Benefit-Cost Analysis of Disaster Mitigation: A Review

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Abstract: Many proponents of disaster mitigation claim that it offers potential benefits in terms of saved lives and property far exceeding its costs. To provide evidence for this, and to justify the use of public funds, agencies involved in mitigation can use benefit cost analysis. Such analysis, if well done, offers a testable, defensible means of evaluating and comparing projects, it helps decision makers choose between mitigation projects, and provides a means to assess the way we spend public funds. In this critical overview of the more contentious issues and latest developments in benefit cost analysis, I emphasize the pragmatic choices that one can make in accordance with good practice in project evaluation.

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1. **Introduction**

Hazard mitigation can help turn natural disasters into natural hazard events. The people of any country can ameliorate many of the consequences of events like floods, fires and earthquakes by mitigating actions such as relocating homes from the flood plain, regularly clearing dry brush near buildings and attaching shelves to walls permanently. These examples offer but a peek into an entire toolbox of mitigation activities and behaviors limited only by resources and imagination. While many people, armed simply with common sense, find the anticipatory and precautionary qualities of mitigation obvious, mitigation remains the poor relative to reactionary disaster relief and recovery. For example, the leading organization in the United States for disaster mitigation, response and recovery, the Federal Emergency Management Agency (FEMA,) spent about $28 billion on recovery between 1988 and 2001 but less than 10 percent of that (about $2.6 billion) on mitigation over the same period (FEMA website.) Of course, mitigation can only do so much to reduce the impact of both natural and man-created disasters, but the challenge currently facing both FEMA in the U.S. and other agencies around the world continues to be justifying expenditures on mitigation programs. In 2003, FEMA will commit over $1 million to an independent study to assess and quantify the savings generated by its hazard mitigation programs.

Traditionally, hazards researchers make a distinction between avoidance, mitigation and preparedness (see for example, Mileti, 1999.) However, the more we reflect on how to deal with disasters the more we see a blurring of any such distinction. Relocating homes from a hurricane pathway constitutes avoidance, but is a traditional mitigation program. Mitigating structures through reinforcement leaves them in the earthquake zone, but reduces the damage that subsequently occurs when the earthquake strikes. Preparedness ranges from a cache of 5 gallons of potable water and plastic sheeting to evacuation plans of the Florida peninsula, and tries to reduce the secondary impacts once a disaster has occurred. FEMA includes in its list of hazard mitigation tools design and construction, land use planning, organizational plans and hazard control (FEMA, 1997.)

By its nature, most mitigation involves employing resources in advance of a disaster to reduce subsequent losses. As such, mitigation has a lot in common with an investment in which we trade present consumption possibilities for greater consumption in the future. This similarity also reveals a means by which we can assess the value of mitigation—by calculating the present value of expected future net benefits. Since mitigation commits resources today, before anything specific has happened, all those involved in the decision from budget officers through policy makers to taxpayers realize that any public and private money used to purchase hazard mitigation had alternative uses (Zerbe and Dively, 1994 p. 277.) We cannot simply assert the value of mitigation and similarly we cannot claim the desirability of more mitigation over less unless we provide evidence of such superiority. Those with the power to allocate public money must provide justification for the expenditures they propose. Since both private and public budgets have limits, not all worthy projects and investments can be undertaken. Public officials must make choices between projects with varying degrees of local and national support. While political and social exigencies play very important roles in decisions to fund various mitigation projects, a method of measuring a project's value is needed and practiced to provide at the very least a common and defensible basis for choosing one program over another.

Even though in the United States, FEMA funds a considerable portion of mitigation activity, state and local government involvement is essential. Consequently, many decision makers appear at the local level. In fact, a substantial proportion of mitigation occurs at the local level, and the people most familiar with the situation make the decisions. Even though natural disaster mitigation, preparedness and response are rightly seen as national issues, state and local government employees must get involved and cooperate. Successful hazard mitigation programs also require the cooperation and active involvement of private individuals and organizations. Since assessing and implementing any mitigation program involves a very large number and variety of people, any measure of program performance and expected return becomes unwieldy if we consult all those involved and affected. Any method used to measure the performance of mitigation programs performance should recognize as many impacts as feasible, and include the best data available from as many of those involved as possible. Benefit cost analysis, and its variants of cost-effectiveness and cost-utility analysis, apply theory-based methods to determine the value of a mitigation program across a wide range of elements of society, from individuals to groups and organizations as well as society as a whole. Even though a number of limitations exist to the method, the basic problem involves trading the desire to "do it right" with the need to make a decision concerning program value on-time and on-budget. The very best practice of BCA makes the required assumptions and analysis choices explicit while remaining as true as possible to the theoretical foundations of the analysis.

2. The theoretical basis for Benefit Cost Analysis

We will not offer a review of the entire development of neo-classical economic theory, but rather briefly consider the theoretical basis for benefit cost analysis to see why it stands as the most appropriate methodology for assessing the performance of hazard mitigation. Modern economic theory proposes the fundamental idea that both individuals and society as a whole have a common goal of maximizing well-being, aware of the constraints imposed by limited resources and competing needs and desires. Any project that reallocates resources could make some members of society better off and others worse off. All those made better off increase their own, and society's well being, while those made worse off suffer some burden, and society also suffers this loss. A mitigation project that reinforces buildings against severe ground movement makes many people better off by reducing the damage, and possible injury, from an earthquake. This will save lives, reduce injuries, lower property damage and shorten the severity and duration of business interruption. The benefits are relatively easy to identify. The costs of such a project include the resources used in the building reinforcement that would otherwise have gone to other projects, including both physical and human resources. The costs are relatively easy to identify. So long as all these resources receive adequate compensation for their use in the project, the project produces net benefits to some individuals and society as a whole. We can express net benefits as the difference between benefits and costs (positive), or as the ratio of benefits to costs (greater than one.) The method of benefit cost analysis lies firmly on the proposition that any project that produces positive net benefits is a good use of resources, and among competing projects, the more preferred ones produce the greatest net benefits.

