

A Primer for Understanding Benefit-Cost Analysis

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A. Overview

Benefit-cost analysis (BCA), and cost-benefit-analysis (CBA), which are generally regarded as equivalent terms, are accounting frameworks used to evaluate the financial consequences of decisions.¹ In this sense, BCA is similar to analyses that corporations conduct in order to evaluate investment decisions. However, it differs in two significant ways: first, the objective of BCA is to increase public welfare, not profit. This serves to increase both the technical and political complexity of the exercise, because the exact definition of “public welfare” is elusive. Second, because BCA often encompasses non-market goods, such as the value of a recreational visit or wildlife viewing at a park, the required data is often not found in market transactions. Such data must instead be generated through resource-intensive surveys or other statistical analyses. For instance, for the value of a park that has no entry fee, analysts might instead estimate the value of a recreational visit by asking park users how much they would be willing to pay to use the park or determine the costs visitors incur to travel to the park.

The United States Federal government widely uses BCA under the direction of presidential executive orders.² Under these orders, the White House Office of Management and Budget (OMB) requires the use of BCA by government agencies within the executive branch, and provides a set of guidelines under which BCA is to be conducted. The Office of Information and Regulatory Analysis (OIRA), which is part of OMB, is a major user of BCA for evaluations of regulatory decisions. BCA is also used by state and local governments, albeit to a lesser (and much less consistent) extent (Schwartz *in press*). For example, the State of Washington, through the Washington State Institute for Public Policy (WSIPP), performs analyses of significant new social programs for the state legislature.³

If used properly, the BCA framework can reduce poorly conceived government spending.⁴ In fact, agencies such OIRA have already reduced wasteful spending, but not to the full

I thank Nevena Lalic, Julia Purcell and Kiana Scott for helpful suggestions that improved readability.

¹ Zerbe has attempted to treat BCA as “better-defined subcategory of CBA”, whose legal foundations tend to ameliorate or eliminate the criticisms of CBA. Zerbe, Richard O. 2007. “The Legal Foundation of Cost-Benefit Analysis.” *Charleston Law Review* 2(1): 93-184.

² Executive Order (EO) 12291 (Reagan 1981), EO 12498 (Reagan 1985), EO 12866 (Clinton 1993), EO 13258 (Bush 2002), EO 13422 (Bush 2007), EO 13497 (Obama 2009).

³ See <http://www.wsipp.wa.gov/>

⁴ The rationale for government investment is externalities. Externalities are effects that are not accounted for in decisions. They arise from the expenses of operating markets, that is, from transaction costs. It is helpful in

extent possible, as not all issues have been fully examined.⁵ Moreover, BCA for hard-to-quantify social initiatives under the purview of state and local governments is severely lacking. Schwartz's (*in press*) recent survey of state-level analysis programs found states to have an average grade of a D+ (with D- being the lowest possible score), demonstrating the vast room for improvement in the use of BCA at lower levels of government.

Though many factors hinder BCA quality and hinder implementation at the state, county, and municipal level, perhaps the primary reason is that comprehensive, accurate BCA is expensive and difficult, especially for social policy. Many of the governance bodies tasked with overseeing issues such as county health programs or urban housing and homelessness lack adequate resources to conduct BCA. These smaller groups often lack trained analysts and funding for research, a problem exacerbated by the fact that social policy typically engenders significant non-market benefits and costs. Such non-market values raise the difficulty and complexity (and thus cost) of an analysis. Further, since social policy at lower levels of government is often decentralized and carried out by numerous organizations, appropriate data sets often do not exist. Due to these issues, organizations often cannot conduct an accurate, useful BCA.

It is our contention that BCA results in more efficient policy-making throughout all policy sectors, which in turn betters social welfare. In a world of limited resources and seemingly unlimited demands, it is imperative that governments allocate funds judiciously and efficiently. Given this, there is a great need to make BCA more feasible and more accessible as all levels of government and in all governance sectors. In what follows, we first describe the usage of BCA, particularly regarding how its usage might be expanded and improved. Next, the basic methodological framework is presented, paying particular attention to the role and value of information in BCA. Finally, we provide a simplified example of a BCA that demonstrates relevant concepts and speaks to the challenges faced in seeking to expand BCA usage.

B. The Use of Benefit-Cost Analysis: When and to what extent is BCA used?

All financial analyses entail a tradeoff between the cost of the analysis and the value of information gained. A comprehensive BCA can be resource intensive, especially for social policy initiatives, where benefits (and costs) typically accrue in non-market arenas. For areas such as health and the environment, collection and generation of data can be time-consuming and expensive. This serves as a barrier to broader implementation of BCA, as proper data collection can make BCA appear cost-prohibitive.

There are two fundamental ways to address the issue of conducting BCA given a fixed program or analysis budget. The classic solution is embodied by the concept of

considering a CBA analysis to consider how transactions costs can be reduced to achieve either quasi-market solutions or the best form of government intervention.

