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Towards Principles and Standards for the Benefit-Cost Analysis of Safety

Scott Farrow and W. Kip Viscusi

Abstract

Benefit-cost analysis (BCA) is frequently applied to decisions involving public safety which requires analyzing risk and assessing options to manage risks. Principles and standards may assist analysts, decision-makers, and the public in developing and interpreting such BCAs. Principles and standards at best represent commonly held views among a community of practice. Such views are continually evolving with advances in the field. This paper presents a modularized format towards principles and standards that may assist in focusing discussion and decisions about whether such proposals actually reflect principles and standards within the benefit-cost analysis community of practice. Among topics covered are welfare measures, benefit or cost transfer, and valuing uncertain outcomes.

KEYWORDS: safety, risk, principles, standards, welfare

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I. Introduction

This article proposes principles and standards for benefit-cost analysis (BCA) that are of particular importance to public safety policies. Applied economists and policy analysts are often under pressure to deliver their analysis in a specified time frame subject to a particular budget (Committee to Evaluate Measures, 2006; DeMartino, 2011). In the U.S. Government and in some states, analysts may be creating BCAs for which comparison of results across policies is desirable. Moreover, application of consistent standards for analysis facilitates public scrutiny of the economic basis for the policies. It is in such applied work where analytical principles and standards may facilitate producing analyses and encourage replicability, comparability, credibility, and usability. Our principles and standards provide a set of recommended best practices for the analysis of policies affecting public safety but do not necessarily reflect requirements that the analysis must meet.

Public safety issues arise with respect to both privately marketed goods that affect the public and government policies that have a strong public good component, such as highway safety. Public safety concerns arise in a wide range of activities in general categories such as security, physical safety, natural hazards, environmental risks, public health, product safety, and employment hazards. Each of these areas of potential risk exposure has specific component risks such as those posed by crime, terrorism, food products, floods, and transportation. Fundamental to each component is that there is a chance of a bad outcome including risks arising from nature as well as those arising from individual behavior. Typically, there are also personal choices that affect one's exposure to risk as well as possibilities to alter the risk or its consequences through adaptive actions, preventative activities, and the purchase of insurance.

Just as the range of public safety policies is quite broad, the applications of BCA to policy decisions involving public safety are also diverse. The different contexts in which BCA is utilized are associated with different literatures, communities of practice, and outlets for publication. Agencies implementing risk policies range from local police and health departments to state offices and national agencies such as the Federal Emergency Management Agency (FEMA), the U.S. Coast Guard, the Transportation Security Administration (TSA), the U.S. Environmental Protection Agency (EPA), the Consumer Product Safety Administration (CPSC), the Food and Drug Administration (FDA), the U.S. Army Corps of Engineers, and the U.S. Department of Transportation (DOT). Agencies at different levels of government use formal BCA with varying frequency in all these applications. In many instances, preparation of a formal BCA is required by law or by executive order. The role of BCA in the decision-making process ranges from being a minor component of the policy decision to being the key test that the policy must pass.

Consequently, this article focuses on principles and standards for applying BCA with respect to public safety actions directed at reducing risk to the public.[1] How risks should be incorporated theoretically and empirically into BCA is the focus of our proposed principles and standards. One can view these guidelines as being embedded in a larger set of principles that may be generally applicable to BCA.

Context: Applied Welfare Economics and Risk

Economic behavior and markets play a fundamental role in determining the levels and consequences of risk. However, the effect of these economic contexts on risk levels is often less direct than for standard consumption goods as the risk may be bundled as one of many product attributes. It is often possible to buy, sell, and manage risk in various direct or indirect ways so as to change probabilities, reduce damages, and shift the cost associated with adverse outcomes.

In general, theoretical economic analysis of uncertain outcomes such as those involved with public safety has as its foundation expected utility theory (e.g. Luce and Raiffa, 1965; Raiffa, 1968; Pratt, Raiffa, and Schlaifer, 1995; Hirshleifer and Riley, 1992; Just, Hueth and Schmitz, 2004; and Eeckhoudt, Gollier, and Schlesinger, 2005). Although alternative models of choice under uncertainty have proliferated in recent decades, most of these have been developed to incorporate empirical anomalies and various forms of irrationality and inconsistencies in behavior. The expected utility model remains the standard reference point for normative decisions. The expected utility model is based on a series of assumptions that establish a rational basis for decision, such as the assumption that increasing the probability of an adverse outcome makes the risky "lottery" less attractive.

