construction on the Rhine-Herne Canal in Germany, where greater traffic variety and broader types of navigational problems may render QT unacceptable. Therefore, the decision as to whether or not to use QT must be made with all of these considerations in mind for the particular project to be evaluated.

The use of simulation models in the estimation of benefits and costs of a project provides the analyst with potential for greater accuracy than these other performance models. In practice, the true values of costs and benefits cannot be known ahead of time with complete certainty, nor can the actual lifetime of a project be precisely estimated. Neither can future traffic flows and freight rates

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21 See Holguin-Veras and Walton, pp. 4-13.

be observed during the time when the cost-benefit analysis is made. These uncertainties are often ignored by analysts in making project decisions. However, when uncertainty is ignored, the measured benefits and costs can at best be rough estimates of the actual values of these variables. The simulation model approach takes into consideration the uncertainties associated with these future values by assigning probability values to the occurrence of a number of possible scenarios and applies this information to the cost-benefit analysis. Recognition of the existence of uncertainty in the estimations helps those who are making the decisions with respect to acceptance or rejection of the project to evaluate the quality of the information being presented to them. Such knowledge may afford the decision maker greater insight into problems in the analysis that require further study, or may pinpoint factors that might influence the success or failure of a project. Armed with such information, the decision maker should be better able to make recommendations about modifications in the project, both prior to and during construction, that would ensure its successful implementation, or to make the decision to terminate a project before its completion.[22] While there are other methods of accounting for uncertainty (the two other methods most often cited are decision trees and sensitivity analysis), simulation modeling is considered the most powerful and flexible method of accounting for uncertainty.

Simulation models typically consider many possible combinations of variables rather than merely a few estimates. Some simulation models require many thousands of combinations of variables. Because many simulation techniques are rather complex, they have historically been difficult to apply because the calculations were beyond the capabilities of many studies. However, with improvements in computer technology over the last twenty years, simulation models have grown in popularity. Now many analysts consider simulation to be the most powerful tool for modeling port and waterway performance and comparing the status quo with the same facility after new project construction.

Simulation models have several advantages over other performance models. First and foremost is their more general applicability to a variety of facilities, including ports and inland waterways. Another lies in the technique's ability to model such large numbers of variables which often have complex relationships in real applications. Further, simulation models have the ability

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[22] See Richard O. Zerbe, Jr. and Dwight D. Dively, *Benefit-Cost Analysis*, pp. 369-394.

to allow the relationships among variables and the probability distribution of events to change over time and to overcome the problems with independence of variables and events. Because simulation models provide information regarding a whole range of likely outcomes and an estimation of the expected value of such outcomes, they may allow the project to be modified to ensure its success even if some unlikely outcome occurs.

The disadvantages of simulation modeling are related to the complexity of such models and the expense of developing and implementing the model. Simulation may not be a cost-effective approach to providing information on costs and benefits of a small, simple project. When projects are large and complex, however, it is generally the best performance model to use.

One way around the costs of model development and implementation is to apply some already existing "standard" simulation model to the specific project evaluation. There are several of these "standard" models in current usage. The MIT Port Simulation Model can be generally applied to all kinds of port operations and can simulate most types of activities that occur at multipurpose ports. The PORTSIM model, developed by the World Bank, is used for evaluating the economic feasibility of investments in port infrastructure. The UNCTAD Port Operations Model evaluates the benefits and costs of alternative port operations strategies.[23] Several private consulting firms have developed proprietary models that have been used in port and inland waterway studies. Besides the model development and implementation cost saving afforded by the adaptation of these pre-existing models, another benefit of the widespread use of some standardized model is that it allows a more direct economic comparison of projects around the world than can be accomplished when modeling techniques are different for each project.

The Choice of Categories: CBA vs. EIS

We have described several ways in which waterway project evaluation studies might be categorized, and we have selected, for simplicity's sake, the dichotomy of CBA versus EIS studies for our listing here. Critics of our choice of ways to categorize may say that, by definition, this grouping does not actually separate types of cost-benefit studies but, in fact, separates studies using

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[23] See Holguin-Veras and Walton, p. 5.

cost-benefit analysis from other types of studies. This criticism is valid, up to a point. However, we choose to include both types of studies in the analysis because, despite the general differences in the purposes and methodologies involved in the two categories, there are some cases where the two analyses have some overlaps in methodology or in purpose--that is, of instances where certain parts of the analysis involved in one type of study can be used in the other type.

For example, while input-output analysis is an extremely useful technique for answering questions about impacts of, say, a city's already existing port or the maritime industry of a state, information gleaned from its multipliers or coefficients is sometimes used in some benefit or cost projection of a yet-to-be-constructed project. Further, it has already been shown that, at least in practice, EIS (or PIS) has often been used *ex ante* to support port projects when the appropriate methodology was, arguably, CBA. So, even though the two types of studies are not generally substitutable in their purpose, they cannot be taken as completely independent methodologies.

Regardless of their differences, in practice, some variation of the term "cost-benefit" often appears in the title of a study that, from a formal methodological standpoint, has little or nothing to do with CBA. For that reason, the two types of studies are often mistaken for each other by all of those who have some use for the literature except those experts who are intimately familiar with the differences in the usual purpose of these studies. Therefore, because the literature is rife with examples of "cost-benefit analysis" that may not always meet the principles set forth in the previous section of this study, later in this section we present summaries of both types of studies. However, we do emphasize that **real attempts at CBA modeling are the major concern of this study!** Consequently, before we present a survey of studies that have been done, we need to see an example of studies that have identified (and sometimes created) problems with CBA and, at the same time, caused greater awareness among analysts of these problems so that changes in regulations regarding public project funding could be made to correct some of these problems with the use of CBA in practice.

Cost-Benefit Analysis in Empirical Waterway Studies

Cost-benefit analysis was used as a method of evaluating public projects at least as early as the 1930s, when Congress stipulated an assessment of a waterway project's benefits and costs in the Flood Control Act of 1936. The procedure became considerably more popular in the 1960s. Part of this popularity stemmed again from U.S. federal government standards and regulations during that time period,[24] but much of the impetus promoting the use of CBA was provided by Eckstein's work on water resource development that culminated in his seminal 1959 textbook on the subject, *Water Resources Development: The Economics of Project Development*. Many public works projects of national significance and supported by federal funding used some type of CBA to justify the construction of the facility.

While economic impact studies (of other types) were still firmly established to promote existing facilities, by the 1970s the CBA methodology had trickled down to state and some local project development, so that CBA began to outnumber other kinds of studies for new project development. It became at least trendy from an academic standpoint, if not in fact required for funding, to use CBA for demonstrating the feasibility of projects.

In 1977, Waters[25] noted that most local port authorities continued to use port economic impact studies (EIS/PIS) to promote the expansion of facilities to the general public to gain support for bond issues and other means of financing new projects. He compared cost-benefit analysis with economic impact analysis for port projects and showed that EIS/PIS suffered from a variety of significant theoretical defects, mostly relating to the short-run static nature of the EIS methodology, problems with the underlying assumptions used in the expenditure approach to EIS, and the simplistic nature of EIS multipliers. Therefore, He concluded that EIS was therefore, inherently flawed and should be replaced by CBA for most port planning purposes.

The Waters study prompted a reply by Chang[26] in which he defended EIS/PIS as a tool for informing the public of an existing port's importance to the region rather than a tool for evaluating future facilities and stressed that these two methodologies were not, in most cases, substitutes for

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[24] Several other countries began pushing similar standards and procedures around the same period. For example, the Federal Republic of Germany established requirements for use of cost-benefit studies for large public projects in their Federal Budget Regulations of 1969. See Dietmar Ernst, Klaus Lohrberg, Dirk Mester, and Volker Orlovius, "The Use of Cost-Benefit Analyses for Investments in Inland Waterways."

[25] See Robert C. Waters, "Port Economic Impact Studies: Practice and Assessment."

[26] See Semoon Chang, "In Defense of Port Economic Impact Studies."

each other. Chang admitted, however, that an EIS conducted by a port might influence the public into approving an expansion project that could "do more harm than good to the region's economy or which could replace other non-port projects that may have more benefit" to the region. At the same time, however, he suggested that if CBA were used, a project's benefit-cost ratio could be raised or lowered by one's choice of the social rate of discount. Because most costs of a project occur early in the project's life, while benefits begin only after the project's completion and accrue over a much longer period of time, an artificially low rate of discount overstates a project's benefits relative to its costs. Therefore, CBA was not immune to manipulation that would cause an unworthy project to be accepted.

In the United States, such criticism of CBA (and public project funding in general) led to action at the federal government level. In 1977, a special task group appointed by President Carter began studying the process of public waterway planning and project assessment to identify potential problems in the process. Among their findings were problems in the application of cost-benefit analysis to public project appraisal. Among other problems in the overall planning process, the group found problems with the "accuracy, propriety, and integrity of water resource cost estimation and benefit derivation."[27] Part of the problem stemmed from the potential one mentioned above by Chang, the use of a too-low social rate of discount, but other problems in the application of CBA became noticeable to economists and policy makers. By 1979, potential problems in CBA were making headlines in various media. In February 1979, *Business Week* reported that the Carter Administration was paying attention to independent CBA experts who were critical of U.S. Army Corps of Engineers practices with respect to waterway project evaluation.

