Methodology Guide:

BENEFIT-COST ANALYSIS

Overview

Benefit-cost analysis, sometimes referred to as cost-benefit analysis, is one of the most common economic analysis methods used to inform project decision-making. Benefit-cost analysis compares a project's benefits and costs, allowing one to assess whether the benefits justify the costs and what the net present value of benefits are. For example, a project manager who wants to decide whether to pursue a proposed natural infrastructure project could monetize the potential benefits (for example, flood damages avoided, increase in recreational activities and visitors, and improved habitat for commercial fisheries) and costs (for example, installation and maintenance costs) associated with the project and then calculate the ratio of benefits to costs, as well as net present value. It is also helpful for comparing project alternatives when there are several possible ways to achieve a goal.

You do not necessarily need to monetize all benefits and costs to perform a successful benefit-cost analysis, but you must be able to monetize some of them. In the preliminary planning stages of a project, you may not know all the benefits or costs. However, economists will often start by monetizing the most considerable known or anticipated benefits and costs. This tactic may help you to show that the benefits outweigh the costs without monetizing everything. You can then describe the remaining benefits or costs qualitatively (in words) through a narrative, particularly for those that are very difficult to quantify. This narrative may be enough to satisfy your needs to inform decision-making.

When to Consider

Use a benefit-cost analysis when you want to know if the stream of benefits that are anticipated to occur over the life of a project exceed the costs. You may also use this method when you want to compare the net benefits among various projects and use that as one factor in determining which project to undertake. Conduct a benefit-cost analysis if:

- You want to assess whether the net present value of avoided flood damages from restoring wetlands exceeds the net present value of restoring mangroves.

- You want to assess whether the benefit-cost ratio of a new recreational fishing dock construction exceeds a value of "1" and therefore indicates that the project should be undertaken.
- You want to assess whether installing green roofs has a better return on investment than gray infrastructure options.

Important Results

A benefit-cost analysis provides several results that can be used to evaluate a project:

- Net Present Value = [Present Value of Benefits] - [Present Value of Costs]
  Net present value is the net benefit (current value of benefits minus the current value of costs) after discounting future benefits and costs for the length of the project. Access the Choosing a Discount Rate quick reference for guidance on how to discount future benefits and costs.

  A positive value indicates that the benefits outweigh the costs. Here is an example of how you might report results.
  The benefit-cost analysis indicates that restoring wetlands provides a greater net present value than restoring mangroves, as restored wetlands provide $350,000 more in net benefits associated with avoided flood damages (expressed in current-year dollars).

- Benefit-Cost Ratio = [Present Value of Benefits] / [Present Value of Costs]
  The *benefit-cost ratio* is the ratio of the benefits to costs (current value of benefits divided by the current value of costs). A value greater than "1" indicates the benefits exceed the costs. The larger the ratio, the more the benefits outweigh the costs.

  Here is an example of how you might report results.
  The benefit-cost ratio result from the benefit-cost analysis study is 1.4, indicating that the benefits of building a new recreational fishing dock exceed the costs by 40 percent.

- Return on Investment = (([Present Value of Benefits] - [Present Value of Costs])/[Present Value of Costs]) x 100%
  A *return on investment* is similar to a benefit-cost ratio, except the ratio is multiplied by 100%. A return on investment greater than 0% indicates the benefits exceed the costs.

  Here is an example of how you might report results.
  The benefit-cost analysis study indicates the return on investment of installing green roofs (150%) exceeds the return on investment of installing traditional gray infrastructure (100%).

Should you use net present value, benefit-cost ratio, or return on investment to inform your decision? All three are informative. While net present value shows the exact dollar amount of net benefits expressed in current dollars, the benefit-cost ratio and return on investment indicate if the benefits exceed costs and by what percentage.

Strengths

- Compared with other economic analyses, benefit-cost analysis provides the most comprehensive information for decision-making in that you can compare benefits and costs directly against each other quantitatively (in numbers).
- Benefit-cost analysis allows you to directly compare alternatives against each other using the individual results for each alternative.
- Results from conducting a benefit-cost analysis include valuable information such as net present value, return on investment, and benefit-cost ratio (see more in detail below).

Challenges

- The methodology generally requires substantial time and trained expertise, particularly for monetizing benefits.
- Collecting data required for the analysis can be resource-intensive.
- Benefit-cost analysis is not set up to take into account equity and distribution considerations. That is, this analysis tells you little about who enjoys the benefits and who incurs the costs. These aspects refer to the distribution of benefits or costs over a population. An analyst conducting a benefit-cost analysis can provide a list of those that benefit and those that do not.

Key Suggestions, Interpreting Results, and Potential Mistakes

Key Suggestions

- If possible, work with an economist to conduct a comprehensive benefit-cost analysis. This guidance document does not provide an exhaustive set of the steps and information needed to do a complete analysis.
- The benefit-cost analysis should not make the decision—but should inform the decision. The project with the highest benefit-cost ratio or net benefit is not necessarily the best decision. Other considerations may also be important. If decision-makers only use the final benefit-cost analysis result, they may overlook the qualitative co-benefits that are important to a community, or even the motivation for the project. It is important to consider all benefits in decision-making regardless of whether they are included directly in the benefit-cost analysis quantitatively or qualitatively.