Benefit cost analysis requires a complete enumeration of all gains/benefits and losses/costs associated with a project and as such produces a “bench mark” for measuring the impact and performance of the project. Unfortunately, we find the term cost-effectiveness used much more in the assessment of public projects. Strictly speaking, cost effectiveness analysis (CEA) is a particular type of benefit cost analysis that clearly specifies benefits and usually fixes them at a particular level, often expressed in non-monetary terms. Boardman, et al (2001, p.437) argue that cost effectiveness analysis (CEA) is done when a full BCA cannot. They list three circumstances that may lead to doing CEA rather than BCA: when the largest, or most important benefit cannot be monetized (e.g. when a policy saves lives, but analysts are unwilling to place a value on those lives); when some benefits can be measured, but others cannot; and when the project impacts inputs to other processes, such as may be the case in mitigation, where mitigation products are valued not for themselves, but for what they contribute to the lowering of damage in a disaster. The medical field uses CEA heavily for programs producing well-defined benefits such as “a 10 percent reduction in a disease caseload.” When the benefits of a mitigation project are not fixed or constant across all applications of the mitigation technology, we should not use a technique that specifically holds benefits constant and only a full assessment of costs and benefits will allow a proper assessment of the project. In many cases, it is only through the process of doing the BCA that we can achieve a full enumeration and description of the benefits and costs of a project. In this regard the more limited cost effectiveness analysis leaves decision makers to either assume, or ignore, many of the other, non-specified, benefits generated. Other methods of assessing mitigation projects exist, including cost-utility analysis (CUA). By recognizing the difficulty of measuring or enumerating some benefits, CUA essentially measures the benefit goal using an index of utility or welfare. This adds more dimensions to cost effectiveness analysis. (Boardman, et al, 2001, p. 444) These other methods do not ignore benefits, but treat them in quite a different and essentially non-numeric way compared to BCA.

Benefit cost analysis uses the economic definition of efficiency as its theoretical basis. Most simply stated, the economic efficiency of a program requires that no change will increase the welfare (happiness) of at least one person without decreasing the welfare of any other person. The corollary of this means we achieve greater economic efficiency by choosing the allocations of resources that increase welfare without decreasing welfare. Unfortunately, few programs will make people better off and no one person worse off. A modified measure, called the compensation principle, measures the net benefit of a program, under the assumption that those made worse off could receive compensation from those made better off, leaving a residual improvement for some people. Benefit cost analysis implements this compensation principle by measuring the benefits and costs generated by a project, and calculating the net benefit by subtracting temporally coincident costs from benefits.

Having established the principle on which BCA rests, many issues, primarily of a practical nature, but some that require a theoretical resolution, emerge in the actual measuring of these benefits and costs. We should measure benefits and costs at their "true" economic values, those that reflect the value of each resource in its best (highest valued) use. Only under quite restrictive circumstances will the price a resource trades at tell us this economic value. Even if we observe a market in which these resources trade, we cannot rely on the market price if any non-competitive influences on that market exist. When a market does not prevail, we have no prices to refer to, and we must measure value by the opportunity cost, or value-in-alternative-use method. Some of the theoretical issues of determining economic value in the absence of markets remain unresolved, and even with market prices, we must attempt to take account of non-competitive influences on those observed prices (Sen, 1972.)

Other issues related to measuring benefits and costs include the treatment of values over time for projects that span many years. At least two major questions emerge in this regard: should we discount future net benefits realizing we must wait to receive them, and how do we acknowledge the inevitable uncertainty that comes when we predict benefits and costs occurring in the future? Both these issues have generated considerable discussion in the peer-reviewed literature, and Stiglitz (1982) provides a comprehensive analysis of discounting while Arrow and Lind (1970) provide the seminal discussion of dealing with risk and uncertainty. The current practice of BCA uses a positive discount rate to adjust future net benefits to the present, but sensitivity analyses included in the BCA usually present estimates of the influence of differences in rates on the net benefit measures. While few analyses use a zero discount rate, such a value would imply the equal treatment of all future generations with the present one. Interestingly, in a survey of 2160 economists, Weitzman (2001) found only 49 economists who believed the appropriate rate of discount for BCA should be zero or less. The sample produced a mean discount rate of approximately 4 percent; however, the discount rate did vary with the length of the project, falling as the life of the project increased.

Knowing that BCA has a strong theoretical foundation does not make it any easier to perform a state-of-the-art analysis. In practice, addressing all the controversial issues in BCA presents an almost impossible challenge. Pragmatic considerations place limitations on how much any one BCA can address any, and all of, these issues. But identifying and understanding them makes for better practice because the analysts must explain and justify their actual decisions. Since all BCA requires assumptions and modeling choices, where the analysts, faced with limited time and financial resources and constrained by the availability of data, make choices of method or analysis, and stand ready to defend them. No matter how well the authors of a BCA deal with the contentious problems, the primary value of the method lies in the information it can provide decision makers. Ultimately, BCA must be seen as an input to a larger decision making process rather than an end in itself. Most disaster mitigation projects involve decisions with physical, economic, political, social and emotional dimensions. Just as the decision to undertake a project should not be based on engineering considerations alone, neither should it rest on political or economic considerations alone. When done at the level of best practice, BCA provides essential and valuable information to assist the decision makers to choose the “best” projects, and to review past decisions to improve those coming next.