The expected utility model hypothesizes that individuals have a utility value for each of the possible outcomes and that they weight the utility values linearly using the probabilities associated with those outcomes as the weights. Such analyses focus on the probability and the utility of outcomes without a distinction regarding good or bad probabilistic outcomes. In other words, in the theoretical literature "risk" is not necessarily linked to a negative outcome, only a probabilistic outcome in which the dispersion of possible outcomes has implications that either increase or decrease utility. The chance that you will win the lottery, and its complement that you will lose and win nothing, is

[1] This article was originally developed as one of a series of papers on principles and standards in which authors addressed both cross-cutting concerns in benefit-cost analysis, such as discounting, and a particular topic, here public safety.

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consequently a "risk." Abstracting from the cost associated with the lottery ticket, this risk has favorable implications unlike the adverse risks that tend to be the focus of public policy efforts.

What role expected utility theory should play in policy decisions involving risk depends on who is affected and to what extent. When asking how beneficiaries of flood control projects value the reduction in flood risks, there should be recognition of the preferences over uncertain outcomes of those who will be protected by the policy. Thus, individual risk preferences may be quite germane in constructing society's willingness to pay for the benefit, which is the fundamental benefits principle of BCA. However, some policy risks, such as the uncertain cost of the flood control project, can be spread across the entire population with little financial consequence for any particular individual. In this case, the individual stakes are sufficiently small that risk aversion is not a concern for a societal BCA. How risk enters the societal tally of benefits and costs depends on the distribution and magnitude of the outcomes. Most applied benefit-cost analyses, consistent with standard practice for analyzing expected value outcomes, undertake the analysis in a manner so that it is possible to reduce expected utility to expected value. This approach is typical both for individuals and aggregates based either on reasoning that projects have a small impact on individual income either directly or through the availability of insurance, or that society effectively holds a portfolio of policy investments that insures against individual risk (OMB, 1992; 2004; Boardman et al., 2011, p. 215-218; Arrow and Lind, 1970). When large risks are borne by individuals, *ex ante* measures of the willingness to pay of individuals will incorporate recognition of individual risk aversion, such as an option price (Just, Hueth, Schmitz, 2004; Fisher and Pindyck, 2000; Boardman et al., 2011, p. 203-214). People's willingness to pay to avoid personal catastrophic losses from natural disasters could, for example, enter the analysis, but even here the valuation of the risk can be converted to a certain monetary equivalent. Where risks are more collective or systematic, perhaps because they involve large interrelated systems such as finance or broadly scaled public health concerns, then a stronger case might be made for departures from expected value (Boardman et al., 2011, p. 215-218).

Perhaps more than many other areas of economic scholarship, the research relating to risk and uncertainty is rapidly evolving. How people actually make such decisions may be quite different than what expected utility theory predicts. For example, making decisions involving very small probabilities of catastrophic outcomes may be quite difficult. The creative tension brought by those working at the boundary of psychology and economics, which has developed into a field known as behavioral economics, is appropriately pushing the structure of theories with empirical observation and competing theories. Recent reviews include those by Robinson and Hammitt (2011) and DellaVigna (2009). Similarly, policy issues with large degrees of uncertainty, such as homeland security and long term environmental policies, have pushed research on decision modeling towards greater robustness or adaptability (Hansen and Sargent, 2008; Dixit and Pindyck, 1994; Lempert and Collins, 2007).

However, for purposes of providing guidance with respect to how the government should make decisions involving public risks, the expected utility framework provides the current standard default framework for decisions in the economics literature. Although there are political pressures that often lead the government to institutionalize individual irrationalities, as discussed in Viscusi (1998), these tendencies should be resisted. Notwithstanding the substantial research that has demonstrated numerous inconsistencies and irrationalities in individual choice, we generally advocate a set of principles and standards that embody a consistent and rational approach to policy evaluations and governmental decisions.

Risk and uncertainty are used here synonymously. The probabilities associated with different possible outcomes or states of the world often are based on a subjective risk framework since there may be few classical risks that are known with precision (Hirshleifer and Riley, 1992, p. 9-10; Raiffa, 1968). Probabilities such as the average motor-vehicle fatality risk are well understood risks because we have a great deal of information about the probabilities based on observing a large population and events with frequent occurrence. In contrast, hazards such as the dangers of climate change or the mortality risks posed by newly identified diseases such as swine flu are not as well understood and fall into the category of uncertainties. In situations in which a distinction between risk and uncertainty appears useful so as to emphasize the important role of unknown randomness in situations of uncertainty, then it will be used. However, for purposes of policy decisions, we will treat probabilities of an adverse outcome symmetrically whether they are precisely understood risks or dimly understood uncertainties. Perhaps the most important distinction is that in situations of uncertainty there is often the opportunity to learn more about the level of the probabilities, creating opportunities for information acquisition. Because elements of risk are important in areas outside of public safety, many of the same concerns surveyed here are also relevant in other application areas. A more extreme case than uncertainty is that of ignorance in which we do not know even the different possible states of the world to assign probabilities.