⁵ Graham, John D. 2008. "Saving Lives Through Administrative Law and Economics". *University of Pennsylvania Law Review*. 157(2): 101-245.

proportionate analysis, which holds that analysis expenditure should be justified by the return to whatever information is gained. Since additional time and resources expended towards gathering data, building more complex models, or disaggregating effects, increase analysis costs, the cost of acquiring such information should at least be equaled by the expected decision-making benefit provided by the informational gain (Farrow and Viscusi 2010). Essentially, this means that an analysis should itself be subject its own internal BCA. This idea applies to the various nested levels of analysis, including the number and types of policy options considered, types of benefits and costs, distributional impacts included, and the extent to which such impacts should be assessed (Wiener et al. 2009).

This approach, however, ignores the public goods nature of information. Information has value not only for the project at hand but for future similar projects, and this social value will not be considered by a piece-meal approach. In many instances it does not appear feasible to determine the value of information for a single study. Data thought insignificant, and thus not worth further expenditure, could very well be highly important for making an accurate prediction of the policy outcome.

Policies often have large indirect or ancillary effects that might not be picked up by an analysis only of the targeted market. While it is often appropriate to conduct a more rudimentary, less precise analysis, the model must still be at the very least directionally correct in order to be useful (that is, point in the right direction). This problem arises frequently in social policy. BCA, as a policy decision analyzed using a comprehensive (and resource intensive) general equilibrium (GE) (see below) model, might demonstrate an entirely different directional effect than if the analysis was scaled down. For instance, a partial equilibrium (PE) analysis of subsidized college tuition indicates that such a policy would increase the number of students. However, a more comprehensive general equilibrium analysis actually reveals that the end effect would be a decrease in enrollment once all relevant markets equilibrate (due to decreased wages for college graduates) (Heckman et al. 1999). Instead of a linear relationship between analysis expenditure and analysis accuracy, there may be a funding threshold, below which no benefits are gained from gathering more information for conducting a BCA.

Certainly, not all analyses require a GE framework; in most cases, a PE analysis is sufficient. The above example is meant to speak to the broader issue that BCA will gain greater traction and be implemented more widely at the various scales of policy decision-making (and will produce more benefits) if the cost of reaching the directionally correct information threshold is reduced. There is a huge potential benefit to be obtained then from creating and maintaining large data systems that provide detailed, timely, and relevant information otherwise unavailable (Culhane and Metraux 1997), effectively reducing the cost of conducting a useful, accurate BCA.

The value of social information represents the preferred means by which to address the issue of conducting BCA in a resource-limited world. By making data widely available, the cost of conducting BCA can be greatly reduced. This means that an analysis can reach a more accurate informational threshold at a lower expenditure level. Culhane et. al (2010) discuss the concept (and huge potential benefits) of developing integrated data systems for social policy in great detail. Specifically for BCA application, integrated data systems offer several significant benefits. First, the development of a shadow price repository or database

provides a ready source for practitioners to get key values to plug into a model rather than having to root around for or calculate such values themselves. Not only would this greatly reduce the cost burden associated with obtaining such figures, but it would also increase standardization and accuracy. One would expect that such a common, peer-reviewed source would furnish the most up-to-date, accurate figures, and using the same metrics allows for more faithful comparisons of different analyses.

Second, since social policy BCA often requires analyses across different markets, the analyst must seek to acquire data from several different agency sources and consult different policy-sector literature bases. For instance, education policy has an effect not only in the field of education but on crime, health, and social-welfare outcomes as well. Developing a comprehensive, queryable database that collects data from different governmental bodies would provide a common, unified source that analysts could consult. This would help ensure that analyses are conducted using standardized, accurate data, making analyses more comparable as well as less expensive.

Finally, such an integrated data system could also serve as a library BCAs already conducted. This would allow analysts to easily consult and compare with others' work and help further the state of the art. Moreover, if these analyses are embedded within the database and employ data stored there, analyses can also be replicated. This would greatly increase transparency.

Clearly, the field of BCA would benefit greatly from the implementation of integrated government data systems and an increased effort towards data accessibility. If the cost of acquiring and employing data can be decreased, it can be expected that BCA will be used more extensively in policy decision-making. Further, it can be expected that analyses will be more comprehensive and more accurate. This in turn should greatly improve policy decision-making and provide increased social benefits.

C. Basic Steps in Benefit-Cost Analysis

Benefit-cost analysis generally proceeds in five important steps:

- 1) **Define the scope and assumptions of the BCA**
- 2) **Identify outcomes and quantify costs and benefits for each alternative**
- 3) **Choose a discount rate and calculate the present value of costs and benefits**
- 4) **Choose a measure for comparing alternatives and carry out the necessary calculations**
- 5) **Discuss risk and uncertainty**

In this section, we discuss these steps in detail. In the following section, we provide an example to further clarify the concepts we introduce below. The simplified methodology outlined below is drawn from the author's more detailed BCA texts Zerbe and Bellas (2006) and Zerbe and Dively (1994). The reader should also refer to Stokey and Zeckhauser (1978); Gramlich (1990); Hanley and Spash (1993); Brent (1998); and Jones (2005) for additional guidance. Boardman et al. (2010) provides the most recent, up-to-date methodological text.

Further, US Office of Management and Budget Circulars A-94 and A-4 provide similar guidance in regards to government projects and regulation (US OMB 1992; 2003); these documents also serve as common resources for BCA standards and practices.

