Solutions for Cost Benefit Analysis Concepts and Practice 4th Edition by Boardman

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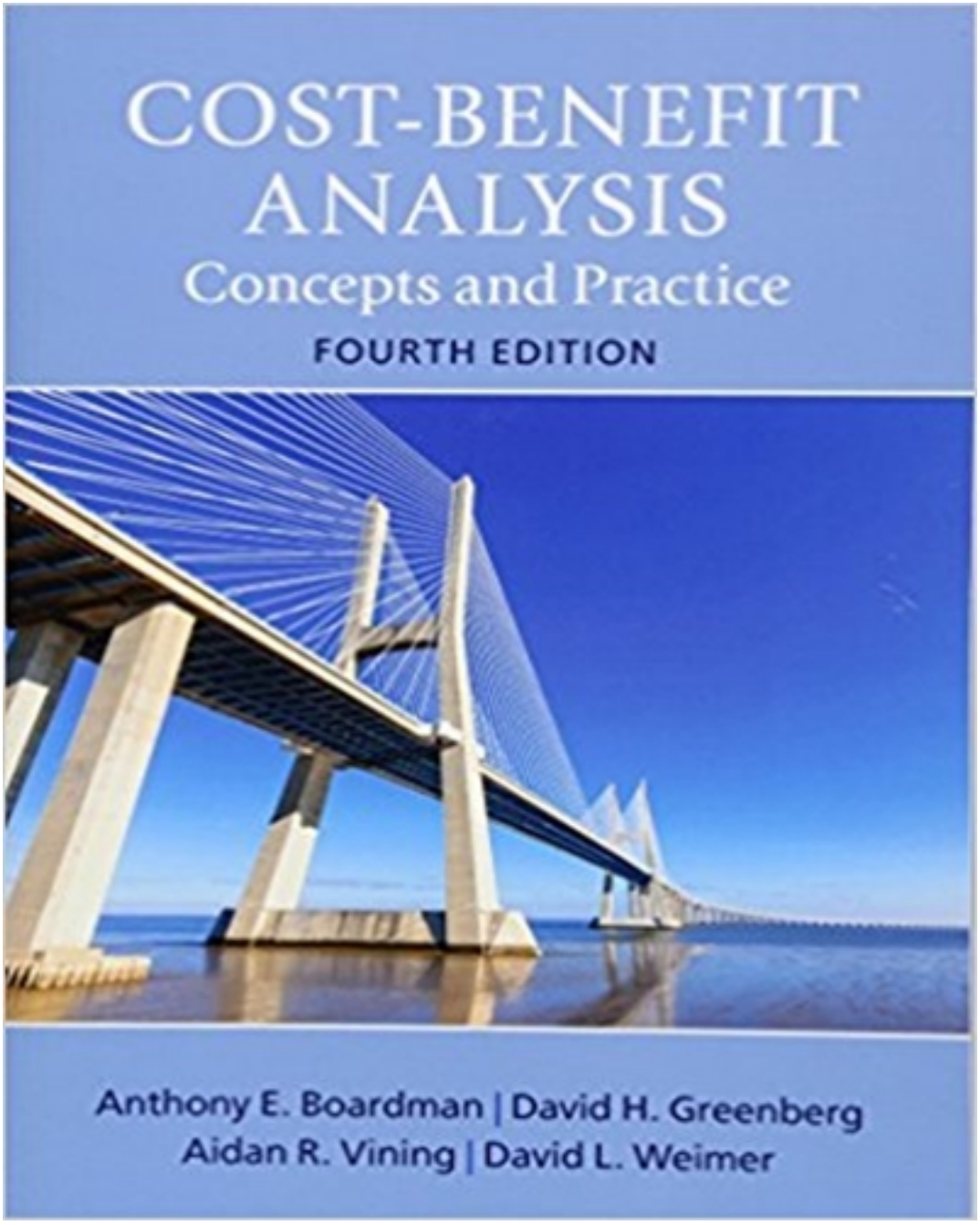


# Solutions

**Chapter 2 Exercises**

**1. Many experts claim that, although VHS came to dominate the video recorder market, Betamax was a superior technology. Assume that these experts are correct, so that, all other things equal, a world in which all video recorders were Betamax technology would be Pareto superior to a world in which all video recorders were VHS technology. Yet it seems implausible that a policy that forced a switch in technologies would be even potentially Pareto improving Explain.**

**1.** Obviously, the switch itself from Betamax to VHS would be costly: the stocks of existing VHS tapes and equipment would lose their value and equipment for producing them would have to be retired earlier than would otherwise be the case. As the replacement would almost certainly occur gradually, there would be a transition period during which positive "network" externalities, the benefits from having compatible systems, would be reduced.