Even if the underlying policy context does not involve an element of risk, the empirical analysis of the policy choice may introduce aspects of uncertainty. Most obviously there can be measurement error of theoretically correct components of the BCA as well as variability across responses in the system and random error. Morgan and Henrion (1990, p. 56-69) elaborate on the various sources of uncertainty in quantitative analysis and list the following categories:

1. Random error and statistical variation
2. Systematic error and subjective judgment
3. Linguistic imprecision
4. Variability
5. Inherent randomness and unpredictability
6. Disagreement
7. Approximations

Debate has gone on for centuries about the distinctions embodied in these and other possible categories, in part because some uncertainties may be associated with more than one category. The purpose of this listing is not to establish a framework to compartmentalize the different sources of uncertainty but to point out that a variety of issues about risk and uncertainty occur at both theoretical and empirical levels of a policy analysis.

Principles and Standards: Sources and scope

This article is not the result of a committee deliberation. Nor is it based on an explicit hierarchy of sources such as used in accounting (U.S. GAO, 2005), as there are no existing standard-setting organizations for BCA. The result is that we place substantial reliance on textbooks, professional articles, and current government guidance as well as our views based on teaching, consulting, research, and government practice.

Common sources of standards for the benefit-cost analyst in Government are guidance documents issued by the U.S. Office of Management and Budget (OMB, 1992, 2004) or similar institutions in some other countries. These documents and supplemental guidance issued by individual agencies describe expectations about BCA in the text, but generally do not break out individual standards. The guidance applies to government projects and regulation pertaining to safety, risk, and uncertainty. In addition, some prominent authors on BCA have published their consensus views on principles and standards (Arrow, et al., 1996), and recent texts on benefit-cost analysis and applied welfare analysis include those by Boardman et al. (2011), Jones (2005), Brent (1998), Zerbe and Dively (1994), Hanley and Spash (1993), Gramlich (1990), Stokey and Zeckhauser (1978), as well as collections of major articles such as those in Schmitz and Zerbe (2009), Zerbe (2008), and Layard and Glaister (1994).

Essentially all applications of *ex ante* BCA used to project policy outcomes involve aspects of risk and uncertainty, such as uncertainties about particular variables in the analysis. Evaluations of public safety policies often bring the issues to the core of the analysis since various aspects of risk are intrinsically involved. The areas of application that may be considered as

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pertaining to public safety and that are significantly driven by risk and uncertainty include but are not limited to the following:

1. Security: crime, terrorism, defense
2. Safety: traffic, building codes
3. Natural hazards: waterway control, fire, wind, flood, earthquake, tsunami
4. Environment: water, hazardous waste, pollution, climate change
5. Public health: disease, sanitation
6. Products: food, motor vehicles, tobacco, drugs, and other consumer products
7. Employment: occupational risks

Our principles for analyzing such policies are intended to be general, few in number, and to provide a touchstone for more detailed standards. Standards are meant to provide specific guidance for modeling or empirical estimation in BCA, and in fact could be called guidance. We do not consider the "standards" as being necessary and sufficient for a good analysis, but we believe that analyses that are inconsistent with these standards could either be improved by following the standard or should depart from the standard only after a reasoned justification.

While the standards are not explicitly linked to principles in the presentation here, their development included that link. Theoretical and empirical issues related to risk and public safety issues addressed here may be usefully combined with principles and standards for other issues such as those related to general versus partial equilibrium, the cost of public funds, or other topics. The standards are separated into standards with respect to the theory of BCA and empirically oriented standards, where each of these has sections devoted to established and emerging standards. The modularized format for such principles and standards is somewhat unusual in that they are short, follow a specific template, and provide broad-based references; the proposed principles and standards are presented this way in order to focus discussion and to facilitate possible decisions regarding their use.

II. Proposed Principles for the Benefit-Cost Analysis of Public Safety

1. Provide realistic representation of the risks and the policy context. The analysis should faithfully represent economic reality based on behavioral responses and uncertainty based on our current understanding. Where components of the analysis are not well understood, there should be an explanation of the lack

of understanding due, for example, to resource limitations or inherent uncertainties that cannot be resolved.

2. Applied welfare economics is the theoretical foundation for public safety and BCA generally. The foundational principles defining what is to be measured are those that are generally accepted in professional economics literature. There is explicit recognition that such foundational elements are not unanimous and evolve, often through interaction with other disciplines.

