CHAPTER 1

Introduction to Cost-Benefit Analysis

In the Affair of so much Importance to you, wherein you ask my Advice, I cannot for want of sufficient Premises, advise you what to determine, but if you please I will tell you how. When those difficult Cases occur, they are difficult, chiefly because while we have them under Consideration, all the Reasons pro and con are not present to the Mind at the same time; but sometimes one Set present themselves, and at other times another, the first being out of Sight. Hence the various Purposes or Inclinations that alternately prevail, and the Uncertainty that perplexes us.

To get over this, my Way is, to divide half a Sheet of Paper by a Line into two Columns; writing over the one Pro, and over the other Con. Then during three or four Days Consideration, I put down under the different Heads short Hints of the different Motives, that at different Times occur to me, for or against the Measure. When I have thus got them all together in one View, I endeavor to estimate their respective Weights; and where I find two, one on each side, that seem equal, I strike them both out. If I find a Reason pro equal to some two Reasons con, I strike out the three. If I judge some two Reasons con, equal to some three Reasons pro, I strike out the five; and thus proceeding I find at length where the Balance lies; and if after a Day or two of farther consideration, nothing new that is of Importance occurs on either side, I come to a Determination accordingly. And, tho' the Weight of Reasons cannot be taken with the Precision of Algebraic Quantities, yet, when each is thus considered, separately and comparatively, and the whole lies before me, I think I can judge better, and am less liable to make a rash Step; and in fact I have found great Advantage from this kind of Equation, in what may be called Moral or Prudential Algebra.

—B. Franklin, London, September 19, 1772[1]

INDIVIDUAL VERSUS SOCIAL COSTS AND BENEFITS

Benjamin Franklin's advice about how to make a decision illustrates many of the important features of cost-benefit analysis (CBA). These include a systematic cataloguing of impacts as benefits (pros) and costs (cons), valuing in dollars (assigning weights), and then determining the *net benefits* of the proposal relative to the status quo (net benefits equal benefits minus costs).

When we as individuals talk of costs and benefits, we naturally tend to consider only our *own* costs and benefits, generally choosing among alternative courses of action according to whichever has the largest individual net benefits. Similarly, in evaluating various investment alternatives, a firm tends to consider only those costs (expenditures) and benefits (revenues) that accrue to it. In CBA we try to consider *all of the costs and benefits to society as a whole,* that is, the *social costs* and the *social benefits.* For this reason, some experts refer to CBA as *social* cost-benefit analysis.

CBA is a policy assessment method that quantifies in monetary terms the value of all consequences of a policy to all members of society. Throughout this book we use the terms *policy* and *project* interchangeably. More generally, CBA applies to policies, programs, projects, regulations, demonstrations, and other government interventions. The aggregate value of a policy is measured by its net social benefits, sometimes simply referred to as the net benefits. The *net social benefits, NSB,* equal the social benefits, *B,* minus the social costs, *C:*

$$NSB = B - C \tag{1.1}$$

Stated at this level of abstraction, it is unlikely that many people would disagree with doing CBA. In practice, however, there are two types of disagreements. First, social critics, including some political economists, philosophers, libertarians, and socialists, have disputed the fundamental utilitarian assumptions of CBA that the sum of individual utilities should be maximized and that it is possible to trade off utility gains for some against utility losses for others. These critics are not prepared to make trade-offs between one person's benefits and another person's costs. Second, participants in the public policy-making process (analysts, bureaucrats, and politicians) may disagree about such practical issues as what impacts will actually occur over time, how to monetize (attach a dollar value to them), and how to make trade-offs between the present and the future.

In this chapter we provide a nontechnical but reasonably comprehensive overview of CBA. Although we introduce a number of key concepts, we do so informally, returning to discuss them thoroughly in subsequent chapters. Therefore, this chapter is best read without great concern about definitions and technical details.