Such criticism was taken to be unwarranted by many Corps analysts because the Corps had been an agency at the forefront of requiring justification of federal waterway projects through cost-benefit analysis at times when many smaller, more local projects had not yet embraced the methodology and were still using arguably less rigorous methodologies to support project construction. However, critics such as Eckstein, Haveman, Carroll, and Rao pointed out a number of problems in Corps studies that they considered abuses of the methodology. Among these were

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[27] See Joseph L. Carroll and Srikanth Rao, "Economics of Public Investment in Inland Navigation: Unanswered Questions."

the following:

1) counting as benefits all of the dollar savings created by diverting cargoes from rail to barge;
2) making unreasonably high traffic volume projections on proposed waterways;
3) understating the barge traffic capacity of existing waterways, thus enhancing the perceived benefits of expansion; and
4) using unreasonably low rates of discount.[28]

Though there is almost always some disagreement among CBA experts regarding the measurement of benefits and costs of any project, the direction of these kinds of mismeasurements is clear. If these inaccuracies were widespread in waterway project evaluation, they would have biased the assessment methodology towards the acceptance of a number of unworthy projects.

In the 1970s, the discount rate problem was, at least in part, caused by the federal government itself, in that its level was often mandated by the U.S. Congress.[29] But selection of the proper discount rate became a particularly significant problem during that time period because of the high rates of inflation that drove market interest rates to their highest levels of this century beginning in the late 1970s and lasting into the mid-1980s. Real rates of interest were considered to be very high, but were difficult to measure because of the amount of economic instability during that time period. In more recent years, the low inflation and low private interest rates have reduced the amount of uncertainty as to the correct level of the real interest rate. When nominal rates are low, as are current rates, the selection of a level near that of the current rate makes criticism of the appropriate discount rate less valid. When nominal rates are low, it becomes more difficult to understate the appropriate rate of discount by much, and much easier to overstate it. So, accusations of bias towards project approval because of too low a discount rate in CBA studies occur less often now than they did in the 1970s and 1980s. However, since no one can know with certainty what the appropriate rate of

[28] See "Cost-Benefit Trips Up the Corps," *Business Week*, February 19, 1979.

[29] In 1968, Congress legislated a discount rate for water projects based on "the yield during the preceding fiscal year on interest-bearing marketable securities of the United States which at the time of computation is made have terms of 15 years or more remaining to maturity." In 1974, the rate selection was limited even more by ceiling clause stating that "in no event shall the rate be raised or lowered more than one-quarter of one percent for any year." See Jeffrey L. Funk, "A Methodology for Estimating the Benefits from New Lock Construction."

discount is for a project, differing expectations among different analysts regarding interest rate stability over the life of a project means that the discount rate problem will never go away completely.

The other three inaccuracies listed above, while perhaps relatively less important in the 1970s, represent more fundamental difficulties in benefit and cost assessment. For example, the error in measurement of benefits as a cost saving between rail and water carriage rates is a continuing problem in CBA. Freight rates are prices, and prices are not necessarily equal to costs, except in perfectly competitive markets. Whenever there is any kind of market power among firms, therefore, counting price differences as cost savings tends to overstate the gains from such differences. Because price differences were used in practice in most studies, Eckstein found this measurement error to be widespread in waterway project evaluation. Since that time, the problem has been addressed again and again, but it has not been completely resolved in empirical measurement. Further, because a waterway project may actually lower rates charged by rail and other competing modes, if rates are to be used, these *ex post* rates are a more appropriate measure of rate differences than are rates prevailing before the project is completed. These numbers may be difficult to obtain.

Haveman argued that the problem of underestimating waterway capacity was also significant in biasing projects towards acceptance. Here, again, freight rates of competing modes before and after project completion have been, in practice, a useful tool of assessing project benefits. But the Transportation Act of 1966 required the Corps of Engineers to base benefit calculations on the (higher) prevailing rates rather than estimates of those that would exist after the project's completion. Such a procedure overstates benefits from improvements in capacity.

Projections of increases in traffic along a waterway can also violate one of the fundamental tenets of CBA. Often, traffic volume increases come at the expense of another mode or another waterway. In order to assess benefits from increased traffic caused by a project, these gains must be offset by any losses in traffic that occur at other waterways and among other modes. A fundamental problem exists here because separate projects cannot be considered independent of each other, even over some significant period of time. For example, suppose new locks are built on waterway A, their approval being based on benefits from increased traffic on the new expanded waterway. Suppose that, ten years later, a second project on waterway B is approved, with one of the gains being a reduction in cost because some traffic will be diverted from waterway A. Then the benefits from the waterway A project will be less than were projected at the time of its approval. Because these two projects are not independent, then, there must be long-run, systemic benefit and cost assessment in a dynamic framework to prevent the overstatement of project benefits.

A Case of Early Criticism of CBA: The Tennessee-Tombigbee Project

By the late 1970s, several of the problems with CBA mentioned above appeared in cost-benefit studies for large potential waterway projects. These large projects brought to the forefront among CBA experts and public funding sources the discussion of the applicability of cost-benefit analysis as a tool for evaluating public waterway projects (and other projects requiring public funding). Critics of these studies have used the studies as prime examples of bias by the U.S. Army Corps of Engineers toward construction of unworthy projects. While one can contend that these studies followed the basic tenets of CBA and generally complied with federal guidelines for waterway projects that existed at the time, critics argued that subjective valuations of benefits and costs, and manipulation of the discount rate level to further alter the results, caused these projects to be constructed when they should have been rejected. The sheer size of expenditures on these projects is a major reason for the amount of attention given by the critics to these projects. These projects include construction of the Tennessee-Tombigbee Waterway (TTWW), the Locks and Dam No. 26 on the Mississippi River, and the Tellico Dam project in eastern Tennessee.

At the time of these projects' approval, federal regulations and legislation that applied to waterway projects were found in the U.S. Department of Transportation Act of 1966, the National Environmental Policy Act of 1969, the Rivers and Harbors and Flood Control Act of 1970, and the Principles and Standards set forth by the Water Resources Council in 1973.[30] One overall effect of these statutes was to require analysts to face some kind of objective judgment regarding the actual importance and necessity of the project--is it a small, local project that has few effects of any kind other than a change in revenues and perhaps small changes in income and employment for a local

[30] See Carroll and Rao.

area? Or is it a large project of national or international significance that has a large, perhaps unknown, number of ramifications, both positive and negative, both on markets and society as a whole, for the economy(ies) in question? Or is it somewhere in between, and if so, where? The complexity of the study justifying funding must be sufficient to appropriately answer these questions.

Second, analysts must consider the manner in which a project's benefits and costs are measured. Clearly, the significant benefits and costs of small and insignificant projects tend to be more objective and easier to measure than the more vast array of benefits and costs associated with larger projects. The larger the project, the more room for subjective inclusion of some benefit or cost, and the more room for variance in the measurement of those that are included. It is not surprising, then, that larger projects are riskier, and their outcomes more uncertain, than the typical small project.

Further, it is important to recognize that, particularly with large projects, the distribution of projected benefits and costs should be a consideration. Large benefits that accrue to one geographic area, for example, that exceed large costs incurred wholly by another area may make a project politically inappropriate, even though its B/C ratio implies the project's acceptance.

All of these principles are in accordance with the fulfillment of the theoretical tenets of CBA, as described in the previous section. However, one must recognize that because the most significant projects require the most subjectivity, the application of cost-benefit analysis is as much an art as it is a science. While certain principles and guidelines can be standardized, there will always be room for disagreement as to valuations of fundamentally subjective valuations, regardless of the methodological limits, unless those values are set by undeniably arbitrary means.

Initial reviews of the Tennessee-Tombigbee Waterway project showed that the original study, completed in 1966, did not meet the criteria set forth by legislation at the time and underestimated potential detrimental environmental impacts. Continued public support was also achieved by the lure of potential user fees to help defray costs of construction and maintenance. However, the criticisms increased as the project's construction continued, given the several subsequent studies that, during construction, continued to estimate increases in the project's overall capital costs, from an initial $325 million in 1966 to over $1.6 billion in 1976. At the same time, critics showed that the newer studies always raised benefits to coincide with cost increases, so that the B/C ratio remained above one. In 1976, the B/C ratio for one possible continuation project was calculated at 1.06, based on a discount rate of 3.25 percent. However, it was clear by that time that the overall benefits must have been adjusted to keep the B/C ratio above unity given that, by that time, the project had been recommended for expansion to include channel widening, deepening, and straightening along parts of the waterway.

