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

1.1 Individual Versus Social Costs and Benefits

Benjamin Franklin's advice about how to make decisions 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 the impacts in dollars (assigning weights), and then determining the *net benefit* of the proposal relative to the current policy (net benefit equal incremental benefits minus incremental costs).

When we as individuals talk of costs and benefits, we naturally tend to consider our *own* costs and benefits, generally choosing among alternative courses of action according to whichever has the largest net benefit from our perspective. 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 analysts 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 broad purpose of CBA is to help social decision-making and to increase social value or, more technically, to improve allocative efficiency.*

CBA analysts focus on social costs and social benefits, and conduct social cost–benefit analysis. However, it is tedious to keep including the word "social". We usually drop it and simply refer to costs, benefits, and cost–benefit analysis. Thus, B denotes the social benefits (the aggregate benefits to all members of society) of a policy, and C denotes the social costs (the aggregate costs to all members of society) of the policy. The aggregate value of a policy is measured by its *net social benefit*, sometimes simply referred to as the net benefit, and usually denoted NSB:

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

The term social is usually retained in the expression net social benefit to emphasize that CBA does concern the impacts on society as a whole.

Implicitly, the benefits, costs, and net social benefit of a policy are relative to some "benchmark." Usually, the "benchmark" is the status quo policy, that is, no change in the current policy. Generally, the benefits, costs, and net social benefit of a policy measure incremental changes relative to the status quo policy.

Stated at this level of abstraction, it is unlikely that many people would disagree with doing CBA from an ethical perspective. 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 people 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 value to them), and how to make trade-offs between the present and the future.

In this chapter we provide a non-technical 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.

1.2 Types of CBA Analyses

CBA may be conducted at different times in the project or policy life cycle. One type of CBA is called *ex ante* or prospective CBA. *Ex ante* literally means "before." Thus, *ex ante* CBA is conducted before the decision is made to undertake or implement a project or policy. The policy may or may not be under consideration by a government agency. If it is, then *ex ante* CBA informs the decision about whether resources should be allocated to that specific project or policy or not. Basically, *ex ante* CBA attempts to answer the question: *would* this policy or project be a good idea, that is, would it have a positive net social benefit?

Another type of CBA is called *ex post* or *retrospective CBA. Ex post* literally means "after." Thus, strictly speaking, *ex post* CBA is conducted after a policy or project is completed. It addresses the question: *was* this policy or project a good idea? Because *ex post* analysis is conducted at the end of the project, it is obviously too late to reverse resource allocation decisions with respect to that particular project. However, this type of analysis provides information not only about a specific intervention, but also about the "class" of similar interventions. In other words, it contributes to learning by government managers, politicians, and academics about the costs and benefits of future projects and whether they are likely to be worthwhile. Such learning can be incorporated into future *ex ante* CBAs. The potential benefit, however, depends on the similarity between the future project and the project previously analyzed. For example, *ex post* CBAs of experiments involving the efficacy of new surgical procedures or new pharmaceutical products can usually be generalized to larger populations. However, if the proposed intervention is much bigger than the experiment, there may be unknown scale effects. Also, if the proposed program has a more extended time frame than the experiment, behavioral responses may affect costs or benefits unpredictably.

Most projects take many years to "complete." The impacts of a highway or subway system, for example, often continue for many decades (even centuries) after initial construction. In such cases, and, in fact, for any ongoing policy or project, prudent government analysts might well wish to conduct a CBA sometime after the policy or project has begun but before it is complete. To clarify that such an analysis applies to a still ongoing project, such studies are sometimes called *in medias res* CBAs (to maintain our fancy use of Latin). They attempt to answer the question: is continuation of this policy or project a good idea? An *in medias res* CBA can be conducted any time after the decision to undertake a project has been made (but before it is complete). Such studies are also called *post-decision analyses*.