3. The practice of Benefit Cost Analysis

Conducting a benefit cost analysis involves following the relatively simple menu below, somewhat edited from Boardman, et al (2001, p. 7):

- [1. Select the portfolio of alternative projects]
- 2. Decide whose benefits and costs count.

- 3. Catalog the impacts and select measurement indicators (units).
- 4. Predict the impacts quantitatively over life of the project.
- 5. Monetize (attach dollar values to) all impacts.
- 6. Discount benefits and costs to obtain present values.
- 7. Compute the net present value [of each alternative].
- 8. Perform sensitivity analysis.
- 9. Make a recommendation based on the net present value and sensitivity analysis.

I have highlighted point 1 and part of 7 since their relevance emerges only if comparing multiple projects. While only an illustrative list, it does not provide a complete statement of the current state of the art of BCA, and fails to mention nearly all the contentious issues surrounding the use, and details, of the method—for example point 5 is clearly not simple. However, it gives the essential elements, and provides a starting point for a discussion of most of these issues and the strengths and weaknesses of the method.

3.1 The scope of the analysis

In theory, a BCA analyst should identify all those individuals who might enjoy gains, or suffer losses, from a hazard, or a related hazard mitigation activity. Generally analysts try to identify those affected directly, and those affected indirectly. In many cases direct affects outweigh the indirect ones, but researchers from environmental economics have found extremely large values for the preservation of certain natural resources by the wider society (so called existence values). So while the direct/indirect dichotomy is useful in establishing a hierarchy of impacts, we must realize that for some hazards and some mitigation projects large existence values may exist. We can make a similar distinction between primary and secondary impacts of disasters. Primary impacts measure the benefits and costs to those directly affected and we can measure these by the willingness of people to pay to enjoy the benefits or to avoid suffering the costs. But through the economic system of inter-related markets, these changes in people's welfare and wealth generate secondary impacts, often called multipliers. The distinction between primary and secondary shares much with that made between direct and indirect impacts. Regardless of these distinctions, the BCA analyst must identify who's welfare will increase, and who's will decrease as a result of hazard mitigation, but only as a result of that program, holding all other things constant.

The scope of a mitigation project deals with the geographic, or spatial, extent of impacts and their timing and duration. For a project with highly localized impacts, we should consider only the benefits and costs falling on the local population, businesses and government authorities. Decision makers will also focus on these impacts because of the direct impact their budgets. While theoretically imprudent, decision makers can also ignore impacts that occur at a great distance, say outside their jurisdiction, or after a long period of time because they see them as relatively small and unimportant, or simply someone else's problem. A local project can have some impact at a distance, if for example, the project uses federal funds, or if the project results in migration of resources. Similarly some projects may have inter-generational impacts that do not appear at first glance. If a project has such inter-generational impacts, future generations should receive standing, despite the difficulties in doing this. We could criticize the analysis of mitigation projects that have large environmental impacts if they do not consider global impacts (Boardman, et al., 2001, p.9.) Even if a hazard mitigation project has some real impact on people living in other countries it may be infeasible to calculate the dimensions of that impact and include it in a BCA (Bar-Yam, 2000.)

A common feature of many BCAs involves choosing from whose perspective the accounting takes place. We should consider the impact of the project from society's point of view as this would include all effects. Yet often the analyst must determine the net benefits to a particular sector of the community, organization or level of government. We find examples where the BCA analyst calculates the impact on taxpayers, or the impact on the government, or the net benefits to homeowners. While a comprehensive analysis would take all these views, including the impact to society, and calculate a net benefit to all groups, and sub-groups, the resources available may not allow for all these calculations.

Every BCA requires that we circumscribe the population of interest, which determines whose benefits and costs we will measure. If done explicitly, the resulting estimates provide decision makers with the best available information on which to base their policies.

3.2 Benefits and costs

The value of hazard mitigation lies in avoiding damage and loss. Mitigation provides protection and so we can calculate its value in the event of an actual disaster by asking the counterfactual: what would society have lost had mitigation not occurred? This makes defining and calculating benefits and costs more difficult because we rarely observe the counterfactual in history, and we must anticipate it for future events. Past disasters provide “real” data on the benefits and costs of mitigation to the extent that we find two, or more, similar communities affected by the disaster, that vary by the application of the mitigation project. Without past data on hazard mitigation impacts, we can employ physical models and simulations to provide estimates of benefits and costs. Analysts must also consider the effect of the mitigation project on the economic environment when defining the counterfactual. For example, without a flood protection project, little new economic activity will enter the region prone to flooding as people avoid the area due to the risk of flooding. With a flood protection project, economic activity of greater value might enter the region. We can attribute the change in economic value between the before and after situation to the mitigation project since the subsequent development occurred because of the mitigation. In this situation only small losses would have occurred without mitigation, but society avoided far greater losses once the mitigation took place.