1. Define the Scope and Assumptions of the BCA

As a first step, the BCA should clearly state the problem to be analyzed and define from whose perspective it is being conducted.⁶ It should also identify *whose* costs and benefits will be considered, i.e. the actors who have economic standing.

In practice, a BCA does not include everyone affected by a policy alternative. The decision about whom to include or exclude in a BCA relates to the **economic standing** of those affected. Most analyses are done in a particular context that determines standing. For instance, a municipality might only consider effects on municipal revenues or limit effects to those felt within its borders. The state government might not consider effects of its pollution policy on neighboring states and the federal government might not consider effects on foreign countries. Many projects will have only minor effects on certain groups and it may be considered too expensive to include these effects, especially given the principle of proportionate analysis.⁷ In addition, certain sentiments may be disregarded as being irrelevant; for example, one might suffer harm from envy, but this harm would (and should) generally go unrecognized in a BCA. A useful example concerns the value of stolen goods to the thief: clearly, these goods have value to the thief, but in considering whether or not these goods should be returned, one would not count their value to the thief given that his holding of stolen goods is illegal.

Once the problem definition, perspective, and economic standing issues are settled, the analyst should seek to determine the **period** over which the BCA is to be conducted. This is often a subject of controversy. Indeed, consider a situation in which a client requests a BCA for a large convention hall construction project that has very high costs in the first three years, and only generates benefits once it reaches some degree of popularity seven years later. Under these circumstances, a ten-year perspective will likely conclude that the project is not worthwhile, while a twenty-year perspective might lead to the opposite conclusion. Given the possible impact of the analysis period on the outcome of the BCA, it is important for the client and analyst to explore this question in detail before the BCA is undertaken.

The next component of scope definition is the choice between a **partial equilibrium analysis** and a **general equilibrium analysis**. When the number of markets included in the BCA is restricted, it is called a “partial equilibrium” analysis; when the number of markets included in the analysis is large, it is called a “general equilibrium” analysis.

⁶ While the BCA will most often be conducted from the client’s point of view, the analyst may be called upon to examine a different perspective in some cases.

⁷ According to the principle of proportionate analysis, the depth and scope of a CBA analysis (and therefore the resources allocated to it) should be proportionate to the expected magnitude of the effects of the project it relates to. Note that it is often the smallest effects that are most expensive to identify and properly quantify.

For example, consider a small town that conducts a BCA to determine whether to purchase a garbage truck or continue to outsource garbage collection (this example will be studied in detail in the following section). The effects of the town's decision on other markets, such as the truck market, energy market, or even the waste hauling market are negligible in this case since the decision involves only one truck and a small tonnage of waste. Such an analysis, limited in its inclusion of markets, would be a partial equilibrium analysis.

On the other hand, if a BCA is conducted for a country-wide policy to subsidize the buying of trucks for waste hauling, the analysis should consider markets more broadly. When the effects in several markets are taken into account, the analysis is said to be a **general equilibrium analysis**. Consider a national oil tax and all of the markets affected: transportation markets, plastic goods and other petroleum product markets, labor markets, and others. An analysis of such a high-magnitude policy should be done from a general equilibrium perspective in which these major markets and their interactions are considered.

Once the scope of the analysis is set, the BCA should also identify the **baseline** against which costs and benefits will be compared, as well as all the **assumptions** and **known limitations** of the analysis (such as poor data quality, for example).

2. Identify Outcomes and Quantify Costs and Benefits

Next, a range of possible policy alternatives, as well as their consequences in terms of outcomes, must be identified. Often, the different policy options are specified to the analyst, but in some instances the analyst might need to identify and develop policy alternatives. If the costs and benefits are not already in monetary units, they must be converted in such units whenever possible. The flow of costs and benefits related to each of the alternatives must be identified for the period of the analysis.

For a BCA, policy costs and benefits are defined in monetary units. When the costs and benefits at issue relate to goods or services traded in a market, it is relatively straightforward to identify them and include them in a BCA. However, many projects have significant non-market benefits and costs, which must be converted to monetary units whenever possible.

The identification of benefits and costs may not always be simple. Costs and benefits can be diffuse. For instance, when considering a road project, an analyst may need to include the cost to homeowners that live near the road in terms of pollution and noise. The amount it would take to compensate these homeowners for bearing the pollution and noise would then also count as a project cost (assuming these individuals are considered to have economic standing in the analysis). If the government instead opts to construct a noise-reducing barrier, the cost of erecting the barrier would naturally have to be included as part of the project cost and all or part of the noise cost would be dropped.

When the goods considered in a BCA are not traded on the market, their valuation can become complicated. For instance, in evaluating the benefits and costs of building a new road, the government might include a calculation of the time savings to users. To do so, the value of users' time must be estimated, and multiplied by the number of users. Prices used to value non-market behavior are called **shadow prices**. Although BCA is a type of financial accounting, it considers many values not counted in business accounting. BCA is used to

evaluate policies that concern air and water quality, endangered species, recreational sites, educational opportunities, human health, and many other diverse and difficult to quantify outcomes. Such non-market values are derived using either revealed preference or stated preference methods.