TYPES OF CBA ANALYSES AND THEIR PURPOSES

The broad purpose of CBA is to help social decision making and to make it more rational. More specifically, the objective is to have more efficient allocation of society's resources. As we show in Chapter 3, where markets work well, individual self-interest leads to an efficient allocation of resources. Consequently, government analysts and politicians bear the burden of providing a rationale for any governmental interference with private choice. Economists lump these rationales under the general heading of *market failures.* Where markets fail, there is a *prima facie* rationale for government intervention. However, and this is important to emphasize, it is no more than that. One must be able to demonstrate the superior efficiency of a particular intervention relative to the alternatives, including the status quo. For this purpose, analysts use CBA.

There are two major types of cost-benefit analysis. *Ex ante* CBA, which is just standard CBA as the term is commonly used, is conducted while a project or policy is under consideration, before it is started or implemented. *Ex ante* CBA assists in the decision about whether resources should be allocated by government to a specific project or policy or not. Thus, its contribution to public policy decision making is direct, immediate, and bureau-specific. *Ex post* CBA is conducted at the end of a project. At this time, all of the costs are "sunk" in the sense that they have already been used up to do the project. The value of *ex post* analyses is broader but less immediate as they provide information not only about the particular intervention but also about the "class" of such interventions. In other words, they contribute to "learning" by government managers, politicians, and academics about whether particular classes of projects are worthwhile.

Some CBA studies are performed during the course of the life of a project, that is, *in medias res.* Like *ex ante* analyses, *in medias res* analyses have the potential of directly influencing a decision—whether or not to continue the project. They also provide information that can be used to predict costs and benefits in future *ex ante* analyses.

There is also a fourth type of CBA—one that compares an *ex ante* CBA with an *ex post* (or *in medias res*) CBA *of the same project.* This comparative type of CBA is most useful to policy makers for learning about the efficacy of CBA as a decision-making and evaluative tool. Unfortunately, there are only a few disinterested published examples of this type of CBA. The scarceness of this type of CBA is not as surprising as it may appear because there is relatively little demand for *ex post* or *in medias res* CBAs and, even if one of these studies is done, there may not be an *ex ante* CBA to compare it to.

It is useful to elaborate on the uses of these four types of CBAs. Table 1-1 summarizes the important ways that these four types of cost-benefit analyses aid government decision making.

Project-Specific Decision Making

Ex ante analysis is most useful for deciding whether resources should be allocated to a particular project or program that is under consideration. An *in medias res* analysis of an ongoing project can also be used for decision-making purposes where it is potentially feasible to shift resources to alternative uses. Although such an analysis may lead to discontinuation of service-orientated programs (e.g., government-funded training programs), it will rarely lead to termination of a physical investment project nearing completion, such as a dam or bridge, because a large share of the costs will likely have been incurred, and benefits subsequent to the analysis will usually exceed the remaining costs. However, it can happen. For example, a Canadian Environmental Assessment Panel recommended the decommissioning of a just-completed dam on the basis of an *in medias res* analysis which showed that, with use, future environmental costs would exceed future benefits.[2] Because *ex post* analysis is conducted at the end of the project,

TABLE 1-1 Value of Different Classes of CBA

	Class of Analysis			
Value	***Ex Ante***	***In Medias Res***	***Ex Post***	***Ex Ante/Ex Post or Ex Ante/In Medias Res Comparison***
Resource allocation decision for this project.	Yes—helps to select best project or make "go" versus "no-go" decisions, if accurate.	If low sunk costs, can still shift resources. If high sunk costs, usually recommends continuation.	Too late—the project is over.	Same as *in medias res* or *ex post* analysis.
Learning about actual value of specific project.	Poor estimate—high uncertainty about future benefits and costs.	Better—reduced uncertainty.	Excellent—although some errors may remain. May have to wait long for study.	Same as *in medias res* or *ex post* analysis.
Contributing to learning about actual value of similar projects.	Unlikely to add much.	Good—contribution increases as performed later. Need to adjust for uniqueness.	Very useful—although may be some errors and need to adjust for uniqueness. May have to wait long for project completion.	Same as *in medias res* or *ex post* analysis.
Learning about omission, forecasting, measurement and evaluation errors in CBA.	No	No	No	Yes, provides information about these errors and about the accuracy of CBA for similar projects.

