A GUIDE for REVIEWING ENVIRONMENTAL POLICY STUDIES

A Handbook for the California Environmental Protection Agency

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HOW TO USE THIS HANDBOOK

The primary purpose of this handbook is to assist California Environmental Protection Agency (Cal/EPA) staff to fully understand the analytical reports that are presented to them by others. This handbook should help the reader "unpack" analytical reports — including identifying the underlying methodology being employed; the measurement techniques being used; and the key assumptions upon which the report findings are based, among other things — so that the information contained in these reports can be appropriately used to assist in environmental decision-making. In addition, although not its primary purpose, the handbook may also be used to facilitate the development of analytical studies focusing on environmental issues.

Environmental decision-makers consume substantial amounts of information presented to them by various interested parties on particular issues. While a substantial literature details how to conduct analyses for these purposes, little written guidance exists on how to critique analytical work once it is completed. This is especially true for individuals who are not technically trained. This handbook is intended to close this gap by providing environmental agency staff with a reference guide to analytical decision-making approaches. In this respect, it is important to note that the handbook is meant to be descriptive, rather than prescriptive. That is, the handbook is not meant to mandate the use of particular economic assumptions, or even the use of economic analytical techniques at all. Instead, its intended use is to improve Cal/EPA's understanding of the implications of the analytical choices made as part of an analysis, so that the basis for analytical findings can be well understood and critiqued.

Because the handbook's intended use is as a tool to *critique* analytical reports, it tends to focus on the shortcomings of various analytical methods. It is important to note that, while all analytic methods have both strengths and weaknesses, if employed correctly they can help policy makers make better decisions. Likewise, decisions are being made in any event—the search for the perfect analytic technique should not be the enemy of the better. Finally, to a great degree many of the techniques examined in this handbook are already implicitly used by Cal/EPA staff. In this sense the handbook simply makes the characteristics of these methods explicit, so that their use can be improved.

This handbook is not intended to be read linearly, as with a traditional report. Instead, its purpose is to provide Cal/EPA staff and others with a resource with which to review reports and analytic material. In this vein, the handbook has been organized to provide accessible explanations of analytic terms and concepts. The reader is encouraged to make use of the handbook's table of contents, index, and glossary, and to flip back and forth between sections so as to locate discussions which are of immediate use. *In particular, readers may be especially interested in starting with Chapter Three—which provides a checklist of key steps to be taken to unpack analytical reports—and employing this chapter as a basis for handbook use.*

This handbook is divided into eight chapters, as follows:

1. Chapter One discusses the rationale for publishing this handbook and the use of analytical tools in policy analysis.
2. Chapter Two describes the broad issues with which policy analysts are concerned, including efficiency, equity and risk. This chapter provides a context for the analytical techniques discussed in the ensuing chapters.
3. Chapter Three describes the key features of analytic decision-making techniques, and provides a stepwise guide to unpacking analytic reports.
4. Chapter Four details the key market and non-market variables to be measured in analytic reports, and provides an overview and description of various measurement techniques.
5. Chapter Five describes the primary analytic methods used to examine environmental policies. These techniques rely on the measurement methods described in Chapter Four, combined with the stepwise framework discussed in Chapter Three, to develop systematic environmental analyses.
6. Chapter Six defines key analytic terms. These terms are highlighted in **bold** in the text of the first five chapters the first time they are mentioned in a section.
7. Chapter Seven lists commonly used analytic resources, such as reference books, analytic articles and data sources.
8. Chapter Eight presents the report index.

Textboxes are used throughout the handbook to provide specific examples or further explore topics of interest. In general, the subject of each textbox is indicated within the text. However, the reader is encouraged to browse the textboxes to garner additional information on analytic techniques.

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1 INTRODUCTION TO ANALYTIC DECISION MAKING

Increasingly, policy-makers are faced with environmental challenges with significant economic and environmental trade-offs. The stakes — real or perceived — can be high. For example, various analyses of global climate change have predicted an apocalyptic outcome if nothing is done to reduce the risk of global warming; and the same outcome if policy-makers impose the measures required to effectively address the potential problem. Divergent concerns over the dramatic implications of environmental degradation and the economic consequences of environmental regulations are not limited to global environmental issues. While the federal Clean Air Act Amendments (CAAA) identified Southern California as having the worst air quality in the nation — with concomitant health and environmental implications — a growing number of public and private sector organizations have pointed to air quality regulations as contributing to the ongoing slump in the California economy.

While the implications of today's environmental issues are large, the threats associated with them often cannot be perceived with the naked eye. The Department of Pesticide Regulation (DPR), along with other state and federal agencies, protects Californians against pesticide contamination on fruits and vegetables at levels that cannot be detected without sophisticated instruments. The U.S. Environmental Protection Agency (U.S. EPA) and regional air quality management districts issue costly regulations to protect the world's citizens against depletion of an invisible ozone layer.

Although there is substantial scientific evidence indicating that these regulations are essential to protecting environmental and human health, without educating ourselves on each one of these issues we must take it on faith that the costs associated with environmental protection result in worthwhile benefits. To a larger extent than ever, the political sustainability of environmental policies resides in the public's faith that the government can accurately assess the environmental risks and costs associated with addressing them.

As environmental challenges become more complex, the need for effective methods to develop **sustainable** policies grows. Increasingly, the public and

In many cases, the use of economic analysis is required by state and federal laws. For example, a growing number of state statutes prescribe the use of economic analysis, or at least require that economic impacts be considered as part of environmental protection policy decisions.

private sectors are turning to advanced analytical methods to sort out the benefits and costs of a particular environmental policy. However, while these analyses frequently result in the development of valuable information, only those individuals with training in sophisticated aspects of policy analysis may be able to translate these data into understandable knowledge. Further, because of their apparent inaccessibility, technical analyses are frequently distrusted by constituent communities. As a result, while there is more information available today about how humans' footprints in the sand affect soil conditions at the beach than any other time in recorded history, much of this information acts to obscure, rather than to enlighten, critical environmental issues. Society may have a greater abundance of information, but less wisdom.

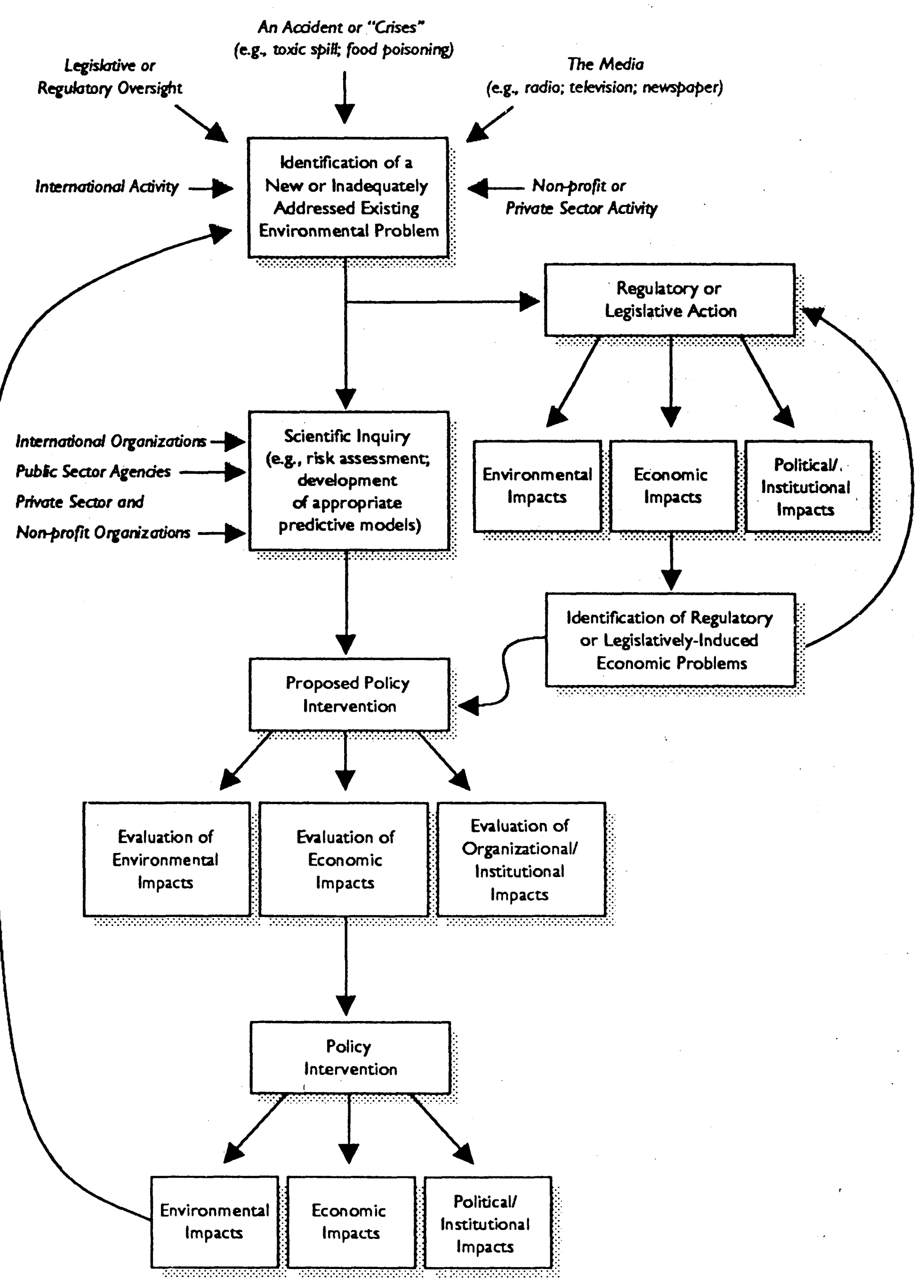
Given this policy-making setting there is a critical need to increase the analytical sophistication of civil servants and others involved in policy debates. Policy-makers — and to the extent possible, the public-at-large — must be able to effectively assess studies using various analytical techniques, dissect them, and understand what drives their conclusions. Through a better understanding of the strengths and weaknesses of analytical methods — and their associated findings — decision-makers and interested parties will have an enhanced capability to use these techniques in policy debates. The result will be more effective — and more politically acceptable — environmental policies.

1.1 POLICY ANALYSES' ROLE IN ENVIRONMENTAL DECISION-MAKING

Governmental decision-making is almost always analytic in a broad sense. Information related to existing or possible future conditions is generally evaluated before a policy decision is made. Judgments are developed concerning what constitutes better and worse outcomes. Constraints and limitations on options or acceptable outcomes are weighed. Reports are analyzed. And somehow, whether by formal method or informal process, a decision is fashioned. Figure One displays one model of the process through which policy decisions are developed.

Informal decision-making has worked, often very well, long before decision-making emerged as a science. However, as decisions have become more complex and controversial, ad hoc approaches have become less likely to result in satisfactory outcomes. This is especially true in the environmental decision-making arena, where complex physical and environmental systems abound, and where

Figure One
The Policy Process



WHAT ARE FORMAL DECISION-MAKING METHODS?

A number of different terms are used in this handbook to refer to analytic decision-making techniques. Although these words are used interchangeably, they each have a distinct meaning, as follows:

- **Formal analysis** refers broadly to any analytic method — based on the scientific or social disciplines — that follows a logical line of reasoning and results in replicable findings.
- **Analytic decision-making techniques** refers to any structured means of organizing various pieces of knowledge into a decision process. These techniques rely on a range of useful disciplines, including **economics**, sociology, political science, psychology, and philosophy.
- **Formal policy analysis** likewise relies on a number of disciplines, but is principally based on economics and political science. Policy analysis differs from analytic decision-making only in that it tends to focus exclusively on solving public problems.
- **Economics** is concerned with predicting human behavior as it relates to satisfying wants and needs with limited resources, and applying this insight to a broad range of issues. Economics is particularly concerned with how scarce resources are allocated. Economics has become a primary discipline in public policy analysis because of its ability to provide decision-makers with a framework from which to achieve public goals through more efficient mechanisms.

Economics is the principal tool used in policy analysis. As a result, it is important to note that many non-economists erroneously view economics as *exclusively* focusing on issues of economic impact. That is, there is a general belief that the term "considering economics" refers only to weighing the impacts on economic indicators — income, employment, and growth — of environmental policies. Although economic impact assessment and estimates of macro-economic changes are an important aspect of economic analysis, resource economics is equally concerned with issues of efficiency and trade-offs. In other words, economic techniques can be used as a part of a comprehensive investigation into the implications of environmental policies.

difficult trade-offs must often be made. As a result, informal decision-making methods are increasingly giving way to more formalized techniques. Formal decision-making approaches can be used to help analyze complex problems, focus policy debate on key concerns, and contribute to consensus-building among diverse parties. (See textbox above for definitions of formal decision-making methods.)

Historically, economics and associated formal analytical techniques have played only a limited role in environmental policy decision-making. As indicated in Figure One, as often as not some specific incident — a toxic spill, the release of a report, discovery of an environmental "crisis," for example, landfill shortages — prompts or renews legislative or regulatory interest in an environmental problem. This interest can initiate legislative or regulatory action even without substantial scientific or economic evaluation. Alternatively, further scientific inquiry may be prompted by the incident or discovery, and this inquiry might in turn act to mold the ultimate environmental policy (e.g., policies developed to address ozone depletion were derived from studies conducted over a ten-year period). Only infrequently, though increasingly, are state or local environmental policies subjected to serious economic review. Even rarer are studies of the proposed policies' potential institutional impacts (e.g., how the policy may affect the way public and private sector organizations behave; the interaction between local, state, federal and international policies).

Analytic techniques are increasingly used in complex and important environmental policy debates. Sometimes analyses of the same policy come up with different conclusions. For example, economic analyses of the South Coast Air Quality Management District's air quality permit trading program—known as RECLAIM—resulted in widely different estimates of future permit prices. However, even with their differences, a close examination of the contents of analytic reports enables decision-makers to make better decisions more confidently.

The technical parts of this handbook focus on understanding the use of formal policy analysis methods. The guidebook does not examine issues related to the political, scientific or technological basis for environmental policies. However, these issues are of keen importance to environmental decision-makers and merit separate attention (see textboxes on pages that follow). For example, while a large proportion of environmental policies are based on scientific methods of risk assessment, there is a great deal of controversy over the appropriate methods to measure, and effectively communicate, the risks associated with environmental hazards. For instance, how to best determine whether an environmental agent poses risks to humans of one-in-a-million, one-in-a-billion, or "no risk" is an area of scientific debate. In a similar vein, scientists continue to disagree about whether or not human-induced emissions of greenhouse gases (including carbon dioxide, methane, oxides of nitrogen, and chlorofluorocarbons) are likely to engender global temperature increases of up to nine degrees Celsius or none. As with economics, policy-making can be improved through a better understanding of the language and principles of environmental science.

Formal policy analysis interacts with scientific inquiry in at least three important ways.

- First, **policy analysis can help direct scientific agendas.** Policy-makers rely on formal analytical methods to allocate scarce public resources among the natural sciences. When "policy" is dropped from scientific analyses oriented towards public programs, the resulting work may have only limited value. For example, despite a half-billion dollars of funding over a ten-year period, the National Acid Precipitation Assessment Program has had very little impact on federal acid rain policy. A later review of the program suggested that this was the result of a bifurcation of the research into individual scientific disciplines, with little attention to what information was needed by policy-makers, and how this information would ultimately be employed.

President Harry Truman was known for "never seeing a decision he didn't like." Regardless of whether or not analytical methods are used, environmental policy decisions must be made. The techniques contained in this handbook can assist policy-makers in making explicit, systematic choices that provide greater environmental protection at lower costs.

- Second, **formal analytic techniques can be used to measure the trade-offs between two scientifically-based environmental concerns.** For example, while scientific methods associate a cancer risk with the use of agricultural chemicals, science also indicates that through the use of agricultural chemicals a greater abundance of fresh fruits and vegetables are available to Americans, and that the consumption of fresh fruits and vegetables may act to reduce cancer risks. Formal analytical techniques can assist decision-makers in achieving the appropriate balance between these two competing concerns.

- Third, **analytic methods can be used to determine the economic implications of existing science-based environmental policies.** For example, through the use of policy analysis regulators can better identify what standards provide environmental protection at the least-cost.

Beyond these limited areas, this guidebook essentially focuses on analytical techniques that are employed *after* the scientific basis for an environmental policy has been established.

1.2 WHAT ARE ANALYTIC DECISION METHODS?

Some individuals — particularly those that believe natural resource protection should be policy-makers' first priority — are critical of the use of economics in environmental decision-making. The use of economic analysis is limited *by statute* for some environmental problems. For example, application of the Endangered Species Act is partially based on protecting endangered species even if the resulting economic impacts on humans may be substantial. While there are legitimate reasons to restrict the use of formal analytic techniques in environmental decision-making, economics and other related disciplines offer powerful analytical tools to environmental policy-makers.

ASTROLOGY, BIOLOGY, AND ECONOMICS

Centuries ago the future was predicted using a variety of methods, including reading goats' entrails, deciphering the patterns of stars in the night sky, or rolling dice. Even today many people still believe that the lines on a palm or the date of birth can foretell the events in a person's life. While in recent times some of these methods have been scientifically shown to have a ring of truth — animal behavior may indeed predict changes in weather or geological conditions — policy-makers are reluctant to place their trust in them.

Instead, decision-makers now turn to the physical and social sciences to help them predict the future. Both of these disciplines are essentially based on the same principle: physical, biological, and economic behavior follows identifiable patterns that tend to repeat themselves. If the causes of a given outcome can be determined — that is, the relationship between various factors and the resulting pattern — then whether or not, and sometimes when, it will happen in the future can be predicted. For example, chlorofluorocarbons (CFC) emissions into the atmosphere create a chemical reaction which, in turn, eats away at the ozone layer. While the ozone layer tends to repair itself, as long as CFCs are emitted at a rate faster than the ozone can be regenerated, the layer will degenerate. From this knowledge scientists induce that, if CFC emissions are dramatically reduced or eliminated, the ozone layer will repair itself to approximately its pre-CFC level, all else being equal.