More generally, it is important to keep in mind the distinction between Pareto efficient outcomes and Pareto efficient moves. If everyone were at least as well off, and some were better off, in some alternative to the status quo, then the alternative would be considered Pareto superior. Yet, if the move to the alternative were sufficiently costly, then it would not be Pareto improving. Only if the move were costless, the common assumption in the comparison of alternative equilibria in economic theory, would the Pareto efficiency of outcomes correspond to the Pareto efficiency of moves. In the real world, moves are rarely costless so that policy alternatives are best thought of as moves rather then as outcomes.

**2. Let's explore the concept of willingness to pay with a thought experiment. Imagine a specific sporting, entertainment, or cultural event that you would very much like to attend- perhaps a World Cup match, the seventh game of the World Series, a Garth Brooks concert, or Kathleen Battle performance.**

**a. What is the most you would be willing to pay for a ticket to the event?**
**b. Imagine that you won a ticket to the event in a lottery. What is the minimum amount of money that you would be willing to accept to give up the ticket?**
**c. Imagine that you had an income 50 percent higher than it is now, but that you didn't win a ticket to the event. What is the most you would be willing to pay for a ticket?**
**d. Do you know anyone who would sufficiently dislike the event that they would not use a free ticket unless they were paid to do so?**
**e. Do your answers suggest any possible generalizations about willingness to pay?**

**2.a.** Students' answers will vary (they should be > or = 0).

**2.b.** Most people would be willing to pay less to obtain something than the amount of compensation they would require to give the same thing up willingly if they already owned it. This difference has been frequently observed and economists refer to it as "the difference between willingness to pay and willingness to accept." Though some of the difference may be attributable to the lower wealth level of the individual in the first case than in the second case, it almost certainly also reflects the way people perceive gains and losses.

**2.c.** Willingness to pay depends on people's wealth. If a person's income rises, then the person is wealthier and is likely to be willing to pay more for goods such as tickets to recreational events. (Recreational events are normal goods.)

**2.d.** Different people can have very different willingness-to-pay amounts for the same good. Indeed, it is quite likely that some people would have a negative willingness to pay for a recreational event that others would be willing to pay large positive amounts to attend -- tastes differ. In CBA, it is important to keep in mind that a project effect may simultaneously be viewed by some as a benefit and by others as a cost.

**3. How closely do government expenditures measure opportunity cost for each of the following program inputs?**

**a. Time of jurors in a criminal justice program that requires more trials.**
**b. Land to be used for a nuclear waste storage facility, which is owned by the government and located on a military base.**
**c. Labor for a reforestation program in a small rural community with high unemployment.**
**d. Labor of current government employees who are required to administer a new program.**
**e. Concrete that was previously poured as part of a bridge foundation.**

**3.a.** Most jurisdictions pay jurors a small per diem and reimburse them for commuting and meal expenses. For most jurors, these payments fall short of the opportunity costs of their time. For employed workers, a more reasonable estimate of the opportunity cost of their time would be their wage rates. Note that, from the social perspective, it makes no difference whether or not workers continue to receive their wages while on jury duty. Society is forgoing their labor, which the market values at their wage rates. For those not employed, the opportunity cost is the value they place on their forgone leisure.

**3.b.** Assume that the government does not charge itself for the use of land that it owns. As long as the land could be used for something other than a nuclear waste facility, the government's accounting would underestimate the opportunity cost of the land. If the land could be sold to private developers, for example, then its market price would be a better reflection of its opportunity cost. If the fact that the land is on a military base precludes its sale to private developers, then the opportunity cost of the land would depend on the other uses to which it could be put by the government.

**3.c.** Government expenditures on wages would overestimate the opportunity cost if the workers would have otherwise been unemployed. The opportunity cost of the workers is the value they place on the leisure time that they are giving up.