Because of criticism of the original study, whose methodology is not available here, the Corps contracted a private consulting firm to project traffic flows and estimate savings to be derived from the project. The Kearney study, contracted in 1975, reanalyzed the project, with a multipart mission:

1) to identify potential users of the TTWW based on surveys of potential users;
2) to calculate estimations of waterway freight rates based on traffic projections and other assumed operating conditions;
3) to compare freight rates on the TTWW to those of alternative modes, given transaction costs of each freight movement;
4) to project future traffic flows on the TTWW using secondary data from the Department of Commerce;
5) to calculate the timing of the future stream of benefits and adjust their value to present value by use of a 3.25 percent discount rate and 50-year lifespan, beginning in 1968; and
6) adjust the stream of benefits downward to take capacity constraints into consideration.[31]

The Kearney study did not remove all criticism of the project. The greatest concerns still revolved around the use of freight rate differentials to measure cost savings (#3) and the use of a discount rate that was too low (#5). Both of those procedures tend to overstate project benefits, so there were grounds for further criticism that the study remained biased towards acceptance. But, as is often the case with such studies, the Kearney modeling procedures were proprietary, so that no details are available as to the methodology of the model. Nevertheless, criticisms continued

[31] See Carroll and Rao, "Economics of Public Investment in Inland Navigation: Unanswered Questions." For a more detailed description also see A.T. Kearney, *An Evaluation of the Transportation Economics of the Tennessee-Tombigbee Waterway.*

regarding the methodology and the perceived biases in the results.

Most of those criticisms continued to involve the inordinate increases in project costs over its construction period, perceived optimism of traffic flow projections on the completed waterway, and the use of freight rate estimates to estimate savings when rate savings are theoretically a proxy for cost savings only when the market form is perfect competition, a market form not frequently seen in actual economies. There were a number of other criticisms, among the most important the finding by Kearney that most of the projected increases in traffic would be barge traffic diverted from the Mississippi River system, a benefit that is offset by costs elsewhere and does not imply any Pareto-improvement.[32] These kinds of criticisms caused the TTWW and many other public expenditure projects involving waterways and other facilities to be subject to litigation, a fact that further increases the cost of such projects to the public.[33]

In spite of the continuing criticism, the project was completed. How does it fare in perspective? From the viewpoint of persons in the geographic areas most immediately affected by the waterway, most would argue that it has been beneficial. It has clearly improved the transportation network for both goods and people (due to highway and bridge improvements near the waterway), in an area where there was a severe transportation deficiency.

However, a recent *ex post* EIS study[34] has gathered data that allows a comparison of some of the projections with actual values. For example, the TTWW was projected to cost (a final figure of) $1.6 billion and to move about 23 million tons of traffic in its first year of operation. In fact, the project's final construction cost was about $1.95 billion and, by 1990, the fifth year of its operation, the TTWW was moving less than 5 million tons of traffic. In 1994, the last year for which data are available, the tonnage moved had risen to about 8 million tons per year. Clearly, some of the project's major criticisms have proven to be warranted in the face of actual values.

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32 See Kearney. *An Evaluation of the Transportation Economics of the Tennessee-Tombigbee Waterway.*

33 James S. Sagner, in "Benefit/Cost Analysis Efficiency-Equity Issues in Transportation," presents a table citing 30 such cases during the period 1971 through 1979. All of these cases involved criticism of CBA or EIS. While the severity of the outcomes varied among these cases and the analysis was not faulty in every case where there was fault, there was fault found in some aspect of the analysis in about half of the cases. The outcomes ranged from rejection of some specific outcome to injunctions against further construction.

34 See Paul Garner and Mac Holmes, *An Analysis of the Annual Economic Impact of the Tennessee-Tombigbee Waterway.*

Modifications in the Principles and Guidelines

As a result of perceived inaccuracies, flaws, and biases in the TTWW and several other studies, a restatement and clarification of U.S. federal government's fundamental criteria for waterway project acceptance was presented by the U.S. Water Resources Council in 1983 in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.* The *Principles and Guidelines (P&G)* takes a broad geographic approach to the measurement of benefits and costs of waterway projects and related land resources, calling for evaluation of "national economic development" (NED) benefits and costs for each project. At the same time, the *P&G* placed less emphasis on the more subjective aspects of benefit and cost measurements, especially as these relate to the environmental benefits and costs associated with a project.

The *P&G* specifies a nine-step process to be used in the calculation of project benefits. Those steps are listed in Table 1.

1) determine the economic study area;
2) identify commodity types, volumes and flows;
3) project waterborne commerce;
4) determine vessel fleet composition and cost;
5) determine current commodity movement cost;
6) determine alternative mode commodity movement cost;
7) determine future commodity movement cost;
8) determine waterways use with and without the project; and
9) compute national economic development benefit.

Table 1. The *P&G* Nine-Step Process

While not explicitly stated in these nine steps, the *P&G* also assumes that problems associated with the application of these steps to actual projects should address such issues as multiport analysis, vessel and cargo origins and destinations, sensitivity analysis (or some suitable substitute), and data sources.[35]

In addition to these specifications regarding benefit measurement, other steps have been taken to standardize, where possible, cost calculations and to make sure that the discount rate is reasonably applied. The *P&G* specifies a six-step process for identifying costs.[36] These are listed in Table 2.

1)	identify potential divergences in financial and economic costs;
2)	identify potential divergences in economic and national economic development costs;
3)	quantify differences in financial and economic costs;
4)	quantify differences in economic and national economic development costs;
5)	document relevant facts, rationale, and calculations; and
6)	display the results of analysis.

Table 2. The *P&G* Six Step Process

The six steps in the cost calculation process are an attempt to provide guidelines that economists can use to translate the actual implementation costs of a project into the broader national economic development costs. Though detailed procedures are not made explicit in the steps themselves, the *P&G* and several manuals produced by the Corps of Engineers provide greater detail for use by analysts. An important emphasis of the *P&G* is that analysts must be able to recognize differences between the actual implementation costs of a project and the total costs to the country (the NED costs) and must be able to document and explain any adjustments to the implementation cost structure to derive NED costs. The lack of such documentation and explanation in earlier CBA studies has often been a major weakness in the studies and a springboard for criticism of these studies.

Summary

This section has examined some of the ways that CBA has been applied in actual waterway

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35 See James Crew and Kevin H. Horn, "Problems of Deep Draft Navigation Benefit Evaluation Procedures."

36 See Charles Yoe, *National Economic Development Procedures Manual: National Economic Development Costs.*

and related studies. It has selected a simple classification system by which most port and inland waterway studies can be distinguished. Some of these studies, called EIS, look at the economic impacts of waterway projects by describing some of the benefits--but usually not the costs--of the project on a short-run basis after the project has been completed. Other studies embrace the more rigorous principles of cost-benefit analysis to examine long-run benefits and costs of projects, usually as an antecedent to a project's construction approval.

Most project evaluation experts agree that cost-benefit analysis, when conducted in a manner that follows the theoretical principles of the methodology, is the best way to evaluate the economic efficiency of a proposed waterway project. Yet, historically, CBA has been abused enough by practitioners that the methodology has been fodder for critics such as environmentalists and others who believe that there is generally too much funding of waterway projects.

Part of the problem with CBA--perhaps because it is considered to be a more scientific approach than other project-evaluation methodologies--is that it is easy to find fault whenever there is a large number of measurements involved that are inherently subjective. Public projects, if they are to be constructed at all, usually have characteristics of what economists call "public goods." What this means, from a practical sense, is that no one knows the correct level of production of such goods because, unlike the market system for private goods, there is no allocative device and pricing mechanism to tell us how much of the good to produce nor what price we should pay for it. Therefore, choices regarding the provision of such goods will always be something of an art, as much as a science, regardless of the mechanism employed to measure the proper allocation. What this means for the actual practitioners of CBA is that there can never be a single right way to conduct cost-benefit analysis, or any other public project evaluation methodology!

That does not mean that there cannot be guidelines. While arguments over subjective measurements will always be a part of public project analysis, there have been legitimate criticisms of CBA over what most experts would consider to be objective measurements. While one can argue that the social rate of discount is subjective because no one knows the real rate of interest, there are genuine concerns when analysts choose a rate that is perceived by almost everyone to be too low! Much of this problem has solved itself in these days of low inflation and low nominal rates, but it may reappear if inflation rears its head again in our economy. Many critics of traffic flow estimates, misuse of rate structures, the lack of recognition of system wide losses that cancel out benefits, and other mismeasurements that have biased earlier studies towards project acceptance have good reason to be critical. But CBA experts have recognized these complaints and have strived, both at the academic level by creating and revising methodologies and at the federal government funding source level, where regulations have been continually updated and clarified, to correct the sources of these criticisms so that any analyst who is employed to evaluate a project today has a much better feel for the kinds of errors he is expected not to make!

The CBA methodology is becoming much more sophisticated and--perhaps more importantly--somewhat more standardized in this era of improved computer technology because it is much easier to use complex stochastic modeling, such as simulation analysis, to provide an array of outcomes for any given project and to project costs and benefits of these outcomes. Yet the problem remains--and may be as severe as ever--that many techniques used in CBA studies are proprietary because so many studies are conducted by private consulting firms. Perhaps the most critical change that CBA experts could make to allay criticism of the methodology is to make the methodology more accessible and easier to understand by potential critics. As long as the nuts and bolts of CBA remain arcane to many persons interested in the outcomes of projects, there will always be some criticism that the measurements are somehow derived by magical means and have little relevance to the real world. Such a request for change should not be taken as a call for consulting firms to give away their secrets. Instead, it is a request for more dialog among all that have genuine interests in the impacts of waterway studies so that a greater understanding of both what we know and what we are concerned with can be achieved.

