

## **COST BENEFIT ANALYSIS – A PROJECT MANAGEMENT TOOL**

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### **Abstract**

*By reducing the positive and negative impacts of a project to their equivalent money value, the Cost-Benefit Analysis determines whether on balance the project is worthwhile. The equivalent money value are based upon information derived from consumer and producer market choices; i.e., the demand and supply schedules for the goods and services affected by the project. Care must be taking to properly allow for such things as inflation. When all this has been considered, a worthwhile project is one for which the discounted value of the benefits exceeds the discounted value of the costs; i.e., the net benefits are positive. This is equivalent to the benefit/cost ratio being greater than one and the internal rate of return being greater than the cost of capital.*

### **1. INTRODUCTION**

As environmental issues grow in complexity and pressures increase for localities to remain fiscally sound in the face of increasing responsibilities, cost-benefit analysis offers local decision makers a potentially potent source of counsel. This decision support tool provides a format for enumerating the range of benefits and costs surrounding a decision, aggregating the effects over time using an approach called discounting, and arriving at a dollar-denominated "present value" that, in concept, is comparable with other governmental uses for scarce financial resources, including leaving them in the hands of taxpayers.

In simple terms, cost-benefit analysis imposes an accounting framework that prescribes classes of benefits and costs to consider, means to measure them, and approaches for aggregating them. Key parameters, like the rate at which to discount, are highlighted, and ways to recognize inherent uncertainties are supplied, as are ways to deal with uncertainties. Even though the approach originated as an analogy to private studies of investment, and thus to calculate a "go-no-go" decision, the technique is flexible and can be used to choose among a range of alternatives, to make

comparable projects of differing lengths, and to identify instances where costs and benefits place identifiable groups at special advantage or disadvantage. Given these attributes, there is little wonder that pressures to apply the technique to important decisions are growing.

A cost benefit analysis is done to determine how well, or how poorly, a planned action will turn out. Although a cost benefit analysis can be used for almost anything, it is most commonly done on financial questions. Since the cost benefit analysis relies on the addition of positive factors and the subtraction of negative ones to determine a net result, it is also known as running the numbers.

A cost benefit analysis finds, quantifies, and adds all the positive factors. These are the benefits. Then it identifies, quantifies, and subtracts all the negatives, the costs. The difference between the two indicates whether the planned action is advisable. The real trick to doing a cost benefit analysis well is making sure you include all the costs and all the benefits and properly quantify them.

Costs are either one-off, or may be ongoing. Benefits are most often received over time. We build this effect of time into our analysis by calculating a payback period. This is the time it takes for the benefits of a change to repay its costs. Many companies look for payback on projects over a specified period of time.

Cost-benefit analysis is a term that refers both to:

- a formal discipline used to help appraise, or assess, the case for a project or proposal, which itself is a process known as project appraisal; and
- an informal approach to making decisions of any kind.

Under both definitions the process involves, whether explicitly or implicitly, weighing the total expected costs against the total expected benefits of one or more actions in order to choose the best or most profitable option. The formal process is often referred to as CBA, or Cost-Benefit analysis.

## **2. THEORY AND APPLICATION**

Cost Benefit Analysis is typically used by governments to evaluate the desirability of a given intervention in markets. The aim is to gauge the efficiency of the intervention relative to the status quo. The costs and benefits of the impacts of an intervention are evaluated in terms of the public's willingness to pay for them (benefits) or willingness to pay to avoid them (costs). Inputs are typically measured in terms of opportunity costs - the value in their best alternative use. The guiding principle is to list all of the parties affected by an intervention, and place a monetary value of the effect it has on their welfare as it would be valued by them.

The process involves monetary value of initial and ongoing expenses vs. expected return. Constructing plausible measures of the costs and benefits of specific actions is often very difficult. In practice, analysts try to estimate costs and benefits either by using survey methods or by drawing inferences from market behavior. For example, a product manager may compare manufacturing and marketing expenses to projected sales for a proposed product, and only decide to produce it if he expects the revenues to eventually recoup the costs. Cost-benefit analysis attempts to put all relevant costs and benefits on a common temporal footing. A discount rate is chosen, which is then used to compute all relevant future costs and benefits in present-value terms. Most commonly, the discount rate used for present-value calculations is an interest rate taken from financial markets (R.H. Frank 2000). This can be very controversial - for example, a high discount rate implies a very low value on the welfare of future generations, which may have a huge impact on the desirability of interventions to help the environment, and so on. Empirical studies have suggested that in reality, people's discount rates *do* decline over time. Because CBA aims to measure the public's true willingness to pay, this feature is typically built into studies.

