# Overview of Benefit-Cost Methods

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Benefit-cost analysis is simply a method for using a common sense approach to investment decisions. The general idea is to select the group of projects that will maximize the present worth of future benefits for an available budget. In a more specific sense, economic analysis can be used to determine the, cutoff level for expenditure and the ranking of projects for a limited budget.

The three most used economic analysis techniques are, simple benefit-cost ratio analysis, rate-of-return analysis, and incremental benefit-cost analysis. According to several surveys, almost all states use some type of economic analysis for comparing alternative projects[1]. This is true for large construction projects and also for safety projects. Recent research has shown that use of benefit-cost analysis, or rate-of-return analysis which gives similar results, can lead to a substantial increase in total benefits as compared to the use of index-based techniques, such as sufficiency ratings[2].

An investment is considered to be economically justified or warranted, if the benefit-cost ration exceeds one. In more general terms, any feasible increment expenditure is economically justified if its incremental benefit-cost ratio is greater than one. In the simplest situation where only one project is considered at each location, where all projects are mutually exclusive, projects are ranked in descending order from the project with the largest benefit-cost ratio to the project with the lowest ratio. If alternatives are not mutually exclusive, then an incremental analysis should be used, as is discussed in more detail later in the paper.

In calculating a benefit-cost ratio, initial costs usually are in the denominator, and the present worth of annual maintenance operating and maintenance costs are also sometimes included in the denominator. The numerator is the present worth of annual reductions in accident costs and other annual benefits. If the present worth of the increase in annual operating and maintenance costs are not added to the denominator then they are subtracted from benefits in the numerator. Also, added to benefits in the numerator is the present worth of the salvage value at the end of the analysis period.

If the investment decision involves allocating a budget for initial costs, the decision is less ambiguous if only initial costs are included in the denominator, and the ranking of projects using benefit-cost ratios will lead to the maximization of future benefits less future costs for a given budget of initial costs. If the present worth of all costs is included in the denominator, then a ranking of projects using benefit-cost ratios will maximize total benefits for a budget of total costs. Since budgets typically are in terms of initial costs, it is consistent to use a ration with only initial costs in the denominator.

### Recommended Discount Rate

There has been considerable disagreement over the correct discount rate to be used in calculating the present worth of future benefits and costs. It is possible to distinguish between discount rates for constant dollars and for inflated dollars. In highway economic analyses, future benefits and costs are almost always calculated in constant dollars, so a zero-inflation discount rate should be used. This type of rate is typically calculated to be about three to seven percent with five percent being a good compromise rate. However, if future benefits and costs are calculated in inflated dollars, then the inflation rate used to inflate future benefits can be added to the constant dollar rate. Since the principal use of benefit-cost ratios in safety decision making is to rank competing projects, the principal effect of the discount rate in safety investment decisions is in determining the trade-off between present and future benefits. Therefore, the real effect of a rate of five percent, for example, is that saving one life now is equated to saving 1.05 lives one year in the future, or (1.05 x 1.05 =) 1.1025 lives two years in the future, and so forth. If a discount rate of ten percent is used, instead of five percent, future savings are valued much lower relative to present savings. Since most of the safety benefits and the taxes used to pay for safety improvements, are from passenger car occupants who are typical consumers, it is appropriate to use a discount rate that is representative of the trade-off between the present and the future that is preferred by typical consumers. This rate in real terms, which is adjusted to exclude the effects of inflation, has been found to be about three to five percent.

### Use of Incremental Analysis

Another point that is sometimes confusing is whether an incremental benefit-cost analysis should be used in ranking projects. For mutually exclusive alternatives (that is, where there is only one alternative at each accident location), a simple benefit-cost ranking gives the same ranking as an incremental analysis. Since there is only one increment at each location both rankings give the same answers.

If there is more than one alternative improvement at each location, then simple benefit-cost ratios do not give the same benefits as incremental analysis. To maximize total benefits for a fixed budget, it is necessary to use incremental analysis. Three different techniques are available for ranking alternatives when there are multiple alternatives at one or more of the locations being considered. These techniques are, incremental benefit-cost analysis with an improved solution algorithm, dynamic programming, and integer programming. An easy-to-use computer program is available for each of these techniques[3].

Each of these three improved methods has been compared with simple benefit-cost analysis using actual accident locations with multiple alternatives, for Alabama and Texas[3]. Brown earlier made a similar comparison of dynamic programming and simple benefit-cost analysis using the same set of Alabama locations[4]. These comparisons indicate that any of the three improved techniques, all of which use incremental analysis, give an increase in total benefits of about 35 to 40 percent, as compared to simple benefit-cost analysis, if locations with multiple alternatives are being ranked.