CBA is an often criticized but important and evolving set of modeling techniques that is essential for evaluating the economic appropriateness of public projects. In spite of the continuing attempts at improvement in the methodology, CBA continues to have its critics, especially in these times of budget-balancing and downsizing-of-government priorities. Nevertheless, CBA is still the most valuable tool for evaluation of new publicly funded projects. While in its application to complex and varying real-world projects there will always be critics arguing over the subjective nature of some of the values derived from such studies, CBA will continue to be a useful tool until someone finds another methodology that is clearly better. That is not likely to happen in the near future.

Examples of Economic Impact/Cost-Benefit Studies

The remainder of this section consists of brief summaries of actual waterway and waterway-related studies that have been written over the last thirty years. Although it is not always possible, for reasons stated earlier, to distinguish the exact methodology, it is often possible--based on the study's purpose and the type and complexity of the problem at hand-- to make an educated guess about the kind of methodology most likely used. The summaries are separated into two general classes: EIS and CBA. While EIS studies may not technically be the same as CBA studies, there is enough overlap in some of the methodologies used, and sometimes in the purpose for which the study is written, that it is necessary to look at both types. Further, some early studies used EIS to make assessments that would now most likely be considered better suited to CBA.

SELECTED EIS/PIS STUDIES

Brief Descriptions

Port of Baltimore (Hille and Suelflow, 1969)

The study measures port revenues per ton of cargo, allowing computation of benefits from additional port services accruing to the port community.

Port of Chattanooga (TVA, 1991)

This study uses secondary data from the U.S. *Census of Manufacturers* and the *U.S. Input-Output Tables* to accompany employment and earnings data from surveys of local manufacturers.

It uses IO data to calculate the portion of production output that is caused by waterborne inputs by using employment as proxy for output and translating tons of output in an industry into amounts of employment directly related to the port.

It uses simulations of TVA's Chattanooga subregional (power service area) econometric model (RESM--Regional Economic Simulation Model) to determine multiplier effects and share them down to the Chattanooga metropolitan statistical area (MSA).

It estimates benefits of cost differentials between water transportation and other modes; however, it ignores consideration of benefits to potential users who do not use the port, other benefits from improved goods distribution, and from property and sales tax revenue increases.

Port of Corpus Christi (Ryan and Adams, 1973)

The study estimates the port's multiplier value by interpolating between basic income and employment multipliers.

Port of Decatur, Alabama (TVA, 1992)

This study uses secondary data from the U.S. *Census of Manufacturers* and the *U.S. Input-Output Tables* to accompany employment and earnings data from surveys of local manufacturers.

Then it calculates from the IO data the portion of production output that is caused by waterborne inputs by using employment as a proxy for output and translating tons of output in an industry into amounts of employment directly related to the port.
It then uses simulations of TVA's Alabama subregional (power service area) econometric model (RESM--Regional Economic Simulation Model) to determine multiplier effects and share them down to the seven-county area surrounding Decatur, which approximates the subregion.

It estimates benefits of cost differentials between water transportation and other modes, but it ignores consideration of benefits to potential users who do not use the port, other benefits from improved goods distribution, and those derived from property and sales tax revenue increases. It uses the same basic methodology as the Chattanooga model, above.

Delaware River Port (Delaware River Port Authority, 1969)

The study measures port revenues per ton of cargo, allowing computation of benefits from additional port services accruing to the port community.

Port of Houston (Martin Associates, 1995)

The study measures port revenues per ton of cargo, allowing computation of benefits from additional port services accruing to the port community.

It calculates revenues on a commodity-by-commodity basis.

It uses re-spending models based on Houston-area consumption patterns and direct data gathered from interviews, rather than relying on I-O models.

The study estimates impacts of retail and wholesale purchase levels only; it considers the revenue, employment, personal income, and tax impacts of these purchases.

It compares the results with economic impacts calculated in the previous (1986) Houston study.

Methodology for this study follows the general form developed by Martin Associates for about 70 other ports in the U.S. and Canada, allowing comparison to these other ports.

Inland and Intracoastal Waterways (Mercer Management Consulting, 1996)

Benefit measures derived in the study are based on employment and income.

The study identifies industries in waterside counties who relied on barge transportation. It uses this information to derive employment impact of the waterways based on persons who could use water transportation, by industry.

The study estimates value of goods carried and value per ton, by industry, and it estimates impacts on waterside county payroll taxes, as well as federal and state payroll taxes.

Port of Jacksonville (Weir and McFarland, 1965)

The study measures port revenues per ton of cargo, allowing computation of benefits from additional port services accruing to the port community.

Ports of Louisiana and the Maritime Industry (Ryan, 1996)

This study uses survey data collected from firms in the state, supplemented by secondary data from the the Louisiana Department of Labor and the U.S. Department of Commerce Bureau of Economic Analysis.

These survey data are combined with secondary data derived from state total employment and wages by industry, U.S. total employment and wages by industry, and Louisiana regional multipliers.

The basic methodology is to use the survey data to calculate the average spending and employment of port-related firms. Then the total industry size for each industry can be calculated by sharing down data derived from the secondary sources.

The study calculates earnings and employment for port industries (the suppliers of services) and port users (demanders of services). The study's purpose is to estimate, *ex post*, the contribution of these industries to the state economy for 1994, where the impact is defined as the direct, indirect, and induced benefits of spending to state income and employment.

It also examines the effects of the industry on state and local tax revenues, based on the assumption that income recipients are average consumers; however, no consideration of costs of incurring these benefits.

Mississippi Waterways (Conn, 1966)

The study computes transportation savings per ton of domestic waterborne commerce.

Port of Mobile (Chang and Dunphy, 1974)

The study measures port revenues per ton of cargo, allowing computation of benefits from additional port services accruing to the port community.

It computes a local multiplier, allowing comparison with other communities.

Ohio Canal (Ransom, 1970)

This study computes returns per dollar of investment.

Port of Portland, Oregon (Port of Portland, 1971)

The study measures port revenues per ton of cargo, allowing computation of benefits from additional port services accruing to the port community.

Port of Portland General Aviation Airport (Shea and Brugo, 1983)

This study measures revenues accruing to the port as a result of aviation services for a small general aviation airport.

It uses interviews and mail surveys for primary data, as well as standard data collected regularly by the port. It also uses origin and destination surveys from 1974 and 1978 to distinguish trip purpose per destination.

It uses state shares as supplied by the Oregon IO model to calculate multipliers and value-added impacts for the local area.

The study concentrates on estimation problems with air freight impact. It estimates cargo weight by type, then converts to dollar values.

It also uses survey samples and secondary census data and attempts to apportion the impact of the airport to the remainder of Oregon, based on employee residence and origin/destination data.

Quebec Ports, Small and Medium Sized (Slack, Vallée, Comtois, and Lagimonière, 1993)

The study looks at 27 small and medium-sized (<10 million tons of cargo/year) ports in Quebec; however, it finds relevant data for only 13 of the 27 ports.

Methodology is a comparison of an extrapolation from commodity impact coefficients derived from earlier consultant's study, combined with survey data of specific firms and port areas.

The study measures income and employment impacts, following the Hickling (1989) and Martin-O'Connell (Martin, 1987) approaches in Canada. It finds that the national IO coefficients are not easy to use for small hinterlands because of great variance in size among industries; instead, the study uses a single "rest of Quebec" coefficient.

The study also finds survey data to be problematic--it attempted surveys of 207 firms, but only received 54 responses.

The study finds high correlation between employment and revenue totals under the two methodologies, but important differences elsewhere.

Port of Seattle (Port of Seattle Commission, 1971)

The study measures port revenues per ton of cargo, allowing computation of benefits from additional port services accruing to the port community.

Port of Tampa (International Marketing Research Center, U. of Florida, 1968)

The study measures port revenues per ton of cargo, allowing computation of benefits from additional port services accruing to the port community.

Tennessee-Tombigbee Waterway (Garner and Holmes, 1995)

This study uses interviews and survey data, coupled with an IO model developed at Troy State University and based on the U.S. Forest Service/University of Minnesota IMPLAN model to measure impacts on three areas: 1) the immediate area surrounding the waterway, 2) the combined area composed of Alabama, Mississippi, and Tennessee, and 3) the nation as a whole. It breaks down direct, indirect, and induced impacts by broad industry category for each of these three areas.

The study also looks at impacts of port and terminal operations and Corps-operated recreational facilities along the waterway.

It measures employment and income benefits from the waterway and the portion attributable to recreation and tourism based on the travel cost method, through direct surveys, and by a sharing down of national IO coefficients.

Port of Virginia (Darton and Meiburg, 1968)

The study computes a local multiplier, allowing comparison with other communities.

SELECTED COST-BENEFIT MODELS

Brief Descriptions

Port of Amsterdam, Netherlands (Schut, 1980)

This study evaluates two plans for the improvement of the lock system at the entrance of the Northsea Canal, which is experiencing bottlenecks due to size of locks because of increasing size of vessels and slow vessel turnaround time.