An additional problem related to the definition of benefits and costs arises when not all affected individuals view mitigation outcomes the same. Although some people will see benefits produced by a project, others may view those exact same impacts as costs. For example, the relocation of residences from the 100-year flood plain may produce benefits of reduced injury and property damage to residents, yet they may lose their connection to land that was historically and culturally important to them, thereby creating a cost in terms of psychological or emotional pain. If these benefits and costs are borne by the same individuals, BCA can easily account for the apparent conflict by measuring and including a net benefit of relocation for these people. We do not need to measure each component separately, but the change in well-being represents the combined effect of both gains and losses. But, if different people bear the benefits and the costs, as when people not relocated bear the costs and those relocated receive the safety benefits, then we have two separate entries in the BCA—the gains to those relocated, and the losses to those who remain. Pragmatically, we must count each change in well-being as either a benefit or a cost, however we remain indifferent to the assignment of impacts to each category so long as gains add to net benefits and losses reduce them.

Identifying benefits and costs separately and correctly helps to realize those groups in society that gain from mitigation and those that might lose. Although the theoretical basis of BCA rests on maximizing economic efficiency, most people do not consider the distribution of those gains irrelevant, especially if policy makers wish to garner support for hazard mitigation activities. The more we can break benefits and costs down into components across individuals, geographical space and over time, the more easily we can see the distribution of impacts, and possibly the need for compensation of those who's welfare decreases due to mitigation.

Many BCAs for hazard mitigation will contain a general taxonomy of impacts using the following terminology. (Thompson and Handmer 1996, p.11)

- Direct impacts (example: strengthening an electricity generating plant reduces the damage in an earthquake, reducing down time.)
- Indirect impacts (example: less down time for the electric plant makes for shorter power outages and reduces business disruption after an earthquake.)
- Intangible impacts (example: better built structures will offer tenants a greater sense of security, just as evacuation plans and frequently checked fire extinguishers create a feeling of safety. People value these "feelings" yet they remain difficult to describe, let alone measure and quantify.)
- Secondary impacts (as mentioned earlier, these impacts could be the same as the indirect impacts, but usually work through the markets that link wholesalers with retailers and retailers with consumers, energy suppliers with producers, for example.)

Experience and consultation with persons and organizations with field knowledge proves essential to identify and categorize all possible impacts and sort them as benefits or costs.

Often increasing the scope of the analysis will improve the chances of obtaining a complete list of indirect and secondary impacts.

The list below identifies some of the possible benefits of hazard mitigation. Potential benefits include the reduction of the following:

- loss of life, injury and pain
- property destruction and damage
- community, personal and local infrastructure disruption
- business interruption, including closures, shutdowns, un- (under-) employment
- loss of or damage to culturally and historically important items
- expenditure on disaster relief by both governments and private organizations
- caution, fear and suspicion both every day, and in hazardous situations

These types of impacts fall into the traditional scope of mitigation benefits, but mitigation may also produce benefits in the related areas of preparedness and response. Mitigation projects can create increased awareness in communities of hazards, their impacts and avoidance, and can assist in response efforts (for example, reinforced communications networks can improve the speed of response and recovery.)

Some of the potential costs of hazard mitigation include:

- direct project expenditures on relocation, construction and transportation.
- increased costs generated by rules and regulations setup in the name of hazard mitigation, e.g. lower property values due to new zoning explain
- denial of access to economic resources (environmental) due to zoning
- increased business expenses to comply with regulations

The BCA analyst will probably start with such lists, but quickly add, or remove, categories depending upon the specific hazard, location and mitigation project under study. Analysts must avoid double counting, something that can occur if they do not properly separate benefits and costs. Good practice requires that the analyst explain all decisions to include or exclude categories of benefits and costs.

3.3 Transfers

A transfer refers to the movement of resources from one person to another, and in general, one gains and the other loses. When the government, through FEMA, allocates federal funds to a disaster, a transfer occurs between taxpayers and disaster victims. Transfers influence and change the distribution of income and resources in the economy. Theoretically, a BCA would only count the so-called transactions costs associated with transfers, if generated at all. These transaction costs involve using economic resources that benefit neither the giver nor the receiver of the transfer. If a hazard mitigation project causes one person to enjoy a benefit because of the transfer of an economic resource from another person, the gain and the loss will cancel each other out, but the transactions cost will remain as a cost.

BCA analysts, or the users of BCA, should deal with transfers if the distribution of impacts of hazard mitigation concerns them. Having made the decision to consider the distribution of gains and losses, the analyst can determine and include distributional weights to represent the relative importance of individuals and groups in society. Layard and Walters (1978) discuss this point in detail, and Boardman, et al (2001) call the resulting analysis distributionally weighted BCA. This type of analysis enumerates benefits and costs by particular groups affected by the mitigation project. When it comes time to sum the component benefits and costs, the procedure weights each value according to the relative importance of the group enjoying or suffering that impact. Of course, how to derive the set of distributional weights remains a difficult, and essentially non-economic question. Even if the decision maker does not use a distributionally weighted BCA, when benefits and costs are identified by group, any particular notion of distributional equity can be incorporated into the decision maker's process as a supplement to the BCA.

All potential gains and losses to those with standing require cataloguing as benefits or costs. When doing a BCA on a program in advance we must anticipate benefits and costs over some period and choose some method to predict values for each component. While relatively easy for impacts observed previously, modeling the impacts of natural hazards and related mitigation projects given the constant technological advances and new products and ways of doing things presents many challenges. Added to this complication is the problem that many benefits and costs do not have an obvious economic value that we can measure by a market price or its equivalent. We can judge a BCA by the attempts made to estimate future benefits and costs when uncertainty is recognized. The analyst can use sensitivity analysis to indicate how the final benefit-cost measures change with various assumptions and future estimates.