3. Do not become paralyzed by the impossibility of preparing an ideal analysis. Analyses may be informative even if they do not adhere to all principles of welfare economics or other theoretical tools. It is often possible to adopt theoretical refinements in an analysis and to refine estimates of the risk but doing so may not alter the overall policy assessment or optimal policy choice.

4. Provide unbiased risk analyses so as not to usurp the decision-makers. Generate information that is valuable to decision-makers using a range of decision approaches involving uncertainty. However, do not embed in these analyses conservatism and similar adjustment factors that prevent the decision-maker from learning about the actual risk probabilities. Do not usurp the decision-maker's role unless the decision-maker has previously given approval or if abiding by the results of the BCA is a requirement imposed on the decision-maker.

5. Strive to report monetized outcomes of risks so that risk outcomes can be compared to costs and other policy benefits. Qualitative, quantified, and monetized measures are all useful, but the goal is a series of numerical analyses that allow a decision-maker to understand the impacts of a decision in a monetary or equivalent metric while also being able to view key quantities and values that lead up to the monetization. Establishing a single monetary metric for policy benefit and cost components facilitates comparisons. While some policy impacts by necessity may remain in qualitative terms, if there are too many such components the analysis tends to become unwieldy and with an accompanying danger that the policy choice will be made independent of the non-monetized components and the overall economic merits of the policy.

6. Assume that there is statistical randomness in the components of the analysis. If a numerical value is considered to be important and not analyzed as a random variable, one should explain why it is not. Discussing uncertainties is an essential component, but the existence of uncertainties with respect to parameters in a policy analysis should not be a barrier to identifying the policy that maximizes the difference between the appropriately risk-based level of net benefits.

7. Avoid false accuracy that abstracts from underlying uncertainties. The modeling assumptions and reporting of numerical values should convey information about the accuracy of the estimates.

8. Consider proportionality of effort. Analytical effort should be expended to the extent that it might change the policy decision as indicated by the value of information gleaned from such an effort. Many policy decisions hinge on a single key component. Identifying the critical parameters and ascertaining their value is a critical aspect of judgment required for effective policy analysis.

9. Choose the appropriate scope of analysis. Judgment is required in selecting the breadth and temporal dimension of the analysis that is pertinent for the risk policy decision, but the scope is often dictated by what factors are relevant for the BCA. For example, the time period for analyzing policy decisions may be different than the time period for assessing policy effects. Longer term technology uncertainties may make it infeasible to analyze decisions with temporally remote effects, such as those affecting future generations. Nevertheless, the analysis should assess important longer term consequences of the decisions and should not be truncated so as to coincide with the period over which policy decisions are being made. In some settings, this is similar to a life-cycle analysis.

10. Acquire information economically. Acquire information about key uncertainties when it is feasible and may affect the outcome of the analysis. The presence of hazards that are uncertain and do not entail precisely estimated risks creates a potential for acquiring information that will foster better understanding of the probabilities. Refining risk assessments is often desirable, but often the best that can be done is to utilize judgmental probabilities. Perfect information about risks is seldom available, and there is a cost to information acquisition. One of these costs is that failure to act often has important opportunity costs.

11. Policymakers should not usurp the policy analysts' role. Political forces and agency biases should not dictate technical issues. Nor should policy investigations of feasible and potentially desirable alternatives be unduly limited.

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III. Proposed Standards

Proposed Established Standards (S): Theoretical and Empirical

THEORY

S-THEORY-1

Issue: Does the potential exist to increase economic efficiency?

Standard: Identify some type of market failure or government failure.

Discussion: The focus of welfare economics and hence of BCA is determining whether an action increases economic efficiency. In the absence of theoretical or empirical evidence suggesting a market or government failure there is little expectation that there will be positive net benefits from action. For example, the existence of externalities from pollution and transaction costs that establishes barriers to Coasean bargains to externalities imply that private actions by consumers or firms will be inefficient. Consequently, it is possible for policies to increase efficiency compared to market outcomes. If the analysis claims that the policy will raise individuals' welfare or firms' profits, then a useful check on the analysis is to inquire what market failure currently prevents these gains from being realized. Analyses that claim that a policy that imposes costs on firms but nevertheless will boost firm profitability often are based on faulty assumptions and should include a compelling demonstration of a market failure that would generate such an outcome.

References: U.S. OMB (1992), most texts.

S-THEORY-2

Issue: What are the benefits of increased safety?

Standard: The standard benefit measure is the willingness to pay of those affected by the policy to reduce the risks of the bad outcomes that would have occurred compared to the base case. In some policy contexts, the benefit measure for policy may be specified as a willingness-to-accept measure. However, empirical anomalies in willingness-to-accept values make willingness-to-pay approaches preferable. Standard practice in assessing policy consequences remains the use of after-the-fact (*ex post*) consumer surplus although *ex ante* values are preferred (see Frontier Theory Standard 1) for prospective analyses and from the standpoint of unbiased benefit assessment.