**3.d.** As the employees are already on the government payroll, the diversion of their time to the program would not involve additional expenditures. The opportunity cost of their time depends on how they would have been using it in the absence of the program. If the government efficiently used labor, then the opportunity cost of their time would be measured by their wage

rates. If the government inefficiently used labor, so that the value of output given up per hour diverted is less than their wage rate, then the opportunity cost would be less than the wage rate.

**3.e.** Once it is in place, the concrete has zero opportunity cost if it cannot be salvaged and reused, regardless of whether or not the government has yet paid the bill for it. This is the classic case of a "sunk cost." Indeed, imagine that if the bridge project were to be cancelled. Then, for safety reasons, the concrete would have to be removed, requiring the use labor and equipment. Consequently, with respect to the bridge project, the opportunity cost of the concrete is negative -- not having to remove it is a benefit of continuing the project!

**4. Three mutually exclusive projects are being considered for a remote river valley: Project R, a recreational facility, has estimated benefits of $10 million and costs of $8 million; project F, a forest preserve with some recreational facilities, has estimated benefits of $13 million and costs of $10 million; project W, a wilderness area with restricted public access, has estimated benefits of $5 million and costs of $1 million. In addition, a road could be built for a cost of $4 million that would increase the benefits of project R by $8 million, increase the benefits of project F by $5 million, and reduce the benefits of project W by $1 million. Even in the absence of any of the other projects, the road has estimated benefits of $2 million.**

a. **Calculate the benefit-cost ratio and net benefits for each possible alternative to the status quo. Note that there are seven possible alternatives to the status quo: R, F, and W, both with and without the road, and the road alone.**
b. **If only one of the seven alternatives can be selected, which should be selected according to the CBA decision rule?**

**4.a.** The seven possible alternatives to the status quo have the following costs (millions), benefits (millions), benefit/cost ratios, and net benefits (millions):

| Alternative | B | C | B/C Ratio | NB |
|---|---|---|---|---|
| Project R without road | $10 | $8 | 1.25 | $2 |
| Project R with road | 18 | 12 | 1.50 | 6 |
| Project F without road | 13 | 10 | 1.30 | 3 |
| Project F with road | 18 | 14 | 1.38 | 4 |
| Project W without road | 5 | 1 | 5.00 | 4 |
| Project W with road | 4 | 5 | 0.80 | -1 |
| Road alone | 2 | 4 | 0.50 | -2 |

**4.b.** Even though Project W without the road has the largest benefit/cost ratio, Project R with the road offers the largest net benefits among the possible projects and therefore would be selected by the CBA decision rule.

**5. An analyst for the U.S. Navy was asked to evaluate alternatives for forward-basing a destroyer flotilla. He decided to do the evaluation as a CBA. The major categories of costs were related to obtaining and maintaining the facilities. The major category of benefit was reduced sailing time to patrol routes. The analyst recommended the forward base with the**

**largest net benefits. The admiral, his client, rejected the recommendation because the CBA did not include the risks to the forward bases from surprise attack and the risks of being unexpectedly ejected from the bases because of changes in political regimes of the host countries. Was the analyst's work wasted?**

**5.** The analyst was mistaken in attempting to apply CBA as a decision rule to alternative policies that had impacts that could not easily be monetized. Nevertheless, the analysis could be restructured as a multigoal analysis with three goals: maximize economic efficiency, reduce vulnerability to surprise attack, and reduce risks from political changes in host country. In this analysis, the net benefits estimated in the CBA can be taken as a criterion for ranking alternatives in terms of maximizing economic efficiency. Thus, CBA is useful in this evaluation not as a decision rule, but rather as a way of systematically measuring progress toward one of several important goals.

**6. Because of a recent wave of jewellery store robberies, a city increases police surveillance of jewellery stores. The increased surveillance costs the city an extra $500,000 per year, but as a result, the amount of jewellery that is stolen falls. Specifically, without the increase in surveillance, jewellery with a retail value of $1 million would have been stolen. This stolen jewellery would have been fenced by the jewellery thieves for $600,000. What is the net social benefit resulting from the police surveillance program?**

**6.** As a result of the increase in surveillance, the jewellery stores (or their insurance companies) receive benefits of $1,000,000, taxpayers incur costs of $500,000, and the jewellery robbers incur costs of $600,000.