Adjusting the scale of the project will affect the size of benefits and costs, which becomes important when comparing alternative projects. If discounted net present value (NPV) measures the project's net benefit, then a larger project will appear superior to a smaller project. A measure such as the benefit-cost ratio will avoid this scale problem. However, we should not pre-judge large projects simply on the basis that they generate large net benefits due to their size alone. The usual decision context has the decision-maker choosing among projects to exhaust a given budget. Very large projects may consume a considerable portion of the budget, leaving money for only a few small projects. Based on economic efficiency alone, we should rank projects by their NPV, and starting with the highest ranked project, proceed down the list until we exhaust the budget. However, as emphasized throughout this survey, decisions to undertake projects do not rest on rankings of economic efficiency alone, and decision makers are aware that large projects require political and social support as well.

3.4 Monetizing impacts

Monetizing an impact requires measuring a benefit or cost and expressing it in terms of the common denominator of currency. The simplest impacts to measure have their consequences reflected in changes in market prices. Under certain conditions, the change in benefits (or costs) to society can be quite well approximated by the change in the consumer and producer surplus. Although technical jargon, these measures simply refer to the surplus of value (benefit) over price paid per unit, and price over cost (of all resources used) per unit. If a mitigation measure prevents the destruction of a power station and shortens disruption of essential services, then the surplus that people enjoy from those services is a benefit that would have otherwise been lost without mitigation. We can use the market price of electricity to calculate the lost surplus under the scenario that the power station was destroyed in the disaster. For smaller impacts, since market prices reflect benefits at the margin, we can use changes in prices to reflect changes in benefits. Unfortunately, market prices only measure benefits and costs accurately in competitive markets. If there is any monopoly power in the market, or some other conditions that prevent markets from working unhindered, prices do not reflect the true costs and benefits to society of a given change. These true values are often called shadow prices, and it may be possible to impute their values from an understanding of how the particular market is being influenced by these non-competitive factors. When mitigation prevents or reduces damage to a resource or input to the production process, we can measure the value of that resource by its opportunity cost—the value that society places on the next best alternative use of that resource.

With the goal of monetizing all impacts of hazard mitigation, the analyst should start with a listing of benefits and costs to be valued using market prices, shadow prices and opportunity costs. However, especially in the case of hazard mitigation, many of the benefits and costs are more intangible than commodities traded in markets, and many impacts do not easily lend themselves to valuation. Some impacts even challenge attempts to monetize, such as the loss of lives, or the destruction of historically important places and artifacts.

3.5 Alternative methods to measure value

Economists have access to a number of methods with which to measure changes in value. All these methods rely on the proposition that willingness to pay to either receive a benefit or avoid a cost reflects value. Market demand and supply schedules and the corresponding surplus generated by market prices directly measure this willingness to pay. When conditions prevent markets from working competitively, or forming altogether, we must find an equivalent of willingness to pay, or surplus, and impute its value. The indirect methods used to estimate values include:

A. Revealed preference methods

Collectively, these methods estimate values based on actual observed behavior, or choices made by individuals. This compares to the other class of valuation methods called stated preference methods. Below we list the major revealed preference methods used in BCA.

A.1. Value of intermediate goods – By carefully studying the production process of the final commodities that used an input affected by a disaster, the analyst can attribute changes in the value of input from changes in the value of the so long as we take care to adjust for any other changes that might have taken place coincidentally. This method often contributes values for specific processes or sectors of the economy in conjunction with other methods. Analysts must avoid double counting using this method since it involves both inputs and final goods.

A.2. Hedonic price model (HPM) – This method imputes the value of such things as differential hazard exposure, or differential mitigation effectiveness from the value of property in an area (or more generally the value of any traded asset.) Controlling for all other factors, housing prices will vary in relation to how buyers and sellers value the differential hazard exposure. For example, a buyer might willingly pay a premium for a house made more earthquake resistant over an otherwise identical house without the treatment. Through their location decisions, and willingness to pay for alternative locations, people purchase bundles of hazard mitigation services that can be valued via the HPM. Data quality remains a problem and the empirical models must include all relevant factors determining property value other than the hazard.

A.3. Travel cost model (TCM) – Analysts can use this method to calculate the value of some economic resource indirectly by measuring differences in associated expenditures across sites that differ in the degree of hazard mitigation. For example, if two otherwise identical recreational sites differ in their hazard risk, or level of mitigation, then people's willingness to travel to one over the other, all other things held equal, will provide the analyst with a measure of the value of the hazard, or its mitigation. Unfortunately, this method may not be capable of separating the effect of mitigation if other characteristics of the site provide much larger value to visitors.

Unfortunately, while economists prefer to use data from actual behavior in markets, the value of many impacts of hazard mitigation cannot be found in market prices or their equivalent. To address the need for values in BCAs, economists have turned to survey-based methods, which while controversial, have become part of mainstream economic practice in the last two decades.

B. Stated preference methods

B.1. Contingent valuation method (CVM) – This method uses responses to hypothetical market scenarios presented in surveys to impute willingness to pay for relevant changes brought about by such policies as hazard mitigation. Both governments and environmental economists accept the basic validity of the method (Arrow, et al, 1993.) As an example of the method, a survey instrument would present a randomly selected group of people information detailing hazards and the consequences in both a mitigated and non-mitigated scenario. The respondents then indicate their willingness to contribute to a fund to pay for the mitigation program. From the responses we can obtain an estimate of the total value for the mitigation program, representing the net benefits these people see coming from the program. Despite the considerable research looking into the issues of sample selection, creating a believable valuation scenario, alternative elicitation methods, how to link value with cost, and how to convert responses into meaningful economic values, much remains to improve the method. Perhaps the strongest criticism of the method remains its hypothetical nature, and failure of the method to establish a connection between respondent's answers and any real consequence to them of their choices, as would be the case in actual markets.