Source: Anthony E. Boardman, Wendy L. Mallery, and Aidan R. Vining, "Learning from *Ex Ante/Ex Post* Cost-Benefit Comparisons: The Coquihalla Highway Example," *Socio-Economic Planning Sciences,* 28(2), 1994, 69–84, Table 1, p. 71. Reprinted with kind permission from Elsevier Science Ltd., The Boulevard, Langford Lane, Kidlington OX5 1GB, UK.

it is obviously too late to reverse resource allocation decisions with respect to that particular project.

Learning about the Net Social Benefits of a Specific Project

In the early stages of a project there is considerable uncertainty about its actual impacts and, consequently, about the true net social benefits. As time goes by, more is known about the impacts, and CBA studies conducted later can estimate the net benefits of the project more accurately. In general, *ex post* studies are more accurate than *in medias res* studies, which in turn are more accurate than *ex ante* studies.

Learning about the Potential Benefits of Similar Projects

Ex post analyses provide information not only about a particular policy intervention but, more importantly, about future similar interventions as well. *Ex post* analyses (and *in medias res* analyses) potentially contribute to learning by political and bureaucratic decision makers, as well as policy researchers, about whether particular kinds of projects are worthwhile. This potential depends crucially on the extent to which the particular project being assessed is being replicated or can serve as a generic model for other projects.[3] CBAs of experiments involving the efficacy of new surgical procedures or new pharmaceutical products usually can be generalized to larger populations. Lessons from other experiments, however, may not be as easily generalized. For example, if the proposed intervention is several orders of magnitude bigger than the experiment, there may be unknown nonlinear scale effects. Also, if the proposed program has a more extended time frame than the experiment, behavioral factors may affect costs or benefits unpredictably.

Learning about the Efficacy of CBA

Comparison of an *ex ante* study with either an *in medias res* or an *ex post* analysis is most useful for learning about the value of CBA itself. Most importantly, a comparison CBA provides information about the accuracy of the earlier *ex ante* CBA which, in turn, provides guidance about the accuracy of future *ex ante* analyses. One study has assessed the accuracy of U.S. regulatory cost estimates (although not of benefits) and found that total costs tend to be overestimated.[4] Information about the predictive ability of CBA is useful for decision-making purposes. Also, comparison studies help analysts understand the reasons for any divergence between predicted and actual benefits or costs. In Chapter 11, we discuss prediction (and valuation) in detail and review some important potential types of errors. Understanding the reasons for these errors helps to reduce them in the future.

THE BASIC STEPS OF CBA: COQUIHALLA HIGHWAY EXAMPLE

CBA may look intimidating and complex. To help make the process of conducting a CBA more manageable, we break it down into nine basic steps, which are listed in Table 1-2. We describe and illustrate these steps using a relatively straightforward example—the construction of a new highway. For each step, we also point out some practical difficulties. The conceptual and practical issues that we broach are the focus of the rest of this book. Do not worry if the concepts are unfamiliar to you; this is a dry run. Subsequent chapters fully explain them.

Imagine that in 1986 a cost-benefit analyst, who works for the Province of British Columbia, Canada, is asked to perform a CBA of a proposed highway between the town of Hope in the south-central part of the Province and Merritt, which is more or less due north of Hope. This highway would be called the Coquihalla Highway. The

TABLE 1-2 The Major Steps in CBA

1. Specify the set of alternative projects.
2. Decide whose benefits and costs count (standing).
3. Identify the impact categories, catalogue them, and select measurement indicators.
4. Predict the impacts quantitatively over the life of the project.
5. Monetize (attach dollar values to) all impacts.
6. Discount benefits and costs to obtain present values.
7. Compute the net present value of each alternative.
8. Perform sensitivity analysis.
9. Make a recommendation.

analyst's CBA is presented in Table 1-3.[5] How did the analyst get these results? What were the difficulties? We will go through each of the nine steps.