The answer to this question depends on whether the jewellery robbers are given standing. After all, they are (unfortunately) part of society.

If the robbers are given standing, society suffers a $100,000 net loss:
$1,000,000 - $500,000 - $600,000 = -$100,000.

If the robbers are not given standing, which would appear to be the more appropriate approach, society enjoys a $500,000 net benefit from the surveillance project:
$1,000,000 - $500,000 = $500,000.

**7. (Instructor-provided spreadsheet recommended.) Excessive and improper use of antibiotics is contributing to the resistance of many diseases to existing antibiotics. Consider a regulatory program in the United States that would monitor antibiotic prescribing by physicians. Analysts estimate the direct costs of enforcement to be $40 million, the time costs to doctors and health professionals to be $220 million, and the convenience costs to patients to be $180 million (all annually). The annual benefits of the program are estimated to be $350 million in avoided resistance costs in the United States, $70 million in health benefits in the United States from better compliance with prescriptions, and $280 million in avoided resistance costs in the rest of the world. Does the program have positive net benefits from the national perspective? If not, what fraction of benefits accruing in the rest of the world would have to be counted for the program to have**

**positive net benefits?**

**7.** The provided spreadsheet shows the following:

| | | Millions of Dollars |
|---|---|---|
| **Regulatory program to monitor antibiotic prescribing by U.S. physicians to reduce the spread of resistant strains** | Regulatory enforcement | 40 |
| | Time cost to doctors | 220 |
| | Convenience cost to patients | 180 |
| | **Total U.S. Costs** | **440** |
| | Avoided U.S. resistance costs | 350 |
| | Better drug compliance | 70 |
| | **Total U.S. Benefits** | **420** |
| | Avoided non-U.S. resistance costs | 280 |
| | Fraction counted as U.S. Benefits | 0 |
| | **U.S. Net Benefits** | **-20** |

To determine what fraction of benefits to non-U.S. resistance costs would have to be included in the CBA to show zero benefits can be determined by changing the value of cell C13 until U.S. Net Benefits rise to zero. Any larger fraction will then yield positive net benefits. The net benefits are about $20,000 when the fraction equals .0715. This might be a good time to talk to students about rounding –here, $20,000 should be rounded to zero.

# CHAPTER 2: CONCEPTUAL FOUNDATIONS OF COST-BENEFIT ANALYSIS

**Purpose:** Introduction to Pareto efficiency (primary definition of allocative efficiency).

## CBA AS A FRAMEWORK FOR MEASURING EFFICIENCY

CBA is a Framework for measuring allocative efficiency.

Allocative efficiency: Resources are deployed in their highest valued use in terms of the goods and services they create.

### Pareto Efficiency

Pareto efficiency: An allocation of goods is Pareto efficient if no alternative allocation can make at least one person better off without making anyone else worse off. CBA can be used to provide information about the relative efficiency of alternative policies.

### Net Benefits and Pareto Efficiency

The link between net benefits and Pareto efficiency is straightforward: if net benefits are positive, then it is possible to find a set of transfers that makes at least one person better off without making anyone else worse off.

**Willingness to Pay (WTP)** is the payment that one would have to make or receive under the policy so one would be indifferent between the status quo and the policy with the payments.

The algebraic sum of the WTP values is the appropriate measure of the net benefits of the impacts of a policy. If and only if the aggregate net benefits of the policy (as measured by WTP of affected individuals) are positive, then there exists a set of contributions and payments that make a Pareto improvement over the status quo.

**Opportunity Cost** places a dollar value on inputs required to implement policies. The opportunity cost of an input is its value in its best alternative use.

### Using CBA for Decision Making

If all impacts are valued using WTP and all inputs are valued using opportunity costs, then the sign of net benefits indicates if it is possible to increase Pareto efficiency. Using a decision rule to implement only Pareto efficient policies is impractical for the following reasons:

- The information burden of measuring benefits and costs for each individual.
- The administrative burden of actually making each required transfer.
- Compensation would induce people to overstate costs and understate benefits.

**Potential Pareto Efficiency (i.e. Kaldor-Hicks criterion)**

Alternative decision rule: Adopt only policies that have positive net benefits.
Reasons for adopting it:

- It is feasible.
- Society maximizes aggregate wealth.
- If different policies have different winners and losers, then, in aggregate, costs and benefits will average out over the entire population.
- It counters incentive to give too much weight to organized groups and too little weight to unorganized groups.
- It is possible to do redistribution wholesale rather than within each separate policy.