The strength of the CVM lies in its ability to measure values such as existence and option value that are rarely expressed in markets. The value of a natural habitat, or a site of historical importance cannot be determined from prices, even if some exist, since many people may hold these things valuable just because they exist, and may never be observed, or experienced first hand. Even at great physical or temporal distance, many people claim to value environmental protection and maintenance of species. CVM studies find relatively large fractions of stated willingness to pay attributable to the existence of an environmental amenity. Although mitigation primarily protects humans and their built environment, which itself has potentially large existence value, mitigation also indirectly protects the natural environment and so the ability of the CVM to measure existence values makes it a valuable tool in BCA of mitigation.

B.2. Conjoint analysis (CJ) – A method that comes from marketing, it can value multi-attribute commodities and lends itself to valuing changes in environmental amenities and hazard exposure. Compared to the CVM, which collects value data from respondents by offering the same commodity at different buy or sell prices, conjoint analysis asks respondents to choose among various "packages" of commodity attributes, with price as one attribute. The analyst can use this information to derive implicit prices for the attributes, which might include different levels of hazard mitigation, risk exposure, damage for a given hazard event, or similar mitigation relevant characteristics. The advantage of CJ analysis lays in presenting respondents with choices they find more believable, and which will consequently elicit more accurate values. At present and despite the increasing use of CJ analysis to value resources and other environmental amenities, the method remains the newcomer to BCA, and more work has to be done to reconcile the differences in values that this method and more established methods such as CVM generate.

B.3. Benefits transfer method (BT) – While not exactly a method of measuring benefits and costs, the procedure of taking estimates of values from other, related, studies and transferring them to the current study is very common in BCA. Also known as data adaptation or data transfer, the successful use of this method involves understanding the similarities and differences between the original study and the values required for the current study. Demonstration projects of hazard mitigation can provide data for this method to determine benefits and costs for larger projects under study.

The above list and discussion proves to illustrate the variety and nature of some methods available to monetize benefits and costs in a BCA. Ultimately, pragmatic considerations will rule the actual choices made when doing an analysis. Stated preference methods are extremely expensive, whether using the NOAA-recommended telephone method or new internet-based options. It is quite possible for useable responses to cost from \$50 to \$500 each in a well designed, pre-tested and carefully executed survey. Standardizing methods and using existing data helps to reduce the cost of analyses, especially when a large number of mitigation projects needs evaluation.

3.6 Discounting

Having identified and valued all measurable benefits and costs over the life of the project, the analyst must convert all values to the present to perform the appropriate comparison: does the mitigation project outperform the other current alternatives, including doing nothing? Discounting is contentious because of the many theoretical and practical arguments for choosing one discount rate over another. The theoretical debate concerning discount rates for BCA pits the social rate of time preference against private interest rates, at the extremes. The rate of interest paid by consumers to bring consumption forward to today varies between 4 percent and 25 percent, depending on many factors including the collateral offered against the loan. In the case of tax-funded government projects then perhaps the displaced private borrowing rate is the appropriate discount rate for public projects. But most mitigation projects involve capital expenditures, not making consumption goods. The rate of return to private capital investments offers another rate at which we can discount future values, and to the extent that public investments displace private investments, we measure the opportunity cost of public funds the private rate of return to capital. But society may place a different value on foregone consumption to fund mitigation projects than either private consumption, or private investment, especially if public projects are intended to influence the distribution of income of both current and future generations (Stiglitz, 1982). Even though we might conclude from this debate that each project should have a different discount rate, the analyst might make the pragmatic choice and use the rate recommended by the OMB (1994, revised 2003.) The analyst would normally vary the discount rate in a sensitivity analysis to see what effect different rates have on the final measure of net benefits.

As mentioned earlier, real interest rates can fall to zero or less, raising the question of using a zero discount rate when discounting future net benefits. A zero discount rate becomes a focal value since it implies that all benefits and costs to have equal standing, no matter whether they occur now or later. It also implies that society as a whole does not mind waiting for benefits, and that present generations are indifferent between having benefits now and waiting for future benefits, even if they accrue to future generations. Despite these arguments, very few economists or government project analysts would use a zero or negative discount rate in a BCA (Weitzman, 2001.)

The choice of discount rate also raises the issue of whether the benefits and costs are monetized in nominal or real currency values. Because the purchasing power of future dollars can differ from that of present dollars, adjusting nominal values measured in future denominations to current values using some applicable price index seems appropriate. However, choosing the correct price index is not always obvious, as in deciding whether the consumer price index for final goods or the producer price index for intermediate goods should be used. Converting nominal to real values guarantees that general inflation does not alter the calculation of net present value. The analyst must take care not to mix nominal and real values: when using nominal values to measure impacts we should use a nominal discount rate, and when measuring impacts in constant dollars we should use the real discount rate.

3.7 Uncertainty

Benefit cost analyses are fraught with uncertainties. The list below includes some of them.

- the nature, strength and timing of the hazard.
- the relationship between the hazard and the mitigation.
- the outcomes and effectiveness of mitigation.
- the technical, economic, and social environment of the future.
- whether impacts are benefits or costs.
- the future value of presently known benefits and costs.
- the length of the project's effectiveness.