During cost-benefit analysis, monetary values may also be assigned to less tangible effects such as the various risks which could contribute to partial or total project failure; loss of reputation, market penetration, long-term enterprise strategy alignments, etc. This is especially true when governments use the technique, for instance to decide whether to introduce business regulation, build a new road or offer a new drug on the state healthcare. In this case, a value must be put on human life or the environment, often causing great controversy. The cost-benefit principle says, for example, that we should install a guardrail on a dangerous stretch of mountain road if the dollar cost of doing so is less than the implicit dollar value of the injuries, deaths, and property damage thus prevented (R.H. Frank 2000).

Cost-benefit calculations typically involve using time value of money formula. This is usually done by converting the future expected streams of costs and benefits to a present value amount.

Cost-benefit analysis is mainly, but not exclusively, used to assess the value for money of very large private and public sector projects. This is because such projects tend to include costs and benefits that are less amenable to being expressed in financial or monetary terms (e.g. environmental damage), as well as those that can be expressed in monetary terms. Private sector organizations tend to make much more use of other project appraisal techniques, such as rate of return, where feasible.

The practice of cost-benefit analysis differs between countries and between sectors (e.g. transport, health) within countries. Some of the main differences include the types of impacts that are included as costs and benefits within appraisals, the extent

to which impacts are expressed in monetary terms and differences in discount rate between countries.

### **3. BACKGROUND**

Cost-Benefit Analysis (CBA) estimates and totals up the equivalent money value of the benefits and costs to the community of projects to establish whether they are worthwhile. These projects may be dams and highways or can be training programs and health care systems.

The idea of this economic accounting originated with Jules Dupuit, a French engineer whose 1848 article is still worth reading. The British economist, Alfred Marshall, formulated some of the formal concepts that are at the foundation of CBA. But the practical development of CBA came as a result of the impetus provided by the Federal Navigation Act of 1936. This act required that the U.S. Corps of Engineers carry out projects for the improvement of the waterway system when the total benefits of a project to whomsoever they accrue exceed the costs of that project. Thus, the Corps of Engineers had created systematic methods for measuring such benefits and costs. The engineers of the Corps did this without much, if any, assistance from the economics profession.

It wasn't until about twenty years later in the 1950's that economists tried to provide a rigorous, consistent set of methods for measuring benefits and costs and deciding whether a project is worthwhile.

Some technical issues of CBA have not been wholly resolved even now but the fundamental presented in the following are well established.

CBA has its origins in the water development projects of the U.S. Army Corps of Engineers. The Corps of Engineers had its origins in the French engineers hired by George Washington in the American Revolution. For years the only school of engineering in the United States was the Military Academy at West Point, New York. In 1936 Congress passed the Flood Control Act which contained the wording, "the Federal Government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs." The phrase if the benefits to whomsoever they may accrue are in excess of the estimated costs established cost-benefit analysis. Initially the Corps of Engineers developed ad hoc methods for estimating benefits and costs. It wasn't until the 1950s that academic economists discovered that the Corps had developed a system for the economic analysis of public investments. Economists have influenced and improved the Corps

methods since then and cost-benefit analysis has been adapted to most areas of public decision-making.

In 1879, Congress created the Mississippi River Commission to "prevent destructive floods." The Commission included civilians but the president had to be an Army engineer and the Corps of Engineers always had veto power over any decision by the Commission.

#### 4. PRINCIPLES OF THE COST-BENEFIT ANALYSIS

One of the problems of CBA is that the computation of many components of benefits and costs is intuitively obvious but that there are others for which intuition fails to suggest methods of measurement. Therefore some basic principles are needed as a guide.

- *There Must Be a Common Unit of Measurement*

In order to reach a conclusion as to the desirability of a project all aspects of the project, positive and negative, must be expressed in terms of a common unit; i.e., there must be a "bottom line." The most convenient common unit is money. This means that all benefits and costs of a project should be measured in terms of their equivalent money value. A program may provide benefits which are not directly expressed in terms of dollars but there is some amount of money the recipients of the benefits would consider just as good as the project's benefits. For example, a project may provide for the elderly in an area a free monthly visit to a doctor. The value of that benefit to an elderly recipient is the minimum amount of money that that recipient would take instead of the medical care. This could be less than the market value of the medical care provided. It is assumed that more esoteric benefits such as from preserving open space or historic sites have a finite equivalent money value to the public.

Not only do the benefits and costs of a project have to be expressed in terms of equivalent money value, but they have to be expressed in terms of dollars of a particular time. This is not just due to the differences in the value of dollars at different times because of inflation. A dollar available five years from now is not as good as a dollar available now. This is because a dollar available now can be invested and earn interest for five years and would be worth more than a dollar in five years. If the interest rate is  $r$  then a dollar invested for  $t$  years will grow to be  $(1+r)^t$ . Therefore the amount of money that would have to be deposited now so that it would grow to be one dollar  $t$  years in the future is  $(1+r)^{-t}$ . This called the discounted value or present value of a dollar available  $t$  years in the future.