An *in medias res* CBA might recommend the termination or modification of a particular policy or project. In practice, CBAs of infrastructure projects with large sunk costs are unlikely to recommend discontinuation of a project that is near to completion or even just after completion, but it does happen occasionally. Interestingly the Tennessee Valley Authority decided to complete the Tellico Dam when it was 90 percent complete, even though the incremental social costs exceeded the incremental social benefits.[2] Also, a Canadian Environmental Assessment panel recommended decommissioning 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.[3]

Many businesses and critics of government complain about the burden of existing regulations and of too much "red tape." *In medias res* CBAs of some regulations might find that the critics are correct and they should be scrapped or changed for the benefit of society as a whole. In fact, *in medias res* CBAs conducted during the 1960s and 1970s of industry-specific economic regulations showed that the costs of regulation often exceeded the benefits, thereby paving the way for deregulation initiatives in the trucking, airline, and telecommunications industries.[4] These decisions were made both economically and politically easier by the reality that, unlike many physical infrastructure projects, regulatory projects usually have significant ongoing costs, rather than sunk, up-front costs. The same point also applies to ongoing social programs, such as government-funded training programs.

In practice, the term *in medias res* CBA is not used often: such CBAs are referred to as *ex post*, retrospective, hindsight, or post-decision analyses. It is particularly important if this is the case, therefore, to be clear when an *ex post* CBA is conducted: it might be any time after the decision to implement a new policy has been made.

There is also a fourth type of CBA – one that compares an *ex ante* CBA with an *ex post* CBA or an *in medias res* CBA *of the same project.*[5] Considerable research has found, for example, that the costs of large government infrastructure projects are often underestimated.[6] In contrast, another study that assessed the accuracy of US regulatory cost estimates found that these costs tend to be overestimated.[7] This comparative type of CBA helps to identify past errors, understand the reasons for them, and avoid them in the future.

1.3 The Basic Steps of CBA: Coquihalla Highway Example

CBA may look quite intimidating and complex. To make the process of conducting a CBA more manageable, we break it down into 10 basic steps, which are listed in Table 1.1. We describe and illustrate these steps using a relatively straightforward example: the proposed 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.

Suppose that in 1986 a cost–benefit analyst, who worked for the Province of British Columbia, Canada, was asked to perform an *ex ante* CBA of a proposed four-lane highway between the town of Hope in the south-central part of the province and Merritt, which is north of Hope. This highway would pass through an area called the Coquihalla (an indigenous name) and would be called the Coquihalla Highway. A summary of the analyst's *ex ante* CBA is presented in Table 1.2. The original numbers were present values as of 1986, which have now been converted to 2016 dollars to make them

Table 1.1 *The Major Steps in CBA*

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

Table 1.2 *Coquihalla Highway CBA (2016 $ Million)*

	No tolls		With tolls	
	Global perspective (A)	Provincial perspective (B)	Global perspective (C)	Provincial perspective (D)
Social benefits:				
Time and operating cost savings	763.0	572.1	568.4	426.3
Safety benefits	70.5	52.8	49.3	37.0
New users	1.6	1.2	0.6	0.4
Alternate route benefits	28.6	21.3	18.4	13.9
Toll revenues	–	–	–	73.2
Terminal value of hwy.	104.3	104.3	104.3	104.3
Total social benefits	968.0	751.7	741.0	655.1
Social costs:				
Construction	661.8	661.8	661.8	661.8
Maintenance	14.9	14.9	14.9	14.9
Toll collection	–	–	16.4	16.4
Toll booth construction	–	–	0.6	0.6
Total social costs	676.6	676.7	693.7	693.7
Net social benefit	291.2	75.2	47.3	–38.6

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, 532–55, table 1, p. 537.

easier to interpret. How did the analyst obtain these numbers? What were the difficulties? We go through each of the 10 steps in turn.