In revealed-preference valuation, the analyst utilizes data from market transactions or observable behavior to estimate the values of nonmarket goods associated with the observable transaction. For example, the travel-cost method uses travel expenditures incurred by visitors to reach a site (such as a national park or a beach) as a proxy for the visitor's **willingness-to-pay (WTP)** for access to the site; this in turn provides an estimate of the value of that site. Another example of revealed-preference valuation is hedonic regression, where component characteristics of a good or service are valued using multiple regression techniques to provide an estimate of their value. This is common in real estate applications for instance, where house attributes (such as a view or proximity to a school) are not priced directly but are reflected in the value of the house.

Stated-preference valuation uses the **survey method**, in which individuals are asked how they would behave in a hypothetical market scenario, and these responses are used to produce value estimates. One commonly used stated-preference method is **contingent valuation (CV)**, where survey participants are presented with a policy scenario, and asked to give a WTP value for a gain or a **willingness-to-accept (WTA)** value for a loss regarding a good or service. A second stated-preference method is conjoint analysis. Rather than asking participants to give a WTP or WTA value for a single good (e.g. air pollution reduction), conjoint analysis presents individuals with a bundle of component attributes; the participant is then asked to choose their most-preferred bundle. The results of the survey can then be analyzed using multiple regression to estimate component values.

The exercise of identifying and quantifying costs and benefits that relate to non-market goods requires a reference point, usually determined by the legal rights of those with economic standing. If those who have a legal right to a good would lose it under a particular policy alternative, their WTA payment for the loss of that good is considered a cost. If those who do not have a legal right to a good would be granted the good under a policy alternative, their WTP for it is considered a benefit.

For example, a government agency could measure the value of reducing noise around a proposed airport by determining how much the affected residents would pay for the noise reduction (a WTP measure), or by determining what price they would need to offer residents to put up with the noise (a WTA measure). The first method assumes that residents have no right to quiet and would need to purchase it; the second assumes that residents have a right to quiet and would need to be compensated for giving up the right. The first measure, the WTP, is constrained by the residents' income; the second, the WTA, is not. Thus, the second measure will be larger than the first, often by a considerable margin.⁸

⁸ Indeed, if an analysis begins with the assumption that an individual does not have the right to the good and asks what the individual is willing to pay for the good, the individual's response will necessarily be constrained by her income – that is, by how much she can afford to pay. If an analysis assumes that the individual already has the right to the good, and asks what she would be willing to accept to forego it, then her total income will include the good, and she will require higher compensation because the value of additional money is now lower

In practice, WTP measures are often used to determine both benefits and costs due to difficulties in determining WTA data. For example, the cost of having one's home condemned under eminent domain might be much more than its market value, as the homeowner would have an incentive to overstate her willingness to accept (WTA). The willingness to pay (as determined by the market price for the house, for instance) might be used instead.

3. Choose a Discount Rate and Calculate the Present Value of Costs and Benefits

BCA evaluates policies that have benefits and costs that will occur both at project outset and in the future; a project might have a large initial cost but primarily will gain benefits in future years, or garner an initial benefit but entail costs in future years. Because benefits and costs are not realized in lump sums (i.e. benefits and costs are cash flows that occur over time), the analyst must take the time value of money into account (i.e. the idea that earning \$100 today is not worth the same as earning \$100 a year from now because investing the \$100 earned today would yield more a year from now, and similarly, that owing \$100 a year from now is preferable to owing \$100 today given the opportunity cost represented by time value of money). That is, cash flows in each year must be discounted to their **present value**.

The present value of a future sum is the amount that, if invested today, would yield the equivalent of that cash flow stream.⁹ It is given by:

$$PV = \sum_{t=0}^N \frac{F_t}{(1+r)^t} \quad (1)$$

where:

F_t = net cash flow at time t

r = discount rate

N = number of future years included analysis

When conducting a BCA, all monetary amounts must be in comparable units – either all in **constant dollars** or all in **nominal dollars**.¹⁰ Constant dollars (also called **real dollars**) take inflation into account, adjusting the value of future benefits and costs to reflect expected inflation. If constant dollars are chosen, then the inflation (deflation) component must be subtracted (added) to the discount rate. Thus, if the market interest rate is 8% and expected inflation is 5%, the real interest rate (by which future benefits and costs are discounted) would be 8% - 5%, or 3%. For analyses in nominal dollars, the market interest rate can be

in her eyes (the income effect). The greater the value of the good under consideration and the lower the income of the individual, the greater will be the difference between WTA and WTP for that good.

⁹ The formula for the present value of a uniform stream is $PV = A[1-(1+r)^{-t}]/r$, where A is the uniform annuity, r is the interest rate and t is the number of payments. The period of the annuity must be the same as the period of the interest rate. For example, if A is a monthly payment, the r must be a monthly interest rate and t the number of months. If the yearly interest rate is 12%, the monthly rate would be $12\%/12 = 1\%$.

¹⁰ Recall that nominal dollars are “year of expenditure” dollars, not adjusted for inflation. Constant dollars are amounts adjusted for inflation.

used without an inflation adjustment. This is because market interest rates contain an expected inflation component. Real rates show less variability than nominal rates, and, for that reason among others, we recommend using real values, usually based on past real rates, rather than nominal values, as better representing what the future will hold.