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Discussion: Public safety issues generally involve probabilities of outcomes perceived as socially "bad," e.g., floods, crimes, and illness, which may or may not be at inefficient levels. As the primary outcome of concern is a "bad," the policy achieves benefits by reducing the frequency or severity of the bad outcome. The problem can be framed as a trade-off between two types of costs: reduced value (cost) of harm and the implementation cost of avoiding the harm. Those benefiting from the forecasted reduction in harm are assumed to treat such reductions symmetrically with more standard benefits. Examples include reductions in pollution that reduce bad health outcomes and reductions in damage from natural disasters or terrorist attacks.

References: Freeman (2004, p. 324-336), Boardman, et al., (2011, p. 202-218)

S-THEORY-3

Issue: What welfare measure should be used?

Standard: Marshallian demand based on willingness to pay.

Discussion: Welfare measures based on consumer surplus typically use Marshallian (uncompensated) demand functions. Willig (1976) developed bounds on the error from the use of Marshallian consumer surplus instead of that based on a compensated (Hicksian) demand. The Willig article has been reprinted in a number of places including Zerbe and Dively (1994, p. 111-113; Jehle and Reny, 2000, p. 170). The error in using the Marshallian demand can be large if only the deadweight loss is being measured (Hausman, 1981; Haveman, et al., 1987).

Further, linear or constant coefficient approximations are frequently used when better information is lacking. Linear forms allow relatively easy closed form solutions and permit basic analytic geometry to be used to construct estimating equations. More advanced work often deals with more general functional forms such as constant elasticity or "exact" surplus measures. See Frontier Theory 2 for exact measures of surplus.

References: Boardman et al. (2011); Freeman (2003, p. 53-68); Zerbe and Dively (1994).

EMPIRICAL

S-EMPIRICAL-1

Issue: What value should be used for point estimates?

Standard: Use the statistical expected value (mean) for point estimates or lacking that, a measure of central tendency.

Discussion: There are two justifications. The first is statistical as the fundamental operations in BCA are addition and subtraction. The addition or subtraction of expected values is also the expected value. Other measures of a random variable are not generally additive in this fashion. Further, first-order approximations of functions of random variables such as products or division use expected values. The second justification is decision-analytic. A risk-neutral individual or social decision-maker makes decisions based on expected values (e.g. Boardman et al., 2011; Arrow and Lind, 1970). If the decision has a small effect on income or other major determinants of preferences, then the decision-maker may be risk-neutral. In situations of risk aversion, the expected willingness-to-pay values for benefits should recognize the influence of risk aversion so that from the standpoint of making the policy choice the expected benefits and costs should be the guide.

References: Arrow, et al. (1996), U.S. OMB (1992).

S-EMPIRICAL-2

Issue: When should some number be used instead of no number?

Standard: In contexts in which there are available data to assess the precision of a number, that number can be used when the mean is significantly different from zero, where statistical significance is often taken to be a 5 percent level of confidence in situations in which such bounds are computable. In some contexts, one must rely on judgmental probabilities as there are either no data or insufficient data to calculate these probabilities.

Discussion: Specifying these values and incorporating them in the analysis can promote sound analyses that systematically recognize the decision maker's estimates of the likely effects. Often such judgmental probabilities can be provided as a sensitivity analysis; e.g., how large must the probability of a terrorist attack be for a particular precaution to pass a benefit-cost test?

A different context for this question arises regarding the use of shadow prices estimated elsewhere, some of which may be generally accepted by analysts and others of more contention. Analysts are typically encouraged to consider whether the shadow price can be adapted for the specific population at hand. See Empirical Standard 3, Boardman et al. (2011, p. 406-436) and Desvousges, Johnson, and Banzhaf (1998).

The role of significance tests depends on whether the information available for the analysis makes this a situation in which principles of classical statistical inference are pertinent, or whether by necessity judgmental probabilities and valuations must be used following Bayesian decision theory. Since numbers are assumed to be random variables, if the point estimate can be tested and a null hypothesis of zero is rejected then the number should be used in the classical statistics case. Perhaps the greatest danger is to abandon quantitative analyses altogether because of the imprecision of available data. Systematic thinking about policy effects is generally assisted by analyses in concrete numerical terms even when such numbers may be imprecise so that the best estimates of the distribution must be relied upon when undertaking the analysis.