Economics applies **statistical** techniques to analyze patterns of behavior within social and economic communities. Statistics is the science of generalizing from observed phenomena. Statistical techniques rely on the fact that a large number of processes follow predictable patterns. For example, rainfall tends to follow a **normal** — bellshaped — **distribution** around a mean value. Accidents, on the other hand, frequently take the form of a skewed **Poisson** distribution. Likewise, economists observe that as prices for consumer goods rise, people tend to buy fewer goods, all other factors held constant. Based on this empirical observation economists predict that *when* prices rise, consumption *will* decline. Through careful examination of such patterns, economists have developed general theories of human behavior that serve as models from which to predict future economic and social activity.

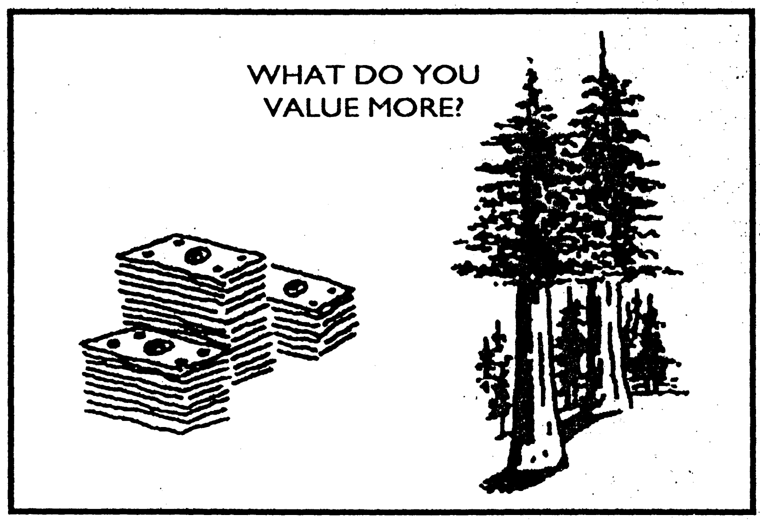
Key strengths of analytical decision methods include the following:

- **Analytic decision methods enable decision-makers to systematically use complex information.** The purpose of decision-analytic methods, such as **benefit-cost** or **comparative-risk analysis**, is to organize information in an understandable and accessible form. Without these methods decision-makers would have difficulty synthesizing seemingly random bits of information.
- **Formal methods enable decision-makers to choose the most cost-effective method of achieving an environmental goal.** There is generally more than one path to reach an environmental goal. Economic methods can be used to choose the least-cost policy approach.
- **Economic-based methods can help decision-makers understand the implications of proposed environmental policies.** Economic issues — such as employment, prices, and long-term income security — are among the top concerns of Californians. And to a large extent the availability of economic wealth enables the United States to provide substantial environmental protection — "wealth makes health." As a result, *the economic implications of environmental policies are of keen interest to the public.* An example of this is the intense and very public debates over protecting the Northern Spotted Owl or the adoption of air pollution programs in Southern California.

1.3 CAN *ECONOMICS* REALLY PREDICT THE FUTURE?

While **economics** can be a powerful tool in predicting social and economic behavior, economic-based analytical techniques suffer from a number of limitations. Most importantly, economic analysis begins with a status quo **baseline**. That is, *the existing characteristics of the economic system being examined form the baseline from which changes are estimated.* As a result, economic analysis can appear to emphasize the validity of current economic relationships and stress the negative implications of any changes to that system. For example, an analysis of employment and income losses associated with protecting an old-growth forest may result in estimates of significant reductions in timber-related employment without examining the economic conditions — including public-sector **subsidies** — that gave rise to the current state of the timber industry in the first place. Likewise, the employment-inducing implications of an environmental regulation are often overlooked in economic analyses. To this extent, it is important to pay careful attention to treat concerns about **efficiency** distinctly from concerns about **macro-economic impacts**.

Correspondingly, the ability to predict future patterns to a certain extent is predicated on the continual repetition of past patterns. That is, standard economic analysis alone cannot typically forecast dramatic breaks with past patterns which result from technological, political, or social changes. For example, economists did not predict the rapid petroleum price increases of the 1970s because these increases were the result of the emergence of a new pattern (i.e., the development and efficacy of the Organization of Petroleum Exporting Countries or OPEC, as well as other political and economic trends). However, many economists did predict the fall of petroleum prices in the early-1980s. These economists based their predictions on past patterns of cartels — as well as the general pattern of declining demand in the face of increasing prices — which indicated that such cohesive behavior tends to degrade over time in response to other economic and political pressures.



Other general limitations of economic analysis include the following:

- **Dominant assumptions importantly influence the outcomes associated with formal policy analysis.** All analyses are driven by a number of key assumptions. These assumptions range from the grand — the perfect operation of markets — to the sublime — the future will value environmental attributes more than the past. ***A primary goal of this handbook is to assist the reader in identifying and weighing the merits of the key assumptions embodied in individual analyses.***
- **A tendency to "monetize" everything.** Economic techniques by their nature tend to result in monetary-based estimates of the changes resulting from environmental policies. This monetization is valuable in that it acts to standardize changes in a way which allows for comparisons between otherwise difficult-to-compare attributes (e.g., how to compare the worth of a life to the worth of a forest). However, to some, monetizing environmental attributes

worth of a forest). However, to some, monetizing environmental attributes reduces the poignancy — and challenges the philosophical importance — of the problem being addressed. For example, what is more important, the "existence" and "bequest" value associated with 350 million acres of old-growth redwood forest, or $1 billion worth of timber and recreational benefits? Because the existence value of a resource does not have a measurable market price, other methods of weighing environmental changes have been developed. These techniques try to make consistent efforts to explicitly and repeatedly identify what important environmental benefits can not be adequately reflected in prices.

- **An imbalance between the ability to estimate the costs and benefits associated with environmental policies.** Economic techniques tend to be quite good at estimating the *costs* — in terms of person-hours, capital investments, employment loss and the like — associated with environmental policies that change the status quo. However, these techniques are less able to estimate the *value of the benefits* — in terms of reductions in polluting air emissions, protected wildlife habitat, and impetus for new technological development — associated with these policies. As a result, economic analysis can encourage decision-makers to focus more attention on the costs of environmental regulations than the benefits.

- **Economics relies on the "marketplace" rather than polling booths to arbitrate public decisions.** Individuals weigh-in the marketplace by trading dollars for goods and services. People can vote in the marketplace with multiple dollar amounts, rather than on a one person/one vote basis. Because peoples' ability to vote in the marketplace is limited by individual wealth, the wealthy frequently have more influence on economic outcomes than the poor. However, majority rule can address this imbalance by transferring resources from rich to poor.

In no way do these limitations represent "fatal flaws" in economic analytical techniques. In all cases economists and others are working to devise means of addressing these weaknesses. More importantly, they serve as reminders that *no* discipline can provide answers to all policy-makers' questions. It is important that decision-makers draw from a variety of disciplines to develop the wisdom they need to address today's complex environmental problems.

2 WHAT IS FORMAL POLICY ANALYSIS?

The discipline of economics, together with other behavioral, legal, and physical disciplines, provides many of the principal tools for formal policy analysis. Policy analysis is based on a four step process:

- First, a **theory** explaining the behavior of interest is developed. A theory is essentially a credible "story" describing why events occur as they do. In general, theories, whether from economics, biology, physics or meteorology, attempt to predict how specified actions lead to certain outcomes.
- Second, **base assumptions are made about the prevailing conditions of interest. Identifying and understanding the assumptions embedded in the theoretical framework is a necessary step to distinguish why two reports arrive at different answers.** The use of assumptions addresses two needs in advancing the study of a topic:
    1. Assumptions simplify the analysis so as to make it analytically tractable, and/or
    2. Assumptions fill in for missing or unattainable data.
- Third, **empirical evidence** that can be used to test the theory is identified and evaluated. Based on this evidence the original theory may be modified or even rejected.
- Fourth, a conclusion is drawn about the validity of the theory, and whether a policy derived from the theory can adequately address the identified problem.

Since 1991, California's unemployment rate has been two to three percent higher than the national average, and personal income growth has been one-half to two percent lower. The state's stringent environmental regulations, among other things, have been cited by some analysts as contributing to the economic downturn. Analytic methods can assist policy-makers in developing cost-effective environmental policies.

2.1 WITH WHAT ISSUES ARE POLICY ANALYSTS CONCERNED?

Environmental policy analysis is primarily concerned with three issues:

- Evaluation of the net gains or costs to society as a whole from *expected* outcomes of environmental policies — this category usually is called *"efficiency analysis."* **Efficiency** analysis focuses solely on calculating societal benefits and costs, without regard to the initial distribution of income and wealth, winners and losers, or how risks might change as a result of a policy or program.
- Assessment of the **distribution** of gains and losses from an outcome across different dimensions, including social, spatial and temporal — this is usually called *"equity analysis."*
- Estimation of the risks posed to society and various groups by **uncertainty**, and responses by individuals and organizations to avoid or mitigate these risks — this is usually called *"risk analysis."*

Economists tend to place the greatest emphasis on achieving efficient outcomes, while lawyers, for example, are pre-disposed to focus on issues of equity and risk-responsibility. However, only the **decision-maker** or **stakeholders** can weigh the relative importance of these three elements. In addition, economics provides little guidance on how to weigh equity concerns as part of decision-making. Even risk analysis requires some assumptions about individuals' preferences that many

ASSUMPTIONS: AT THE HEART OF THE MATTER

The use of different analytical assumptions frequently explains the difference between analytical findings derived from the application of like methodologies. Having a clear understanding about the key assumptions used — and the sensitivity of the results to changes in these assumptions — is a critical part of unpacking any analysis.

For example, in one analysis of the South Coast Air Quality Management District's marketable permits program, or RECLAIM, it was assumed that program implementation would reduce the cost of new pollution-control technologies by an annual rate 3 percent faster than existing trends. However, if this assumption turned out to be incorrect — and current rates of cost decreases remained unchanged — the estimated net savings from the permit program would be reduced by 10 percent.

In another example, cost estimates for a proposed ethanol plant to be constructed in the Sacramento Valley varied widely depending on assumptions about potential rates of return, annual production volumes, and various input costs. In this case the mix of assumptions chosen to develop the estimates could affect the potential economic feasibility of the plant, and affect the ultimate decision about whether or not it would be built.

economists are uncomfortable making. Decision **analysts** prefer that these **normative**, or value-based, trade-offs be explicitly made by decision-makers or stakeholders.

2.1.1 EFFICIENCY

Efficiency seeks to achieve the greatest net benefits in individual satisfaction — the total gains minus the total costs — from a particular policy. In other words, efficiency criteria demands that the identified goal be achieved for the least cost. For example, choosing the least wasteful way of meeting a pollution standard — or obtaining a given goal at the least cost — is efficient. The ultimate efficiency measure — called the **Pareto criterion** — defines an efficient choice as one where everyone is at least as well-off after a chosen action as before the action is taken, and at least one individual is better-off — there are no losers from the policy. Pareto optimal policies are rarely available in the real world, prompting economists to develop less restrictive definitions of efficient actions. These definitions — including the **Kaldor-Hicks criterion**, also known as the "potential compensation principle" — seek to maximize individual benefits across a number of variables. Unlike the Pareto criterion, under Kaldor-Hicks, while most people are made better-off under a policy, some individuals may be made worse-off. As long as those who are better-off can theoretically compensate those who are worse-off and still come out ahead, the policy is considered to be worthwhile. This is also called **Partial Pareto Efficiency** (PPE). Whenever net benefits are greater than zero, PPE is satisfied. That is why economists generally approve of policies which have positive net benefits.

Within efficiency, equity, and risk analysis, economic analysis is typically broken into two categories — ***micro-economics*** *and* ***macro-economics****. Micro-economics focuses on how individual firms or consumers behave. Macro-economics asks how the activity of individual firms and consumers aggregate to affect the overall economy.*

Many types of constraints exist on policy choices, but for economic efficiency analysis the two most important are the **budget constraint** and the **technological or production possibilities frontier.**

- Everyone faces budget constraints of some kind. These are constraints not only on our income and wealth, but also on time and other available resources. Budget constraints act to limit available spending on a particular problem. An efficient outcome is the one which achieves the maximum satisfaction given limited resources and the necessity to trade-off among preferences.

IS ENVIRONMENTAL AND ECONOMIC CHANGE ALWAYS BAD?

People tend to resist change, but is all change bad? The natural environment is mutating all the time — species become extinct, and new ones develop. Some of these changes are the result of non-human events — current theory hypothesizes that the dinosaurs were killed-off by atmospheric changes created by the earthly impact of a large space object. Other, more recent changes are the result of human activity. For example, reductions in fish habitat in the Pacific Northwest are the direct result of overfishing, the construction of waterways and dams, and introduction of silt from timber harvesting.

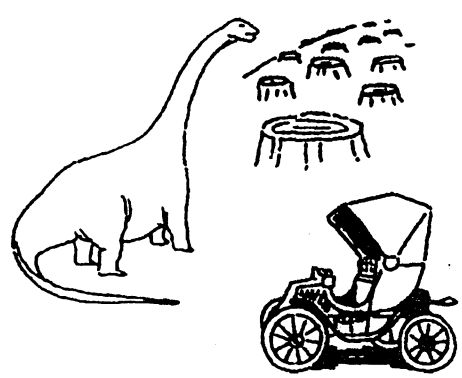
The economic environment is similarly constantly changing, generally as a result of human activity but sometimes due to changes in the natural environment. With the invention and rapid adoption of automobiles and airplanes, far fewer jobs are associated with horses and railroads in 1993 than in 1893. Earthquakes and fires in California and hurricanes in Florida have wreaked havoc on regional economies, but also created the need for new and safer buildings, and induced billions of dollars worth of new economic activity in the affected areas.

Change, while frequently inducing demands for policy action, does not in itself indicate the creation of a problem to be addressed. Instead, as with risk, the incidence of change initiates a two-step process:

1. Assessment of the implications of change; and
2. Development of methods to manage the change should that be deemed necessary.

Environmental decision-making likewise occurs as a continual process in which varying amounts of analytical information are used to address constantly shifting environmental, political, social, scientific, and economic concerns. In this respect even when an environmental policy is implemented through legislative and regulatory action, the development of additional information and new concerns can act to change the policy over time. As a result, environmental policy making is never "finished." The policy itself, once enacted, becomes part of the dynamic environment in which physical and social conditions exist. A problem may change form, policy proposals will be reformulated, and unforeseen constraints may materialize as part of the evaluation and implementation process. The policy process should not be seen as necessarily following a linear track, but rather as part of a loop that feeds back information to the initial step.

SOME THINGS HAVE CHANGED



- The technological or production possibility frontier defines the possible combinations of goods and services given a fixed set of inputs. For example, while having a picnic on Mars might be fun, our ability to get there is quite limited. Likewise we can't both prohibit all logging and maintain a thriving timber industry. The choice set of available policy options is similarly constrained by available technology.

DISCOUNTING — MORE THAN JUST RETAIL BEHAVIOR

The theory of **discounting** addresses the **intertemporal** and potentially **intergenerational** implications of private and public investment choices. Present-value discounting refers to the reduction in value associated with receiving payments in the future rather than the present (i.e., we usually prefer to have something today rather than tomorrow). There are three justifications for discounting. The first is intertemporal preferences, or "impatience." The second is the opportunity cost of capital. Income that is not spent consuming today could be invested, thereby yielding more income to consume with tomorrow. Finally, there is uncertainty associated with future payments on debt incurred in the present. Discounting is used in everyday life, when, for example, individuals choose to use a credit card instead of cash.

As the discount rate used increases, the **present value** — the worth today of the entire stream of net benefits over time — of the investment declines. For example, the U.S. Office of Management and Budget (OMB) recommends the use of a **real** — inflation-free — discount rate of 7 percent. Based on this rate, a dollar received two decades from now is worth only about a quarter today. A dollar received a half-century from now is only worth three cents. That is, we would only pay 3 cents today for a dollar to be received in fifty years. OMB's discount rate does not reflect the low **opportunity costs** of capital that existed during various historical periods, such as during the Great Depression.

The declining values associated with discounting have a significant affect on policy decisions. High discount rates act to shrink the benefits connected with investments that pay-off far in the future, while quick pay-backs appear more beneficial. The use of double-digit discount rates can act to block approval of otherwise worthwhile projects. For example, based on OMB's discounting guidelines the Golden Gate Bridge may have been built with a shorter lifespan as a means to reduce costs. Likewise, as environmentalists like to point out, Louisiana would never have been purchased if OMB's discounting requirements were in place. Choosing a discount rate is not without controversy, and this choice should be reviewed carefully as part of the decision-making process.

WHEN DOES OPPORTUNITY HAVE A COST?

The concept of **opportunity costs** is of critical importance to policy analysis. From an economic perspective, opportunity cost is the answer to the question: how much do I have to give up to use a resource? For example, if a house is worth $200,000, the home-owner's opportunity cost is $200,000. Opportunity costs represent the value of the best alternative use for a resource.

Opportunity costs differ from **accounting costs** in that the latter are the out-of-pocket expenses, depreciation, and historical costs that are used in bookkeeping entries. For instance, a drill press might have cost $10,000 to purchase a decade ago, and it might have depreciated to a zero value today in a firm's books. However, that drill press may be working just as well today, and a new press may cost $15,000. The economic value of the old press, measured by its opportunity cost, is $15,000, adjusted for the difference between the expected remaining life of the old and new presses. However, on an accounting cost basis the old press has no value.

2.1.2 EQUITY

Equity is concerned with how the benefits and costs generated by a policy are distributed. Distribution of benefits and costs may differ by social or economic standing, by location, or even by generation. From a political perspective, the ultimate distribution of policy outcomes may be the single most important issue, superseding even the expected total impacts as a measure of desirability. For example, one policy option might increase society's economic wealth by a billion dollars, but only the wealthiest ten percent benefit; on the other hand, a second option might generate half a billion dollars in benefits, but these are distributed to half the population. The first option may be more efficient, while the second is may be more equitable.

Analytical methods alone do not a decision make. In addition to the use of decision analytic techniques, effective environmental policy making is dependent on public participation, rules of law, and social considerations.