The discount rate has a powerful effect on the determination of whether or not the project is worthwhile; thus, it should be chosen with care. Given the temporal distribution of project benefits and costs, a chosen discount rate can cause a project to pass (or fail) a benefit-cost test. For a project with large near-term costs and benefits occurring in future years, a higher discount rate increases the chance that the project will fail a benefit-cost test, and vice-versa for a project with front-loaded benefits and cost primarily in future years. If the entity for which the BCA is being conducted does not already have a guideline discount rate, the analyst should choose a baseline rate that takes into account the opportunity cost of money, inflation, and the risk of the cash flow(s) (with riskier cash flows necessitating a higher discount rates).

As a default, the Federal Office of Management and Budget states that a real discount rate of 7% should be used as a base-case for regulatory analysis. However, it goes on to say that “[I]f we take the rate that the average saver uses to discount future consumption as our measure of the social rate of time preference, then the real rate of return on long-term government debt may provide a fair approximation. Over the last thirty years, this rate has averaged around 3% in real terms on a pre-tax basis.”¹¹ There is disagreement about the appropriate rate. For example, the *Principles and Standards for Benefit-Cost Analysis* prepared by the University of Washington Evans School Center for Benefit-Cost Analysis recommends rates between 6 and 9%.¹² Other sources recommend rates around 3%. The 3% discount rate guideline will be used for the examples presented in this paper. Given the influence of the discount rate on analysis outcomes, it is important to test a range of discount rates above and below the baseline rate to demonstrate the role of the rate itself (and the time preference it represents) in determining whether a project has positive benefits.

4. Choose a BCA Measure and Carry Out the Calculations

Once a discount rate is chosen, it can be applied to the flows of costs and benefits identified in Step 2 in order to account for the time value of money and thus allow the flows to be compared over time. This information can then be used in calculations that will yield a BCA measure for the project. Projects are typically summarized using the **Net Present Value (NPV)** metric.

The NPV is the present value of benefits minus the present value of costs. An investment is said to pass the BCA test and be financially desirable when the NPV (the present value of benefits minus the present value of costs) is greater than zero. Supposing that the discount rate used in a BCA is r , the interpretation of the NPV measure would be as follows: if the

¹¹ U.S. OMB (U.S. Office of Management and Budget). 1992. —Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. OMB Circular A-94. Washington, D.C.: U.S. Government Printing Office.

¹² The *Principles and Standards for Benefit-Cost Analysis* final report will be made available on the website of the Benefit-Cost Analysis Center in Fall 2010 (<http://evans.washington.edu/node/1262>).

NPV is positive, then the project will return more than r ; if the NPV is negative, the project will return less than r , so more could be gained by investing elsewhere.

A **benefit-cost ratio (B/C)**, the ratio of the present value of benefits to the present value of costs, has often been used to summarize project analyses. Using this metric, the ratio must be greater than one for the project to be financially acceptable. However, the B/C ratio has an important drawback, as ratios can be misleading when the two projects being compared have different costs (different denominators). The requirement that the B/C ratio be greater than one indicates whether or not the project is worthwhile in the absolute, but does not provide a basis for comparison against other project. This is a problem of scale: a project with total costs of \$100,000 may generate a greater increase in real wealth than one with total costs of \$100, but the ratio of benefits to costs may not be as high. Zerbe and Dively (1994) show a method for making B/C ratios comparable. Their adjustments will allow the B/C ratio to give an accurate ranking of alternative projects.

Another metric that is often used to describe projects is the **internal rate of return (IRR)**. The IRR is the discount rate which results in the net benefits (net present value) of a project being exactly zero.¹³ Though like the B/C ratio, the IRR does not reflect the magnitude of project benefits, it can demonstrate the efficiency of a project; for approval, a project would need to have an IRR that is higher than the opportunity cost. Higher IRR figures reflect a higher return rate on an investment. In theory, a firm or governance body should undertake all projects available that have a B/C ratio greater than one or an IRR greater than the opportunity cost of capital. However, governments are resource limited, and typically must choose the best project from among several that pass a B/C or IRR test. While B/C and IRR metrics can identify bad and good projects, only the NPV can identify the best project that engenders the greatest net benefit. *Thus, NPV is the standard summary metric for BCA.*

5. Address Risk and Uncertainty

BCA almost always involves the consideration of future cash flows, which inherently entails risk and uncertainty. **Risk** is usually defined as an uncertain outcome to which a probabilistic distribution can be assigned. **Uncertainty** typically refers to an uncertain outcome for which precise quantitative description is unfeasible or unavailable. Uncertainty is often summarized as an event with an unknown probability distribution. For the most part, this distinction is unimportant in BCA; well-quantified risks and poorly quantified uncertainties can both be addressed using sensitivity techniques and probabilistic analysis (see below). Any uncertainties that cannot be addressed quantitatively are then addressed qualitatively in the discussion of analysis results.

There are typically multiple uncertainties in a BCA model. To account for this, analysts often use a probabilistic simulation technique known as Monte Carlo analysis. In a Monte Carlo analysis, the BCA model is simulated a large number of times (often 10,000); each time, parameter estimates are “drawn” from their associated probability distribution, and these values are then employed within the model for that particular iteration. The resulting

¹³ One should be aware that the IRR may give a wrong answer or multiple answers. For adjustments to the IRR that result in correct answers and only one answer see Zerbe and Dively ()

distribution of analysis outcomes based upon using 10,000 different values for a given parameter can then demonstrate the potential impact of uncertainty on the accuracy of the analysis. Similarly, a **sensitivity analysis** can vary a given parameter within the model to examine the relationship between change in that parameter and model outcomes. A sensitivity analysis typically isolates one uncertain parameter and manipulates the value, whereas a Monte Carlo analysis varies all uncertain values in concert and randomly chooses each value (based upon a specified distribution).