### Accident Costs

The next thing I would like to discuss is some of the recent research on accident costs. This research has shown that use of a market, or willingness-to-pay, approach supports the use of increased costs for fatalities and injuries. This recent research, using detailed data on injuries, shows that injuries in fatal accidents are much more severe than injuries in injury accidents of the same coding. These research results were taken into account in developing the accident costs in Table 1, which is based on McFarland and Rollins[5]. Estimates of accident costs as related to a severity index for roadside obstacles also have been developed using similar accident cost values[6].

TABLE 1 ACCIDENT COSTS BY AREA AND SEVERITY

| Area and Type of Cost | Accident Cost by Severity (1980 dollars) | | | |
|---|---|---|---|---|
| | Fatal($) | Injury($) | PDO($) | Average($) |
| Rural | | | | |
| Direct | 34,695 | 6,536 | 1,906 | 3,715 |
| Indirect | 848,442 | 4,108 | 202 | 15,309 |
| Total | 883,137 | 10,644 | 1,298 | 19,024 |
| Urban | | | | |
| Direct | 30,186 | 5,755 | 1,283 | 2,581 |
| Indirect | 796,670 | 2,990 | 236 | 4,562 |
| Total | 826,856 | 8,745 | 1,519 | 7,143 |

### Estimation of Accident Severities and Costs at a Location

A final point I would like to address is a problem that often arises when one attempts to use relatively large accident costs for fatal accidents. The problem typically arises when the actual number of accidents by severity is used to calculate accident costs at each accident location. There are at least four ways that accident severities can be estimated at each accident location:

1. Using actual accidents at each accident location;
2. Using statewide averages for locations of the type being considered;
3. Using a statistical analysis, such as that recommended by Tamburri and Smith[7]; and
4. Using a Bayesian statistical approach, such as that recommended by Flowers[8].

The main point that is made here is that choosing one of the above methods for estimating accident severities is inter-related with the choice of accident costs for each severity. That is, one of the reasons that there is a reluctance to use the higher accident cost values for fatal accidents in benefit-cost analyses of safety improvements is, that their use tends to give distorted estimates for total accident cost at some locations. When using the first method, there may be a problem because locations with fatalities tend to be chosen for correction even when they are similar to other locations that have more accidents, but have less fatal accidents. The second, third, and fourth approaches represent attempts to solve this problem.

The second approach, using statewide averages, entails calculating accident costs using statewide percentages for fatal, injury, and property-damage-only accidents for each type of accident location. One difficulty in implementing this approach is in deciding what categories to use in calculating average percentages. For example, in calculating percentages for tree accidents, should one use trees in general or should trees be divided into subcategories, such as by distance from the edge of the travel lane? Or is it possible to use a fixed object category to represent tree accidents? Another difficulty is that specific locations may be more hazardous than the average location of a type, and this approach does not allow for this consideration.

The third approach uses statistical tests developed by Tamburri and Smith[7]. The principal difficulty with this approach is that the assumed normal distribution is not a good representation for accident severities, especially in urban areas. Any time there is at least one fatal accident at a location, it is likely that this fatal accident will be judged to be statistically significant and the actual proportions by severity will be used, as in approach one. Even though their approach may work fairly well for rural locations with a large number of accidents, for example more than thirty, it is not a good rule for most situations because the assumption of a normal distribution is not met.

The fourth approach is to use a Bayesian procedure. As outlined by Flowers[8], this approach uses a weighted average of the severity proportions at a specific location and the statewide average proportions for the type of location being considered. There are two ways of setting the relative weights placed on the location proportions and the statewide proportions. First, the safety analyst can subjectively set the relative weights, depending on his judgment of how well each of the two sets of proportions represent the true proportions at the location. Second, the weights can be set using formulas provided by Flowers, in which case the resulting numbers are properly called synthetic Bayesian numbers. Since the latter approach could be more uniformly applied throughout a state, it is probably the preferred of the two approaches. The latter approach gives more weight to the specific location proportions when there are a larger number of accidents on which to base such proportions.

It is recommended that states use the higher accident costs given in this paper and also consider using a Bayesian approach, with use of synthetic Bayesian numbers, to estimate the proportions of accidents by severity in calculating accident costs at each accident location.

**References**

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