When the dollar value of benefits at some time in the future is multiplied by the discounted value of one dollar at that time in the future the result is discounted present value of that benefit of the project. The same thing applies to costs. The net benefit of the projects is just the sum of the present value of the benefits less the present value of the costs.

- *CBA Valuations Should Represent Consumers or Producers Valuations As Revealed by Their Actual Behavior*

The valuation of benefits and costs should reflect preferences revealed by choices which have been made. For example, improvements in transportation frequently involve saving time. The question is how to measure the money value of that time saved. The value should not be merely what transportation planners think time should be worth or even what people say their time is worth. The value of time should be that which the public reveals their time is worth through choices involving tradeoffs between time and money. If people have a choice of parking close to their destination for a fee of 50 cents or parking farther away and spending 5 minutes more walking and they always choose to spend the money and save the time and effort then they have revealed that their time is more valuable to them than 10 cents per minute. If they were indifferent between the two choices they would have revealed that the value of their time to them was exactly 10 cents per minute.

The most challenging part of CBA is finding past choices which reveal the tradeoffs and equivalencies in preferences. For example, the valuation of the benefit of cleaner air could be established by finding how much less people paid for housing in more polluted areas which otherwise was identical in characteristics and location to housing in less polluted areas. Generally the value of cleaner air to people as revealed by the hard market choices seems to be less than their rhetorical valuation of clean air.

- *Benefits Are Usually Measured by Market Choices*

When consumers make purchases at market prices they reveal that the things they buy are at least as beneficial to them as the money they relinquish. Consumers will increase their consumption of any commodity up to the point where the benefit of an additional unit (marginal benefit) is equal to the marginal cost to them of that unit, the market price. Therefore for any consumer buying some of a commodity, the marginal benefit is equal to the market price. The marginal benefit will decline with the amount consumed just as the market price has to decline to get consumers to consume a greater quantity of the commodity. The relationship between the market price and the quantity consumed is called the demand schedule. Thus the demand schedule provides the information about marginal benefit that is needed to place a money value on an increase in consumption.

- *Gross Benefits of an Increase in Consumption is an Area under the Demand Curve*

The increase in benefits resulting from an increase in consumption is the sum of the marginal benefit times each incremental increase in consumption. As the incremental increases considered are taken as smaller and smaller the sum goes to the area under the marginal benefit curve. But the marginal benefit curve is the same as the demand curve so the increase in benefits is the area under the demand curve. As shown in Figure 1 the area is over the range from the lower limit of consumption before the increase to consumption after the increase.

When the increase in consumption is small compared to the total consumption the gross benefit is adequately approximated, as is shown in a welfare analysis, by the market value of the increased consumption; i.e., market price times the increase in consumption.

- *Some Measurements of Benefits Require the Valuation of Human Life*

It is sometimes necessary in CBA to evaluate the benefit of saving human lives. There is considerable antipathy in the general public to the idea of placing a dollar value on human life. Economists recognize that it is impossible to fund every project which promises to save a human life and that some rational basis is needed to select which projects are approved and which are turned down. The controversy is defused when it is recognized that the benefit of such projects is in reducing the risk of death. There are many cases in which people voluntarily accept increased risks in return for higher pay, such as in the oil fields or mining, or for time savings in higher speed in automobile travel. These choices can be used to estimate the personal cost people place on increased risk and thus the value to them of reduced risk. This computation is equivalent to placing an economic value on the expected number of lives saved.

- *The Analysis of a Project Should Involve a With Versus Without Comparison*

The *impact* of a project is the difference between what the situation in the study area would be with and without the project. This that when a project is being evaluated the analysis must estimate not only what the situation would be with the project but also what it would be without the project. For example, in determining the impact of a fixed guide way rapid transit system such as the Bay Area Rapid Transit (BART) in the San Francisco Bay Area the number of rides that would have been taken on an expansion of the bus system should be deducted from the rides provided by BART and likewise the additional costs of such an expanded bus system would be deducted from the costs of BART. In other words, the alternative to the project must be explicitly specified and considered in the evaluation of the project. Note that the with-and-without comparison is not the same as a before-and-after comparison.

Another example shows the importance of considering the impacts of a project and a with-and-without comparison. Suppose an irrigation project proposes to increase cotton production in Arizona. If the United States Department of Agriculture limits the cotton production in the U.S. by a system of quotas then expanded cotton production in Arizona might be offset by a reduction in the cotton production quota for Mississippi. Thus the impact of the project on cotton production in the U.S. might be zero rather than being the amount of cotton produced by the project.