D. Benefit-Cost Analysis in Practice: City of Ortin Example

The application of the basic steps of BCA will be discussed below using a simple, fictional example. Consider the following problem faced by the city of Ortin:

1. Defining the Scope of the Analysis

The Ortin city council is attempting to decide whether the city should purchase a garbage truck and conduct its own waste management service, or to continue to contract out for garbage collection from a private firm. In this instance, policy-makers have already specified the range of alternatives to be explored; the analysis will only examine the two pre-specified alternatives. Had the council requested that the analyst develop and examine a range of waste management policy alternatives, the BCA might include a wide range of other policy alternatives such as a dual waste and recycling management pick up program or a deposit program on consumer goods.

In this case, we know that the BCA is done on behalf of the city's treasury department, so all costs and benefits are considered from the perspective of their impact on the city's budget. Benefits and costs to other parties, including town citizens, are not included in this analysis.¹⁴ In addition, the period of analysis is relatively straightforward: it is the duration of the hauling contract and the life expectancy of the garbage truck (5 years). Finally, due to the minimal impact of the City of Ortin's decision on the labor, hauling, and trucking markets, the BCA for the City of Ortin would be a partial equilibrium analysis.

The city's "guideline" discount rate is 3% in real (inflation-adjusted) dollars.¹⁵ The predicted lifespan of the truck (five years) provides an appropriate time horizon for the analysis. Since in our example, there would be no reentry barriers facing the city preventing a return to contracting out for collection, and the city is not making any infrastructural investments (e.g. a new garage for the garbage truck), there are not project benefits or costs occurring after the fifth year. Thus, this analysis only needs to carry out to five years time.

2. Identifying and Quantifying Costs and Benefits

¹⁴ The interests of the company providing the garbage hauling services, for example, are not considered in this analysis.

¹⁵ A real interest rate is one in which inflation is subtracted and so that all figures are in constant dollars.

The total benefits to the City are the costs that can be avoided by purchasing a new truck rather than continuing with the hauling contract: the total costs of the garbage hauling contract over the period of interest. Similarly, the relevant costs are those of the truck purchase option. In this relatively simple example, there are no non-market values to take into account.

Purchasing a new truck would cost the city \$60,000, and the salary of the driver-hauler would cost \$35,000 per year. These data are market-based data, which the analyst can readily derive by pricing garbage trucks and determining the market rate for waste collectors. However, these are not the only costs that would occur should the city implement its own waste management program. Since it would own the truck, the city would now be responsible for maintenance and fuel costs; though both maintenance and fuel costs are still reflected in market transactions, calculating these estimates requires a bit more data gathering and analysis work on the part of the analyst. For instance, vehicle maintenance costs must not only reflect fixed maintenance costs (such as oil changes and tire replacement) but the probability of incurring unexpected maintenance costs such as part failure or a flat tire. To estimate this, the analyst might use repair data from other municipalities.

This is a ready example of the potential utility of an integrated database; such a database might provide the analyst with a data set of vehicle maintenance costs incurred in other areas or agencies, or better yet, provide a shadow price of vehicle maintenance cost per mile traveled. The analyst could then estimate the number of miles the garbage truck would travel (which must be done to estimate fuel costs in any case) and ensure that the price is accurately scaled (in terms of the price of parts, etc.) for a garbage truck, and thus readily provide an estimate of maintenance costs. Without the database or shadow price, the analyst would either need to devote much more time and effort to deriving an estimate or else make do with a rougher estimate, resulting in either a more expensive or less accurate BCA. Moreover, real-world policy BCAs are required to be much more detailed than this simple example. For instance, the city might wish to know the environmental benefits and costs of the two policies or subsequent economic impacts, requiring even more data and shadow price estimates.

In this example, the expected yearly maintenance cost (reflecting both fixed maintenance costs and the probability of necessary repairs) is \$2,000, and fuel expenses are estimated to be \$1,000 per year. The truck manufacturer informs the city that truck can be expected to last five years given the expected workload, and the estimated scrap value at the end of that period is estimated to be \$12,000 in constant dollars.¹⁶ The current garbage collection contract costs Ortin \$50,000 per year.

¹⁶ Constant dollars are those relating to a base year so that inflation that subsequently occurs or is expected to occur is subtracted.