While equity is concerned with who receives benefits, economic analysis also indicates that the receipt of an additional dollar has a dissimilar marginal value to different income groups. In formal terms, the **marginal utility of income** may not be constant as income and wealth increase — a family with poverty level income may value an additional dollar more than a wealthy family. In other words, a strict monetary-based comparison, as in the example above, may not be appropriate if the affected groups have substantially different income levels. Consequently, distribution to the less-well off population, while engendering a smaller absolute monetary gain, may be

> **ENVIRONMENTAL JUSTICE**
>
> The term "environmental justice" has been used increasingly as part of the debate over the distribution of environmental costs. Recent studies have suggested that polluting facilities are more likely to be sited, and laws less likely to be enforced, in proximity to minority and low-income families. The goal of **environmental justice**, according to the U.S. Environmental Protection Agency's Office of Environmental Justice, "is to achieve equal environmental protection so that no segment of the population, regardless of race, ethnicity, culture or income, bears a disproportionate burden of the consequences of environmental pollution."

preferred by society both because it benefits a particular community and because the aggregate increase in utility may actually be larger—ultimately the true measure of efficiency.

Equity goals can be evaluated in several ways, depending on the relationship between the relevant individuals and the expected policy results. There are two different perspectives on how to examine equity issues related to individuals, as follows:

- **Horizontal equity** states that individuals in similar situations should be treated similarly (e.g., a policy that affects rice farmers should apply to all rice growers equally). For example, the American justice system is based on the principle that "all are equal in the eyes of the court."
- **Vertical equity** states that individuals in dissimilar or unequal situations should be treated dissimilarly in an effort to make them more equal. Under vertical equity, for example, the poor receive more benefits from government than the wealthy. Affirmative action programs are intended to remedy perceived racial inequities through differential treatment of individuals based on race.

Vertical and horizontal equity are not mutually exclusive goals (e.g., the federal tax system increases the tax rate with rising income, but taxes those in the same tax bracket at the same rate).

Two other notions of equity arise associated with policy outcomes. These are equity related to the fairness of an <u>outcome</u> (e.g., are the resulting levels of income equal?) and the fairness of the <u>process</u> (i.e., was there equality of opportunity or access for the individuals involved?). Those interested in equitable outcomes attempt to develop policies which guarantee particular results, while those concerned with equitable processes seek to provide everybody with equal opportunity (see "When is Fair "Fair"?" textbox).

WHEN IS FAIR "FAIR"?

In California's dynamic economy jobs are lost and gained all the time. For example, the state supports fewer mining jobs today than it did a decade ago, while, until the onset of the 1991 recession, construction jobs had almost doubled. Federal and state governments may want to intervene for other reasons, but the simple fact of a declining industry does not, necessarily, raise society-wide equity concerns. For example,

- Over the last few years law firms throughout the state have been forced to reduce their staff and restrict their number of new hires as a result of declining private sector demand for legal services. Should the state government establish special programs addressing the needs of unemployed attorneys?
- The state's aerospace industry has been in steady decline since the late-1980s as a result of reduced federal spending on military equipment. Should public funds be spent to retrain unemployed aerospace engineers?
- Small metal-working firms in Southern California have been forced to either close or move out of the state partially as a result of federal, state and regional environmental rules. Should assistance be provided to these firms to encourage them to remain in business in Southern California?
- The 1991 recession resulted in particularly high statewide unemployment rates. Should the federal or state government extend unemployment insurance benefits beyond their typical expiration date?

In general, policy-makers become especially concerned about the equity implications when a specific policy is likely to result in the dislocation — whether through employment reductions, or elimination of housing — of a particular population. Policy-makers tend to be less concerned when general economic trends act to disrupt certain populations.

Equity is measured by distributional impacts, which can be divided into three dimensions:

- **Socio-economic**, focuses on groups of individuals within society, whether economic, ethnic, racial or political.
- **Geographic**, can be divided by natural, economic or political boundaries. Geographic impacts differ from socio-economic impacts in that they (1) affect individuals in a certain locale; (2) cut across socio-economic groups; and (3) impact other physical and biological resources as well. The consequences of geographic impacts can be similar to those found in socio-economic analyses, but also include potential changes in land use patterns, biological inventories, ecological balance, and other issues.

- **Intergenerational and intertemporal,** which focuses on how impacts differ across time. The fundamental trade-off being assessed in intergenerational environmental analysis is how consumption and investment should be valued now and in the future. For example, consumption of environmental resources today may deprive future generations of these resources. Likewise, investments in environmental amenities today requires sacrifices by the existing generation on behalf of tomorrow's generation (see "Discounting: More Than Just Retail Behavior" textbox).

Weighing distributional impacts requires applying values to the decision about who is most deserving of benefits and costs. Unlike the "efficiency" and "**maximum return at minimum risk**" standards used by financial analysts, decision analysts have not developed consistent criteria with which to value distributional impacts. While the decision-making process can be used to gather the relevant

RISK ASSESSMENT: AN UNCERTAIN FOUNDATION

Environmental policy analysis begins with an assessment of the threats or risks posed to the natural environment and public health. As a result, policy analysis is to a large degree dependent on accurate scientific findings. While we've come a long way since scientists roundly agreed that the world is flat, controversy over particular scientific methods and outcomes continues to this day.

Scientists weigh a number of factors when evaluating the **risks** associated with a pollutant or human activity. There is always some **uncertainty** about each of these factor's ability to predict the event in question. However, based on this chain of factors, scientists estimate the risks related to the pollutant or activity. Key links in this chain include the following:

- The probability that a pollutant will be released, or that harm will result from an activity.
- The quantity of the pollutant released or the activity level.
- The dispersion patterns of the pollutant or activity.
- The pollutant concentration or the scale of the activity relative to its surroundings.
- The population exposed to the pollutant or impacted by the activity.
- The "uptake rate" or population exposure.
- The **dose-response** relationship of the pollutant or activity to the exposed population.

In each step, scientific uncertainty may be compounded, potentially resulting in a wide range of estimated risks. As a result, while science can offer profound and useful insights into the risks Californians face, analysts must be careful to apply scientific findings appropriately.

information and to construct a framework in which to assess the trade-offs inherent in distributional questions, it is up to the policy-maker to reflect his or her constituents' preferences in this matter.

2.1.3 UNCERTAINTY AND RISK

Issues of **uncertainty** are important to consumers and producers, and, depending on the level of uncertainty associated with a particular economic activity, these issues can affect their decisions dramatically. Most individuals will take actions to avoid undue amounts of risk, and in most cases this means giving up some higher level of income or wealth to choose a more certain course. Insurance — where people and firms are willing to pay a "premium" to spread and share their risks with others — is based on this premise. Using similar principles, financial investments are arranged in "portfolios" that attempt to balance uncertainty about investments with potential returns. While the preferred choice from an "efficiency" standpoint may be to accept higher risks, consumers and managers often will turn to a more certain outcome that limits potential losses at the expense of higher returns.

Uncertainty refers to a lack of knowledge about future outcomes. Risk is the potential loss from an uncertain outcome.

Policy makers face similar types of uncertainties, particularly in environmental decisions. No policy is formulated with absolute certainty. Environmental quality, such as for air or water, can be affected by many factors other than the directly offending human activity. For example, the level of polluting air emissions can be affected by a particularly hot summer or an unexpected change in economic activity. These outside influences can alter environmental quality measures and mask the impacts of activities with which policy makers are most concerned (see "Issues of Risk Assessment and Risk Tradeoffs" textbox).

2.1.4 WHAT WE KNOW ABOUT UNCERTAINTY

Uncertainty comes in two forms. The first relates to our understanding of how various natural and human processes work. The second relates to future events and trends.

The first form of uncertainty relates to the basis on which any analysis is built. Because virtually all natural and human-constructed systems are highly complex, no single theory, modelling method, or data source can capture all of the forces that drive these systems. Even beyond theories themselves, uncertainty usually exists about the historic information on which the theories are constructed and tested. For example, the data collected on a particular topic may not match the

ISSUES OF RISK ASSESSMENTS AND RISK TRADE-OFFS

The science of **risk *assessment*** focuses on determining the hazards associated with exposure to various environmental conditions. For example, one aspect of risk assessment is concerned with estimating what quantity of a particular toxic chemical it takes to induce certain types of cancers in humans. Likewise, risk assessment seeks to determine the probability that death or injury will result from using different transportation modes, including airplanes, automobiles, or rail. There are a variety of ways of assessing risk, ranging from the development of personal knowledge through experience — if I put my hand in the fire, it will hurt — to methods based on inference — if the ingestion of a particular chemical by a rat hurts the animal, it may also harm humans.

The art of **risk *management*** focuses on reducing the possibility of mortality or morbidity associated with the environmental conditions examined in risk assessment. Risk management policies include limiting the incidence of a particular chemical in the environment; requiring certain protective devices be used when engaging in a risky activity; and accepting the risk in return for the benefits derived from the action.

Risk management practices are frequently usefully informed by economics. In many cases risk management involves trading-off between economic, health, and environmental benefits, both on an individual and societal level. For example, while a driver is probably safer in an $80,000 Mercedes Benz than in an $8,000 Isuzu, few people are likely to mortgage the house for the Mercedes, at least not as a way of reducing the risk of harm from accidents. Likewise, driving 65 miles per hour (mph) carries a greater risk of a fatal accident than driving 55 mph, yet this well-publicized fact does not prevent many drivers from exceeding the speed limit. And while society is willing to provide every citizen with some basic amount of health care, through formal public programs or emergency assistance, the public has not yet shown a willingness to provide all individuals with the most expensive medical services available upon demand.

time frame or spatial qualities necessary to test a theory. The reporting may be of mixed quality, especially if it is done as an adjunct to other activities, or it may not even be clear what should be measured. This **measurement error** can introduce substantial uncertainty into any analysis.

The other dimension of uncertainty is the one we consider in our own lives every day — what does the future hold for us? This type of uncertainty comes in two forms, the first arising from our inability to fully understand complex systems; and the second from the inability of governments and other organizations to be able to absolutely commit to certain policies forever due to electoral or managerial changes. Uncertainty resulting from the operations of complex systems can, in some cases, be estimated through various mathematical techniques; however, knowledge of such basic natural phenomena as weather and earthquakes remains primitive. Understanding institutional uncertainty is important in accounting for human and organizational behavior.

Uncertainty about human institutions and technological ingenuity is not easily quantified, but it does color how individuals and firms respond to new policies. In one dimension of institutional uncertainty, even if one governmental agency commits to a certain strategy, another related agency can greatly affect the implementation of that policy. For instance, the California Air Resources Board (CARB) can not set air quality standards without considering potential actions by the U.S. Environmental Protection Agency. Thus, firms choosing their own emission management strategies must consider whether the U.S. EPA might trump the CARB decision in the future. Uncertainty about the ability to rely on continuance of a government policy can create greater risks that push behavior away from what would be considered optimal. Likewise, the operations of the marketplace engenders significant uncertainty about a wide range of factors, including future fuel prices and economic growth. Technological uncertainty similarly can be affected by the policy choice itself, as certain strategies can encourage or discourage new innovations.

ASSESSING EFFICIENCY, RISK AND EQUITY: WATERSHED PRESERVATION AND AIR QUALITY STANDARDS

To examine what is a relevant policy analysis process, a small-scale project — a small urban **watershed** rehabilitation program — can be contrasted with a broad policy proposal — region-wide air quality standards. The former requires a substantially less extensive, but more detailed, evaluation than the latter. The impacts of changing the watershed might be measured with more accuracy due to the limited local focus and more easily understood **ecological** mechanics, but the impacts are much less widespread than from reaching the air quality goals. The economic analysis of the watershed project can be evaluated with simple analytic tools that rely on narrow cost and benefit estimates; the air quality policy analysis requires a broad multi-sector regional model that considers how the economic impacts weave through the economy, and that reflects the high degree of uncertainty about analytic results due to the complexity of the problem and lack of data. Based on this example, issues of efficiency, equity and risk can be examined.

Efficiency - Efficiency is obtained when the maximum benefits are achieved for a given cost. For the watershed, the benefits might include a restored fishery, better water quality and an enhanced riparian habitat. The costs might include construction, runoff regulation measures and land-use controls. Each of these items is relatively well defined, and the value can be estimated with economic techniques and weighed by decision-makers with some assurance of accuracy. For the air standards, the benefits are much broader and more difficult to estimate. For example, benefits might include improved health, better visibility, and reduced structural and crop damage. Estimating the costs of air quality standards is difficult as well, because this requires modelling the complex economic system contained in the air basin.

Equity - The ability to estimate the distribution of gains and losses with some accuracy depends on the scale of the problem and the reliability of the supporting data. For the watershed, local residents are the likely gainers; but they may also be losers to the extent that they either have to modify their discharges or change their building plans. Taxpayers in general may be losers to the extent that they subsidize the activities involved in the restoration. The job losses and other socio-economic impacts are likely to be small. The air standards issue presents a number of difficulties related to measuring equity outcomes, including having sufficient data on the characteristics of affected groups; estimating the range and intensity of geographic impacts that are forecasted with imprecise airshed models; and determining how this action might change future consumption and investment patterns in the region.

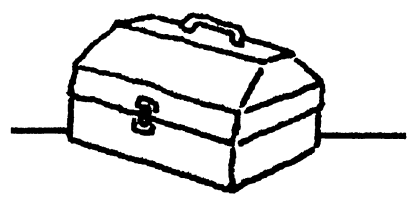
Risk - The risk associated with any policy option is related to the existence of and response to uncertainty. For the watershed, the level of uncertainty is relatively small for the people affected by the decision. For the flora and fauna though, the risk of failing to achieve the required level of sustainable activity may be substantial if the understanding of the ecology is not sufficient. For the air standards, there is generally a trade-off in risks, between achieving an ambient standard by a certain time versus imposing significant economic hardship. Understanding the bounds on possible outcomes may be more important here than estimating an expected result, especially since almost all single-point forecasts will be wrong.

3 WHAT IS IN OUR ANALYTICAL TOOL KIT?

This chapter provides a discussion of the key elements of analytic decision-making. The chapter is divided into three primary sections. First, the key features of analytic decision-making are presented. Then, a step-by-step guide to evaluating analytic decision reports is provided. Finally, a case study illustrating how to apply the approaches previously presented is discussed.

Analytic decision-making techniques provide a means to assemble differing analytic components into a systematic decision process. Although analytic decision-making approaches vary, they all have the following common features:

- Follow a structured and consistent approach
- Explicitly define the problem
- Explicitly define policy objectives
- Specify the range of alternatives
- Specify any constraints on alternatives
- Separate objective inputs from subjective inputs
- Are based on a bounded choice set and analytical limitations.



In addition, policy analysis seeks to measure outcomes, and compare these outcomes with desired results.

3.1 KEY FEATURES OF FORMAL ANALYTIC DECISION-MAKING TECHNIQUES

Analytic reports usually include the following features, which are part of well-structured analyses:

- **Follow a structured and consistent approach.** Decision-making techniques rely on using a structured and consistent framework which exists independently from the specific problem or policy under consideration. This framework feature is important for several reasons. It can provide a means of integrating both descriptive inputs and goals; can be thoroughly tested and substantiated based on previous applications; and is based on sound behavioral and economic theories. A structured approach provides a neutral mechanism for decision-making, favoring neither specific policies nor specific outcomes. Likewise, a structured approach establishes a common forum within which multiple decision-makers who might disagree on policies or desirability of outcomes can integrate their concerns.

- **Explicitly define the problem.** Environmental problems are generally defined by scientific evidence that indicates potential or actual change to human health or the environment. The characteristics of the problem will dictate the type of and need for analytic information. Environmental problems exhibit a large number of different characteristics, including:

  - **Size** — is it a large problem, such as global warming, or a smaller problem, such as a toxic waste spill?
  - **Scope** — how many issues are involved and how are they interrelated (e.g., the trade-offs inherent in preserving both the winter salmon and the Delta smelt in the Sacramento River)?
  - **Speed** — is the problem slowly imposing environmental change, such as the potential for global warming, or is it happening more rapidly, such as drought-induced water shortages?
  - **Permanence** — can the impacts of the problem be reversed?
  - **Risk Level**— does the problem pose a clear and present danger or some lower risk level?

- **Explicitly define policy objectives.** Policy *goals* or *objectives*—which are based on underlying *values*—are the outcomes desired from addressing the identified problem. Goals can range from complete elimination to partial mitigation of the problem. For example, acceptable damage and risk thresholds could be established, or the economic impacts associated with the problem could be ameliorated.

The more explicit the policy objective, the more readily it can be measured. For example, saying that "this policy should be fair" provides virtually no guidance. Alternatively, saying "this policy should minimize the redistribution of income away from the identified segments of the affected population" virtually defines the entire aspect of the problem. By being explicit, the policy debate can more clearly differentiate among the goals, the means of achieving the goals, and the quality of the supporting analyses.

Policy analysis tends to define goals in terms of "**objective functions.**" An objective function is a means of measurably indicating which outcome sets are preferable to all other possible outcomes. Objective functions may include economic variables (such as cost), health variables (such as lives saved), environmental variables (such as habitat created) and many other possible considerations. Conflicting objectives — such as goods now versus goods later — may coexist in an objective function. But if the function is to be analytically useful, these conflicts must be specified in terms of explicit trade-offs of one objective versus another.

- **Specify the range of alternatives.** The purpose of the decision process is to enable participants to choose the best alternative. This implies that at least two distinct, feasible options be available. Often there are a large number of choices and subsets of choices possible. Other things being equal, the larger the set of options considered, the better the analysis. Eliminating or failing to consider an alternative might not only alienate some **stakeholders**, but risks ignoring what might prove to be the preferred choice. However, as it is necessary to evaluate each alternative in terms of the objective function, there is a practical limit to the number of alternatives which can reasonably be considered. A practical approach to limiting the number of options is to group alternatives which have common or partially overlapping outcomes. Also, as the technical analysis progresses, it is sometimes possible to prune the list of choices to eliminate "dominated" alternatives, that is, options which perform worse than others on all considerations within the objective function.