One of the projects, a new lock system along the canal, has already been studied in 1971 and rejected; an alternate proposal is to build a new outerport at IJmuiden at the sea entrance to the canal. This proposal was also studied in 1971 and found feasible, based on money-valued costs and benefits.

That former study estimated benefits from differences in projected goods flows with and without the new facility, and took into consideration possible alternative transportation for the goods (other Dutch ports versus nearby foreign ports) and the potential differences in the distribution of benefits internationally.

Benefits were valued based on economies of ship size and reduced time in port as measured by reductions in freight rates and port tariffs.

Considerable benefits were expected from increases in containerization. The project's costs involved capital costs, maintenance, overhead, and marketing.

Projected B/C ratios were in the neighborhood of 1.3 or less, depending on assumptions.

Environmental effects and socio-economic effects on employment were ignored by the original study.

Problems with the 1971 study leading to the 1980 reevaluation involve two aspects: 1) Higher fuel costs after the oil crisis of 1973 were not considered because the event had not occurred; therefore, traffic flow projections were overly optimistic. 2) Many complaints appeared regarding omission of environmental costs of the new port.

An additional complication arose because a study of the Port of Rotterdam contended that it could handle the projected new traffic created by the Outerport, so the facility was not needed.

Further, another alternative use of funds, an expansion of the state-owned Dutch Steelworks, with its own associated benefits and costs, was not fiscally compatible with the Outerport construction.

The 1980 study reassesses many of the benefits and costs, and produces a B/C ratio that varies from .2 to 1.2, depending on assumptions.

Exact methodology was not given, but uncertainties encountered with goods flows due to fuel cost problems, unknowns with respect to employment benefits from several alternatives, the variety of potential alternatives to be weighed, etc., suggest use of a simulation model.

The study concludes that Amsterdam should concentrate on specific cargo types and optimize its existing facilities to accommodate that cargo mix. Given the importance of environmental impacts, valuation of benefits and costs is likely to be very subjective, by any method.

Belgium, Transportation System (Dubus, 1988)

Purpose of the study is to evaluate social costs of traffic accidents on roads, railways, and inland waterways in Belgium.

The study assesses benefits of improved safety through fitting of improved braking systems to road vehicles, providing automated signal-controlled halting of trains, and radar surveillance on ships.

The study evaluates use of a system of rates (user charges or taxes) suggested by the EC for use of the transportation infrastructure to internalize the marginal social costs of accidents by building an accident fund to compensate victims and to fund the social security service accident sector.

The model does not attempt to calculate a B/C ratio; instead it measures total social costs of accidents, based on production losses due to injury or death, medical care costs, pain and suffering, property damage, police, signalling system, and emergency service costs, legal costs, and insurance company overheads. It ignores costs of other preventive measures and uses national statistical data to calculate mean costs for each of the categories listed.

It calculates total user charge revenues as the difference between marginal socio-economic costs and premiums paid to insurers, and calculates per capita rates based on the estimated number of users of a particular mode.

For waterways, the study suffers from a small data set--only four victims in Belgian inland navigation over the study period.

The study calculates socio-economic costs of accidents per mode as a percent of GDP.

Methodology uses secondary data and simple microeconomic modeling, similar to studies used by analysts in Germany and France, allowing comparison of findings to these other studies.

Port of Escobar, Argentina (Williams, 1984)

Purpose of the study is to evaluate benefits of construction of a new port to reduce congestion at Buenos Aires.

The study uses simulation model to predict freight flows through the existing versus the projected port for 10 aggregate cargo types, and changes in these cargo flows over other modes. It assumes as exogenous many factors governing transportation patterns and levels, and derives sensitivity tests for a range of circumstances likely to prevail for several years. The model contains 50 or more equations, with iterations and loops.

The study deals specifically with lightering operations because of depth restriction problems on the Parana River, to be serviced by the projected port. It uses a multi-level logit model to separate lightering demand from other traffic.

The model is easily generalized to handle other forms of competition between modes (land versus water, etc.).

Gallipolis Locks and Dam, Ohio River (Funk, 1983)

The study compares costs and benefits from new lock construction versus costs and benefits of rehabilitation of the existing lock and dam, given projected future traffic increases.

It applies procedures of the U.S. Water Resource Council for estimating benefits, and attempts to avoid the usual complaints regarding Corps of Engineers overestimations of future traffic by using traffic projections calculated by an independent consulting firm.

It projects unconstrained (zero delay) system traffic demand through an origin-destination model of individual commodities. It uses Corps models to estimate traffic and lock delays for these projected traffic in selected years from 1980 to 2040.

It examines several construction, rehabilitation, and deactivation alternatives, including staged construction projects, new lock construction at nearby alternative sites, and the use of helper boats to break large tows to speed locking of traffic. Project completion date depends on the alternative chosen.

The study measures benefits as reductions in costs of moving existing traffic (showing as reduced delays) and reduction in the costs to new waterway users (exemplified by differences in waterway and alternative mode freight rates).

It uses a simulation model for the entire Ohio River navigation system to estimate benefits by comparing with waterway movements without improvements. It uses several alternative discount rate and fuel tax scenarios to allow for adjustments in both project and transport costs.

Green River Locks (Goicoechea, Sweeney, Sharp, and Burns, 1983)

This study is based on a quadratic mathematical programming model also used by the Institute for Water Resources, and picks Green River as a test case of the modeling techniques.

The study uses queuing theory and other deterministic approaches.

It is limited in its application by the fact that its goal is optimization of a single objective function--maximum economic benefits; it is also limited by use of the queuing-theory approach to data input estimation.

The study allows calculation of user charges and revenues as a function of these charges in dollars per ton mile to allow for cost recovery.

It estimates impacts of congestion fees at locks, allowing estimates of commodity flows displaced from or attracted to the waterway.

It allows investigation of impacts of exogenous forces, such as navigation subsidies.

It shows impacts of rehabilitation of old locks and construction of new ones, including effects on other locks in the system.

The study suffers from the possibility that, in solving for an optimal solution to maximize benefits, multiple optima might occur, rather than a unique solution. Further, with changes in some inputs, the entire set of equilibrium solutions may change. Consequently, the model may provide conflicting answers to the feasibility problem.

Lock Henrichenburg, Federal Republic of Germany (Ernst, Lohrberg, Mester, and Orlovius, 1979)

This study consists of an evaluation of a project to construct a new shaft lock to allow larger barges and pushed barges to use the Dortmund-Ems Canal. The current lock is considered too small to allow for an expected increase in steel-industry traffic on the canal. There are actually two alternative projects to be considered: 1) replace the present lock with a similar one at the end of its useful life, in about 15 years, or 2) build a larger lock in the immediate time period. Opportunity costs lie in the differences in benefits and costs of these two projects--the study must measure how projected ore shipping would be affected on the waterway versus alternative transport modes.

No information is given on exact methodology, but it appears to be similar to several other studies for Germany listed here, following standard CBA tenets. Sensitivity analysis is a likely technique.

The study finds a high B/C ratio of nearly 5, and strong dependence of ore movements on the construction of a larger lock.

Port of Istanbul (Tuğcu, 1983)

This study is a simulation model for a seaport system of two quays, Salipazari (European side of the Bosphorus) and Haydarpasha (Asian side of the Bosphorus).

The study accounts for differentials in wage structure and unloading rates between the two quays--this requires two separate sets of data.

The study considers three different expansion projects, each involving different time periods for construction, and combinations of these projects. It also considers choice of the best investment year.

The Main and the Main-Danube Connection, Federal Republic of Germany (Ernst, et al., 1979)

This study is an evaluation of a project under construction at the time of the study. The project initially received a positive evaluation, but a second CBA study, conducted in 1974, disagreed with the original results and rejected the project. Rejection occurred because of a number of concerns: the low projected cost advantage of water transportation over competing rail in Bavaria; the high number of locks required; long relative transport distances compared to rail; much traffic on the Main-Danube canal is directly related to water-level problems on the Rhine; high costs related to variations in waterway elevation due to great altitude differences along the waterway; and few secondary benefits such as recreation and flood control.

Purpose of this study, given the fact that the project is approved for completion, is to optimize investment resources by considering ways to optimize traffic make-up and flows after completion of the project. This involves promoting pushed-barge convoys to reduce vessel waiting time at locks, as well as greater night use of the waterway. Changes in traffic make-up may divert concentration of resources to the Main because the 35-lock chain there effectively limit draft, and the river's sharp turns limit convoy length.

The study requires data regarding technical evaluations of correcting problems of associated waterway depths. It calculates economic benefits of regulating the draft on the Main. The new plan involves deepening of the lower Main, using the locks already under construction from the previously accepted (and then rejected) project.

The current project yields a high B/C ratio, attributable to larger, deeper-draft vessel size, high traffic volumes, and increased capacity of the locks bringing them closer to optimality after channel deepening.

Methodology is not clear, but this study appears similar to the other German models cited. Sensitivity analysis is a likely technique for handling uncertainty.

McClellan-Kerr Arkansas River System (Liew and Liew, 1980)

The study uses a multiregional variable IO model to examine the impact of changes in transportation costs on trade flows and regional economic development when a navigation project is constructed. Emphasis is on model development to allow comparison of with- and without-project impacts of waterways.