1. Specify the set of alternative projects. Step 1 requires the analyst to specify the set of alternative projects. In this example, the provincial government required the analyst to consider only two alternative four-lane highways, one with tolls and one without. The provincial department of transportation decided that the toll, if applied, would be $40 for large trucks and $8 for cars. Thus, the analyst has a tractable set of alternatives to analyze.

TABLE 1-3 Coquihalla Highway CBA (1986 $ Million)

	No Tolls		***With Tolls***	
	A Global Perspective	***B Provincial Perspective***	***C Global Perspective***	***D Provincial Perspective***
Project Benefits:				
Time and Operating Cost Savings	389.8	292.3	290.4	217.8
Horizon Value of Highway	53.3	53.3	53.3	53.3
Safety Benefits (Lives)	36.0	27.0	25.2	18.9
Alternative Routes Benefits	14.6	10.9	9.4	7.1
Toll Revenues	—	—	—	37.4
New Users	0.8	0.6	0.3	0.2
Total Benefits	494.5	384.1	378.6	334.7
Project Costs:				
Construction	338.1	338.1	338.1	338.1
Maintenance	7.6	7.6	7.6	7.6
Toll Collection	—	—	8.4	8.4
Toll Booth Construction	—	—	0.3	0.3
Total Costs	345.7	345.7	354.4	354.4
Net Social Benefits	148.8	38.4	24.2	–19.7

Source: Adapted from Anthony Boardman, Aidan Vining, and W. G. Waters II, "Costs and Benefits through Bureaucratic Lenses: Example of a Highway Project," *Journal of Policy Analysis and Management,* 12(3) 1993, 532–555, Table 1, p. 537.

In practice, however, there are often difficulties even at this stage. For many projects, including this one, the number of potential alternatives is huge. This highway could vary on many dimensions including the following:

Road surface: It could be surfaced in bitumen or concrete.

Routing: It could take different routes.

Size: It could have two, three, four, or six lanes.

Tolls: The tolls could be higher or lower.

Wild animal friendliness: The highway could be built with or without "elk tunnels."

Timing: It could be delayed until a later date.

Changing the highway on just a few these dimensions would greatly increase the number of alternatives. For example, with four dimensions, each with three possible values, there would be 81 alternatives! Neither decision makers nor analysts can cognitively handle comparisons among such a large number of alternatives. Resource and cognitive constraints mean that analysts typically analyze only a few (less than six) alternatives.[6]

CBA compares the net social benefits of investing resources in one or more particular potential projects with the net social benefits of a project that would be displaced if the project(s) under evaluation were to proceed. The displaced project is often called the *counterfactual.* Usually, the counterfactual is the *status quo,* which means there is no change in government policy (i.e., in this case, no new highway). In Table 1-3 the analyst computes the benefits, costs, and net social benefits if the highway were built (with or without tolls) relative to the benefits, costs, and net social benefits if the highway is not built (the status quo). Thus, one can interpret these benefits, costs, and net benefits as *incremental* amounts.

Sometimes the status quo is not a viable alternative. *If a project would displace a specific alternative, then it should be evaluated relative to the specific displaced alternative.* Thus, if government has committed resources to either a highway project or a rail project, and there is no possibility of maintaining the status quo, then the highway project should be compared with the rail project, not the status quo.

This CBA example pertains to a specific proposed highway. There is no attempt to compare this highway project to alternative highway projects in British Columbia, although one could do so. Rarely does the analyst compare a highway project to completely different types of projects, such as health care, antipoverty, or national defense projects. As a practical matter, full optimization is impossible. The limited nature of the comparisons sometimes frustrates politicians and decision makers who imagine that CBA is a *deus ex machina* that will rank *all* policy alternatives. On the other hand, the weight of CBA evidence can and does help in making broad social choices across policy areas.