- **Specify any constraints on alternatives.** Constraints can be "fatal flaws" which make an alternative unacceptable. Potential options may be limited — constrained — by various factors, including technological (is it feasible), budgetary (is it affordable), legal (is it allowable), political (is it socially acceptable), or ecological (is it environmentally sustainable). Legal constraints can also work the other way, acting to require that certain elements be incorporated into the policy analysis. To the extent that certain outcomes are identified as being unacceptable, it might be appropriate to terminate evaluation of the alternative which induces these outcomes. However, prudence is advisable in eliminating a potential choice because it might be the one which performs best in terms of all other considerations in the objective function.

> ***Positive** inputs reflect observations and inferences using different analytic methods — engineering, scientific, and behavioral — of* what is (i.e., an objective measure of the status quo). ***Normative** inputs refer to judgements concerning the way outcomes ought to turn out (i.e., they reflect subjective preferences). "Should" is normative; "is" or "will be" are positive.*

- **Separate objective or technical (positive) inputs from valuative or subjective (normative) inputs.** Paradoxically, there is nothing "objective" about an "objective function." Indeed all of the normative judgments to be included in the decision process are appropriately contained in an objective function. What IS "objective" about the objective function is that it embodies the goals or objectives to be accomplished by the decision.

The positive or technical aspect of the analysis lies in determining the outcomes or impacts of each of the alternatives. This technical analysis should be performed by specialists in disciplines appropriate to the impacted area (e.g., economists for economic impacts; epidemiologists and meteorologists for air quality impacts, etc.). While these technical experts have the best understanding of what *might* happen, in their capacity as experts they should strive to keep their findings value-free. The beauty of analytic decision-making is that it permits the positive and normative aspects of a problem to be addressed by those most suited to understanding each of these aspects.

- **Bounded choice set and analytic limitations.** All of the above discussion of analytic decision-making is based on the assumption that the problem is well defined, and that the range of alternatives is limited to a tractable number of choices. Under these circumstances the discipline imposed by the analytic process forces clear definition of objectives, and reasonable consideration and consolidation of alternatives.

However, the analyst, and especially the consumer of the analysis, must be sensitive to analytical limitations. Key factors that can limit analytic decision-making include the following:

- Analytic methods tend to specify problems and solutions in mathematical forms. As a result, qualitative differences and unmeasurable characteristics are frequently not included in analyses. It is important to be aware of what is left out of the analytic framework, and to **heuristically** consider the importance of these omitted aspects to the ultimate decision (see "Being a Sensitive Analyst" textbox).
- Analytic studies require a certain degree of simplification to assess the general implications of a policy proposal. However, by simplifying the analysis, certain costs may be intentionally or unintentionally ignored. Commonly omitted costs include the following:
  - *Adjustment costs*, which may result from accelerated shifts to new technologies, leading to premature obsolescence of existing investments.
  - *Implementation costs* of government agencies, including hiring new personnel, purchasing different equipment, and developing expertise in emerging issues.
  - *Compliance costs* of the regulated community and *monitoring and enforcement costs* of the regulatory agency. Neither of these cost components are well understood by analysts due to the great variety of regulatory schemes and degrees of enforcement.
  - *Transaction costs* may arise for policies in which market forces are being harnessed to achieve regulatory goals. For many items, individuals and

HOW TO BE A SENSITIVE ANALYST

Almost all economic analysis should be subjected to **sensitivity tests**. Sensitivity tests involve changing a model **parameter** and observing how the resulting analysis changes — how sensitive the analytical results are to a particular variable. Sensitivity tests enable analysts to examine the robustness of study findings given uncertainty about the data and the assumptions upon which the analysis relies. For example, if the analyst is unsure about critical model parameter estimates — such as price elasticities or rates of technological adoption — alternative analyses based on different assumptions can be developed. Sensitivity tests can act to demonstrate that an analytic result is fairly strong even in the face of different assumptions, or that an inherent risk exists in choosing a policy because the understanding of it is insufficient to accurately predict its outcome.

Scenario analyses are based on developing fully integrated, plausible, and internally consistent "stories" about the future. Scenario analyses typically reflect three potential cases: the expected conditions over time, and two bounding cases reflecting the best and worst outcomes thought possible.

firms must acquire information, search for a trading partner, negotiate a deal, write a contract and enforce its terms. All of these activities add costs to market-based activities.

- *Costs of delay in the decision process* which arise because project developers typically have to acquire financing early in the development process. If the project is delayed, the rate of return must be increased to compensate their investors and creditors.

3.1.1 IS THE APPROPRIATE ANALYTICAL METHOD BEING USED?

A number of methods exist to analyze a given policy problem. Although choice of analytical method is both an art and a science, method selection is primarily driven by the problem — characteristics — and number of constraints both on the problem itself and the resources available to address it.

A first step in method selection is to examine the issue of concern. Questions to be considered include:

- What is the expected relative magnitude of the policy impacts — both in environmental improvements and on the activities of the regulated community?
- Is the goal to achieve a certain environmental or performance standard or to set the standard?
- Should environmental and health benefits be estimated in the analysis?
- Who might incur costs or gain benefits from meeting the policy goals?
- What is the time horizon of the analysis?
- What is the geographic and demographic scale and scope of the impacts?
- How much flexibility is allowed the regulated community in meeting the policy goals?

The descriptions of the various methods contained in Chapters Four and Five can be used to answer these questions and assess the appropriateness of employing a certain approach.

A second step is to assess the available resources to analyze the policy, in terms of time, analysts, data and money.

The measurement techniques described in Chapter Four can be resource-intensive. *Market-based evaluation methods* usually require the least amount of resources, and frequently can be done on the "back of an envelope." Most of the required data necessary for these techniques is readily available and many analysts are trained in their use. *Regional economic models* require more time because they build on complicated economic relationships. Some credible models are available "off the shelf," but for smaller regions or newer policy issues, economic models must be built from scratch. *Environmental valuation methods* require much more time and money for original studies. Most of these studies rely on expensive surveys that require several months for data collection and compilation before the actual analysis is undertaken.

The analytic decision-making techniques in Chapter Five usually do not require a large amount of resources beyond those used for the measurement techniques, except the time necessary to interact with decision-makers and stakeholders. *Cost-effectiveness* and *benefit-cost analysis* are the most straightforward methods, only requiring a simple aggregation of the measurement technique results. *Least-cost planning* requires a step beyond benefit-cost analysis in that different policy actions must be weighed and ranked. *Decision analysis* is the most complex method because decision-makers must articulate their own values as part of the process — something that might require several iterations by the analyst.

3.2 A STEP-BY-STEP APPROACH TO UNPACKING ANALYTICAL REPORTS

A STEPWISE APPROACH TO UNPACKING ANALYTICAL REPORTS

- ☐ Read the report.
- ☐ Read it again.
- ☐ Identify the problems being addressed and the options being considered.
- ☐ Identify the constraints placed on policy options.
  Budget; legal; political; economic; social; institutional; risk related; technological.
- ☐ Identify the baseline conditions assumed in the analysis.
- ☐ Identify the analytical methods employed (Chapter Five).
  Cost-effectiveness; benefit-cost; least-cost planning; decision analysis; risk-related analysis.
- ☐ Identify the measurement techniques used (Chapter Four).
- ☐ Identify the data sources and time period covered.
- ☐ Identify key assumptions.
- ☐ Examine key assumptions.
- ☐ Identify who bears the benefits and costs of the status quo and the proposed changes.
- ☐ Spot check mathematics.
- ☐ Determine whether key policy questions have been addressed.
- ☐ Examine report presentation.
  Are findings incremental, or cumulative?
- ☐ Identify and obtain similar analyses.
- ☐ Discuss report with study authors.

The other side of proactively developing an analysis is evaluating an analytical report that has already been prepared. And it is this activity — understanding existing analysis — with which this guidebook is most concerned.

The following steps should be taken to evaluate analytical reports. In undertaking these steps it is important to note that reports themselves will rarely follow the sequential pattern described below. Instead, the report reviewer may have to "search" an analysis to locate needed answers.

- ☐ 1. **Read the report.** It is generally a good idea to read — or at least "scan" — the report once before undertaking a serious examination. A quick read provides an analyst with a sense of the structure, content, and flow of the document, and establishes an important context for the ensuing critical review.
- ☐ 2. **Identify the problem statement and list of alternative means of addressing the problem considered in the report.** It is important to note that the problem statement and alternatives may not include the universe of issues with which the policy-maker is interested. In other words, the report scope may or may not be comprehensive. Likewise, the analysis contained in the report should exclusively focus on the stated issues.
- ☐ 3. **Identify the constraints on policy options considered in the report.** These constraints may or may not be comprehensive. All identified constraints should be appropriately incorporated into the analysis.
- ☐ 4. **Identify the baseline conditions — including ecological, technological, economic, and social — assumed in the analysis.** Baseline conditions should be consistent across analyses of like problems. For example, is an analysis of agricultural energy use based on continued groundwater overdraft in the Central Valley; or does it assume that an equilibrium pumping level is achieved before the policy is implemented? Is a salmon fishery analysis based on pre-drought instream levels or existing levels? Is an analysis of the state's economy based on recessionary levels or historic average growth? **Frequently the difference between two analyses can be found in their baseline assumptions.**
- ☐ 5. **Identify the analytical method employed in the report.** Is, for example, benefit-cost or cost-effectiveness analysis the dominant technique used in the document? Each technique implies that different questions are under consideration. How do the questions asked in the analysis influence the findings? See Chapter Five for a discussion of these methods.
- ☐ 6. **Identify the measurement techniques used in the analysis.** To the extent possible analysts prefer quantitative measurement techniques. This is because two analysts working independently are more likely to

produce the same results when quantitative criteria are employed (i.e., the analysis is more easily replicated). However, use of quantitative methods should neither preclude the use of qualitative measures, nor minimize their importance. See Chapter Four for a discussion of potential measurement variables and methods.

☐ 7. **Identify the data series, collection methods, and time period upon which the analysis is based.** Data used in analytical reports are generally derived from sources unrelated to the analysis being conducted. It is important to understand where the data comes from, so as to be able to evaluate its quality and suitability to the analysis. Section 4.6 provides a discussion of accounting units and stance.

☐ 8. **Identify the key assumptions upon which the analysis relies.** Key assumptions may include the following:

- Assumptions related to the population considered by the analysis, both in terms of size and characteristics. For example, assuming that all firms in the statistical population are for-profit firms may lead to a different conclusion than inclusion of both for- and not for-profit firms in the study.
- Assumptions about the benefits and costs considered by the analysis.
- Assumptions about the geographic area considered by the analysis.
- Assumptions related to the time horizon over which the analysis is conducted. There are a number of important issues which relate to the time period considered. For example,
  - The time horizon should match the identified issues. If the primary impact of the policy being examined is expected to occur ten years after its implementation, the analysis should extend at least ten years.
  - Appropriate economic growth rates which relates to the time period being considered should be included in the analysis.
  - Appropriate discount rates should be used to bring future benefits and costs to present values.
- Assumptions related to technological change and the interaction between innovation rates and the policies being considered.
- Assumptions about the characteristics of any markets being examined. For example, does the market at issue have a central exchange point or is it diffuse?
- Assumptions about uncertainty. For example, does the analysis contain a range of possible scenarios, including the use of different assumptions?

☐ 9. **Evaluate whether the analysis reflects standard assumptions.** For example, consumers generally reduce their demand for goods and services in the face of rising prices; producers generally reduce production in the face of rising costs; prices of goods and services generally rise with demand; and producers tend to substitute capital — or technology — for labor when wages increase. Analytical documents should explain the rationale behind the use of non-standard economic assumptions.

☐ 10. **Identify the groups that currently pay for or benefit from existing conditions, and how benefits and costs to these groups might change under the policy being analyzed.** Policy impacts may be narrowly focused or widely dispersed. Likewise, a particular interest group may accumulate all the benefits of a proposal at a cost to the rest of the population. Or a certain locality may be forced to bear the brunt of costs for a project that benefits the entire state. Analytical reports should clearly delineate those who will benefit or sacrifice under the policy being evaluated.

☐ 11. **Spot check the mathematics presented in the report.** It is often useful to replicate some of the basic math that is used in analyses. In addition, more complex issues may merit sensitivity testing of the study's results.

☐ 12. **Determine whether key policy questions have been addressed.** Relevant policy questions can be grouped by whether they address economic efficiency, distributional impacts, risk, and the time frame of the policy action itself, as follows:

- What are the expected net gains or costs to society resulting from the selected policy goal(s) (i.e., efficiency concerns)? What changes in net wealth or income as measured by economic activity occur as a result of achieving the stated goal? Who receives the benefits and costs engendered by the policy? Based on environmental risk, what are the net changes in ecological or resource values? What are the net values of expected health-risks? See Sections 2.1.1 and 4.1.

- How are different groups impacted by the policy goal(s) (i.e., equity concerns)? Who is burdened and who benefits from the policy? How are the disaggregated impacts of the net societal gains or costs distributed amongst various socio-economic and geographical groups? How do non-economic community characteristics change as a result of the policy? How do government revenues and expenditures change with a policy outcome? See Sections 2.1.2 and 4.2.

- How much is society willing to pay for greater certainty in the future (i.e., issues of risk and uncertainty)? How great a factor is natural uncertainty in the probable success of the policy? How much uncertainty is associated with a particular technological solution versus its expected results? Will the policy have sufficient political support to be accepted and sustained? How does the policy affect businesses' financial stability? To what degree does today's investment in a policy foreclose tomorrow's options? Does reducing the risk to an environmental resource adequately maintain the resource for future generations? See Section 2.1.3.

- Is this the right time to invest in achieving the policy goal(s)? What is society willing to pay to delay implementing a policy to gather additional information that may decrease uncertainty about its outcome? Are the long-term conditions expected to differ from the current short-term situation? See Chapter Five for a discussion on various methods.
- Have all stakeholder voices been heard? Is society willing to sacrifice some material benefit, or to delay policy implementation to insure that due consideration has been afforded all parties.

IT'S ALL AT THE MARGIN

Marginal analysis is one of the main analytical tools used by economists. For economists, to be "marginal" does not mean something is "borderline" or "questionable," but rather that it is "incremental." A marginal change is an increment of movement that is additional to all other changes that have already occurred. For example, a regulation may have the marginal benefit of reducing ambient ozone in an air shed by one additional ton. If existing policies already act to decrease ambient ozone to a safe level, the marginal benefit of this additional emissions reduction may be zero.

Marginal values are quite different from **average** values. For example, if the benefits associated with reducing ambient ozone by 100 tons is $100 million in decreased health care costs, the average benefit per ton is $1 million. However, the marginal benefit of the first ton of ozone reduction may be a great deal more than $1 million, while the benefit of removing the 99th ton may be much lower than $1 million, particularly if the air is already considered healthy after 50 tons of ozone have been removed.

☐ 13. **Examine the way in which the analytical findings are presented.** For example, policy implications may be presented as incremental or cumulatively.

☐ 14. **Identify and obtain similar analysis.** In some cases either analyses of the same issue, or evaluations of a different policy but with the same decision technique, can be usefully reviewed as a method of comparing and contrasting report strengths and weaknesses.

☐ 15. **Work with the study's authors to clarify and further explain report assumptions and methodology.** Regardless of the analytical capabilities of the reviewer, almost no report is perfectly understandable on the first or even second reading.

3.2.1 UNPACKING AN ANALYTICAL REPORT: A CASE STUDY

This section further describes the handbook's recommended step-wise process of analytical evaluation by presenting a case study report assessment. The document selected for this case study — *Commuting, Congestion, and Pollution: The Employer-Paid Parking Connection* — published in 1992 by the Reason Foundation — was not chosen because it is a "good" or "bad" report. Rather, the report reflects a complex and topical issue, and provides a rich source to investigate application of the analytical tools discussed in this handbook.

After "Step One, Read the Report," applying Section 3.2 steps to the study results in the following evaluation:

STEP TWO   IDENTIFY THE PROBLEM STATEMENT AND LIST OF ALTERNATIVE MEANS OF ADDRESSING THE PROBLEM CONSIDERED IN THE REPORT

Commuting, Congestion, and Pollution: The Employer-Paid Parking Connection (or *Parking Connection*) was undertaken to evaluate changes in polluting air emissions, traffic congestion and associated economic impacts that would be induced by a proposal to amend the Internal Revenue Code's so-called "special rule for parking." The proposed amendment would allow employees the option either to receive the fair market value of employer-paid parking as taxable cash income or to continue to receive employer-paid parking on a tax-free basis. Specifically, the report authors propose that the Internal Revenue Service's special rule for parking be amended as follows:

> The term "working condition fringe" includes parking provided to an employee on or near the business premises of the employer if the employer offers the employee the option to receive, in lieu of parking, the fair market value of the parking subsidy, either as a taxable cash commute allowance or as a mass transit or ridesharing subsidy.

Employer-paid parking is a form of matching grant whereby an employer offers to pay an employee's parking costs if the employee is willing to pay all other work-related driving expenses. *Parking Connection* estimates that in 1986 69,503 workers in the Los Angeles Central Business District (LA-CBD) were offered employer-paid parking.

Although there are a number of other methods of addressing traffic congestion and mobile source air pollution, the analysis contained in *Parking Connection* is limited to the one alternative outlined above. The report does, however, refer the reader to other studies which examine potential methods of reducing congestion and associated polluting emissions.

STEP THREE IDENTIFY THE CONSTRAINTS ON POLICY OPTIONS CONSIDERED IN THE REPORT

Parking Connection does not explicitly identify potential constraints — legal, institutional, or economic — on policies to address traffic congestion and mobile source polluting air emissions. However, the report implicitly notes that political sustainability, ease of implementation, and impacts on public and private sector costs are of some importance to the success of any congestion-related proposal. For example, *Parking Connection* argues that the proposed policy has several advantages that may make it easier to implement than alternative mechanisms to address congestion and air pollution. These advantages include:

1. No employee would lose any existing parking subsidy.
2. Offering commuters the option to choose between free parking and cash means that parking would have an **opportunity cost** — the cash not taken, thereby encouraging employees to make a conscious choice about their actions.
3. Employers would be no worse off than the existing system if an employee chooses the cash alternative.
4. The lowest-paid workers would gain the most after-tax cash from the policy because they are in the lowest tax brackets.
5. The policy would be easy to implement and enforce, since it would require employers to report any tax-exempt parking subsidies on their employee's payroll forms in the same way they already report tax-exempt fringe benefits.
6. Federal and state income tax revenues would increase when employees choose to receive cash in lieu of free parking since cash is taxable.