The study assumes that changes in input costs, including transportation costs, should change all technical and trade coefficients in the IO model as firms substitute cheaper transportation services for more expensive ones. IO models that assume static values for these coefficients are, therefore, unacceptable tools of analysis, hence the "variable" connotation of the model used in this study.

The study derives price-possibility frontiers to project new equilibrium prices of commodities caused by changes in transport costs.

The study uses a simulation model to project how these changed costs and prices in one region influence commodity prices in other regions and for all commodities.

The Arkansas navigation region is the primary study area. Analysts choose two other regions and ten industrial sectors in order to model the results of a hypothetical five-percent change in transportation cost as its effects flow through the ten commodities in the three regions, hence the "multiregional" connotation.

The study presents several scenarios as to the breadth of the cost change and examines the effects on the coefficients under each scenario.

Mid-Continent (U.S.) Loran-C Expansion (Wiseman and Veronda, 1979)

This study measures benefits of increasing the capacity of the Loran-C system used for the civil marine community to provide land-use benefits by adding three transmitter stations to the system.

The study defined benefits as improvements in emergency medical services, rural fire suppression, police management, and highway accident location and traffic records.

The study's benefit-cost guidelines concentrate on those accruing to the U.S. mid-continent, with those outside this region excluded.

It looks at benefits over a 9-year time period, at a 10% discount rate.

It evaluates two different Loran receivers in its cost calculations. It assumes high operating costs and a small range of benefits and estimates the project's payback period under these scenarios.

The study uses sensitivity analysis, varying benefits and costs over a ±20% range. It then recalculates B/C ratios for values within this range. It finds the overall B/C ratio to be 1.6 or greater in all cases.

Mittelland Canal, Federal Republic of Germany (Ernst, et al., 1979)

The Mittelland project was begun in 1965 to widen and deepen a cross section of canal during a more fundamental planned renovation. This 1979 study uses CBA to confirm the correctness of the original planning decision, up to the point of the project's completion (it is a 30-year project).

This is a relatively simple study, in that to confirm, the CBA needs to show that transport cost reductions on the inland waterway are greater than the capital costs that exceeded those of the fundamental renovation (i.e., it only considers the marginal cost of the canal widening).

Among benefits measured, those caused by increased vessel-size capacity on the waterway are critical; others, such as vessel turn-around time, are of minor importance. This assumption allows concentration on the canal dredging rather than on postponable alternative projects.

In hindsight, results of the original feasibility study are confirmed by the 1979 study for the completed parts of the project.

The study takes the basic approach of early U.S. Army Corps of Engineers studies. It measures opportunity costs by projecting vessel sizes, origins, and destinations, and then imputing cost differentials with and without the project's construction. It takes into account time savings from two-way traffic, as well as cost savings from increased use of the waterway as an alternative to other modes.

The study includes sensitivity analysis to show the stability of the result when subjected to exogenous shocks in the economy.

The original feasibility study from the early 1960s seems to have included some kind of simulation model, coupled perhaps with queuing theory, to make original estimates of benefits from larger vessels, faster turnaround time, optimal lock operation, etc.

The Moselle, Federal Republic of Germany (Ernst, et al., 1979)

Because of earlier improvements on this river and related improvements on the Saar, traffic has tripled over a six-year period and is projected to double again in another ten years. This is complicated by the fact that the Moselle's dams are all single-lock. The study evaluates the need to build second locks at each dam below the entrance of the Saar.

Benefits accruing to this chain of locks are due to shorter waiting time at locks, less service interruption when a lock is being repaired, better handling of peak traffic, and changes in the priority rule regarding passenger and recreational ships versus cargo.

Problems relate to the high capital costs of such an extensive project. Further worries concern the risk of overestimated future traffic flows.

This CBA compares keeping existing locks with building the lock chain, measures and compares lock capacities, and projects the effects of these differences given projected traffic flows into the 1990s.

Traffic flow analysis assumes significant increases in pushed-barge traffic. This affects the traffic flow patterns to more night traffic, changing congestion estimates during daylight hours.

The project is not justified based only on gains from increased capacity; other considerations include deeper-draft vessels and projected fuel cost increases. An alternative project is also being considered to deepen the dredged sections and a slower expansion of the lock chain. This alternative also creates problems of complementary investments on some waterways and abandonment of others for deep-draft traffic.

Sensitivity results used to handle exogenous shocks show that the deepening project is warranted under various traffic flow scenarios. Even so, now the project's benefits and costs must be extended across the French border, so political implications of international redistribution of benefits and costs must be considered, as well as effects on rail traffic.

Port of Pohang, South Korea (Y-T Chang, 1992)

This study uses a simulation model that estimates the waiting-time distribution of vessels for the existing port versus facility expansion by construction of a new berth, which would allow ship-turnaround-time cost savings.

The study uses the power residue method to generate vessel interarrival time and service time in port.

The Rhine, Federal Republic of Germany (Ernst, et al., 1979)

Because of the size and importance of this waterway to the overall movement of goods on the entire German system of waterways, any CBA done for projects on the Rhine must be evaluated in the context of overall system benefits and costs. Changes in capacity along this riverway create bottlenecks and other problems on its tributaries.

The study discussed here involves four separate projects: 1) deepening of the Lower Rhine and stabilizing the bottom, which also depends on complementary investment by the Netherlands on the Dutch section; 2) deepening of the Middle Rhine; 3) deepening of the "mountain section" of the Rhine; and 4) prevention of erosion on the Upper Rhine.

The study separates benefits into those accruing to each project. Benefits are shared by other rivers in the system, such as the Saar and Moselle. Improvements generally accrue from increases in vessel size and associated cost savings, plus more stability of use due to deeper draft, and fewer seasonal water-level variation.

Costs, other than capital costs of the projects, include seasonal problems with high water levels caused by channel narrowings to raise water levels, safety problems induced by unfamiliarity of skippers with new channel depths (which vary considerably in the mountain section), etc.

Sheer size of such projects and the variability of problems each creates makes accurate CBA particularly difficult. Partial completion of the Upper Rhine canalization project has caused further erosion elsewhere. This new problem prompted the undertaking of a new CBA to compare an alternate proposal to correct erosion by adding bead load. But this project proved to have a higher B/C ratio.

This study shows how seriously analysts must take the interdependence of projects with regard to costs and benefits.

Rhine-Herne Canal, Federal Republic of Germany (Ernst, et al., 1979)

This is the second largest inland waterway in Germany, with several locks suffering residual structural damage during WWII due to nearby mining activity, causing high maintenance costs to redress subsidence damage and longitudinal stress. Many locks are often closed for repair, causing queuing problems for vessels, so many needed replacement by 1972, when construction began. The original study for new construction was done in 1970, and was based on engineering considerations. However, the construction plan called for larger locks, with two chambers at each dam. No real CBA was done at the time.

So, this CBA study was done later to verify the decision *ex post*. It uses traffic forecasts to 1990, and looks at three alternative project plans: 1) replace locks with those of the same dimension as the originals; 2) replace locks with larger ones without any other canal improvements; and 3) replace locks with larger ones and make other improvements in the canal, including channel deepening. Another "project" was also considered: 4) no investment, so close the canal when the life of old locks ends. They needed this alternative to compare with alternative 1.

Traffic modeling analysis used in this study involves emergence of pushed-barge traffic and vessels of larger size. Reduction in the number of ships is promoted best through alternative 3.

Evaluation shows a big gain in the B/C ratio between alternatives 1 and 2, with a small cost but large benefits differential. It also shows that larger locks are more important on the western portion of the canal, and so recommends fewer large locks built on the eastern portion. It further shows a big increase in benefits of reduced transport cost through a deepened channel.

Methodology follows that of other German models, and uses sensitivity analysis to adjust for exogenous shocks such as misforecast traffic

REFERENCES

Adler, Hans A. *Economic Appraisal of Transport Projects.* EDI Series in Economic Development. Baltimore: The Johns Hopkins University Press, 1987.

Bentkover, Judith D., Vincent T. Covello, and Jeryl Mumpower, eds. *Benefits Assessment: The State of the Art.* Dordrecht, Holland: D. Reidel Publishing Company, 1986.

Berg Andreassen, Jan A., and Charles E. Adams, Jr. "Navigational Project Evaluation--A Stochastic Approach to O/D Network Modeling." *Transportation Quarterly*, 43, 3 (July, 1989), 435-450.

Blaauw, Henk G., and Henk J. Verhey. "Design of Inland Navigation Fairways." *Journal of Waterway Port Coastal and Ocean Engineering*, 109, 1 (February, 1983), 18-30.

Carroll, Joseph L., and Srikanth Rao. "Economics of Public Investment in Inland Navigation: Unanswered Questions." *Transportation Journal*, 17, 3 (1978), 27-54.

Chang, Semoon. "Employment and Wage Impact of the Port of Mobile by County and Region." (unpublished research prepared for the City of Mobile), 1975.

Chang, Semoon. "In Defense of Port Economic Impact Studies." *Transportation Journal*, 17, 3 (1978), 79-85.

Chang, Semoon, and Loretta M. Dunphy. *Economic Analysis of the Port of Mobile.* Mobile, AL: University of South Alabama, 1974.