Table 1: Cash Flow Streams - City of Ortin

Choice	Initial Costs	Year 1 (MDF)	Year 2 (MDF)	Year 3 (MDF)	Year 4 (MDF)	Year 5 (MDF)	TOTAL
Truck Costs	\$60,000	\$38,000	\$38,000	\$38,000	\$38,000	\$26,000	\$238,000
Contract Hauling Costs	0	\$50,000	\$50,000	\$50,000	\$50,000	\$50,000	\$250,000
Cost Differences	(\$60,000)	\$12,000	\$12,000	\$12,000	\$12,000	\$24,000	\$12,000

In Table 1 shows the cash flow streams for Ortin. The first row contains the costs should the city purchase a truck. The second line represents the costs of contract hauling. The term “MDF” accounts for maintenance, driver and fuel costs. The base comparison is a continuation of the status quo: contracting out for waste collection. Determining this reference point is crucial to BCA, as benefits and costs of a project must be defined relative to what would happen without the project being implemented. In this example, this is somewhat inconsequential (because a BCA will select the same project regardless of which one is used as the baseline for comparison in this case), as the city has decided it must collect garbage by one means or another, and there are no transaction costs to switching from the current policy. However, if the city was deciding whether or not to provide a waste collection service at all, or looking to initiate a solid waste service for the first time, it would be crucial to develop the true null alternative to these policies (i.e. what would happen in the absence of a policy implementation).¹⁷

Upon a summary analysis of the cash flows, it appears that Ortin would spend \$60,000 immediately and recoup its costs plus an additional \$12,000 over the five-year period (this additional \$12,000 can be seen in the Year 5 column, attributable to the salvage value of the truck. The true question, however, is whether or not the project would be a good investment. A benefit-cost analysis can help illuminate the answer to that question. Because the costs of the hauling contract and of the garbage truck occur at different points in time, one cannot simply infer from Table 1 above that the benefits, for instance, are \$250,000. Rather, the cash flows in each year must be discounted to the present value of the benefits.

3. Choose a Discount Rate and Determining the Present Value of Benefits and Costs

For the purposes of this example, we will use City of Ortin’s guideline discount rate of 3%. Thus, we apply the 3% rate within equation 1 above ($r = 0.03$) to determine the present value of benefits and costs for each of the five years of the projects lifespan. The present

¹⁷For example, in such a case, comparing the collection service to a situation in which all of the garbage that would be collected simply sits in people’s backyards would overestimate the benefit of the trash service; what would actually happen in the absence of any waste collection service would likely be a combination of trash sitting out and behavioral adaptations (such as waste reduction, composting, trips to the dump, etc.) that would shift the baseline.

value of cash flows for the two alternatives, assuming a discount rate of 3%, is shown in Table 2 below (recall that truck costs are the “costs” in our analysis, while the savings generated by eliminating the hauling contract are the “benefits”):

Table 2: Present Values of Programs

	Initial Costs	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Nominal Truck Costs	\$60,000	\$38,000	\$38,000	\$38,000	\$38,000	\$26,000	\$238,000
PV of Truck Costs	\$60,000	\$36,893	\$35,819	\$34,775	\$33,763	\$22,428	\$223,678
Nominal Contract Hauling Costs	0	\$50,000	\$50,000	\$50,000	\$50,000	\$50,000	\$250,000
PV of Hauling Contract Cost	\$0	\$48,544	\$47,130	\$45,757	\$44,424	\$43,130	\$228,985
Cost Difference	(\$60,000)	\$12,000	\$12,000	\$12,000	\$12,000	\$24,000	\$12,000
PV of Cost Difference (Net Present Value)	(\$60,000)	\$11,650	\$11,311	\$10,982	\$10,662	\$20,703	\$5,308

4. Computing a Summary Metric and Comparing Alternatives

As appears from the calculations above, if the City of Ortin used a 3% discount rate, the net present cost to the city of contract hauling is \$228,985 (NPV = (-228,985)), whereas the net present cost of purchasing and operating the garbage truck is \$223,678 (NPV = (-223,678)). Thus, when compared to the baseline (contract hauling), the NPV of purchasing and operating a garbage truck would be \$5,308. Since this figure is greater than zero, we would conclude that the project is financially desirable. Note that this decision is highly dependent upon the discount rate chose. If, for instance, the city used a 7% real discount rate, the project would not pass the BCA test: the net present value of the project would be -\$2,242.

Let us review the elements of the BCA for the city of Ortin: the baseline is the present program, the waste hauling contract. The sum of the present value of any savings that can be made over the costs of this program constitutes the net present value (\$5,308). The present value of the costs of the truck program is lower than the present value of the contract program, so the NPV is positive. Table 6 demonstrates the results for each of the four evaluation criteria. The B/C ratio is obtained simply by setting the NPV of the truck purchasing option over that of contract hauling. The IRR can be obtained readily using

computer software; instead of setting the interest rate in the case flow equation and calculating NPV, NPV is set to zero and cash flow equation is solved for r (the interest rate).

Table 3 BCA Measures

NPV	B/C ratio	IRR
\$5,308	1.024	6%

The first three criteria all show that buying the truck would be preferable. In each case, Ortin would make 3% or better on its investment. Notice that our analysis is useful but incomplete, in that we have not accounted for uncertainty or risk and not addressed other issues such as administrative costs. Some of these issues are discussed below.