STEP FOUR IDENTIFY THE BASELINE CONDITIONS — INCLUDING ECOLOGICAL, TECHNOLOGICAL, ECONOMIC, AND SOCIAL — ASSUMED IN THE ANALYSIS

To evaluate the impacts of the proposed statutory change, *Parking Connection* first summarizes the existing implications of employer-paid parking in the Los Angeles CBD in terms of vehicle miles travelled, gasoline consumption, transportation expenditures, and associated air pollution and traffic congestion. The report then compares this baseline to the estimated impacts that would result from offering workers the option to cash-out the value of employer-paid parking.

Since publication of *Parking Connection* several changes have occurred which, if incorporated into a revised baseline, could result in different benefits than those estimated in the report. For example, since 1992 the Metro Red Line has opened in Los Angeles, and since 1993 the dollar value of employer-paid parking above $155 per month is counted as taxable income by the federal Internal Revenue

Service. However, without further analysis it is unclear whether or not these changes would act to reduce or increase the estimated benefits associated with the policy.

STEP FIVE IDENTIFY THE ANALYTICAL METHOD EMPLOYED IN THE REPORT

The primary focus of the report is to assess the economic efficiency implications of the proposed alternative. *Parking Connection* does not address how the benefits and costs of employer-paid parking are currently distributed across different geographic areas or socio-economic groups, nor how this distribution would change as a consequence of the proposal. In particular, while the report asserts that low-income commuters would benefit disproportionately from the policy because they are in lower tax brackets, it does not provide compelling evidence to support this claim. Likewise the study fails to identify clearly the costs to be borne by employers as opposed to employees. *Parking Connection* does, however, refer the reader to an earlier publication which attempts to address some of these issues (step fourteen).

STEP SIX IDENTIFY THE MEASUREMENT TECHNIQUES USED IN THE ANALYSIS

Parking Connection relies on statistical analyses of a 1986 survey of 5,060 employees, working for 118 employers, in downtown Los Angeles. The survey was designed to be representative of the entire population of office workers in the LA-CBD. Based on this survey data, the report authors developed a regression model (logit) that included employer-paid parking as an independent variable along with other customary variables, such as income, occupation, travel time, and travel cost to work. This logit model was used to predict how employer-paid parking affects commuters' travel choices.

To assess the economic impacts and changes in travel behavior associated with the proposed policy, the report estimates changes in commuter behavior that would be induced by an increase in parking prices equal to the after-tax cash value of the tax-exempt parking subsidy each commuter would be offered. Because the report does not include a detailed description of the 1986 commuter survey or the statistical results of the regression model, it is not possible to evaluate the quality of these analyses in more detail (see Chapter Four). In this case, it would be useful to examine earlier publications — which are referenced in the report — which include a more detailed description of the commuter survey and the statistical results of the regression model (step fourteen).

As indicated in Tables One and Two, estimated impacts on a number of variables include the following:

Solo Drivers: The report estimates that provision of free employee parking (i.e., the status quo) in Los Angeles' Central Business District increases the share of solo drivers in the area from 48 percent to 69 percent, a 44 percent increase overall. Offering employees the option to cash-out employer-paid parking (i.e., the proposed policy) is estimated to reduce the share of solo drivers from 69 percent to 55 percent, a 20 percent decline.

Parking Demand: The per employee spending on parking by all employees who are not offered employer-paid parking — including transit users and carpoolers — in LA-CBD is $563 annually. In contrast, the per-employee spending on parking for all employees who are offered employer-paid parking is $750 a year. Employer spending on parking is high because the quantity of parking demanded by commuters when it is provided to them for free is 34 percent greater than the quantity demanded at market prices (i.e., demand forces price up). On an aggregate level, employer-paid parking policies act to increase total parking expenditures in downtown Los Angeles from $39 million to $52 million annually, or by $13 million a year.

Parking Connection estimates that if a cash option were offered to employees, employer spending on parking would decline to $626 per employee per year on average (i.e., spending per employee per year would fall by $124 as a result of reductions in parking demand). In aggregate the report estimates that introduction of a cash option would decrease total parking expenditures by approximately $9 million.

Vehicle Miles Travelled (VMT): Some employees currently respond to employer-paid parking by shifting from carpools and mass transit to solo driving. This behavior increases automobile VMT. For example, commuters who pay to park drive 18.1 VMT per day, while commuters who are provided with employer-paid parking are estimated to drive one-third more: 24.1 VMT per day. The additional six VMT per day per employee induced by employer-paid parking results in an aggregate 1,311 VMT per employee per year. On an aggregate basis, the report estimates that employer-paid parking acts to increase VMT per year in Los Angeles from 272 million to 363 million miles, an increase of 91 million miles.

Parking Connection estimates that providing the option to cash-out the value of parking would decrease VMT per day from 24.1 to 20.1 VMT. This 4 VMT per day reduction corresponds to an 868 VMT decline per employee annually. On an aggregate basis, the report estimates that the cash-out option would decrease annual VMT from 363.4 million miles to 304.6 million miles, a decrease of 58.8 million miles, or about 16 percent.

Gasoline Consumption: Commuters who pay to park use 231 gallons of gasoline per year on average to drive to and from work, while commuters who receive employer-paid parking are estimated to consume 308 gallons of fuel per year. This corresponds to an aggregate increase in gasoline consumption of 5.3 million gallons due to the employer-paid parking policy, from 16 million gallons to 21.4 million gallons.

Parking Connection estimates that provision of the cash-out option would decrease gas consumption to 258 gallons per year per employee. On an aggregate basis this corresponds to a decrease in gasoline consumption of 3.5 million gallons to 17.9 million gallons.

Transportation Expenditures: *Parking Connection* estimates that employer-paid parking acts to increase spending on parking by $187 per employee per year (see Parking Demand above), and acts to increase employee spending on driving by $380 per year. On an aggregate basis, this means that expenditures for automobile use and parking are estimated to increase by $39.4 million per year as a result of employer-paid parking, from $118.2 million to $157.3 million.

The report estimates that provision of a cash option would decrease spending per employee on parking by $124 per year, and would decrease employee spending on driving by $246 per year — a total decrease of $370 per employee annually. In aggregate, this corresponds to a decline in private costs from $157.7 to $131.6 million — a savings of $26.1 million per year.

Because employer-paid parking increases VMT, it also increases the external (social) costs of automobile use in Los Angeles. *Parking Connection* attempts to estimate the increased costs of air pollution and traffic congestion induced by employer-paid parking. However, the report does not attempt to quantify other external costs, such as property value declines related to increased noise, aesthetic degradation, neighborhood disruption, road maintenance and operation costs, or contributions to global climate change. Estimated impacts on congestion and air pollution are presented below.

Congestion Costs: Traffic congestion is a major external cost of solo driving, because when one more automobile uses a road that is already near capacity, the additional car causes traffic to move more slowly, thereby imposing costs on other drivers and transit riders.

Parking Connection estimates that employer-paid parking acts to increase congestion costs by $262 annually per employee to whom it is offered. These additional expenses represent a 33 percent increase in congestion costs, from $784 to $1,046 per employee per year. On an aggregate basis, these costs correspond to an increase of $18.2 million, from $54.4 million to $72.7 million. The report estimates that provision of an option to cash-out employer-paid parking would reduce the external costs of congestion by $11.8 million per year, to $60.9 million annually.

Pollution Costs: On average, commuters who pay to park impose air pollution costs of $157 per year, and those who park free impose air pollution costs of $209 per year — a difference of $52 annually. On an aggregate basis, these additional expenses correspond to an increase in air pollution costs of $3.6 million, from $10.9 million to $14. 5 million. Offering employees an option to cash-out free parking is estimated to decrease pollution costs by $2.3 million to $12.2 million annually.

Based on the figures presented above, employer-paid parking is estimated to increase the total cost (private plus social) of automobile use in Los Angeles by $61.3 million, from $183.6 million to $244.9 million. By offering employees the option to take cash in lieu of employer-paid parking, the social costs of automobile use is estimated to fall $40.2 million, from $244.9 to $204.7 million — a 16 percent decline.

Table One
Travel Behavior & Expenditures of Commuters to LA Central Business District

		Employer Pays for Parking		
Behavior/Expenditure	**Driver Pays to Park**	**W/O Cash Option**	**W/Cash Option**	**Difference**
Solo Driver Share	48%	69%	55%	14%
VMT (per employee per day)	18.1	24.1	20.0	4.1
VMT (per employee per year)	3,919	5,230	4,383	847
Gas Used (gallons/employee-year)	231	308	258	50
Parking Expenditures ($/employee-year)	$563	$750	$626	$124
Employees ($/employee-year)	$563	$0	$0	$0
Employers ($/employee-year)	$0	$750	$626	$124
In-Lieu Cash Expend. ($/employee-year)	**$0**	**$0**	**$380**	**$(380)**
Auto Use Expenditure ($/employee-year)	$1,137	$1,517	$1,271	$246
Parking & Auto Expenditure ($/employee-year)	$1,700	$2,266	$1,897	$369
Park & Auto & In-Lieu Cash Expenditures ($/employee-year)	**$1,700**	**$2,266**	**$2,277**	**$(11)**

Assumptions: (1) Days worked per year = 217
(2) Auto Use Cost = $0.29 per mile
(3) Auto Fuel Efficiency = 17 mpg
(4) Cost of Parking = $83.82/month; $1,006/year.

Source: Shoup, D.C., and R.W. Willson, Commuting, Congestion, and Pollution: The Employer-Paid Parking Connection, Policy Insight No. 147, Reason Foundation, Sept. 1992.

Table Two
Travel Costs of Commuters to LA Central Business District

Behavior/Expenditure	Driver Pays to Park	Employer Pays for Parking: W/O Cash Option	W/Cash Option	Difference
VMT (millions per year)	272.4	363.4	304.6	58.8
Gasoline Consumption (million gallons)	16.0	24.1	17.9	6.2
Congestion Cost ($millions/year)	$54.4	$72.7	$60.9	$11.8
Pollution Cost ($millions/year)	$10.9	$14.5	$12.2	$2.3
Total External Cost ($millions/year)	$65.4	$87.2	$73.1	$14.1
Auto Use Expenditure ($million/year)	$79.0	$105.4	$88.3	$17.1
Parking Expenditure ($million/year)	$39.2	$52.3	$43.3	$9.0
Employees ($millions/year)	$39.2	$0	$0	$0
Employers ($millions/year)	$0	$52.3	$43.3	$9.0
In-Lieu Cash Expend. ($millions/year)	**$0**	**$0**	**$26.6**	**$(26.6)**
Private Cost of Auto Use (1)	$118.2	$157.7	$131.6	$26.1
Social Cost of Auto Use (2)	$183.6	$244.9	$204.7	$40.2
Adjusted Private Cost of Auto Use (3)	**$118.2**	**$157.7**	**$158.2**	**$(0.5)**
Adjusted Social Cost of Auto Use (4)	**$183.6**	**$244.9**	**$231.3**	**$(13.6)**

Assumptions: (1) Days worked per year = 217
(2) Auto Use Cost = $0.29 per mile
(3) Congestion Cost = $0.20 per mile
(4) Number Offered Free Parking = 69,503
(5) Auto Fuel Efficiency = 17 mpg
(6) Cost of Parking = $83.82/month; $1,006/year
(7) Pollution Cost = $0.04 per mile

Source: Shoup, D.C., and R.W. Willson, Commuting, Congestion, and Pollution: The Employer-Paid Parking Connection, Policy Insight No. 147, Reason Foundation, Sept. 1992.

Footnotes: (1) Driving plus parking ($millions/year) as reported in Shoup, et. al. (1992).
(2) Private plus external ($millions/year) as reported in Shoup, et. al. (1992).
(3) Driving plus parking ($millions/year) as recalculated by Diamant (1993).
(4) Private plus external ($millions/year) as recalculated by Diamant (1993).

STEP SEVEN IDENTIFY THE DATA SERIES, COLLECTION METHODS, AND TIME PERIOD UPON WHICH THE ANALYSIS IS BASED

Most of the data used in *Parking Connection* is for 1986, with several notable exceptions. In particular, the report relies on estimates of congestion costs that appear to represent a middle value across a variety of studies published between 1986 and 1991. The most recent study cited [Cameron, 1991] estimates a congestion cost of between $0.01 to $0.37 per mile travelled. In addition, the report relies on estimates of the external cost of air pollution that are based on 1987 data.

The use of data of different vintages is not particularly troublesome. However, the apparent mixing of costs displayed in 1986 and 1987 current dollars represents a minor methodological flaw. The report could be improved by recalculating estimated costs in terms of constant dollars for a given base year. By so doing all of the costs (e.g. the private costs, congestion costs, and air pollution costs) would be directly comparable. However, given the significant range of uncertainty associated with congestion costs — which are estimated at anywhere between one cent to 37 cents per mile — this modification would not likely affect the report's findings.

STEP EIGHT IDENTIFY THE KEY ASSUMPTIONS UPON WHICH THE ANALYSIS RELIES

Parking Connection relies on a number of assumptions, including the following:

Days worked per year	=	217.
Number of People Offered Free Parking	=	69,503.
Congestion Cost	=	$0.20 / mile (1991).
Air pollution cost	=	$0.04 / mile (1991).

Although the assumptions used in *Parking Connection* seem plausible, they provide a good opportunity to examine the use of weighted averages, arithmetic means, or median values in analytic reports. The choice of which type of average to use could greatly influence the report's findings. For example, Table Three displays the comparison of "average" commuting distances. Based on the number of cars, round-trip commuting distance, and average number of riders, the difference between mean, median, and weighted average values is quite significant. As shown in the table, the mean commuting distance is 25.8 miles, the median distance equals 10.0 miles and the weighted average distance is equal to 32.2 miles.

TABLE THREE

A Comparison of "Averages"

Number of Cars	Length of Commute (Miles)	Average Number of Riders per Car
2,000	5	1
1,000	10	1
1,000	15	2
1,000	20	2
1,000	100	2

Mean Length of Commute	=	25.8 miles
Median Length of Commute	=	10.0 miles
Weighted Average Length of Commute	=	32.2 miles

Parking Connection does not explore the range of uncertainty associated with various assumptions. Given that estimated congestion costs vary significantly, the report would benefit from a presentation of the outcomes associated with use of different congestion cost estimates (e.g., sensitivity testing).

STEP NINE EVALUATE WHETHER THE ANALYSIS REFLECTS STANDARD ASSUMPTIONS

In general the report appears to follow standard analytical assumptions. However, because the analysis is static, *Parking Connection* ignores the impact the policy-induced decline in parking demand would have on parking prices. Based on standard economic theory of supply and demand, a 20 percent decrease in private vehicle commuting would act to put downward pressure on parking rates. Employers would realize savings both through lower parking and cash-out expenditures.

STEP TEN IDENTIFY THE GROUPS THAT CURRENTLY PAY FOR OR BENEFIT FROM EXISTING CONDITIONS, AND HOW BENEFITS AND COSTS TO THESE GROUPS MIGHT CHANGE UNDER THE POLICY BEING ANALYZED

As previously discussed, *Parking Connection* focuses on the aggregate benefits and costs of the proposed policy, rather than the distribution of benefits and costs. However, the narrow focus of *Parking Connection* may lead readers to ignore important resource transfers — from employers to employees — that could occur within the overall rubric of the proposal. Under current law conditions, a total of 69,500 employees are offered free parking, of which 52,100 actually occupy employer-financed parking spaces at a employer cost of $52.4 million. Given the option of accepting cash in lieu of free parking, the report estimates that 43,100 employees would continue to choose free parking, at a cost of $43.4 million, and approximately 9,000 employees would trade their parking spaces for cash, at a cost of $9 million. However, 17,400 employees who had previously declined free parking — and received nothing from their employer — would take the cash equivalent of $1,006 per year. These drivers would be provided with $17.4 million a year in cash payments from their employers. As a result, proposal implementation would engender continued employer payments of $43.3 million for parking; a transfer of $9 million from parking expenditures to cash payments to formerly "parked" employees; and an additional $17.4 million a year in direct cash outlays, a transfer which the report neglects to include in its analysis. Total employer expenditures under the proposed alternative would be $69.9 million annually instead of the reported $52.4 million — $17.4 million higher than estimated in the report (see also step thirteen).

Although this additional transfer of resources may not affect the overall *social* benefits of the policy, it does have important policy implications. First, *Parking*

Connection claims that one of the advantages of adopting the proposal alternative would be that "...employers are no worse off if an employee chooses the cash alternative or gives up the parking subsidy because the cash alternative is no more costly than the parking subsidy." However, the data presented in the report indicates that this claim is incorrect. Although it is true that the employer-specific cost of offering a *single* employee free parking or a cash payment is equal, offering *all* employees the option of receiving cash in-lieu of free parking would be substantially more costly to employers than simply providing free parking. The large difference in out-of-pocket costs stems from the fact that employers would bear the costs of providing *all* employees either cash or free parking under the proposed alternative, while they only bear the costs of providing parking for employees who drive to work under the current employer-paid parking rules.

Second, given that employers may be unwilling to spend additional sums on their parking programs, in the face of a cash-out policy they may modify their parking programs entirely, potentially imposing greater restrictions on access to it. Such a change, however, could result in similar outcomes as predicted in the report — fewer employees would be eligible for free parking and would drive to work, thereby reducing the social costs associated with private vehicle commuting.

Third, if employers do not, or for some reason, cannot, modify their parking policies in the face of the cash-out option, the transfer of resources from employers to employees would result in some change to local economies. In the case described in *Parking Connection*, almost $20 million which originally had been spent on employer-driven goods and services would instead be spent on consumer-driven goods and services, with concomitant changes to local suppliers. Such a transfer could also encourage employers to relocate to localities where less expensive parking is available.

And finally, it is unclear from the report analysis how rapidly employers can move in and out of the parking market. For example, it is possible that under the policy employers would have to both finance the cash-out, and the expense of excess parking places. In this sense the report findings reflect a partial equilibrium analysis.

STEP ELEVEN SPOT CHECK THE MATHEMATICS

A random check of report mathematics did not identify any calculation errors.