1.3.1 *Explain the Purpose of the CBA*

Step 1 requires the analyst to explain why she is conducting a CBA. She should answer the question: *what is the rationale for considering a change in policy*, in this case, building a new highway? Stated broadly, the goal of CBA is to improve social welfare. More specifically, CBA attempts to maximize allocative efficiency, which we discuss in Chapter 3. That chapter argues that, where markets work well, individual self-interest leads to an efficient allocation of resources and, therefore, there should be no government intervention. *Prima facie* rationales for CBAs are *market failure* or *government failure*.[8] Where there is market failure, analysts use CBA to assess whether a particular intervention is more allocatively efficient than no intervention (or some other alternatives). Sometimes there is government failure: a government policy or project is currently in effect, but this policy appears to be less allocatively efficient than no intervention or some other alternative policy. In either of these situations CBA attempts to ascertain whether a new policy or program is more allocatively efficient than the existing policy. The analyst should explain the market failure or government failure that provides a purpose for the study.

In 1986, the existing routes to the interior of northern British Columbia were highly congested, dangerous (with many traffic accidents), and would not have the capacity to handle anticipated increases in traffic volumes. For political reasons, the government was unwilling to impose tolls on the existing routes. Widening the main road would have been prohibitively expensive because much of it was in a river canyon. The focus of the study was, therefore, on whether to build a new highway between Hope and Merritt in an alternative location, specifically in the Coquihalla Valley, which follows the Coldwater River.

1.3.2 *Specify the Set of Alternative Projects*

Step 2 requires the analyst to specify the set of alternative projects. In this example, there were only two feasible alternative highway projects: one built with tolls and one without. The provincial department of transportation decided that the toll, if applied, would be \$78.3 for large trucks and \$15.7 for cars (in 2016 dollars). Thus, the analyst had a tractable set of only two alternatives to analyze.

In practice, there are often difficulties even at this stage because the number of potential alternatives is often quite large. Even restricting the analysis to a highway in the Coquihalla valley, it could vary on many dimensions including, for example, the road surface (either bitumen or concrete), routing (it could take somewhat different routes), size (it could have more or fewer lanes), toll level (could be higher or lower), wild animal friendliness (the highway could be built with or without “elk tunnels”), or timing (it could be delayed until a later date). Resource and cognitive constraints mean that analysts typically analyze only a few alternatives.[9]

CBA compares one or more potential projects with a project that would be displaced (i.e., not undertaken) if the project(s) under evaluation were to proceed. The displaced project is often called the *counterfactual.* Usually, the counterfactual is the status quo policy or no change in government policy. It does not mean "do nothing." It means that government continues to do what it has been doing: while there would be no new highway, the existing highway would continue to be maintained. Table 1.2 presents the social benefits, social costs, and net social benefit if the highway were built (with or without tolls) relative to what the social benefits, social costs, and net social benefit would be if the highway were not built (the status quo). Thus, one can interpret these social benefits, social costs, and net social benefit as *incremental* amounts. *In practice, as in this example, the term incremental is often omitted for convenience, but it is implicit*.

Sometimes the status quo policy is not a viable alternative. *If a project would displace a specific alternative, then it should be evaluated relative to the specific displaced alternative.* If, for example, the government has committed resources to either (1) constructing a new highway project and maintaining the alternative routes) or (2) not constructing a new highway but expanding the capacity of the existing routes, and there is no possibility of maintaining the status quo, then the new highway project should be compared with the expansion of the capacity of existing routes, rather than with the status quo policy.

This CBA example pertains to a specific proposed highway. There is no attempt to compare this project to alternative highway projects in the rest of British Columbia, although one could do so. Rarely do analysts compare a project in one substantive arena of government, such as transportation, to projects in other arenas, such as health care or national defense. The limited nature of these kinds of 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, CBA evidence from different arenas can allow decision-makers to rank potential projects in terms of their net social benefit.

1.3.3 *Decide Whose Benefits and Costs Count (Standing)*

Next, the analyst must decide who has *standing*; that is, whose benefits and costs should be included and counted. In this example, the analyst conducted the CBA from the provincial perspective because taxpayers living there would pay for it, but thought that it was important to also take a global perspective. A CBA from the provincial perspective considers only the impacts (i.e., benefits and costs) that affect British Columbian residents, including costs and benefits borne by the British Columbian government. The global perspective considers the benefits and costs that affect anyone, irrespective of where they reside. Thus, it includes benefits and costs to Americans, Albertans, and even tourists using the highway from the United Kingdom or China. Including these two perspectives on standing with the no-tolls and with-tolls alternatives gives the four columns in Table 1.2 labeled A through D and effectively means there are four distinct perspectives on costs and benefits.