Interpreting Results

- Be careful to avoid double counting benefits. A good rule of thumb is that willingness to pay values should not be aggregated with other benefit values to prevent double counting. For example, willingness to pay benefits should not be combined with beach day use fees because both place value on beach usage. Similarly, estimates of existence value should not be combined with specific ecosystem service values.
- Identify the necessary level of effort. Sometimes you do not need to monetize every cost or benefit to make an informed decision. Are you trying to show a positive net benefit (net present value)? If so, start by monetizing what you expect would be the largest benefits, perform the analysis, and see if you get to your goal without spending resources on monetizing everything.
- Consider uncertainty in your estimate. Document your assumptions, and try to understand how the assumption might impact or bias (increase or decrease) an estimate. You may want to develop a range of values to help demonstrate that the benefits include uncertainty and to understand your best and worst case scenarios.
- It is important to define the relevant population for whom you are calculating the benefits and costs. For individual investments, such as a green roof on a private home, the relevant population may be the homeowner. The homeowner may then only consider the private benefits and costs and not include any externalities in the decision. For example, the homeowner may not consider the benefit to society of reduced urban heat island effects or improved air quality. For government-funded projects, the relevant population is generally society, although, then, "society" can vary from society at the local level to society at the global level. When calculating societal costs and benefits, externalities to the relevant population should be incorporated into the calculation (i.e., secondary costs or benefits incurred by third parties, such as pollution or air quality).
- Select the geographic region you are considering for the analysis. Should benefits and costs be assessed for the locality, state, country, or world? Where you define these bounds depends on the stakeholder that is interested in the analysis. If the stakeholder cares about society at large, they may want to consider a broad definition of society, generally representing the broadest area incurring costs or benefits. If the stakeholder only cares about local constituents (e.g., they are tasked with showing financial impacts to their town), then they may want to consider only local costs and benefits, even if there are positive or negative externalities (that is, effects that spill over) to neighboring areas. However, it is critical that the same geographic definition is used when accounting for both costs and benefits.
- Clearly state the aspects of your project that your benefit-cost analysis does not address. Explicitly state that the analysis does not include cultural benefits, for example, if that is the case. Explain how those will be accounted for.

Potential Mistakes

Common mistakes in performing a BCA can include:

- Not including future, anticipated maintenance costs over time. This may be particularly important in comparing natural infrastructure project alternatives to gray infrastructure projects for coastal protection. While gray infrastructure projects may require significant investments in upkeep over time relative to the natural projects, natural infrastructure projects have a tendency to perform better (accrue increasing marginal benefits) over time as, for example, vegetation becomes more established.
- Not using the same time horizon when comparing projects (e.g., one project lasts 5 years and one project lasts 15 years). This results in a comparison that is not "apples to apples."
- Not understanding the sensitivity, error, or context of a result. Benefit-cost analysis results are often presented as a single point instead of a range. For example, an analysis may calculate the net benefit using the average annual avoided losses (as a benefit) to prevent coastal flooding over a 30-year window. The actual benefit could range widely depending on whether a 100-year storm hits during that 30-year period. Understanding how the result incorporates uncertainty or risk may help you determine how you want to use those numbers based on your tolerance for risk.

Key Steps

This section outlines some of the key tasks to help you perform a benefit-cost analysis.

1. **Identify the categories of costs and benefits**

   Identify the specific benefit and cost categories you expect to result from your project. Monetize these benefits and costs in conjunction with Step 2. In performing a benefit-cost analysis, it is important to identify all the benefits and costs so you have a complete understanding of the factors that will help you make a decision, even if you are not able to incorporate all the benefits in the analysis. This matrix outlines natural infrastructure benefit and cost categories and estimates and may be helpful if natural infrastructure is something you are considering proposing.

2. **Choose an appropriate time horizon of your project or project options**

   Consider what the lifespan of your project might be and how long costs and benefits will accrue. For example, while the implementation and maintenance costs associated with a coral reef restoration project might be 30 years, the benefits would accrue for 50 years or more. When comparing multiple projects, you may want to assess over a similar time period. Sometimes this time horizon may be your best guess of how long the benefits will accrue, and other times you might select a more arbitrary time horizon. It is also essential to account for the lag time

needed for natural infrastructure features to get established and generate benefits. When comparing multiple projects over a set, comparable time horizon, consider how long the benefits will occur for each project. For example, if you are considering Project A with a benefit that lasts 5 years and Project B with a benefit that lasts 20 years, you may underestimate the benefits of Project B if you select a time horizon of 5 years. For those same two projects, if you select a time horizon of 20 years, you may want to determine what you would do to supplement Project A (since its benefits end after 5 years) to realize benefits from years 6 to 20. You may have a better direct comparison if you compare benefits and costs of Project A (benefits in years 1 to 5) plus Project C (benefits in years 6 to 20) to Project B (benefits in years 1 to 20) because their time horizons would now be similar.