Chang, Young-Tae. "Cost-Benefit Analysis on a Port Development Project Using a Simulation Program." *Selected Proceedings of the Sixth World Conference on Transport Research*, II (1992), 1435-1446.

Clark, Morris William, Jr. *Methods, Models and Data Sources Applicable to Transportation Economics Studies.* IWR Technical Report 83-TR-1. Fort Belvoir, VA: Navigation Analysis Center, U.S. Army Corps of Engineers, Institute for Water Resources, May 1983.

Conn, B.L. *An Assessment of Major Benefits to Mississippi from Waterborne Commerce.* Oxford, MS: Bureau of Economic and Business Research, University of Mississippi, 1966.

"Cost-Benefit Trips Up the Corps." *Business Week*, February 19, 1979, pp. 96-97.

Crew, James, and Kevin H. Horn. "The Impact of Rail Rates or Costs Upon Waterway Project Planning: An Uncertain Future." *Proceedings of the Twenty-second Annual Meeting of the Transportation Research Forum*, XXII, 1 (1981), 432-440.

Crew, James, and Kevin H. Horn. "Problems of Deep Draft Navigation Benefit Evaluation Procedures." *Journal of the Transportation Research Forum*, XXX, 2 (1990), 526-536.

Cummings, Ronald G., Louis Anthony Cox, Jr., and A. Myrick Freeman III, "General Methods for Benefits Assessment." in *Benefits Assessment: The State of the Art.* Judith D. Bentkover, Vincent T. Covello, and Jeryl Mumpower, eds. Dordrecht, Holland: D. Reidel Publishing Company, 1986.

Dai, Melody Dzwo-Min, *Delay Estimation on Congested Waterways.* IWR Report 93-R-8. Fort Belvoir, VA: Navigation Division, U.S. Army Corps of Engineers, Institute for Water

Resources, March 1993.

Darton, Donald C., and Charles O. Meiburg. *The Contributions of the Ports of Virginia to the Economy of the Commonwealth.* Charlottesville, VA: Bureau of Population and Economic Research, University of Virginia, 1968.

Davis, Robert K. "Lessons in Politics and Economics from the Snail Darter." *Environmental Resources and Applied Economics: Essays in Honor of John V. Krutilla.* V. Kerry Smith, ed. Washington, DC: Resources for the Future, 1988.

Delaware River Port Authority. *Value to the Delaware Valley Region of Break-Bulk General Cargo Passing Through, but Processed in the Ports of Philadelphia.* 1969.

DeSalvo, Joseph S. "Measuring the Direct Impacts of a Port." *Transportation Journal,* 33, 4 (1994), 33-42.

Dubus, P. "Subtopic 4--Quality of Life and Social Costs: (A) Safety." *Resources for Tomorrow's Transport.* Introductory Reports and Summary of Discussions from the Eleventh International Symposium on Theory and Practice in Transport Economics. Organization for Economic Cooperation and Development: Brussels, 1988.

Eckstein, Otto. *Water Resources Development: The Economics of Project Evaluation.* Cambridge, MA: Harvard University Press, 1958.

Ernst, Dietmar, Klaus Lohrberg, Dirk Mester, and Volker Orlovius. "The Use of Cost-Benefit Analyses for Investments in Inland Waterways." *Permanent International Association of Navigation Congresses Bulletin,* 3, 34 (1979), 25-45.

Figura, Roger S. "Public Seaport Operations: A Dynamic Cost-Benefit Model." *Maritime Policy Management*, 6, 3 (1979), 217-228.

Funk, Jeffrey L. "A Methodology for Estimating the Benefits from New Lock Construction." *Transportation Quarterly*, 37, 4 (October, 1983), 597-621.

Garner, Paul and Mac Holmes. *An Analysis of the Annual Economic Impact of the Tennessee-Tombigbee Waterway.* Livingston, Alabama: Center for Business and Economic Services, 1995.

Goicoechea, Ambrose, Don Sweeney, Francis M. Sharp, and John J. Burns. "A Transportation Model for Economic Policy Analysis of National Inland Waterways Navigation." *Proceedings of the Twenty-fourth Annual Meeting of the Transportation Research Forum*. Arlington, VA., XXIV, 1 (1983), 767-778.

Goss, R. "Economic Policies and Seaports." *Maritime Policy and Management*, 17, 1990, 231-244.

Grier, David V., and L. Leigh Skaggs. *A Review of 16 Planning and Forecast Methodologies Used in U.S. Army Corps of Engineers Inland Navigation Studies.* IWR Report 92-R-4. Fort Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources, June 1992.

Grosdidier de Matons, Jean C. "Economic and Financial Appraisal of Port Projects at the World Bank: A Review of Policy and Practice." *Maritime Policy and Management*, 13, 4 (1986), 259-275.

The Gulf Intracoastal Waterway in Texas. Austin, TX: Texas Department of Transportation, 1994.

Hanke, Steve H., and Richard A. Walker. "Benefit-Cost Analysis Reconsidered: An Evaluation of the Mid-State Project." *Water Resources Journal*, 10, 5 (1974), 898-909.

Hansen, William J., and Daniel D. Badger. *National Economic Development Procedures Manual: Recreation.* Volume IV. IWR Report 91-R-7. Fort Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources, July 1991.

Hickling and Associates. *A Study of the Impact of Ice Breaking in Eastern Canada.* Winnepeg, 1989.

Hille, Stanley J., and James E. Suelflow. *The Economic Impact of the Port of Baltimore on Maryland.* College Park: University of Maryland, 1969.

Holguin-Veras, Jose, and C. Michael Walton. *A Categorized and Annotated Bibliography to the Performance Analysis of Port Operations.* Interim Report SWUTC/95/721912-1. Austin, TX: Southwest Region University Transportation Center, Center for Transportation Research, University of Texas at Austin, March 1995.

Hunt, Constance E. "Reducing Environmental and Economic Costs of Inland Waterway Operation and Maintenance." *Transportation Research Circular*, 322 (1987), 14-18.

International Marketing Research Center. *The Economic Impact of the Tampa Port.* Gainesville, FL: University of Florida, 1968.

James, Arthur P. *A Three-To-Get-Two-Region Nonsurvey Input-Output Model with Complementary Feedback Effects.* unpublished Ph.D. dissertation. Columbia, MO: University of Missouri-Columbia, 1989.

Kearney, A.T. *An Evaluation of the Transportation Economics of the Tennessee-Tombigbee Waterway.* April, 1976.

Kim, Ung Soo. *Regional Development Impacts and Their Measurements.* IWR Contract Report 85-C-6. Fort Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources, November 1985.

Lewis, W. Cris, and Terrence F. Glover. *Linear Programming/Economic Base-Evaluation Model for Estimating the Regional Development Impacts of Water Resource Projects: User Manuel.* IWR Report 84-UM-1. Fort Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources, September 1982.

Liew, Chong K., and Chung J. Liew. "Use of a Multiregional Variable Input-Output Model to Analyze Economic Impacts of Transportation Costs." *Transportation Research Record 747.* Washington, DC: Transportation Research Board, National Academy of Sciences, 1980, 5-12.

Males, Richard M., Walter M. Grayman, and Craig A. Strus. *Development of Prototype Software for Risk-Based Benefit-Cost Analysis of Major Rehabilitation Proposals (Phases I and II).* IWR Report 94-R-5. Alexandria, VA: U.S. Army Corps of Engineers, September 1994.

Martin Associates. *The Local and Regional Economic Impacts of the Port of Houston.* Lancaster, PA, 1995.

Martin, J.C. "Economic Impact Analysis: A Port-specific Approach." *Portus*, 4, 1987, 33-35.

McFarland, William F., Dock Burke, Jeffery Memmott, and Jesse L. Buffington. *Economic Analysis of Transportation Expenditures: A Literature Review.* Research Report 1106-2.

College Station, TX: Texas Transportation Institute, 1989.

Mercer Management Consulting. "The Importance of Inland and Intracoastal Waterways to State Economies." Summary Review before the Subcommittee on Water Resources and Environment. Washington, DC: U.S. House of Representatives, February 28, 1996.

Miller, Ronald E., and Peter D. Blair. *Input-Output Analysis: Foundations and Extensions.* Englewood Cliffs, NJ: Prentice-Hall, Inc., 1985.

Pilsch, Martin C., Jr. "Automated Bulk Terminals--Does the Cost Override the Benefit?" *World Wide Shipping*, February/March, 1992, pp. 63-64.

Port Economic Impact Kit. Washington, DC: Maritime Administration Office of Port and Intermodal Development, 1979.

Port of Portland. *Economic Impact of the Port of Portland, Oregon.* Portland, OR, 1971.

Port of Seattle Commission. *Seattle Maritime Commerce and Its Impact on the Economy of King County.* Seattle, WA, 1971.

Ransom, R.L. "Social Returns from Public Transit Investment: A Case Study of the Ohio Canal." *Journal of Political Economy.* September/October 1970, 1041-1060.

U.S. Department of Transportation. *The Regional Port Impact Model Handbook, Volume 1: Guide for Preparing Economic Impact Assessments Using Input-Output Analysis.* Washington, DC: Maritime Administration, 1982.