STEP TWELVE DETERMINE WHETHER KEY POLICY QUESTIONS HAVE BEEN ADDRESSED

Parking Connection suggests several broad policy implications that are generally supported by the presented data. First, employer-paid parking appears to encourage more commuters to drive to and from work in Los Angeles; increases regional traffic congestion and air pollution; and increases the amount of society's resources spent on driving and parking. Second, elimination of employer-paid parking would reduce reliance on automobiles; decrease traffic congestion and air pollution; and free up society's resources to be used to pay for alternative goods and services. Third, the proposed alternative — to allow employees to receive cash in lieu of free parking — would provide many of the same benefits as eliminating employer-paid parking, but may be easier to implement and enforce than a complete ban on employer-paid parking. While these findings appear to be fairly robust, it is unclear from the report the extent to which they are generalizeable to areas outside of the LA-CBD.

Partially as a result of the research contained in *Parking Connection*, the State of California recently enacted legislation which requires employers to offer their employees a cash allowance equivalent to the parking subsidy that the employer would otherwise pay to provide the employee with a parking space. In addition, the Clinton Administration included the parking cash-out proposals as the primary transportation measure in its *Climate Change Action Plan* to reduce greenhouse gas emissions, and has announced its intention to submit cash-out legislation to Congress in 1994.

STEP THIRTEEN EXAMINE THE WAY IN WHICH THE ANALYTICAL FINDINGS ARE PRESENTED

Other than the potential reader confusion that could be engendered by the issues identified in step ten, report findings are clearly and comprehensively presented.

STEP FOURTEEN OBTAIN SIMILAR ANALYSIS

As indicated in the previous steps, there are a number of reports — some of which were developed by the authors of *Parking Connection* — that could be usefully examined as part of a comprehensive analysis of the issue. The existence of these reports points to the need both to avoid examining a single report in isolation, and the importance of dedicating specific Cal/EPA staff to ongoing issues, so that they can develop an expertise in the subject area.

STEP FIFTEEN WORK WITH THE STUDY AUTHORS TO CLARIFY AND FURTHER EXPLAIN REPORT ASSUMPTIONS AND METHODOLOGY

The report authors provided important insights into their analytical findings after the initial study review had been completed. In addition, the authors indicated that the evaluation conducted by the handbook authors prompted additional attention to a number of key issues — including the implications of the employer to employee resource transfers discussed in step ten — which would be further explored in future research.

4 MEASURING OBJECTIVES AND UNINTENDED CONSEQUENCES

As noted in Chapter Three, a key feature of analytic decision-making is its ability to identify objectives and develop means of measuring their attainment. In addition to the desired policy goals, government intervention can also result in unintended consequences, which can also be assessed using various measurement variables. These policy "yardsticks" fall into two general categories: **economic efficiency** and **distributional impacts.**

Once an analytical structure has been used to define a problem, having a "measurable" policy objective does not mean that the outcome must be denominated in monetary terms. Analytic decision-making methods are available for weighing multiple goals and objectives described in different terms. A decision-maker should be ready to attach "weights," either explicitly or implicitly, to the various goals within a proposed policy. This concept should not be surprising since policy-making always involves trade-offs in what society wants to attain.

Although distributional and efficiency concerns are frequently measured using the same variables — such as job or income changes — it is important to understand the distinction between the two. Efficiency criteria focus on aggregate benefits and costs, or the overall economic changes induced by a policy. For example, assigning a parking place close to a building to an employee who drives to work every day may be efficient. Distributional criteria focuses on who receives the benefits or costs of a policy. For example, the parking space may be provided to the boss as a perk.

The evaluation methods described in this chapter represent these most commonly used in policy analysis reports, and include the following:

Market-based Evaluation Methods

- **Engineering-economics** or **life-cycle analysis** is used to determine the costs of purchasing, installing and using a long-lived economic asset such as a building or automobile.

- **Discounted cash flow and internal rate of return** are used to weigh the costs of purchasing and using an asset against the income and other benefits that the asset provides over a period of time. This method provides a simple assessment of the returns to investing in an asset.
- **Mathematical programming** models are used to determine the best mix of resource inputs required to produce a certain output (e.g., the amount of land, fertilizer, water, equipment and labor needed to achieve a certain crop yield that maximizes a farmer's profits).
- **Econometric analysis** is a statistical method of assessing past economic behavior, such as the sensitivity of demand to changes in prices or how changes in inputs affect production.
- **Accounting analysis** uses the financial characteristics of particular firms to estimate the impacts on costs and production from policy changes. This method serves as a useful measure of short-term effects and a check against the findings of more sophisticated techniques.

Regional Economic Impact Models

- **Input-output models** provide a simple analysis of the economic flows through a regional or national economy that result from policy changes.
- **General equilibrium models** are more sophisticated regional impact models that take into account that the value of a resource changes as the mix of other resources and demand for a product change.

Valuing Environmental Assets and Health Benefits

- **Hedonic pricing** uses the differences in the value of comparable fixed economic assets, such as houses, to assess the market price attached to environmental quality (e.g., air and water quality, existence of vegetation or a view).
- **Travel-cost method** estimates the value for a recreational asset by calculating how much individuals are willing to expend in travel time and cost to reach the location.
- **Contingent valuation methods** ask people directly how much they value an environmental asset for which a market does not exist (e.g., the continued vitality of wetlands).
- **Politically-revealed preferences or control costs** represent the value placed on protecting against damage to the environment or health through the political process. This approach uses the costs of meeting regulatory standards as the

proxy for the benefits of reducing environmental or public health risks.

- **Damage functions** take scientifically-derived physical changes to the environment and apply these impacts to economically-estimated values for environmental attributes to calculate expected damages from specific contaminants, hazards or actions.

Frequently a mix of these methods will be used in an analytic report. For example, damage functions often use values derived from contingent valuation studies, and programming models rely on engineering economics and econometric analyses for their initial costs estimates.

4.1 MEASUREMENTS OF ECONOMIC EFFICIENCY: WHAT ARE THE NET GAINS TO SOCIETY?

Economic efficiency is concerned with the expected net gains or costs to society resulting from a policy choice. Efficiency-related economic attributes associated with environmental policies tend to fall into one of three categories, as follows:

- ***Direct economic impacts*** - focus on changes in net wealth or income. This encompasses one component of economic well-being — aggregate societal benefits and costs. Measured changes include productivity, employment, income, potential direct cost increases or savings to consumers or producers, and indirect or secondary impacts on consumers or producers through changes in economic activity.

  In assessing direct economic impacts it is important to avoid double-counting benefits and costs. For example, higher incomes generally lead to inflated land prices, so higher purchase and rental costs should be netted out of aggregate wealth increases. *Regional impact, mathematical programming and input-output models are used to evaluate these impacts.*

IS AN EMPLOYED SOCIETY A WEALTHY SOCIETY?

More jobs do not necessarily mean more societal wealth. The *kinds*, as well as the total number, of jobs created are of importance to wealth generation. For example, in low-income Bangladesh it takes many more workers to grow and harvest a ton of rice than in wealthy America, yet few would argue that Bangladesh, with more rice-related jobs, is better-off than the United States. The use of labor is but one variable in the economic equation, and efficiency gains depend on how the many relevant factors in this equation — technology, resources, education levels, among others — interact.

- *Environmental and aesthetic amenities* - focus on net changes in ecology or resources, including ecological restoration, as measured by the reintroduction and ongoing well-being of specific animal and plant species into an area. Although the natural sciences are employed to measure ecosystem changes, economics can be employed to translate natural attributes into monetary values. These characteristics — including functioning natural ecosystems with abundant wildlife; recreational opportunities; ambient levels of noise, dust and odors; visibility; landscape — must be valued by individuals in some manner. *Non-market valuation techniques, such as hedonic estimation, contingent valuation and travel-cost models, are used to quantify approximately the monetary benefits of natural resources.*

- *Human health aspects* - are concerned with the net value of expected health risk reductions. Health attributes are either related to reducing the chance of death (mortality), or decreasing the incidences of illness (morbidity). While health scientists are primarily responsible for measuring changes in mortality or morbidity, economic methods can be used to translate these changes into dollar terms. For example, economic benefits and costs can be associated with avoiding illness or death attributable to pollutants and toxics; the value of lives lost or disrupted; the value attached to "peace of mind" or anxiety about potential health threats engendered by environmental hazards. *Non-market evaluation methods are used — including damage functions based on dose-response models and hedonic estimation — to estimate the economic value of morbidity and mortality.*

4.2 MEASUREMENTS OF DISTRIBUTIONAL IMPACTS: WHO ARE THE WINNERS AND LOSERS?

Distributional concerns center on a policy's implications to different groups, including who is burdened and who benefits from the policy. Distributional impacts fall into one of four categories, as follows:

- *Equity impacts* - include effects on various socio-economic and geographical groups. Equity impacts focus on the economic well-being of individuals or groups. Equity-related costs and benefits include:

  Jobs - Employment changes can be measured by identifying economic sectors which gain or lose jobs as a result of a policy, and by evaluating the overall "churning" effect induced.

  Income and wealth - Job and income changes can be specified and quantified by income, number of individuals affected, and mean and median income and job changes within a class.

Regional impact and input-output models can be used to identify equity impacts by economic sector; and demographic distributional models can be used to identify geographically-determined impacts.

PROFIT FUNCTIONS

In examining the profit motives and cost factors for producers, economists develop **profit functions** that represent a simple model of a firm's financial and technological traits. A profit function has four components:

- **Revenues** equal the price of the product or service times the quantity of output.
- **Costs** equal the price of inputs — such as labor or investment — times the quantity of inputs.
- **Constraints** on resource availability.
- **Technology** is reflected by a mathematical representation of the production process—the **production function**—that describes how inputs are combined to produce an output.

Assumptions frequently made to support profit functions include:

- Firms are in a **competitive market** (i.e., the prices for products and inputs are not influenced by the behavior of an individual firm).
- Firms have access to **perfect information** about present and future conditions, which may be conveyed through the market's pricing mechanism.
- Firms are **risk-neutral** about their choices (i.e., they are indifferent between two choices that have the same expected outcomes, regardless of whether one may involve higher risks).
- The world is unchanging or **static**, implying that no **dynamic feedback** effects exist.
- The production process eventually has **decreasing returns to scale** (i.e., the cost of producing each additional unit increases with total output).

Obviously, these assumptions are not always even good approximations of a particular situation, and must be modified to accurately assess the problem. On the other hand, the analysis becomes more complex as the assumptions are adjusted to accommodate real-world conditions such as **monopolies, uncertainty** and **dynamic** effects.

- *Community amenities and cohesiveness* - focus on the desirability of a community-wide change induced by a given policy. Included in this category is an evaluation of the non-market attributes that affect the desirability of a community (e.g., vitality, interrelationships, crime rates, education level, congestion and urban sprawl, and interclass tensions). The category also includes cultural factors, such as ethnic identity, religious practices, and other bases of community organization. Policy-makers should understand these intricate relationships and their sensitivity to policy initiatives. *In general, these factors are difficult or impossible to quantify using solely economic tech-*

niques. The disciplines of sociology and psychology can be usefully employed to examine these issues.

- ***Relative competitiveness*** - relates to the desirability of a political jurisdiction as a place to locate a business. This factor can be affected by government services and regulatory levels, availability and cost of key market inputs, and the attractiveness of the environment and community. *While attempts have been made to rank various locales for their attractiveness based on a variety of attributes — including regulatory burden, workforce training and education, crime rates, climate, tax rates, and housing costs — economists have not developed a single quantifiable "index" to measure business climate.*

- ***Fiscal impacts*** - focus on how government revenues and expenditures change as a result of a policy. Government revenues are derived from economic activity. As a result, changes in this activity will affect public sector revenues, and potentially the level of government services. For example, property tax breaks for a large factory may lead to lower aggregate property tax revenues,

CONSUMER PREFERENCE OR UTILITY FUNCTIONS

Economic analysis typically focuses on the individual as the core of the decision-making process. Consumers are assumed to make choices that best satisfy their preferences given budget and income constraints. Economists assume that consumers have roughly similar preference functions, and that these preferences can be aggregated among individuals to determine the total social net benefit associated with an activity.

Other typical assumptions about consumer preferences include:

- Consumers can best decide for themselves what they want, and others' preferences do not affect their own choices.
- Consumers have preferences about all available goods and services, and these preferences are separable among goods and services.
- Consumers have well-ordered, consistent or **transitive** preferences among goods and services.
- Consumers do not exhibit large discrete jumps in their preferences (i.e., they care about a particular good until it reaches some threshold level at which point they care a substantial amount). Ecosystems, on the other hand, may follow such behavior (e.g., aquatic life often can tolerate heavy metal contamination up to a threshold, beyond which the ecosystem fails).
- Consumers always prefer more of a good or service in the range of analysis (i.e., "more is better").
- As consumption of a good increases, the benefit of an additional unit provided eventually decreases.
- Consumers are either **risk-neutral** or **risk-averse** (i.e., they prefer certainty over risky situations).

but increased business activity, which in turn could engender higher sales and income tax revenues, and, in the long run, higher property tax values as the wealth of the community grows. However, regional fiscal policies often simply shift revenues from one jurisdiction to another (e.g., competition for professional sports franchises). *Government revenue projection models can be used based on regional impact and macroeconomic models to project fiscal impacts.*

4.3 MEASURING MARKET-TRADED GOODS AND SERVICES

There are a number of different ways to measure changes in **market-based** economic activity. These include:

- Internal rate of return or discounted cash flow,
- Engineering-economics,
- Mathematical programming models,
- Statistical and econometric analysis,
- Accounting analysis,
- Regional economic impact modeling techniques.
- Static simple equilibrium model,
- Input-output models, and
- General equilibrium regional models.

Each of these measurement techniques is evaluated below.

4.3.1 DISCOUNTED CASH FLOW AND INTERNAL RATE OF RETURN

Description: Discounted cash flow (DCF) and Internal Rate of Return (IRR) are two related and useful means of comparing the economic benefits of alternative projects. When comparing projects with different time periods, it is not enough to know costs and benefits. The timing of the flows of benefits and costs must also be considered. DCF uses a specified **present value discounting rate** (PVDR) to account for the time value of money. This rate can be used to take into account the implications of **inflation, opportunity costs** and payback **risk.** Summing the DCF over the life of the project yields the **net present value** (NPV). In general, the higher the NPV, the more desirable the project, while a project with a negative NPV is not worth doing (see also Section 5.2 Benefit-Cost Analysis).

IRR analysis is an application of DCF in which the **time value of money** is taken into consideration, but not by any explicitly specified PVDR. Instead, a PVDR which results in a net present value of zero is calculated. This calculated PVDR, expressed as a percentage, is defined as the IRR. The higher the IRR, the greater

TIME IS MONEY

Things change as time goes by. We all get older, equipment wears out, and new technologies are developed. Money too "degrades," and generally loses value over the years. This is chiefly because of **inflation, lost earning potential,** and **risk,** all of which act to eat away at our purchasing power. For example, fifty years ago a favorite candy bar could be had for a nickel; today the same luscious mound of nuggety chocolate costs sixty cents. While sometimes the value of a dollar increases — California real estate in general requires fewer dollars to purchase in 1994 than it did in 1990 — over time dollar value tends to steadily degrade.

Because time is the enemy of money, in general a dollar today is worth more than a dollar tomorrow. In addition to inflation, interest may include a factor that reflects the value of the money as a source for capital investment, with higher value associated with more risky, but potentially more lucrative, projects. That is one of the reasons financial institutions are willing to pay **interest** to hold on to our paychecks. This is called the **time value of money.**

the benefits of the project. The IRR in effect shows the percent payback of the investment. A negative IRR indicates that the project is not worth doing. Most spreadsheet programs have a built-in formula to compute the IRR.

Data Requirements: For both DCF and IRR the cash flow—that is the stream of costs (investments) and returns (benefits or payback)—must be specified over the project's life. Cost or investments are negative cash flows, while benefits or payback are positive cash flows. For each year, the net benefits (benefits minus costs) are summed. In DCF these are discounted back to a base year using the PVDR. If costs and benefits are expressed in real (constant dollar) terms, the

TIMEFRAME BANDITS

Failure to establish a common timefame can lead to sub-optimal decisions. For example, consider a decision between two air pollution control devices to be made on the basis of cost-effectiveness. Device A has an installed (capital) cost of $100 and a $10 per year operating cost. Device B, which is equally effective as Device A in controlling pollution, has an installed cost of $200 and an operating cost of $5 per year. Which device is more cost-effective? After 10 years, device A has a total cost of $200 (at a zero present value discount rate). Device B has a total cost of $250. Is A more cost-effective? The answer is "yes" for a 10-year timeframe, but "no" for a 25-year timeframe. After 25 years, A costs $350 while B costs $325. What if device A has an operating life of 15 years while B lasts 20 years? A is cost-effective for a 15-year timeframe, B is cost-effective for a 20-year timeframe, but A wins for a 30-year time frame.

PVDR should not include any allowance for inflation. If current dollar costs and benefits are specified, the PVDR must include the anticipated inflation rate.

The base year is usually the first year in which investments are made, although any base year can be specified in the analysis. The sum of the discounted cash flows for all years of analysis provides a measure of the benefits.

Table 4-1 illustrates a DCF analysis for a twenty-year timeframe, based on the example in the "Timeframe Bandits" text box. By examining the 0% PVDR (undiscounted) columns it can be seen that Projects A and B have net cash flows of $200 and $250, respectively, indicating that B is more desirable. However, at the OMB-mandated 7% PVDR, Project A has a higher net present value than B — $59 versus $14.4 — indicating that A is indeed preferable if the future payments are worth 7% less per year.

The net benefits in each year can also be used to compute the IRR, as indicated at the bottom of Table 4-1. Note that the higher IRR for A (15.1% versus 7.75% for B) indicates that Project A is preferred.

Table 4-1 also illustrates the relationship between DCF and IRR. Note the right most columns under Project A and Project B. These show discounted cash flows for each year using the IRRs for A and B as a present value discount rate. The sum of each of these columns (net present value—NPV) is $0. This is not a coincidence – it illustrates that the IRR is computed by adjusting the PVDR until the NPV is zero.