Uncertainties arise from limitations of the data, or our understanding of the relationships between the natural environment, technology and human behavior, or failure to model all relevant relationships in the BCA calculations. Good practice requires that the analyst identify as many sources of uncertainty as possible and an attempt made to account for them rather than convey the impression that all benefit and cost values are fixed and guaranteed. The simplest way of including uncertainty into the calculation of net present value is to use the expected value of uncertain impacts. This requires that the analyst knows all possible values for the benefit or cost, and specifies the associated probability distribution over those values. More often than not we know little about these two components of the expected value calculation, so we must settle for a best estimate of the mean, or median value. If the analyst can specify the probability distribution of net benefits it should be presented in the BCA to provide not only the mean, or average net benefit, but also the range and variance of net benefits. While decision makers have little experience dealing with analyses that provide more than one single-valued conclusion, providing some statistical measure of the variability of the calculation to uncertainty is at least honest and consistent with the data and the modeling.

According to the OMB guidelines for performing BCA, it is inappropriate to use variations in the discount rate to adjust the calculation for particular project risks. But many analyses can capture uncertainty by adding a factor to the discount rate to compensate for the added risk associated with uncertainty (Zerbe and Dively 1994 p328.) According to standard portfolio investment analyses where variation in return is used to measure risk, a premium could be added to the discount rate to account for the uncertainty in benefits or costs increasing the variance of the estimate of net benefits. If the uncertainties arise from benefits and costs that fall on individuals, these risks should be discounted at a private rate that individuals would choose. Alternatively, to the extent that public projects are a way of spreading the risks across the population through the funding mechanism (taxes usually) government investment decisions should be discounted at a rate that ignores uncertainty (Graham 1981; Arrow and Lind, 1970, reprinted 1994, p.163.) Unfortunately, no definitive prescription for handling uncertainty in BCA has emerged.

Sensitivity analysis can provide the analyst with a means of communicating the uncertainties in the analysis. It also allows the analyst to indicate the effect of the assumptions made regarding the data, the relationships between elements of the project under review, and any modeling used to obtain values. Zerbe and Dively (1994, p.372) list two general formats for sensitivity analysis: the variable-by-variable approach and the scenario approach. In the first approach, alternative values for certain benefits and costs are inserted in the calculations and the new values of net benefits recorded. The analyst does this for each value, or category of impacts, with high and low values the most common choices for alternatives. Rather than indicate the sensitivity of the net benefit measures in such a piece-meal fashion, the second method creates scenarios of values for variables together to produce something like a “best-case” and “worst-case” scenario. Sensitivity analysis can also show how the net benefit measure varies with the scale and scope of the project.

When using sensitivity analysis to reveal the effect of assumptions, the analyst should pay most attention to assumptions regarding the models used to estimate benefits and costs. In the case of hazard mitigation projects, the technical and physical links between the hazard, the mitigation action, and the natural and built landscape are key elements in determining the effectiveness of mitigation. Often the analyst will employ sophisticated statistical methods such as Monte Carlo to generate the empirical distribution of estimates. Since value estimates and net benefit calculations rest on many parameters not directly measured or observed for the particular project, such as the discount rate, the inflation rate if real values are calculated, the duration of the project and any terminal net benefits, these become the primary candidates for sensitivity analysis. Because a sensitivity analysis can produce a large number of different net benefit values, often the best way to present the findings is to produce interval estimates of important values as a function of the values of selected parameter (Boardman, et al 2001 p171.)

4. Other Special considerations for Hazard Mitigation BCA

Doing benefit cost analysis for a particular hazard mitigation project properly means comparing the well-being of citizens in two states or the world: after a disaster with mitigation and after a disaster without mitigation. As mentioned earlier, because the comparison involves a counter factual, such an analysis cannot be performed based on observation alone. This problem leads to the more frequent approach of comparing a before-mitigation world to an after-mitigation state. However, the comparison likely includes the impacts of more than just the mitigation project since many things other than mitigation activity could have, and probably did, change between the two states. The challenge to BCA for hazard mitigation is to creatively describe and hence measure the world in the two properly comparable states—disaster with mitigation, and disaster without mitigation. Analysts can combine data from past disasters and mitigation projects with models of new mitigation projects and disasters as they occur to create more realistic frameworks with which to identify impacts and value them. Doing BCA for hazard mitigation requires special cooperation between the people “on the ground”—emergency response teams, risk management people, local bureaucrats, researchers such as flood engineers, seismic experts and building engineers, and economists who can use the methods discussed here to put values to the impacts these other experts identify.

Analysts cannot measure many impacts of natural disasters—the so-called intangible benefits and costs. Some of these have emotional and psychological dimensions. While many benefits of hazard mitigation are losses reduced or avoided, these losses are both physical, in terms of property and commodities, and emotional. Economists are not devoid of emotion, but recognize that valuing changes in emotional states is extremely difficult. Just as in legal cases in which harm has been done to a person, the overriding principle is to make the person whole again, to the extent this is possible through compensation. When non-monetary, intangible, impacts cannot be included in the BCA directly, Thompson and Handmer (1996, p.61) conclude that the analyst identify and list the effects with as much discussion as possible to assist the decision maker when considering their relative importance. The aim of BCA must always be to value impacts that have changed people's well-being, either positively or negatively, using methods consistent with these more widely applied social and legal principles.