Remen, Robert I. "California and the Pacific Rim Trade." *Transportation Research Circular*, 391 (1992), 7-11.

Roop, Stephen S., Daryl U. Wang, Richard W. Dickinson, and Gordon M. Clarke. *Closure of the GIWW and its Impact on the Texas Highway Transportation System: Final Report--Volumes I and II.* Research Report 1283-2F. College Station, TX: Texas Transportation Institute, 1993.

Rose, Warren. *The Port of Galveston: Employment and Income Impact.* Houston, TX: University of Houston, 1970.

Ryan, Robert H., and Charles W. Adams. *Corpus Christi: Economic Impact of the Port.* Austin, TX: Bureau of Business Research, University of Texas at Austin, 1973.

Ryan, Timothy P. "The Economic Impacts of the Ports of Louisiana and the Maritime Industry." (unpublished research, University of New Orleans, March, 1996), pp. 1-26.

Sagner, James S. "Benefit/Cost Analysis Efficiency-Equity Issues in Transportation." *The Logistics and Transportation Review*, 16, 4 (1980), 339-388.

Schut, Matwey. "Economic Evaluation Methods for Port Infrastructure Projects: An Application to the Planned Outerport of Amsterdam." *Transport Research for Social and Economic Progress: Proceedings of the World Conference on Transport Research.* London, April 1980, 860-881.

Shea, William F., and Mary L. Brugo. "Overview of Methodology Used to Determine the Economic Impact of the Port of Portland Aviation Facilities." *Transportation Research Circular*, 259 (1983), 2-8.

Slack, Brian, Danielle Vallée, Claude Comtois, and Luc Lagimonière. *The Economic Impacts of Small and Medium Size Ports.* Publication #890. Montreal, Ouebec: The Centre for Research on Transportation, Montreal University, March 1993.

Smith, Frederick J. "Estimating Economic Impacts." *World Wide Shipping*, September, 1990, pp. 40-45.

Smith, Frederick J. "How Important is Your Port?" *World Wide Shipping*, February/March, 1989, pp. 36-38.

Sonstegaard, Miles, and John Ozment. "Benefit-Cost Analysis of Constructing a Rail Connection and Intermodal Facility at the Mississippi River Port of Yellow Bend in Arkansas." Fayetteville, AR: Mack-Blackwell National Rural Transportation Study Center, 1995.

Tennessee Valley Authority. *The Economic Impact of Commercial Navigation on the Chattanooga Metropolitan Statistical Area.* Knoxville, Tennessee: February, 1991.

Tennessee Valley Authority. *The Economic Impact of Commercial Navigation on the Decatur, Alabama Port Region.* Knoxville, Tennessee: December, 1992.

Tennessee Valley Authority. *Environmental Statement, Tellico Project.* Chattanooga, TN: TVA, Office of Health and Environmental Science, February, 1972.

Tennessee Valley Authority. *Alternatives for Completing the Tellico Project.* Knoxville, TN: 1978.

Tuğcu, Seyhan. "A Simulation Study on the Determination of the Best Investment Plan for Istanbul Seaport." *Journal of the Operational Research Society*, 34, 6 (1983), 479-487.

U.S. Army Corps of Engineers Huntington District. *Gallipolis Locks and Dam Replacement, Ohio River.* Appendix A-N, 1981.

U.S. Department of Commerce, Bureau of Economic Analysis. "The Input-Output Structure of the U.S. Economy, 1977. *Survey of Current Business.* May, 1984, 42-84.

U.S. General Accounting Office. *The Tennessee Valley Authority's Tellico Dam Project--Costs, Alternatives, and Benefits.* Report to Congress. Washington, DC, October 14, 1977.

U.S. Water Resources Council. *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.* Washington, DC: U.S. Government Printing Office, 1983.

Waters, Robert C. "Port Economic Impact Studies: Practice and Assessment." *Transportation Journal.* Spring, 1977, pp. 14-18.

Weir, Norman E., and Stuart W. McFarland. *The Impact of the Port of Jacksonville on the Economy of the Community.* 1965.

Williams, Ian N. "Predicting Freight Flows through a New Port." *Developing Countries: Proceedings of Seminar G of the Planning and Transport Research and Computation Company.* Sussex, England, 1984, 265-276.

Wilson, Hoyt G. "Port Pricing and Investment Planning." *The Logistics and Transportation Review*, 15, 3 (1979), 401-418.

Wiseman, R.L., and C.N. Veronda. *The Costs and Benefits of a Mid-Continent Expansion of Loran-C.* Report No. DOT-TSC-RSPA-79-3. Cambridge, MA: U.S. Department of Transportation, March, 1979.

Wood, Thomas W. "The Economics of Mixed Cargo and Cruise Ship Traffic in a Port." *Journal of Transport Economics and Policy*, XV (1982), 43-53.

Yochum, G.R., and V.B. Agarwal. "Static and Changing Port Economic Impacts." *Transportation Policy and Management*, 16, 1988, 157-171.

Yoe, Charles. *National Economic Development Procedures Manual: National Economic Development Costs.* IWR Report 93-R-12. Fort Belvoir, VA: U.S. Army Corps of Engineers, Institute for Water Resources, June 1993.

Zerbe, Richard O., Jr., and Dwight D. Dively. *Benefit-Cost Analysis.* New York: Harper Collins College Publishers, 1994.

Glossary

Accounting stance – the geographic boundaries beyond which any project-caused costs or benefits are ignored

Backwardly linked industry – industry A is positioned backward of industry B when A lies along the chain of industries which develop inputs for B

Central objective (of cost-benefit analysis) – acceptable projects must satisfy a compensation test; equivalently, they must provide a potential Pareto improvement Commensurable – a monetarizable welfare effect

Compensation test – a project approval criterion which is met only if project beneficiaries receive sufficient benefits to be able to fully compensate project losers; actual compensation is not required

Computable general equilibrium (CGE) model – a model of the entirety of an economy's markets where the model is capable of simultaneous solution for all market-clearing prices

Consumer surplus – the area under a demand curve and above the price line

Discount rate – the social rate of time preference used in cost benefit analysis

Economic impact – any aspect of economic change caused by a specific economic event

Economic multipliers – any of several alternative multiplier concepts, especially output, employment and income multipliers, used to gauge the secondary economic effects of an economic event

Employment multipliers – an economic multiplier used to estimate secondary effects pertaining to the changing number of persons employed consequent to an economic event

Excess demand – the vertical subtraction of supply from demand

Excess supply – the vertical subtraction of demand from supply

Expected surplus value – the average welfare gain for a project/decision having a probabilistic outcome

Forwardly linked industry – industry B is positioned forward of industry A when B is directly or indirectly dependent on A for some productive input

General equilibrium supply and demand – general equilibrium relationships embed all price repercussions and feedbacks that will occur subsequent to a supply or demand shift

Income multipliers – an economic multiplier used to estimate secondary effects pertaining to changing income consequent to an economic event

Incommensurable – a welfare effect that can be measured in physical units but cannot be monetarized

Indirect economic impacts – summed repercussions of an economic event exclusive of the event itself; usually referring to changing output values

Induced economic impact – a type of secondary economic impact originating from the respending of new income by households

Input-output analysis – an economic modeling method relying on the linearization of intersectoral commodity flows

Intangible – a welfare effect that defies both monetarization and physical measurement

Monetarized welfare effect – a welfare effect that can be fully expressed in value ($) terms

Nonmarket valuation – any technique for monetarizing welfare effects which does not require prior market trading of the commodity being assessed

Opportunity cost (private or social) – the private or social value sacrificed when a commodity or resource is unavailable for its next best use

Option price – the maximum constant payment an individual would make in every period in exchange for a set of risky, prospective returns during the same period

Output multipliers – an economic multiplier used to estimate secondary effects pertaining to the changing value of an economy's goods consequent to an economic event

Pareto improvement – a policy/project-caused social change for which no individual suffers a negative welfare effect and at least one individual experiences a gain

Potential Pareto improvement – a policy/project-caused social change for which summed welfare effects are positive

Producers surplus – the area above the supply curve and below the price line; equivalent to the area below an input demand curve and above its price line

Rate of time preference (private or social) – the rate y necessary to render an individual or society indifferent between the sure receipt of $100 today and $100•(1+y) in one year

Secondary economic impacts – summed repercussions of an economic event exclusive of the event itself; usually referring to changing output values

Sequential partial equilibrium analysis – an ordered method of monetarizing multimarket welfare effects from price changes consequent to a price change in a related market

Simple multiplier – any input-output multiplier that includes direct and secondary (indirect) effects, but excludes induced effects

Total multiplier – any input-output multiplier that includes direct, secondary (indirect), and induced effects

Utility – the amount of satisfaction received by a consumer for such things as using a product, having an enjoyable experience, or consuming a resource

Value-added – the value of a product over and above the opportunity costs of its production

Welfare economics – a branch of economics emphasizing collective decision making

Welfare effect – the effect of a policy or project on either a consumer's or a producer's economic well being

Willingness to pay – the sum which, if collected from a project beneficiary, would precisely offset the additional producer profit or consumer utility obtained by the beneficiary as consequence of a project