Sensitivity analysis or other uncertainty methods may investigate the implications of the standard. For instance, although an estimate (coefficient) may be insignificantly different from zero, theory may indicate that the estimate is unbiased and the best available (e.g. minimum variance among linear unbiased estimates). The lack of significance may be viewed as an issue of needing more information or an inadequate sample size. Analysts may wish to investigate the robustness of their results using insignificant estimates. Further, classical measures may be unknown or poorly understood, as with terrorism risk, and so Bayesian methods for elements of a statistical distribution may be used.

References: Standard econometrics textbooks, Raiffa (1968), and Pratt, Raiffa, and Schlaifer (1995).

S-EMPIRICAL-3

Issue: When should the analyst use a point estimate developed in one location or context in a new analysis, which is a procedure often called benefit transfer or cost transfer?

Standard: To the extent possible, the point estimate should be adjusted for conditioning factors using a benefit transfer function. Whether such adjustments are made or not, the analyst should explain the reasons why the data and results obtained elsewhere are applicable to the new analysis.

Discussion: The underlying statistical population should be similar between the initial study site and the new analysis. For example, the use of recreational benefits in one area, such as a beachfront, may not be appropriate in another. There also may be differences in the population characteristics and utilization of the beachfront and these often can be recognized through the use of the pertinent elasticity of demand with respect to these characteristics, such as income. Also, the value of a statistical life based on workers may not be appropriate in other settings in which deaths occur, such as those due to terrorism, or to other populations, such as the elderly. The willingness to pay based on estimates for the average U.S. population may not be reflective of the willingness to pay of those affected by the policy. Sensitivity analysis or other uncertainty methods may investigate the implications of a point estimate transferred by one location to another as from Empirical Standard 4.

References: Boardman et al. (2011, p. 433-436); Freeman (2003, p. 453-456), Desvousges, Johnson, and Banzhaf (1998), Viscusi (2011).

S-EMPIRICAL-4

Issue: How should the variability in outcomes due to parameter assumptions be assessed?

Standard: Investigate the sensitivity of the point estimate result at least with respect to key alternative values as might exist in the literature. In addition, consider a systematic adjustment of key variables in the analysis by changing their value by a common amount, such as 25 percent (stress testing).

Discussion: Sensitivity analysis as a "what if" investigation of empirical alternatives can investigate specific issues in the literature or policy debate; systematic variation in parameter values improves comparability of outcomes. More advanced approaches are discussed as Frontier Empirical Standard 1.

References: Boardman, et al. (2011, p. 177-187).

S-EMPIRICAL-5

Issue: What is the link, if any, between the discount rate and uncertainty?

Standard: Use the appropriate real or nominal discount rate as specified by the sponsoring agency. Do not add an uncertainty premium into the discount rate. Various justifications for different levels of the discount rate implicitly include some return for risk when private sector crowding out is assumed; and the risk-free rate has been supported based on risk pooling across governmental investments. Lower interest rates are often based on pure time preference rates.

Discussion: Consider a typical discounting calculation as involving a value, which is the numerator, and a discount rate term in the denominator. Some initial approaches in the literature suggested adjusting the discount rate using information on the price of dispersion (risk) and the quantity of risk associated with the project (Zerbe and Dively, 1994, p. 332-333; see also Burgess and Zerbe, 2011). More recently, the focus has been on adjusting the numerator for risk and discounting at rates believed to be associated more directly with time. Thus, the role of risk can be incorporated in the expected benefits at any point in time rather than through the discount rate, which imposes a mathematical structure on the influence of uncertainty over time that may not be reflective of the temporal influence of uncertainty.

What are being discounted are the monetized values—the expected benefits and costs at different points in time—not physical units. If the unit dollar benefit value is constant over time, then discounting physical units is appropriate. But often there is a growth in these unit benefit values due, for example, to increases in income or greater scarcity of resources. If the unit benefit value is growing at a rate g and the discount rate is r, where r>g, then it is appropriate to discount the value of physical units over time or the benefit value based on current unit benefit amounts using a discount rate of r-g. See also the Frontier Empirical Standard 2.

References: Boardman et al. (2011, p. 263-265), U.S. GAO (1991), Lind (1982), Portney and Wyent (1999), Viscusi (2007), Summers and Zeckhauser (2008), and Dasgupta (2008).

S-EMPIRICAL-6

Issue: What characteristics of random variables should be reported?

Standard: The mean, median, and measures of dispersion such as the range, the interquartile range, and standard deviation of key outcomes such as benefits, costs, and net present value.