5. Risk and Uncertainty

While we discussed the issues of risk and uncertainty in the previous section, an application of these concepts to the city of Ortin example can be helpful. In this example, the city has estimated the truck fuel costs at \$5,000 (\$1,000 per year). This is based on an estimated gas mileage of 10 miles per gallon, and a price of \$3 per gallon. Suppose though that data indicates that the mileage may be as low as 8 mpg or as high as 12 mpg, and that projections for fuel costs indicate it could be as low as \$2.90 or as high as \$3.10 per gallon. We may therefore want to run the analysis using the range of these estimates to obtain a minimum and maximum figure for the cost per mile (a form of sensitivity analysis). If the city is most concerned with minimizing a potential loss scenario, we will likely be interested in the lowest estimate for mileage and the highest estimates for gas prices (representing the “worst-case scenario” for the city). This would be the most conservative analysis. Under the most conservative circumstances, we would then obtain a figure of \$0.39 per mile. The most optimistic figure would be \$0.24 per mile (high estimate for mileage and low estimate for gas prices). Including such nuanced estimates for the costs and benefits of the various programs under consideration makes the BCA more robust and provides a more reliable tool for decision-makers because it will allow them to better assess in which scenarios their decision will be optimal.

To demonstrate the application of a rudimentary Monte Carlo analysis, consider that the analyst must predict the scrap value of the truck, which will be determined by the market for scrap metal at the end of the five year period, as well as the cost of gas and the truck’s mileage per gallon. The estimates used for each of these parameters in the initial analysis are not likely to equal the observed values should the policy be enacted. For instance, the analyst cannot know what the state of the scrap metal market will be in five years. Moreover, the analyst likely cannot really specify that there is a given probability of the scrap value being x_1 and a probability of it being x_2 and calculate an expected value in such fashion. To account for this uncertainty, the analyst could instead then have the Monte Carlo simulation draw from a distribution with a mean of the predicted value (\$12,000) and a specified standard error term. If the scrap metal market is volatile, this might be a larger term, and vice versa if it is expected to remain fairly static. Each iteration would also conduct a draw from the estimated distribution of gas prices and miles per gallon. The

results of each model iteration can be evaluated to determine the expected distribution of project outcomes given these multiple sources of uncertainty. Decision-makers can examine the distribution of outcomes to see if purchasing and operating the truck engenders positive net benefits (relative to contract hauling) at their desired level of risk. For instance, the city might only wish to purchase and operate the truck if there is a 90% probability that this option will engender net benefits; the Monte Carlo analysis would demonstrate how many of the simulations achieve this level (for the 90% probability threshold, 9,000 of the 10,000 simulations would need to demonstrate positive net benefits), providing an estimate of the likelihood that the project achieves this threshold given the multiple uncertainties involved.

Finally, even in the narrow Ortin example there is a social value to information beyond its value to city of Ortin. The data collected and analyzed by the city furthers the base of knowledge available for future analyses. In analyzing important social problems that are acted upon by governance bodies across jurisdictional boundaries and policy sectors, such as public transportation, health and human services, and housing and homelessness policies, the social value of information will be particularly high, much larger than the social information value shown in the Ortin example. There are multiple, extensive effects stemming from these cross-sector, transjurisdictional social policy issues, and comprehensive data on these effects can serve the analytical needs of numerous policy applications.

E. Conclusion

Whether done in a highly complex fashion for a multi-billion dollar Federal project or in a simple, “back-of-the-envelope”-type application for a minor city government rule change, benefit-cost analysis is predicated on the value of information. The basic role of BCA is to provide information that serves to improve decision-making and leads to more efficient policies. Graham (2008) makes a strong empirical case that despite various sources of criticism, BCA has proved efficacious in this regard. As a tool for policy-makers, BCA helps facilitate more efficient, effective, and beneficial decision-making at every level of policy.

By monetizing policy outcomes, BCA can produce comprehensive assessments of policy interventions that can be compared within a portfolio of policy options. Rather than focusing on sector-specific metrics such as health outcomes, educational attainment, or crime statistics as policy end-goals, BCA takes a broader approach to improving social welfare. This full monetization gives policy-makers access to a range of policy options otherwise unavailable. BCA allows for cross-sector policy comparisons, such as comparing the crime-reducing benefits of education spending and criminal-justice enforcement efforts. In social policy, where many policy effects accrue outside of the targeted policy focus (Vining and Weimer 2010), this is especially important, as alternative solutions can often prove to foster increased efficiency and better outcomes; without the ability to compare and then employ diverse policy strategies, social welfare would suffer.

However, these same demands of comprehensiveness and consistency make BCA a highly demanding and complex endeavor. While it is imperative that BCA be employed more widely, comprehensively, and consistently in decision-making, this will only be achieved as long as decision-makers and analysts have the resources to do so. The implementation of BCA can be furthered either by: (a) devoting more time and resources to conducting

analyses; or (b) reducing the cost of conducting analyses, in terms of both time and funds, such that appropriate, comprehensive BCAs are more accessible. In our view, the later option represents the most efficient method. The development of integrated data systems that contain not only raw data, but refined data in the form of key estimates and shadow prices as well as the methodology and results of other BCAs, would make it much more feasible for analysts at all levels of government and the non-profit sector to conduct BCA. Moreover, for those agencies and individuals already employing BCA, such integrated data systems would reduce the cost of increase the quality of their analyses. Given the sizeable gains already wrought through the application of BCA (again, see Graham 2008), it seems a reasonable hypothesis then that expanding the use and increasing the quality of BCAs in policy-making would in turn sizably increase social welfare. Hopefully, these gains can be realized in the near future.

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