**Application of the Decision Rule in Practice**

1. Adopt all policies that have positive net benefits (if all policies are independent).
2. If policies interfere or enhance each other, choose the combination of policies that maximizes net benefits.
3. Benefit-Cost Ratio = Benefit/Cost
4. The benefit/cost ratio can confuse choice: Does one choose the policy with the best ratio or the highest net benefits? One should generally choose the policy with the largest net benefits because the ratio can be manipulated (i.e., is something a negative benefit or a positive cost?).
5. Care must be taken to determine interactions among projects so that combinations of projects providing the greatest aggregate net benefits can be identified (i.e., find interferences and synergies).

**FUNDAMENTAL ISSUES RELATED TO WTP**

**Theoretical Limitations of WTP as Basis for Social Orderings**

- The rule for creating a social ranking of alternatives is not fully satisfactory.
- Arrow's Theorem (AT): K. Arrow (1951) proved that any social choice rule that satisfies a basic set of fairness conditions could produce illogical results. The conditions are:
  - Individuals may have any transitive preferences (axiom of unrestricted domain).
  - If alternative1 is unanimously preferred by all individuals over alternative 2, then alternative 2 should not be chosen (axiom of Pareto choice).
  - The ranking of two alternatives should not depend on what other alternatives are available (axiom of independence).
  - No one person should have dictatorial power (axiom of non-dictatorship).

AT states that any rule that satisfies all four conditions will fail to ensure a transitive social ordering of policy alternatives. Therefore, **the net benefits rule needs to violate at least one axiom if it is always to produce a transitive social ordering of policies.** In order to ensure the use of WTP in implementing the potential Pareto principle will produce a transitive ordering of policies, assumptions (violating the axiom of unrestricted domain) must be placed on individual

preferences (i.e., the utility function of individuals must be such that the individual demand functions that they imply can be aggregated into a market demand curve that has the sum of individual incomes as an argument). Also, all individuals must see the same prices.

Also, compensating variation (a commonly used measure of WTP) can produce Scitovsky reversals. Scitovsky reversals result when the sum of compensating variations for a group of individuals is positive for a move from one Pareto-efficient policy to another and from the new policy back to the original. Therefore, the sum of compensating variation being positive is a necessary but not sufficient condition for a potential Pareto improvement. One can avoid these theoretical problems by assuming policies affect only the price of a single good (i.e., assume away price effects in the markets for other goods).

**Dependence of WTP on Distribution of Wealth**

The WTP of a person depends on the wealth of the individual. So, if the distribution of wealth of society changes, then individual WTP changes, and perhaps, the ranking of alternatives could change. Dependence of net benefits on distribution of wealth is not a problem if losers are actually compensated (*a la* Pareto principle). In the potential Pareto principle, however, it is possible that the policy could lower the sum of utilities if people with different levels of wealth have different marginal utilities of money (since the benefits and costs would be valued differently by different income groups). Therefore, the potential Pareto principle weakens for policies with costs and benefits concentrated on different wealth groups. However, if the potential Pareto principle is applied consistently, winners and losers would even out and the overall effect would be an increase in aggregate utility for everyone.

Critics of CBA question the validity of Pareto efficiency because it depends on the present distribution of wealth. They advocate creation of a social welfare function that maps utility, wealth, or consumption of society into an index ranking alternative distribution of goods. An efficient policy is then one that maximizes the value of the social welfare function. The social welfare function, in practice, must be provided by the analyst. The analyst can either:

- Compare policies in terms of both efficiency and distributional criteria, or
- Report net benefits by wealth or income group as well as for society as a whole.

**Dependence of Net Benefits on Assumptions about Standing**

**Jurisdictional Definition of Society.** CBA usually defines society at the national level. The distinction becomes relevant in policies that spill over national boundaries. Problems also occur at sub-national levels where governments want to look only at their (state, county, etc.) level. To overcome this problem, the analyst can conduct parallel analyses at different levels (i.e., local and national or national and global) as required by either the client or project specifics.