Discussion: In practice, the social welfare function is not known nor is that of the decision-maker. It is useful to provide to stakeholders and decision-makers information about the variability in the outcomes so that the decision-maker(s) can be informed about elements that may influence their choice. The range, meaning the minimum and maximum, leaves interpretation to the decision maker of the probability within that range. To the extent possible additional information such as a 95 percent confidence range or full information about the distribution should be presented. Further, the visual display of quantitative information can be valuable. Probability density and cumulative distributions have been used with varying success to communicate uncertainty to decision-makers. There may of course be values at the extreme of a particular distribution that may imply quite different policy choices than derived from the mean values. This may provide a reason for further assessment of the key parameter values, but the potential influence of extreme values on the policy choice does not imply that the decision based on the means is incorrect.

References: Arrow, et al., (1996); Krupnick, et al. (2006).

Proposed Frontier Standards (FS): Theoretical and Empirical

THEORY

FS-Theory-1

Issue: How should the analyst value uncertain outcomes?

Standard: Monetize individual values using an *ex ante* measure that explicitly accounts for uncertainty.

Discussion: Current thinking is that elements of uncertainty are appropriately captured in people's valuations of *ex ante* costs and benefits taking into consideration risk preferences such as risk aversion. The value of a statistical life is one such *ex ante* measure that reflects prior individual preferences with respect to reducing risks of death. Addressing the value of uncertain outcomes more generally, such as valuing the chance that one might be interested in using a natural resource at some future date, has turned out to be empirically difficult although substantial theory exists. Approaches include obtaining the option price which is the monetary metric linking the expected utility of the gamble with the utility of the certainty equivalent; adjusting expected damage (*ex post* measure) using theoretical adjustments; using the larger of expected surplus or option price if fair insurance is available; and using quasi-option or real option values if the decision-maker can adapt to new information and decisions are irreversible. For example, committing to irreversible capital investment today may give up the option value of investing tomorrow as new information arrives, which is a real option value. Alternatively, people may be willing to pay for a form of (approximately) state-independent payment consistent with option price, for example the purchase of sprinkler irrigation which incurs a certain cost but may stabilize income in either wet or dry years.

References: Boardman et al. (2011, p. 202-213); Freeman (2006, p. 209-252), Dixit and Pindyck (1994), Viscusi (1992), Viscusi and Aldy (2003).

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FS-Theory-2

Issue: What welfare measure should be used?

Standard: Use "exact" consumer surplus based on compensated demand.

Discussion: Duality theory provides methods for exactly calculating compensating or equivalent variation measures of consumer surplus given estimated parameters. Methods are based either on integrating an estimated Marshallian demand curve back to underlying expenditure and indirect utility functions, or to assume a known utility function to derive appropriate Marshallian demands. If econometric methods are used to estimate the parameters, the variance of the estimate can be computed given the known, but generally non-linear, structure of the exact consumer surplus measure. Under some conditions, non-market valuation linked to market observables can be carried out although failure of integrability, separability, or some non-market conditions may invalidate exact estimation.

References: Freeman (2003 p. 69-72, 101-122), Hausman (1981).

FS-THEORY-3

Issue: How should insurance be included in the BCA?

Frontier standard: Use to inform an *ex ante* evaluation based on premiums or an *ex post* measure of damages based on insurance claims paid.

Discussion: If insurance were actuarially fair, then by definition insurance premiums would equal the expected loss. Notwithstanding the practical difference between insurance premiums and losses, risk-averse people often purchase insurance and the premiums they pay would provide an estimate of the *ex ante* willingness to pay for the level of risk reduction. With insurance loading and multiple risks, the estimate is biased. Many people may forego the purchase of insurance even though they are risk-averse if the premiums are too high so that their valuations will not be entirely captured by insurance premiums. When an insured event occurs, there is a transfer of funds based on a partial estimate of damages given the degree and extent of coverage. For example, voluntary risk premiums paid to avoid flooding may inform estimates of the value of structural improvements to reduce flooding.

References: Boardman, et al. (2011, p. 211-213), Freeman (2003, p. 210-221), Krutilla (1966), Schleisinger (2000).

FS-Theory-4

Issue: Does a budget constraint change the recommended decision rule?

Standard: With constrained budgets the incremental net welfare measure, usually expected net present value, should equal or exceed a threshold value larger than zero.

Discussion: Equality constrained optimization problems typically yield the result that the change in the objective function due to a choice variable (the first-order condition identifying the incremental impact) should equal the shadow price of the constraint, the Lagrangian multiplier. As all first-order conditions equal the same shadow price for a budget constraint, the standard follows. The implication is that some projects that may pass an unconstrained benefit-cost test (positive expected net present value) will fail the test based on limited resources. For example, the optimal allocation of homeland security expenditures across sites should equalize the marginal expected social costs avoided and the shadow price of the constraint. A related standard based on benefit-cost ratios is discussed in the references for choosing among a set of projects with a fixed budget.