Theoretical Basis: The formula for DCF depends on whether the discounting is continuous or discrete. For the continuous form, the formula is:

$$DCF = Fe^{-rt}$$

Where:

e = the base of natural logarithms

r = the PVDR

t = the number of periods (usually years).

F = future benefit or cost

For discrete discounting starting at the beginning of the time period, the formula is

$$DCF = F(1+r)^{-t}$$

For discrete discounting using the middle of at the time period, the formula is:

$$DCF = F/(1+r)^{(t+0.5)}$$

The IRR is typically computed using the above formula and iteratively solving for the r that yields a zero NPV.

Table 4-1
Discounted Cash Flows (DCF) and Internal Rates of Return (IRR)

		PROJECT A				PROJECT B			
Year	Benefit	Cost	DCF at 0% PVDR	DCF at 7% PVDR	DCF at 15.1% PVDR	Cost	DCF at 0% PVDR	DCF at 7% PVDR	DCF at 7.75% PVDR
0	0	-100	-100	-96.7	-93.2	-250	-250	-241.7	-240.8
1	30	-10	20	18.1	16.2	-5	25	22.6	22.4
2	30	-10	20	16.9	14.1	-5	25	21.1	20.7
3	30	-10	20	15.8	12.2	-5	25	19.7	19.2
4	30	-10	20	14.8	10.6	-5	25	18.4	17.9
5	30	-10	20	13.8	9.2	-5	25	17.2	16.6
6	30	-10	20	12.9	8.0	-5	25	16.1	15.4
7	30	-10	20	12.0	7.0	-5	25	15.1	14.3
8	30	-10	20	11.3	6.1	-5	25	14.1	13.3
9	30	-10	20	10.5	5.3	-5	25	13.1	12.3
10	30	-110	-80	-39.3	-18.3	-5	25	12.3	11.4
11	30	-10	20	9.2	4.0	-5	25	11.5	10.6
12	30	-10	20	8.6	3.4	-5	25	10.7	9.8
13	30	-10	20	8.0	3.0	-5	25	10.0	9.1
14	30	-10	20	7.5	2.6	-5	25	9.4	8.5
15	30	-10	20	7.0	2.3	-5	25	8.8	7.9
16	30	-10	20	6.5	2.0	-5	25	8.2	7.3
17	30	-10	20	6.1	1.7	-5	25	7.7	6.8
18	30	-10	20	5.7	1.5	-5	25	7.2	6.3
19	30	-10	20	5.3	1.3	-5	25	6.7	5.8
20	30	-10	20	5.0	1.1	-5	25	6.2	5.4
Net Present Value		**-400**	**200**	**59.0**	**0.0**	**-350**	**250**	**14.4**	**0.0**
Int. Rate of Return			**15.10%**				**7.75%**		

Common Applications: IRR and DCF are used in economic comparisons of projects or policies of all types. In these analyses the initial year's cash flow is negative, reflecting the original investment. In latter years the benefits of the investment usually yield positive cash flows. Both methods are commonly used when financial considerations are the deciding factor in choosing among competing alternatives which accomplish similar objectives.

Strengths and Limitations: Both DCF and IRR are of greatest use in comparing investments with complicated cash flows and different project lives. However, neither method includes considerations of budget limitations. For example, limitations on available funds might preclude an option which has a higher IRR or NPV.

CHOOSING A DISCOUNT RATE: IN THE EYE OF THE BEHOLDER

Academics and policymakers alike debate over what **discount rate** to use in various situations. Although some academics argue that a single rate should be applied in all circumstances, the current consensus is that the appropriate rate depends on the perspective of those who are being affected by a policy decision. That is, the appropriate discount rate may vary based on the issue and impacted population.

Consumers face a wide range of situations based on **socio-economic status** and other characteristics. For example, being an older low-income renter —with a limited lifespan and little economic benefit from reduced energy charges—can increase the personal discount rate for energy-saving purchases by up to nearly 100 percent, implying a one-year payback period. Consumers face **uncertainty** about being able to retain investment benefits compared to more certain costs. Also, as investments take up a larger share of income, consumers become more **risk-averse** about potential losses. Consumers generally are not regular participants in the fluid financial markets, thereby limiting their access to ready credit. Some studies have found that people typically divide their budget to save for future needs at a different discount rate than the rate that they use for purchases. This situation has led to the dichotomy where some analysts advocate using the "savings account" rate while others push a higher "credit card" rate for consumers.

Businesses have more ready access to the financial markets, and as a result their discount rates are much more easily estimated. However, two issues arise when assessing the private sector's discount rate. First is the **risk** premium level that is inherent in every investment decision. Firms often limit their risk exposure by compressing the expected payback period—frequently to as short as three years, implying a 35 percent discount rate. Second is the impact of corporate and income taxes. U.S. corporations face **marginal tax rates** in excess of 35 percent; this acts as a "wedge" between the **cost of capital** reported in the financial markets, which is "after tax" and the true cost faced by managers. For example, the allowed **rate of return** to shareholders for **public utilities** is about 10 percent including **inflation**; however, the corporate "before tax" discount rate can exceed 15 percent.

Government infrastructure projects frequently displace private investment, either as direct replacements, as in the case of water systems, or by drawing capital out of the financial markets through taxes or borrowing. In either case, the appropriate discount rate is generally thought to be equivalent to the private sector rate. This rate equals the expected return on **marginal** projects that would have been chosen if the capital was made available. It is important to note that these projects should have <u>an equivalent level of risk</u> to that of the government investment. For example, the rate for a water project should match that of private public utilities, not of a speculative gold mine.

Social policy discount rates have been the primary focus of recent debate. Several different approaches to social discounting have been proposed. The *social rate of time preference* is based on using a **risk-free** rate as revealed in the marketplace. The indicator most often used in this method is the U.S. long-term Treasury Bond rate. The *golden rule* leads to using a rate equal to overall **productivity** increases. This approach implies maintenance of a "**steady state**" of consumption through time. Finally, advocates of *intergenerational equity* believe the social discount rate should either decline as the time horizon increases or even be set at zero. A zero social discount rate is based on the observation that many public goods and natural resources do not depreciate over time, and that a person tomorrow should have the same **rights** to those resources as a person today. However, a discount rate of zero leads to people being better off in the future at the expense of people living now.

DCF is a good method for comparing alternatives with similar timeframes. IRR is preferable in comparing projects with different investment or benefit patterns over time. IRR is also helpful in situations where it might be difficult to determine an appropriate discount rate. (See "Choosing a Discount Rate: In the Eye of the Beholder" textbox)

4.3.2 ENGINEERING-ECONOMICS OR LIFE-CYCLE ANALYSIS

Description: Engineering economics provides a method to account for the variable and fixed costs associated with operating a technology, facility or program. The costs can be described in terms of per unit of output, on an annual basis, or over the entire **life-cycle** of a technology.

The results of engineering-economic analyses usually are key inputs into subsequent analysis, from financial evaluation to regional impact models. By using a common set of **assumptions**, the costs of various technologies can be ranked on the basis of economic **efficiency**. A ranking analysis assumes that a firm's goal is to minimize costs. However, even if this assumption does not hold, the principles of engineering economics can be used to calculate common costs for other types of analysis.

At the core of an engineering economic analysis is the method used to compare costs among project alternatives. In the case where two alternatives have the same expected economic life, a **life-cycle analysis** can be conducted. Life-cycle analysis involves first calculating the **discounted present value** of all costs necessary to operate the project over its lifetime. These costs can include energy, labor, material purchases, monetized environmental impacts, as well as other factors. Then, the total investment costs for constructing the project are added to arrive at a total life-cycle cost.

If the project alternatives have different **expected** lifetimes, then a **levelized annual payment** can be calculated. For example, the cost of a traditional incandescent lightbulb can be compared with the cost of a new energy-saving fluorescent light. The former might last two years, while the latter may not fail for a decade. In the analysis the life-cycle costs for each is totaled. Then the annual payment necessary to recover the costs over the expected lifetime is estimated. This calculation is exactly the same as that for a home mortgage — it is equivalent to the annual loan repayment, including principal and interest. The annual payment is the same each year, and does not vary with project usage. Variations in this approach include calculating the levelized annual rental payment that takes into account year-to-year escalation in construction costs due to inflation and other factors. Both engineering economics and life-cycle analysis can be used as a part of broader decision analytic techniques, including **cost-effectiveness**, **benefit-cost**, **least-cost planning**, and **decision analysis**. It is important to note that the methods rely on **accounting costs**, not **opportunity costs** (i.e., engineering economic data comes from out-of-pocket expenses, not costs associated with giving up other opportunities to use the same resources). As a result, the method assumes that the resources committed to a project are being used for their highest economic value.

Data Requirements: In engineering economics, five key pieces of information or assumptions are required:

- The initial investment or "fixed" costs to acquire and install the technology, build the facility or begin the program.
- The annual expenditures to operate and maintain the technology, facility or program.
- The expected lifetime of the technology, facility or program.
- The operating characteristics of the technology, including output at various capacity rates and expected reliability.
- The **interest** or **discount rate** used to determine the appropriate **rate of return** on an investment.

For example, if an initial investment of $1,000 is made, operating costs are $25 per year, the expected life is 20 years and an interest rate of 5 percent is employed, the investor would want to receive $101 per year to break-even. The annual operating or variable costs of the technology — labor, fuel, raw materials, repairs — also can be varied over the lifetime of the facility or program.

Assumptions: Several key assumptions are usually made in an engineering economic analysis, as follows:

- First, that investors attempt to recover their initial up-front costs at a constant rate over the lifetime of the technology or project.
- Second, the technologies or programs being compared will provide the same type of product or benefits. While the analysis can be adjusted somewhat for differences, it works best with homogeneous a output, such as electricity.
- Third, the life of a technology can be accurately forecasted, and that, on average, it will be retired at the end of its **economic life**. The analysis assumes that the facility or program will not provide any benefits beyond the forecasted life, so future consumers should not pay any investment costs.
- Fourth, the benefits that accrue from the project will decline over time at a steady rate. This implies that economic **depreciation** equals physical deprecia-

tion. For example, a technology with a 20-year lifetime would have an annual five percent decline in output.

- Fifth, variable cost increases can be forecast with reasonable accuracy, and capital investment costs are known with certainty. This can be an improper assumption in some circumstances. For example, the decommissioning costs of nuclear power plants were substantially unknown at the time most of these facilities were built.
- And finally, demand for the output of the technology or the program will remain high enough to financially support its costs throughout its economic lifetime.

Strengths and Weaknesses: Engineering economics is a relatively transparent method to compare the costs of various technologies and policies. Its explicit assumptions are relatively straight-forward, and its results are based on a single expected cost.

However, the implicit assumptions act to limit the analysis, especially since economic costing does not always mesh with technological performance. This is a particular problem when trying to forecast expected lifetimes and annual benefits. It is difficult to know the true expected lifetime for many technologies, especially if maintenance efforts are more or less successful than initially projected. For example, an electric fossil-fueled power plant often operates well beyond the 30-year life used to set annual cost recovery rates. As a result, consumers have paid inappropriately high rates in the early years of plant operation.

Another problem with engineering economics is that the benefits from the facility typically rise significantly over time until the point of its retirement, but the analysis generally assumes that the costs to generate those benefits stay constant or decline. For example, reconsider the technology that cost $1,000, with annual costs paid by consumers of $101 per year. If the upfront **capital** cost of the technology was to double in 10 years to $2,000, the annual costs for this plant would increase to $178 per year. If consumer demand was rising and the policy was to charge the true costs of the benefits gained, the technology should be priced at the higher cost which reflects the **marginal costs** of meeting the higher demand. However, under engineering economics analysis, consumers would continue to pay $101 per year, a price that does not reflect the marginal costs of the output. The solution to this problem is to use **trended rate-basing** or **annual rental payments** which start with lower initial annual costs and rise as the cost of the technology or policy increases over time. This methodology has been explored in-depth at the California Public Utilities Commission and has been used in several electric utility rate cases.

Finally, engineering economics does not allow for incorporation of other direct impacts, such as environmental damage, uncertainty or distributive issues. Any trade-offs with direct economic efficiency must be made through side calculations, such as **scenario** or **sensitivity analyses**.

4.3.3 MATHEMATICAL PROGRAMMING MODELS

Description: Mathematical programming techniques, such as **linear, quadratic** or **non-linear programming**, take engineering economic analysis one step further by accounting for **profit-maximization** in the technology-ranking procedure. Programming models simulate a firm's decisions based on prospective cost and production information, but ignore other aspects of human behavior, such as **risk aversion.** Through use of these models a set of technology costs can be calculated for a range of outputs, and the technology which allows for the highest profit levels can be chosen through a mathematical search process. The models essentially produce a **normative** analysis of "what should be."

Programming models follow a similar pattern to the analytical framework described in Chapter Three. They have an **objective function** whose goal is to find the largest difference between revenues and costs, so as to maximize profits. The technologies employed are described mathematically in a set of **constraint equations** that calculate how costs vary with production input levels. The model represents a **static** snapshot in which a firm might move from one technology to another because of changes in the objective function or the constraints. The model then proceeds along a series of steps:

- The first step is to define **feasible solutions** where all constraints are satisfied.
- The second step is find the **optimal or preferred solution** from among the feasible solutions (i.e., what is the highest value of the objective function). If a constraint is **binding**, one can determine the **shadow value** or **opportunity cost** associated with relaxing the constraint by calculating how the objective function changes when that constraint is slightly relaxed.

Common Applications: Different types of mathematical programming models have been constructed to assess the cost and production structure of various industries, including petroleum production and refining, and the agricultural sector. These models generally fall into two categories:

- *Linear-programming models* find the maximum feasible solution for a linear objective function in the face of linear constraints. This simplicity allows linear-programming models to use large data sets and derive faster solutions for large problems. However, linearity can impose restrictive **assumptions** about the type and form of economic phenomena being modeled.

- *Non-linear programming models*, such as *quadratic programming* or *positive mathematical programming (PMP)*, use non-linear constraints and objective functions that allow for more flexible modelling (e.g., price-sensitive product demand) of economic phenomena.

Common Applications: Mathematical programming models have been used to evaluate the economics of just about every industry. Some of the most common uses are for farming operations, petroleum refineries, airline scheduling, and industrial plant management.

Assumptions: Programming models are built on a number of different key assumptions, including:

- Short-run cost minimization equals profit maximization. As a result, within the appropriate constraints the models should arrive at the same solution whether they maximize the revenue function or minimize the cost function.
- Technology costs are well understood and can be specified with a high degree of certainty.
- Input units are divisible down to a sufficiently small amount.
- For linear and quadratic programming, the constraint equations are linear (i.e., the input factors are only multiplied by a constant and added up). This implies that the use of an input is *proportional* to the output that uses it, and that total input use is *additive* across all outputs.
- In the case of linear programming, the objective function implies that demand is perfectly "**inelastic**" or is non-responsive to changes in product prices. Quadratic and non-linear models can incorporate demand responsiveness, but at the expense of computational ease.

Strengths and Weaknesses: Mathematical programming provides a transparent method to calculate the most efficient way to achieve the maximum benefits given a set of production technologies and resource constraints. The objective function and constraint equations are relatively straight forward, although models for large problems can be enormous due to the number of constraints.

The primary problem with a programming model — particularly linear and quadratic formulations — is that it usually represents **static, short-term** specifications of a problem. That is, all technologies must be included explicitly, so that accounting for technological innovations is problematic. In other words, the models focus on the short-term, and assume that policy changes will not create feedback into demand and supply prices beyond the simple modelling framework. Expanding the model beyond a single operation also is difficult because it must account for the differences between firms by adding constraint equations. For example, two farms may have identical crops and may face identical prices for water, labor and equipment, but they produce different amounts of those crops. The modeler might then add another constraint for soil type which explains this difference. If a third farm is added which differs for another reason, yet another constraint must be added. The **calibration process** for these models, where results are compared to actual conditions, can lead to elaborate constraint conditions which may not be fully justified by the analysis.

A related problem is that the transition from one technology to another may lead to large, discrete "jumps" in the results, implying that firms shift *en masse* from one production process to another when costs change slightly. This behavior does not mesh with the usual observation that firms use a number of different input combinations for the same type of output.

4.3.4 STATISTICAL AND ECONOMETRIC ANALYSIS

Description: Statistics is the analysis of how real-world or **empirical** events and trends relate to each other given that a certain amount of **random** chance will intervene. Statistics relies on probability theory to develop measures of the *most likely* explanation of what causes certain events. **Econometrics** is the application of mathematical and statistical methods to empirical economic data. The result of this analysis is a **positive** or "what is" description of current and past behavioral patterns related to supply and demand. Econometrics examines how differences in certain conditions, such as prices, local attributes, or other factors, can lead to alternative paths of consumption or production. These behavioral and technological relationships can then be used to estimate changes resulting from policy initiatives. Likewise, uncertainty about past performance can be summarized from the statistical results and used in **sensitivity** testing.

An econometric analysis is composed of a mathematical representation which embodies a set of assumptions derived from a theoretical model. The model includes a **dependent variable**, which is the data the model tries to explain; **independent or explanatory variables**; and **parameters** that specify the mathematical relationship between the dependent and independent variables. Based on this model a **regression** is done to determine how well the model fits actual data. Along with the parameter estimates, the regression produces error estimates that can be used to construct **confidence intervals** that show a possible range for the parameters with a given probability.

Assumptions: Statistical analysis can be conducted over a spatial dimension using **cross-sectional data**; a temporal dimension using **time series**; or both dimensions using **pooled time series.**

- In cross-sectional analysis, the relevant variables, (e.g., available technologies and products) are held essentially constant because only ones currently in use are studied (i.e., no innovation is allowed). Cross-sectional analysis produces estimates without any time dimension.
- Time series analysis, on the other hand, can estimate how conditions (e.g., preferences or technology choices) change over time and assesses the importance of different factors in this transformation. Likewise, time series analysis can estimate both *short-term* and *long-term* impacts.

Econometric demand estimates rely on **consumer preference or utility assumptions.** Because the analysis is of aggregated demand, the underlying assumption is that all of the relevant consumers have the same sort of **utility or preference functions**, and that they are all trying to achieve maximum satisfaction given their budget constraint and trade-offs with preferences for other goods. *Supply estimates* assume that firms are **profit-maximizing**, and that their production process can be represented as a quasi-technology by a mathematical equation. Again, the mathematical representation can impose additional assumptions about how production inputs relate to each other and the output rate.