2. Decide whose benefits and costs count (standing). Next, the analyst must decide who has *standing*; that is, whose benefits and costs should be included. In this example, the analyst's superiors in the provincial government wanted the CBA to be done from the provincial perspective, but asked the analyst to also take a global perspective. The provincial perspective measures only the benefits and costs that affect British Columbian residents, including costs and benefits borne by the British Columbian government. The global perspective includes the benefits and costs that affect everyone, irrespective of where they reside. Thus, it includes benefits and costs to Americans, Albertans, and even tourists from the United Kingdom. Combining these two perspectives on standing with the no-tolls and with-tolls alternatives gives the four columns in Table 1-3 labeled A through D.

The issue of standing is sometimes contentious. While federal governments usually take only national costs and benefits into account, critics argue that many issues should be analyzed from a global perspective. Environmental issues that fall into this category include ozone depletion, global climate change, and acid rain. At the other extreme, local governments typically want to consider only benefits and costs to local residents and to ignore costs and benefits that occur in adjacent municipalities or are borne by higher levels of government. Our highway example deals with this issue by analyzing costs and benefits from both the global and the British Columbian perspectives.

3. Identify the impact categories, catalogue them, and select measurement indicators. Step 3 requires the analyst to identify the physical impact categories of the proposed alternatives, catalogue them as benefits or costs, and specify the measurement indicator of each impact category. We use the term *impacts* broadly to include both inputs (required resources) and outputs. For this proposed highway, the anticipated benefit impact categories are time saved and reduced vehicle operating costs for travelers on the new highway ("Time and Operating Cost Savings" in Table 1-3); the value of the highway at the end of the discounting period of 20 years ("Horizon Value of Highway"); accidents avoided (including lives saved) due to drivers switching to a shorter, safer new highway ("Safety Benefits"); reduced congestion on alternative routes—the old road ("Alternative Routes Benefits"); revenues collected from tolls ("Toll Revenues"); and benefits accruing to new travelers ("New Users"). The cost impact categories are construction costs ("Construction"), additional maintenance and snow removal ("Maintenance"), toll collection ("Toll Collection"), and toll booth construction and maintenance ("Toll Booth Construction").

Although this list of impact categories appears comprehensive, current critics might argue that some relevant impacts were omitted. At the time of the analysis, health impacts from automobile emissions, impacts on the elk population and other wildlife, and changes in scenic beauty were not considered. Also, the cost of the land was excluded.

From a CBA perspective, analysts are interested only in project impacts that affect the utility of individuals with standing. Impacts that do not have any value to human beings are not counted. (The caveat is that this applies only where human beings have the relevant knowledge and information to make rational valuations.) Politicians often state the purported impacts of projects in very general terms. For example, they might say that a project will promote "community capacity building." Similarly, politicians have a strong tendency to regard "growth" and "regional development" as beneficial impacts. CBA requires analysts to identify explicitly the ways in which the project would make some individuals better off through, for example, improved skills, better education, or higher incomes. Of course, analysts should also include the negative environmental and congestion impacts of growth.

Put another way, in order to treat something as an impact, we have to know there is a cause-and-effect relationship between some physical outcome of the project and the utility of human beings with standing. For some impacts, this relationship is so obvious that we do not think about it explicitly. For example, we do not question the existence of a causal relationship between motor vehicle usage and motor vehicle accidents. For other impacts, however, the causal relationships may not be so obvious. What, if any, is the impact of exhaust fumes from additional vehicle usage on residents' morbidity and mortality? How is this offset by fewer airplane flights? Demonstrating such cause-and-effect relationships often requires an extensive review of scientific and social science research. Sometimes the evidence may be ambiguous. For example, controversy surrounds the effect of chlorinated organic compounds in bleached pulp mill effluent on wildlife. Although a Swedish study found such a link, a later Canadian study found none.[7]

Analysts should be on the lookout for impacts that different groups of people view in opposite ways. Consider, for example, flooded land. Residents of a flood plain generally view floods as a cost because they damage homes, while duck hunters regard them as a benefit because they attract ducks. Even though opposing valuations of the same impact could be aggregated in one category, it is usually more useful to have two impact categories—one for damaged homes and another for recreation benefits.