References: Stokey and Zeckhauser (1978); Bellinger (2007, p. 157), Farrow (2007).

EMPIRICAL

FS-Empirical-1

Issue: How does one estimate the statistical distribution of outcomes?

Frontier standard: Implement Monte-Carlo simulation analysis using information on the statistical distribution of input assumptions and their inter-relations in the model.

Discussion: Many software applications now allow Monte Carlo simulation when the user specifies input distributions and inter-relations. The output of such simulation can be reported via tables, graphs, and interpretive data such as the correlation of inputs with outcomes, tornado diagrams, and similar diagnostics. For example, models such as BENMAP (US EPA, 2010) or FERET (Farrow, et al., 2001) utilize different simulation tools to estimate the benefits or net benefits of pollution reduction based on distributions for concentration-response functions and for the value of various health outcomes.

References: U.S. OMB (2003); Boardman, et al. (2011).

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FS-EMPIRICAL-2

Issue: What is the appropriate discount rate with long-term risks?

Frontier standard: As indicated in Standard Empirical 5, the discount rate for near term effects is generally specified by agency or OMB guidance. Discounting of remote risks, such as those faced by future generations, is more problematic and remains an active area for emerging economic research. We do not believe there is wide-spread acceptance of a common alternative approach other than investigating the sensitivity of the analysis to the assumed discount rate although many approaches are under consideration (see references).

Discussion: With exponential discounting, very long-term effects will play a very minor role in the analysis unless the valuation of the magnitudes being discounted also increases over time due to a positive income elasticity or increasing scarcity of the good being valued. Thus, if the discount rate is 3% and benefits are increasing in value by 2.5%, then the net discount rate of 0.5% has a much more modest effect on discounted long-term benefit values than would a 3% rate.

How effects for future generations should be discounted remains a matter of continuing debate which we do not believe has resolved into a specific standard. Such long-term effects have been primarily of academic interest and are included in very few benefit assessments although climate change analyses have brought greater attention to the issue. The most fundamental task is to include longer term consequences when they are potentially important to the policy assessment. Some economists have advocated preferential, lower discount rates for future generations based on intergenerational equity concerns. Suggestions that a zero discount rate be used have been widely rejected since a permanent $1 annual loss would have an infinite value and would swamp all other concerns in the analysis. Others have advocated discounting of future benefits in the same manner as effects for the current generation. A less future-oriented position is based on an assumption that future generations will be more affluent than the current generation so that there should be no preferential treatment of future generations if one ignores intergenerational income inequality. Should differential discount rates be used, such as a declining rate of discount over time, there is also a potential problem of time inconsistency. For example, will the discount rate sequence being applied to policies that have effects on future generation effects be in line with the preferences of that generation, which may have more present-oriented preferences for benefits and costs within their generation than suggested by a steadily declining discount rate over time?

References: Dasgupta (2008), Summers and Zeckhauser (2008), Boardman et al. (2011), Viscusi (2007), Jamison and Jamison (2011).

FS-EMPIRICAL-3

Issue: How can distributional weights be incorporated?

Standard: The basic standard is that no adjustment (weighting) is made for those who receive the benefit or pay the cost. The frontier standard is that sensitivity analysis of this assumption be carried out based on guidance from policy decision makers.

Discussion: The aggregation of individual benefits is problematic, both because individual marginal utility of incomes are not known and because there is no agreement on a social welfare function. The basic standard assumes a constant marginal utility of income across all people and no income inequality aversion as a society. These assumptions should be investigated if there are important distributional implications of the action (e.g. income, race, age, gender). For example, an analyst could adjust impacts by income categories of those affected using "Atkinson" values published by the Bureau of the Census which imply relative marginal utilities of income based on differing incomes. This adjustment is formally equivalent to a risk aversion to income inequality. In the absence of a consensus on distributional weights, a more limited approach is to provide separate information on the distribution of benefits and costs among the various stakeholders of concern and to be able to provide breakdowns of interest to policy decision makers.

References: Boardman et al. (2011), Layard and Walters (1978).

IV. Conclusion

Benefit-cost analysis is frequently applied to decisions involving public safety that require analyzing risk and assessing options to manage risks. Developing principles and standards may assist analysts, decision-makers, and the public in developing and interpreting such BCAs. Principles and standards at best represent commonly held views among a community of practice. Such views are continually evolving with advances in the field. As a result, the proposed principles and standards are presented here as representing standard and frontier practice as of 2011. Over time, some frontier practices may become standard and new frontier standards may develop. The modularized format for the principles and standards may assist in focusing discussion and decisions about whether such proposals actually reflect principles and standards within the BCA community of practice.

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