**Jurisdictional Membership.** This is a question as to whose utility should be counted (i.e., illegal aliens, citizens abroad, legal non-citizens, etc.). One answer is to use legally defined rights. This, however, is not always acceptable (i.e., slaves, Jews in Nazi Germany, etc. did not have acceptable legal rights but should still have been counted). This requires analysts to

challenge rights presumptions. Note: CBA only counts WTP of people (not flora and fauna beyond what people are WTP on behalf of the flora or fauna).

**Exclusion of Socially Unacceptable Preferences.** This uses prohibitions to legal rights as a guide about prevailing social values and whether certain preferences should have standing. There is also difficulty in deciding on standing when dealing with preferences from foreign cultures (and their views on the roles of women, for example).

**Inclusion of the Preferences of Future Generations.** This should be included, but it is difficult to measure the WTP of future generations. Usually this isn't too much of a problem because we can use the value (WTP) of people now as a proxy (very few policies affect only the future). Most people today care about future generations and include the interests of the future in their own valuations.

## CONCERNS ABOUT THE ROLE OF CBA IN THE POLITICAL PROCESS

### Does CBA Debase the Terms of Public Discourse?

There are several objections to the pricing of certain goods (i.e. life):

- Decreases perceived value by implying they can be compared to goods traded in markets.
- Decreases value by weakening the claim that some goods should not be for sale at any cost.
- Undercuts the claim that some goods are priceless.

The way non-market goods are actually monetized undercuts the charge that CBA debases public discourse (i.e., monetization of a life isn't the *value* of a life but what people are willing to pay to avoid risks that will result in one less death in a population).

### Does CBA Undermine Democracy?

The concern is that CBA imposes the single value of efficiency on public policy. This would be justified if the comparison were between a world where public policy is determined solely through democratic processes and a world where public policy is determined strictly through CBA. In real life, however, the actual government is not an ideal democracy (i.e., well-organized constituencies are represented better than less organized constituencies) and CBA only has a modest influence on public policy. CBA actually may contribute to a more democratic process by paying attention to diffuse interests that are typically underrepresented.

## LIMITATION OF CBA: OTHER ANALYTICAL APPROACHES

### Technical Limitations to CBA

Application of potential Pareto principle requires impacts to be monetized. If impacts can't be monetized, then one can do a qualitative CBA or, if only one impact can't be monetized, use cost-effectiveness analysis.

**Qualitative CBA.** Monetize as many impacts as possible. Then make qualitative estimates of

the remaining costs and benefits (rough estimates). The analyst can also utilize estimates founds in other CBA's (if short on time or resources). Even if the impact is not monetized, the analyst should quantify it numerically. The degree of accuracy in these estimates will depend on the cost of obtaining them.

**Cost-effectiveness Analysis.** This can be used if the major benefit can be quantified but not monetized. Policies can then be ranked in terms of cost-effectiveness. It does not, however, allow the analyst to conclude that the highest ranked policy contributes to greater efficiency (as the net benefits criteria do). The analyst can evaluate policies in two ways:

- Get as much impact for a specific cost.
- Get a specific impact at the lowest cost.

**The Relevance of CBA When Goals Other Than Efficiency Matter**

One goal (value) underlies CBA (Pareto efficiency). When efficiency is not the only goal or when impacts can't be monetized, multi-goal analysis can be used. If only efficiency and equality of outcome is important, then a distributionally weighted CBA is used.

**Multi-Goal Analysis.** All policy alternatives should be compared in terms of all the relevant values. Analysts must move from values to general goals to specific objectives that can be used to evaluate alternative policies. Evaluate each alternative with respect to each objective. As no one policy is likely to be best in terms of all objectives, the analyst can only make a recommendation using tradeoffs.

**Distributionally Weighted CBA.** Net benefits are calculated for each of several relevant groups distinguished by income, wealth, or some other factor. The net benefits are then multiplied by a weighting factor and then summed and ranked. The main problem is choosing an appropriate set of weights, such as a weight inversely proportional to wealth (or income) or a higher weight on those with wealth below a threshold (poverty level?).

Dissatisfaction with assumptions in distributionally weighted CBA (such as forcing efficiency and equality of outcome to be commensurate) has led some to suggest that a multi-goal analysis be done instead (where efficiency and equality are different goals). Cost effectiveness analysis might also be a more reasonable approach to a distributionally weighted CBA.