3. **Choose a discount rate**

   Apply the discount rate to benefits and costs over your project's time horizon or project options. Discounting is the process of calculating the present value (in today's dollars) of a cost or benefit anticipated to be incurred in the future. See the Choosing a Discount Rate quick reference guide.

4. **Examine Your Results**

   Estimate and calculate:

   1. benefit-cost ratio
   2. net present value
   3. return on investment

   Visit the section "Important Results."

5. **Consider other important factors**

   Consider other factors that might influence your decision-making, such as co-benefits that you cannot count or equity and distributional considerations. Remember, an economic analysis should inform decision-making but not be the only determining factor.

Benefit-Cost Analysis Interpreting Results Example

The table below shows benefit-cost analysis results for three hypothetical projects. For example, these could be three different wetlands that could be restored. Or these could be three different types of natural infrastructure that reduce stormwater runoff. Which project would you choose?

Table 1. Benefits-cost analysis results for three hypothetical projects.

	Project 1	Project 2	Project 3
Benefit (Present Value)	$500 million	$160 million	$340 million
Cost (Present Value)	$200 million	$16 million	$170 million
Net Present Value	$300 million	$144 million	$170 million
Benefit-Cost Ratio	2.5	10	2
Return on Investment	150%	900%	100%

Project 1 provides the highest net present value and second highest benefit-cost ratio. Project 2 provides the lowest net present value but the highest benefit-cost ratio by a wide margin. Project 3 provides the second highest net present value and the lowest benefit-cost ratio. Assuming the benefits do not overlap (i.e., you could implement both Projects 2 and 3 and realize all $500 million), you are better off selecting Project 2 and Project 3 together than selecting Project 1 because you get $500 million in benefits for $186 million in costs compared to getting $500 million in benefits for $200 million in costs for just Project 1. The (caveated) answer: based on the benefit-cost information, if you have $200 million to spend, go with Projects 2 and 3 for the reason described above. If you have a little more than $200 million, you may want to go with Projects 1 and 2 as they have the two highest benefit-cost ratios. There are several aspects to consider when deciding how the benefit-cost analysis results will be used to inform your decision about the project to implement.

- First, it depends how you are expressing the results. It will depend on the audience under consideration. As illustrated in this example, it is important to decide what benefit-cost analysis results matter most to you in your decision.
- Another key takeaway is to use multiple results from a benefit-cost analysis, as just using net present value does not provide the full picture. While it may seem easiest to just consider net present value, for example, you may want to use all of them.
- Third, as stated already, an important caveat is that these results do not consider how the benefits will be distributed across the population you are considering. Project 1, for example, may be protecting a more vulnerable population, and that is an example of an important qualitative consideration that you will want to consider when using benefit-cost data to inform your decision-making.

Resources to Dive Deeper

Getting Help

- Reach out to our team (*econguidance@noaa.gov*) for specific questions or to brainstorm how to start your benefit-cost analysis.
- Hire a private consultant or request support from academic partners. Researchers, graduate students, and academic scholars may be able to provide guidance or work directly on your benefit-cost analysis.

Other Resources

- The National Institute of Standards and Technology (NIST) released a tool called EDGE$ to help the general public carry out a limited benefit-cost analysis. You may consider conducting a benefit-cost analysis in this tool before carrying out your own to give you a sense of what to expect.
- Federal agency-specific guidance: Federal agencies often provide specific guidance unique to the benefit-cost analyses they expect in their grant applications. Below are starting points on these resources:
    - Department of Transportation (DOT)
        - Benefit-Cost Analysis Guidance for Discretionary Grant Programs
        - RAISE Grants
    - Federal Emergency Management Agency (FEMA)
        - FEMA Benefit-Cost Analysis
    - U.S. Army Corps of Engineers (USACE)
        - Manual - Economics Primer
        - Analytical Methods and Approaches for Water Resources Project Planning
    - Texas A&M University
        - How Project Selection In The Corps Of Engineers Is Affected By Benefit-cost Ratio (BCR) Analysis
    - Environmental Protection Agency (EPA)
        - Benefits Mapping and Analysis Program (BenMAP)

Cost Data

- The Nature-Based Solutions: Benefits, Costs, and Economic Assessments quick reference guide outlines common expected construction maintenance costs when building natural infrastructure.

Benefit Data

- The Green Infrastructure Effectiveness Database contains many articles on the efficacy of natural infrastructure projects and their benefits.
- The Blue Value database contains data and values for the environmental goods and services (benefits) provided by various coastal and marine ecosystems and features.
- The Nature-Based Solutions: Benefits, Costs, and Economic Assessments quick reference outlines common approaches that will result in various benefits.

Additional Resources

- For flood reduction, NOAA developed a broad step-by-step economic framework, What Will Adaptation Cost? for performing a benefit-cost analysis for adaptation strategies for coastal flood prevention.
- A similar guide specific to green infrastructure, A Guide to Assessing Green Infrastructure Costs and Benefits for Flood Reduction.
- NOAA also published a companion piece with two natural infrastructure benefit-cost case studies in the Great Lakes region, Economic Assessment of Green Infrastructure Strategies for Climate Change Adaptation.