5. BCA of hazard mitigation in developing countries

Disasters have the most serious impacts on developing nations. These nations, economically poor by most standards, are the least able to bear the costs of natural and man-made disasters. Estimates put the economic costs of natural disasters 20 times higher, as a proportion of gross domestic product, for developing countries than for industrialized nations (Disaster Relief, 2000.) For the same reason, developing countries are less able, and likely, to divert scarce resources to mitigation activities. Even if the economic return to mitigation is proportionately higher in these countries, the initial costs of mitigation may be too high for governments to consider them. Hazard mitigation is likely to have a low political priority in countries struggling with poor quality resources, little social infrastructure, high unemployment and large foreign debts. Ironically, policies focused on overcoming the most serious problems in developing countries tend to place the population in greater danger when natural disasters occur. In particular, environmental policies (or lack of them) in developing countries tend to exacerbate the damage and loss that occurs in disasters, as was the case, for example, when extensive clearing of land promoted serious landslides in the Hurricane Mitch disaster (Crone, et al, 2001.) Many people in developing countries live in highly concentrated areas in structures that are susceptible to extensive damage and complete destruction in a disaster. Consequently, relatively inexpensive hazard mitigation strategies might reap substantial returns in lives saved and economic losses avoided, yet these programs are slow to evolve as these nations rely on foreign organizations to provide the resources to design and implement them.

The procedure of BCA is the same when assessing a mitigation project in a developing country as in an industrialized country like the U.S. However, there may be considerable differences in the details, especially in valuing benefits and costs, brought about by the widespread failure of markets to operate competitively in developing countries. Many developing nations have large sectors of the economy that are subsistence and non-market, currencies are artificially kept above their true values, labor mobility is culturally and historically low, tariffs and trade barriers distort the true values of imports and exports, and credit markets are highly imperfect. (Boardman, et al, 2001 p. 417) In recognition of these problems, the analyst should not use market prices used to value benefits and costs. Shadow or accounting prices are the preferred values and the LMST (standing for the authors Little, Mirrlees, Squire and van der Tak) methodology uses them for valuing benefits and costs for projects in developing countries. The method makes a distinction between tradable goods (those imported or exported, or close substitutes for these goods) and non-traded goods. All traded goods used or impacted by the project are valued at world prices, rather than domestic prices, and all non-traded goods are valued by their connection to traded goods, as using these inputs, producing them as final goods, or as substitutes for them. Even labor can be valued this way by considering the opportunity cost of labor employed producing non-traded goods rather than traded goods. By using this method, many of the costs and benefits of hazard mitigation projects can be valued. Of course, all those impacts not easily monetized in developed countries remain difficult to monetize in a developing country.

It is tempting to suggest that since the potential benefits of hazard mitigation are so great for developing countries, all mitigation projects should be funded. However, with limited resources and other priorities, it is unlikely that all mitigation projects will be undertaken in these nations. And evaluation of projects is essential particularly when making choices made between many worthy mitigation alternatives. Even if the governments of these countries do not perform the BCAs, or even choose to undertake mitigation activities on their own, if foreign countries and organizations see the opportunity to fund mitigation projects, these decisions should be informed by the same kind of analyses as they would perform on mitigation projects in their home countries and described here.

6. In conclusion, beyond BCA

So what does a practitioner, required to justify program expenses, say to those who would challenge BCA? The pragmatic response sounds defensive, but also defines the approach: given the limited resources devoted to the analysis, follow the best practices and make all modeling choices explicit. Use as much of the available data as possible, choose the best technical and physical models, stay true to the fundamental economic accounting principles that underlie the methodology, and document all decisions and choices carefully and clearly. A critic can understand a transparent analysis, and the analyst can defend it. In a world of incomplete data of varying quality, where we cannot foresee all impacts, or measure every impact, we must make choices. The best practice of BCA explains those choices in the analysis and identifies as many un-categorized, un-measured and non-monetized impacts as possible to assist the ultimate decision maker in assessing the project.

Perhaps the strongest criticism of benefit cost analysis concerns the emphasis on expressing all benefits and costs in monetary terms. Some of the limitations of the measurement methods discussed earlier just reinforce this criticism. This criticism is also often made of economics as a discipline. Monetizing values is simply a convenient metric by which to express value and make comparisons in a world in which comparing apples to oranges is just too difficult. The actions of even the most vociferous critics of economics prove that every choice implies an opportunity foregone, and that with just a little imagination and logic the analyst can link a choice with a foregone opportunity with a known monetary value. The question often left for us to ponder when reviewing a BCA on a particular hazard mitigation project is not what values we place on the monetized impacts, but rather how large, or small, are these compared to the “value” of the non-monetized impacts. Benefit cost analysis alone cannot answer this question, but human experience and reflection can. The need for other considerations establishes for BCA the role as an input to the decision regarding hazard mitigation.

If not BCA, then what method should we use to choose among mitigation projects, and to justify them? Even if other methods, such as cost-utility analysis offer a way around monetizing all benefits and costs, is anything gained, or do we just side-step the tough issues? Everyone involved in disaster mitigation appreciates the emotional, psychological, and social impact of the disasters and knows how mitigation can reduce, and even eliminate some of these impacts. There is already a large body of evidence, from completed mitigation projects and the experience of disasters to document the effectiveness of mitigation. The question remains of presenting this evidence in a way that satisfies the public purse watchdogs as well as helping those wishing to make better mitigation decisions with their limited budgets. No method designed to measure the effectiveness of mitigation projects stands immune to criticism, but if done well, benefit cost analysis offers a consistent, theoretically-based and pragmatic method to present the evidence of the past, and look into the future.

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