The issue of standing is quite often contentious. While national governments usually take only national (i.e., domestic) costs and benefits into account, critics argue that issues that have significant negative impacts on residents of other countries 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 borne by residents of adjacent municipalities or higher levels of government. Our highway example deals with this issue by analyzing costs and benefits from both the subnational British Columbian perspective and the global perspective. Note that it does not adopt or measure the usual default perspective of the nation. Although these perspectives are not technically alternatives, they function as such in this example because they result in different estimates of costs, benefits, and net benefit.

1.3.4 *Identify the Impact Categories, Catalogue Them, and Select Metrics*

Step 4 requires the analyst to identify the impacts of the proposed alternative(s), catalogue them as benefits or costs, and specify the metric for each impact category. We use the term *impacts* broadly to include both inputs (resources employed) and outputs (predominantly benefits). A list of the relevant impact categories is referred to as an *impact inventory*. Preferably, analysts will construct an *impact matrix*, which describes or summarizes the impact of each policy alternative (or the impacts of one policy alternative on different groups) on each impact category.[10] Sometimes the impacts are referred to as "ingredients" and steps 4 and 5 are labeled the "*ingredients method*," although this terminology makes more intuitive sense for inputs than for outputs.

Different groups of residents will benefit from the highway. First, consider the users who currently travel on existing routes between Merritt and Hope, but will switch to the new highway. They will benefit from time saved (initially measured in hours), reduced vehicle operating costs (measured in dollars), and safety benefits due to a shorter, safer highway (initially measured in lives saved and the reduction in the number of accidents). Anticipation of these benefits is likely to attract some new users to travel this route (initially measured in number of vehicle trips). In the transportation literature, these new users are referred to as *generated traffic*. A third group consists of current users of the alternative routes who will continue to use these routes and will benefit from reduced congestion time on those routes (again initially measured in hours), because many other travelers will switch to the new highway. A fourth group is government, which may benefit from toll revenues (measured in dollars). A final benefit category for this project is the *terminal value* (sometimes called the *horizon value*) of the highway (measured in dollars). In practice, this highway will be in place for many years, but the analyst chose to predict and monetize the benefits and costs for only 20 years because no major refurbishment was expected to occur during that period. Sometimes we refer to such a period as the "life of the project." The terminal value reflects the present value of the net social benefit of the highway for all subsequent years. The cost impact categories are construction costs, maintenance and snow removal, toll collection, and toll booth construction and maintenance (all measured in dollars).

Although this list of impacts appears comprehensive, critics might argue that some important impacts were omitted. These include several externalities that spill beyond the use of the highway for transportation, including health impacts from reduced automobile emissions, environmental impacts on the elk population and other wildlife, and changes in scenic beauty. Also, the social cost of the land (the *opportunity cost*) should have been included.

It is important to try to include the full range of consequences of each project. However, from a practical perspective, analysts can consider only a manageable number of important impacts. Impacts associated with sunk costs should be ignored, although the analyst must be careful because recognizing economic sunkness is not simple. For example, when the Tellico Dam was being considered, the Tennessee Valley Authority argued incorrectly that "since the farm land behind the dam had already been purchased, the value of this land should be considered a sunk cost, even though the land has yet to be flooded and could be resold as farm land if the project was not completed."[11] Who owns the land or has paid for it is often irrelevant. If, in fact, the land did have an alternative use, then there was an opportunity cost and land should have been included as an impact category.