Specification of impact measurement indicators usually occurs at the same time as specification of the impact categories. There are no particular difficulties in specifying measurement indicators of each impact in this illustration. For example, the number of lives saved per year, the number of person-hours of travel time saved, and the dollar value of gasoline saved are reasonably intuitive indicators. If environmental impacts had been included, then the choice of indicator would have not been so straightforward. For example, the analyst might have to decide whether to use tons of various pollutants or the resultant health effects (e.g., changes in mortality or morbidity).

The choice of measurement indicator depends on data availability and ease of monetization. For example, an analyst may wish to measure the number of crimes avoided due to a policy intervention but may not have any way to estimate this impact. However, the analyst may have access to changes in arrest rates or changes in conviction rates and may be able to use one or both of these surrogates to estimate changes in crime.[8] Bear in mind, however, that all surrogate indicators involve some loss of information. For example, the conviction rate might be increasing while there is no change in the actual crime rate.

4. Predict the impacts quantitatively over the life of the project. The proposed highway project, like almost all projects, has impacts that extend over time. The fourth task is to quantify all impacts in each time period. The analyst must make predictions for the no-tolls and with-tolls alternatives, for each year, and for each category of driver (trucks, passenger cars on business, passenger cars on vacation) about

- the number of vehicle-trips on the new highway,
- the number of vehicle-trips on the old roads, and
- the proportion of travelers from British Columbia.

With these estimates, knowing the highway is 195 kilometers long and with other information, the analyst can estimate

- the total vehicle operating costs that users save,
- the number of accidents avoided, and
- the number of lives saved.

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For example, the analyst estimated the new highway would save 6.5 lives each year:

Shorter distance:	
130 vkm × 0.027 lives lost per vkm	= 3.5 lives/year
Safer (4-lane versus 2-lane):	
313 vkm × 0.027 lives lost per vkm × 0.33	= 3.0 lives/year
Total lives saved[9]	**= 6.5 lives/year**

Lives would be saved for two reasons. First, the new highway will be shorter than existing alternative routes. It is expected that travelers will avoid 130 million vehicle-kilometers (vkm) of driving each year, and evidence suggests that, on average, there are 0.027 deaths per million vehicle-kilometers. The shorter distance is expected, therefore, to save 3.5 lives per year on the basis of less distance driven. The new highway is also predicted to be safer per kilometer driven. It is expected that 313 million vehicle-kilometers will be driven each year on the new highway. Based on previous traffic engineering evidence, the analyst estimated that the new highway would lower the fatal accident rate by one-third. Consequently, the new highway is expected to save 3.0 lives per year due to being safer. Combining the two components suggests 6.5 lives will be saved each year.

In practice, predicting impacts is very important and very difficult! It is so important in CBA that Chapter 11 is devoted to it (and the related issue of valuation). Prediction is especially difficult where projects are unique, have long time horizons, or relationships among variables are complex. Many of the realities associated with doing steps 3 and 4 are brilliantly summarized by Kenneth Boulding's poem on dam building in the Third World, presented in Exhibit 1-1. Many of his points deal with the omission of impact categories due to misunderstanding or ignorance of cause-and-effect relationships and to prediction errors. He also makes points about the distribution of costs and benefits, which we discuss later.

5. Monetize (attach dollar values to) all impacts. The analyst next has to monetize each of the impacts. To *monetize* means to value in dollars. In the highway example, the analyst has to monetize each unit of time saved, lives saved, and accidents avoided. For this, the analyst needs the monetary value of an hour saved by each type of traveler, the value of a statistical life saved, and the value of an avoided accident. Ideally, these estimates should be specific to British Columbia in 1986. Some of the dollar values used in this CBA were

- leisure time saved per vehicle (25 percent of gross wage times the average number of passengers) = $6.68 per vehicle-hour,
- business time saved per vehicle = $12 per vehicle-hour,
- truck drivers' time saved per vehicle = $14 per vehicle-hour, and
- value of a life saved = $500,000 per life.

These estimates were based on studies conducted prior to 1986. Research over the last twenty years suggests the value of a statistical life saved is much higher, as we discuss in Chapter 16.