- *Cost Benefit Analysis Involves a Particular Study Area*

The impacts of a project are defined for a particular study area, be it a city, region, state, nation or the world. In the above example concerning cotton the impact of the project might be zero for the nation but still be a positive amount for Arizona. The nature of the study area is usually specified by the organization sponsoring the analysis. Many effects of a project may "net out" over one study area but not over a smaller one. The specification of the study area may be arbitrary but it may significantly affect the conclusions of the analysis.

- *Double Counting of Benefits or Costs Must be avoided*

Sometimes an impact of a project can be measured in two or more ways. For example, when an improved highway reduces travel time and the risk of injury the value of property in areas served by the highway will be enhanced. The increase in property values due to the project is a very good way, at least in principle, to measure the benefits of a project. But if the increased property values are included then it is unnecessary to include the value of the time and lives saved by the improvement in the highway. The property value went up because of the benefits of the time saving and the reduced risks.

To include both the increase in property values and the time saving and risk reduction would involve double counting.

- *Decision Criteria for Projects*

If the discounted present value of the benefits exceeds the discounted present value of the costs then the project is worthwhile. This is equivalent to the condition that the net benefit must be positive. Another equivalent condition is that the ratio of the present value of the benefits to the present value of the costs must be greater than one.

If there are more than one mutually exclusive project that have positive net present value then there has to be further analysis. From the set of mutually exclusive projects the one that should be selected is the one with the highest net present value.

If the funds required carrying out all of the projects with positive net present value are less than the funds available this means the discount rate used in computing the present values is too low and does not reflect the true cost of capital. The present



values must be recomputed using a higher discount rate. It may take some trial and error to find a discount rate such that the funds required for the projects with a positive net present value is no more than the funds available. Sometimes as an alternative to this procedure people try to select the best projects on the basis of some measure of goodness such as the internal rate of return or the benefit/cost ratio. This is not valid for several reasons.

The magnitude of the ratio of benefits to costs is to a degree arbitrary because some costs such as operating costs may be deducted from benefits and thus not be included in the cost figure. This is called *netting out* of operating costs. This netting out may be done for some projects and not for others. This manipulation of the benefits and costs will not affect the net benefits but it may change the benefit/cost ratio. However it will not raise the benefit cost ratio which is less than one to above one.

## 5. ACCURACY PROBLEMS

The accuracy of the outcome of a cost-benefit analysis is dependent on how accurately costs and benefits have been estimated.

For example, a peer-reviewed study of the accuracy of cost estimates in transportation infrastructure planning found that for rail projects actual costs turned out to be on average 44.7 percent higher than estimated costs, and for roads 20.4 percent higher (Flyvbjerg, Holm, and Buhl, 2002). For benefits, another peer-reviewed study found that actual rail rider ship was on average 51.4 percent lower than estimated rider ship; for roads it was found that for half of all projects estimated traffic was wrong by more than 20 percent (Flyvbjerg, Holm, and Buhl, 2005). Comparative studies indicate that similar inaccuracies apply to fields other than transportation.

These studies indicate that the outcomes of cost-benefit analyses should be treated with caution, because they may be highly inaccurate. In fact, inaccurate cost-benefit analyses may be argued to be a substantial risk in planning, because inaccuracies of the size documented are likely to lead to inefficient decisions, as defined by Pareto and Kaldor-Hicks efficiency (Flyvbjerg, Bruzelius, and Rothengatter, 2003).

These outcomes (almost always tending to underestimation, *unless significant new approaches are overlooked*) are to be expected, since such estimates:

1. rely heavily on past like projects (frequently differing markedly in function or size, and certainly in the skill levels of the team members),
2. rely heavily on the project's members to identify (*remember* from their collective past experiences) the significant cost drivers,

3. rely on very crude heuristics ('rules of thumb') to estimate the money cost of the intangible elements, and
4. are unable to completely dispel the usually (unconscious) biases of the team members (who often have a vested interest in a decision to 'go ahead') and the natural psychological tendency to "*think positive*" (whatever that involves).

Another challenge to cost-benefit analysis comes from determining which costs should be included in an analysis (the significant cost drivers). This is often controversial as organizations or interest groups may feel that some costs should be included or excluded from a study.

## 6. KEY POINTS

Cost/Benefit Analysis is a powerful, widely used and relatively easy tool for deciding whether to make a change.

To use the tool, firstly work out how much the change will cost to make. Then calculate the benefit you will from it.

Where costs or benefits are paid or received over time, work out the time it will take for the benefits to repay the costs.

Cost/Benefit Analysis can be carried out using only financial costs and financial benefits. You may, however, decide to include intangible items within the analysis. As you must estimate a value for these, this inevitably brings an element of subjectivity into the process.

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