Furthermore, as we discuss in Chapter 7, it is often incorrect to include secondary or "knock-on" effects. Such effects are often redistributional. For example, one might think that hotel businesses and gas stations in Hope, near the southern end of the highway, might suffer negative effects because the new highway would bypass the town. However, highway users would stay elsewhere and buy their gas elsewhere, in Merritt, for example. Thus, while business-owner residents of Hope might be worse off, other business-owner residents in the province would be better off. The effects cancel out, resulting in a net effect of zero. Therefore, they can be ignored in many circumstances.

From a CBA perspective, analysts are interested only in project impacts that affect the utility of individuals who have standing. (The caveat is that this applies only where human beings have the relevant knowledge and information to make rational decisions.) Impacts that do not have any positive or negative utility to human beings are not counted. Suppose, for example, the highway project would decimate the population of a particular avian species. Birds do not have standing. This impact should only be included if some humans regard it as a cost.

Politicians often state the benefits of some projects in very general terms. For example, they might say that a project will promote "community capacity building." Similarly, they tend to regard "growth" and "regional development" as beneficial impacts, possibly because it might lead to increased tax revenue for their jurisdictions. In contrast, CBA requires analysts to identify explicitly the ways in which the project would make some individuals in the province better off through, for example, improved skills, better education, or higher incomes.

Analysts should also be on the lookout for impacts that different groups of people view in opposing directions. Consider, for example, land that periodically floods but would not do so if a proposed project is implemented. Residents on the flood plain generally view these periodic 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 informative to have two impact categories – one for damaged homes, and another for recreation benefits.

In this example, the impact metrics are straightforward – hours of time saved, dollar value of operating and construction costs, for example. If environmental impacts had been included, however, the choice of metrics would not have been as straightforward.

For example, if the change in automobile emissions was included as an impact, the analyst might measure it by tons of various pollutants or the resultant health effects (e.g., changes in mortality or morbidity). The choice of metric often depends on data availability and the 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, she may have access to changes in arrest rates or changes in conviction rates and may be able to use one or both of these measures to estimate changes in crime.[12] 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.

1.3.5 *Predict the Impacts Quantitatively Over the Life of the Project*

The proposed highway project, like almost all public projects, has impacts that extend over time. The fifth task is to predict all of the impacts in each year during the discount period (the life of the project) for each alternative. More specifically, the analyst has to predict the *incremental impacts* of the highway relative to the current policy for the no-tolls and the with-tolls alternatives, and from the provincial and global perspectives. Obviously, there is considerable uncertainty in making these predictions. Analysts may determine the "most likely" impact in each time period or the expected impact in each period. In this initial case example, for simplicity, we ignore uncertainty in the predictions.

There were three different types of road user on the Coquihalla: truck drivers, drivers or passengers in cars on business, and drivers or passenger in cars on vacation. As we see in subsequent chapters, road users were partitioned in this way because their benefits vary quite a bit. For each of these three user groups, the analyst predicted for each alternative for each year: the number of vehicle-trips on the new highway, the number of vehicle-trips on the old roads (alternative routes), and the proportion of travelers that reside in British Columbia. With these estimates, knowing that the highway is 195 kilometers long, and with other information, the analyst could estimate for each year the following incremental benefits: the total vehicle-kilometers saved, the number of accidents reduced, and the number of lives saved.

The analyst predicted that the new highway would save 6.5 lives each year. Lives would be saved for two reasons. First, the new highway would be shorter than the alternative routes. As a result, the analyst expected that travelers would avoid 130 million vehicle-kilometers (vkms) of driving each year, and evidence suggests that, on average, there are 0.027 deaths per million vkms. The shorter distance would, therefore, save 3.5 lives per year (130 vkms × 0.027 lives lost per vkm) on the basis of less distance driven. The new highway was also predicted to be safer per kilometer because it would be a divided highway. It was expected that 313 million vkms would 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 was expected to save 3.0 lives per year due to being safer (313 vkms × 0.027 lives lost per vkm × 0.33). Combining the two components suggests 6.5 lives would be saved each year.

In order to treat something as an impact, an analyst has to know there is a cause–effect relationship between some physical outcome of the project and the utility of human