Data Requirements: The first requirement in statistical analysis is that the data have a sufficient number of observations and variation to develop a **statistically-valid** model. The second requirement is that the explanatory variables meet the needs of the relevant theory underlying the model.

Generally in economics either the quantity demanded or supplied or a cost function are estimated. The explanatory variables for these behavioral and technological relationships might include:

- Prices or quantities for the goods and services in question.
- Prices for substitute or complementary goods and services.
- Prices for inputs to the production process in the case of the supply or cost functions.
- Physical attributes, such as climate or soil type.
- Technological attributes, such as age of facilities, type of equipment or degree of adoption.
- Institutional and social attributes, such as regulatory requirements, exchange mechanisms, demographics or cultural factors.

Strengths and Weaknesses: Statistical analysis has advantages over other empirical analytical methods in that it combines data from many observations (e.g., different consumers or producers) and can be used to make generalizations to a large population. Econometrics is the most common technique used to estimate demand for goods and services. Econometric analysis can span several technological applications, including ones which are no longer in place. The econometric analysis also includes behavioral responses that might affect the use of a technology under different conditions, an effect ignored in **mathematical programming.** The advantage of this approach is that econometrics can capture conditions that lead to the development of new technologies that are currently unknown.

Statistics and econometrics suffer from several drawbacks as well. First, it relies on rather restrictive mathematical assumptions, both in the methodology and in the model specifications. Unfortunately, it is quite difficult to test for when these assumptions are violated or even which model is most appropriate. Second, the parameter estimates may be **biased** or incorrect for a number of reasons, including:

- **Omitted variables,** that might contain explanatory information which is instead erroneously captured by included variables in the model.
- **Serial correlation,** in which successive observations over time are explained by the previous observation.
- **Heteroskedasticity,** in which the error for estimation around a predicted value grows with the size of the value.
- **Multi-collinearity,** in which two explanatory variables are too highly correlated to distinguish how much each separate variable is influencing the outcome.

Third, the model may not be adequately **identified** to distinguish the effect the analyst is trying to assess. This is particularly a problem in separating demand and supply effects, since price influences both the quantity consumed and produced in opposite ways. Analyses that show little or no response to price frequently have this problem. It should be pointed out that, in most cases, standard statistical tests can be used to measure whether or not problems exist in a given econometric analysis.

Fourth, **confidence intervals** are often misinterpreted from statistical studies. These do <u>not</u> imply that an analyst is 90 percent confident that the forecast is correct. Rather a confidence interval states that given the estimation methodology and the historic population, 9 out of 10 estimates done with this approach would result in the same forecast.

4.3.5 ACCOUNTING OR BUSINESS COST ANALYSIS

Description: Accounting analysis focuses on the balance sheet of an industry affected by a policy proposal. Used in combination with an **engineering economic** analysis, this method evaluates the impacts of changing costs on firm profitability. Accounting analysis relies on **case studies** to develop results that might be extrapolated to similar types of firms.

Data Requirements: Relatively complete financial information for either a firm or an industry is necessary for accounting analysis. Usually the most difficult information to collect is revenues for privately-held firms or for individual plants of publicly-held companies. Surveys and business databases, such as the one compiled by Dun and Bradstreet, are the usual information sources.

Strengths and Weaknesses: The most obvious strength of accounting analysis is that it can provide a real-world case study of how a policy might affect businesses in the short term. It has four major drawbacks:

DIRECTLY INDUCING INDIRECT IMPACTS

Companies frequently tout the economic benefits of new plant openings. For example, a freshly-located computer software facility may support 100 jobs with a payroll of $3 million, which in turn brings another 250 jobs to the community, and creates an additional $10 million in increased business activity. How do analysts derive such estimates?

Employment forecasts generally rely on the principles of general equilibrium analysis — that significant economic activity in one market will affect another interrelated market. In the case of a new software facility, the demand for labor increases locally, which in turn causes total income to rise, which then **induces** more purchases by the newly employed labor force at local retail outlets. Store managers respond by hiring more clerks to serve the additional customers. These new store clerks also spend their wages. This spending loop is called the "**multiplier effect**" — essentially the impact an additional dollar has as it travels through the economy. Multipliers range from 1.2 to 2.5 additional jobs created for every one new job directly created.

In addition to the **direct** multiplier effects, the facility has an **indirect** influence on the local economy by increasing demands for the locally-produced goods and services which contribute to the plant's output. For example, an automobile parts supplier may expand to service a new automobile manufacturing plant. The added jobs at the parts supplier is an indirect effect of the factory. These new jobs then lead to additional induced employment, like those impacts described above.

- First, extrapolating the results of accounting analyses to other firms or industries is highly questionable due to the disparities between situations. This danger exists for any type of **anecdotal analysis.**
- Second, in the case of surveys, firms or individuals might give biased responses that they believe will best further their own goals, including protecting the status quo.
- Third, the analysis does not allow for any accommodating responses by the firm's managers. Accounting analysis relies on an extremely **static** assumption that the firm is unable to respond in any manner to higher costs other than to absorb those costs or close shop. While in the case of certain types of small businesses this assumption may be appropriate, for large businesses this supposition may not reflect reality. The business situation is never static, and managers must make decisions which can significantly affect the "bottom line" regardless of what policies are adopted.
- Finally, and perhaps most importantly, there is not necessarily any relationship in the short-run between accounting performance and economic viability.

4.3.6 REGIONAL ECONOMIC IMPACT ASSESSMENT

Regional economic impact assessments are perhaps the most widely-used analytical technique employed by environmental policy-makers. Regional impact assessments seek to determine the region-specific implications of particular environmental policies. In general, this method focuses on **equity-related** changes as opposed to **efficiency-related** changes. That is, regional models tend to measure the distribution of economic impacts, rather than changes in overall economic efficiency.

Regional impact models are used to identify the economic costs and benefits of a policy option. However, in employing these models it is important to investigate how costs imposed on one economic sector may impact another sector (i.e., **partial equilibrium**). For example, job loss in one industry may be offset by increased hiring by other businesses.

There are three basic types of regional impact assessment methods, as follows:

(1) Static Simple Equilibrium Models.

(2) Input-Output Models.

(3) General Equilibrium Models.

The details of these models are described below.

4.3.7 STATIC SIMPLE EQUILIBRIUM MODEL

Static simple equilibrium models, more commonly known in the economic literature as **partial equilibrium** models, assume that the effects of a change in supply or demand are limited to the impacted economic sector. In other words, the initial changes in supply and demand from a policy initiative dominate the analytic results. These are known as **direct economic impacts**. The analysis draws on assumptions and empirical data that measure the responsiveness of supply and demand to changes in prices — or **elasticities** — within the given sector. The assumption is that the participants in the sector make short-term ("**static**") decisions that are consistent with long-term ("**dynamic**") conditions.

A second step can be easily incorporated into partial equilibrium analysis to account for **indirect economic impacts** in secondary-related sectors. In this step, economic impact **multipliers** drawn from larger regional impact analyses are applied to the model.

Strengths and Weaknesses: Where policy effects are localized (e.g., in a small farming community) a **case study** approach is probably more appropriate than use of a more elaborate model, since a large regional analysis would not capture small effects. In most cases under the partial equilibrium assumption, the results from **mathematical programming**, **engineering economics**, or **econometrics** can be directly transferred to the analytic decision-making methods described in Chapter Five. Region-wide induced impacts are better addressed with regional **general equilibrium** models.

4.3.8 INPUT-OUTPUT MODELS

Input-output (I/O) models use disaggregated data on industrial and commercial economic activity at a specified geographic level to project changes in spending, income and employment in an area's principal **business sectors**. The relevant data can be related to a system of inter-industry transactions — the input-output accounts — which trace the flows of dollar expenditures from sector to sector as goods are produced and services are provided. Estimates of demand changes, both positive and negative, for sectoral output as a result of the policy changes are developed and applied to the input-output system to produce projections of **direct, indirect** and **induced** changes in regional output, employment, income and value added.

Common Applications: Examples of I/O models include the U.S. Forest Service's *ImpactPlanning (IMPLAN),* the U.S. Department of Commerce's Regional Impact-Output Modeling System *(RIMS II),* and the California Department of Water Resources' *State 512-sector I-O* model used to develop forecasts in *Bulletin*

160. The multipliers from these models often can be used in **partial equilibrium** studies without having to run the entire model. Also, certain portions of the input data provide a framework for **general equilibrium** models.

Strengths and Weaknesses: Input-output models are the simplest method to evaluate broad policy-induced economic impacts. Input-output models are particularly appropriate when the affected economy is relatively uncomplicated, with a few sectors and assets being employed in a fairly narrow manner (e.g., when most labor is employed on farms or in mining, then input-output is an appropriate analytic tool). For example, I-O can accurately portray changes in smaller California regions such as the Sacramento Valley. These regional economies usually have **marginal** and **average** productivity of assets that are relatively close and that change slowly over time.

CARM: WORKS LIKE A CHARM? The California Agricultural Resources Model (CARM) is a non-linear mathematical programming model that analyzes changes in statewide crop production technology, commodity demand and resource supply. The model was first developed by Dr. Richard Howitt, of the University of California, Davis. A primary assumption of CARM is that farmers make profit-maximizing decisions over a linear production function subject to a series of constraints in a single-year period. CARM focuses only on farm-level impacts, and stops its analysis at the farmgate. CARM's production functions are composed of land, surface water, groundwater, fixed capital, and other variable input costs.

While input-output analysis is a common approach for regional impact assessments, it has several limitations. Input-output analysis is most useful to predict very short-run economic adjustments — it will not capture long-run adjustments to changes in relative prices. Because it assumes production is inflexible, input-output analysis typically overstates economic impacts from a policy change. While input-output analysis can provide useful insights into the short-term impacts of policies, this method has several limitations for long-term forecasts, as follows:

- Input-output analysis assumes fixed-proportion production technologies. A fixed-proportion production technology implies that it is impossible for a firm or industry to substitute across inputs. This assumption has several important implications for regional economic analysis, including:

(1) Production does not adjust to relative price changes. For example, a farm with fixed-proportion production could not substitute efficiency-improving irrigation equipment for water if the cost of water substantially increased.

(2) Production relationships are unrelated to output levels. This is contrary to experience. Some inputs, such as accounting services, increase at a decreasing rate as output grows, while other inputs, such as fuel, typically grow at

an increasing rate as output grows. This limitation is most relevant to policies that engender large production changes.

(3) Technological change and economic restructuring do not occur. Input-output analysis assumes that production relationships remain unchanged through time. Thus, the ability of input-output analysis to accurately predict future economic adjustments is very limited. The potential error in input-output estimates increases as the time horizon of the study increases.

(4) Input-output analysis assumes that regional demands for **intermediate** and **final goods** are unrelated to time. As a result, economic restructuring across regions is assumed not to occur.

- The production relationships described by input-output models are often derived from data originally developed as early as 1977, updated to 1982, and then again updated to 1989. However, the model's fundamental production relationships and trade patterns may reflect the economy as it was in 1977.
- Input-output analysis assumes that supply **constraints** do not limit potential economic expansion. That is, there is always additional labor and materials with which to increase output. Likewise, economic expansion in an input-output model does not affect prices for inputs, such as labor or fuel, nor does it draw labor and resources from other sectors of the economy. The implication is that all increases in regional output are net increases to the economy as a whole and all decreases are net decreases to the economy as a whole. In reality, regional increases or decreases in production may simply be transfers of economic resources from one region to another.

4.3.9 GENERAL EQUILIBRIUM REGIONAL MODELS

General equilibrium models better account for input supply constraints and regional transfers than input-output models. A **computable general equilibrium** (CGE) model is a **mathematical programming** description of a "textbook" economy. The model traces the impacts of various policy choices as they ripple through a regional economy. This representation of the economy includes:

- **Utility-maximizing** consumers (i.e., consumers generally act to gain the maximum satisfaction), whose decisions determine the demand for goods and supplies of labor in a region.
- **Profit-maximizing** producers (i.e., businesses generally focus on the "bottom line"), whose decisions determine the supply of goods and demand for primary input factors (e.g., labor, financing, equipment, land) in a region.

- **Government**, which collects taxes and provides income **transfers**, **subsidies**, and provides public services within a region.

The CGE framework accounts for interregional trade flows, and specifies production technology parameters and market-clearing conditions to determine relative prices, **sectoral** input factor demand and output, value added through production, government receipts, and household income for the regional economy.

Common Applications: CGE models have been used by international development organizations, such as the World Bank, to forecast policy impacts in

EQUILIBRIUM ANALYSIS: PARTIAL VERSUS GENERAL

Economic analysis requires a key assumption about the region being examined to solve for how changes in costs or prices will affect the demand or supply of a good. This assumption is about the type of ***equilibrium*** at which demand and supply will settle. The simplest approach, called ***partial equilibrium***, assumes that most economic sectors are fixed except for the change that the economist is analyzing. For example, if tire producers increase tire prices because labor costs rise, the analysis may exclusively focus on the tire market, assuming that consumers' income remains the same; that the demand for automobiles and gasoline are unchanged; and that the producers' demand for rubber is not altered. The tire market is examined in isolation from all other markets. Partial equilibrium analysis can encompass changes in several sectors, but generally no more than a handful.

The alternative approach is called ***general equilibrium***, where the impacts on all affected markets are considered and influence each other. In the tire market example, increased labor wages may lead to a growth in demand for tires, but higher tire prices may both discourage purchases of new cars and lead to lower demands for other goods as well. This latter effect can act to decrease other workers' incomes and consumers' spending in general, and demand for tires falls as a result of aggregate income reductions combined with higher prices. General equilibrium analysis is more complex than partial analysis because it must represent a larger economic segment.

Partial equilibrium analysis is appropriate if the market being investigated is a small segment of the overall economy and its linkages with other markets do not have strong feedback effects. For example, cleaning up a single streambed in a large city is unlikely to create large effects in other markets that influence the net benefits of the project. General equilibrium analysis is more appropriate in settings where the effects of a policy can be widespread across the region. For example, to fully understand broad air quality rules that affect many industries may require the use of general equilibrium analysis. There are different degrees of equilibrium analysis that are appropriate in different settings, and care must be taken to decide if the scale of analysis will capture the effects of concern.

developing countries. In the U.S., various forms of CGE models have been developed to examine trade, energy, and environmental policies. Most recently, the South Coast Air Quality Management District used a CGE-type model to evaluate its regulatory initiatives.

The Regional Economic Modeling, Inc. EDFS Model, better known as REMI, is a derivative of the CGE approach. REMI utilizes general economic theory, combined with up-to-date national and state-specific data, to estimate the regional implications of public policies. Essentially, the REMI model relies on long-run historical relationships between key variables to predict future economic patterns. The South Coast Air Quality Management District, as well as other regional air quality authorities, use REMI to estimate the economic implications of their environmental rules.

Strengths and Weaknesses: CGE models provide the most complete representation of how an economy theoretically operates. The advantage of using a CGE approach is that it can better identify when an impact may lead to a counterintuitive outcome. CGE models do not completely capture the adjustment costs or market frictions associated with policy-induced production changes for two primary reasons. First, the model acts as if producers are presented with potential costs and productivity implications before making their production decisions, and *allows them to respond as though they know the outcome with certainty.* In reality, producers will choose a strategy without complete information related to the risks of a particular approach, produce their good or service, and be subjected to whatever are the resulting productivity changes and costs.

Second, CGE models are usually *static*, rather than *dynamic*, in structure. What this implies is that consumers and businesses in the model are assumed to be *myopic* — they expect the future to be just like today. This approach fails to account for how consumers and businesses act on expectations about the future. For example, businesses may ask for higher prices today because they expect prices to be even higher tomorrow.

CGE models also exclude legal and institutional factors, including transaction costs and issues of uncertainty. For example, the models assume all markets clear perfectly, including the labor market (i.e., full employment is possible). By ignoring these variables, the models imply that the same outcomes will result no matter what are the initial rules and organizational relationships.

4.4 VALUING ENVIRONMENTAL GOODS AND PUBLIC HEALTH: PUTTING A PRICE ON A SUNSET

A first step in understanding how environmental or health attributes might be measured is to recognize the distinction between "private" and "public" goods. A **private or market good** is an item or service that can be enjoyed by only one person at a time, and access can be controlled by an owner. These goods include a new car, a restaurant meal, or a club membership. Private goods can be traded among individuals. Prices for private goods reflect the value that individuals place on consuming a commodity up to the point at which the cost equals the "marginal" or **incremental benefit**.

Public or non-market goods are those amenities for which excluding any individual from benefiting is difficult or impossible. In other words, these goods are generally "non-rival"—others' consumption does not reduce the amount available—"non-excludable"—people cannot be prevented from enjoying the good—and "indivisible"—the good cannot be divided. Classic examples of public goods include sunsets, national defense, lighthouses and recreational fisheries. Public goods range from "pure" to those where access can be controlled or congestion becomes a problem, such as Yosemite Park.

The benefits received from public goods vary across individuals, and, because these benefits are essentially open to everyone, they can not be traded directly. Thus, unlike private goods, no "market-clearing" price is available as a proxy for each individual's marginal benefit. Likewise, if consuming a resource involves purchasing both a private good (e.g., a tree for its lumber) and a public bad (e.g., destruction of the wildlife that lived in that tree), the market price is unlikely to reflect the value of the public good or bad — no market exists for wildlife, so no explicit value is created through the economic system. Economists call this inability to put a price on a public good a **market failure**, and the value not captured in the market price for the private good is called an **externality**.

Market failures result in a divergence between "optimal," or preferred, *individual* choices and optimal *social* outcomes. If the market price for a private good does not capture the value of a public good which is being damaged or otherwise impacted (i.e., the price is too low), then individuals will tend to over-consume the private commodity and overuse the public good. For example, if gasoline prices do not include the value of damages associated with air pollution, then drivers will buy too much gasoline and travel too far from a societal perspective. By valuing public goods it can be determined how much the preferred social solution differs from the current market-driven outcome.

While economists agree that economic value should be attached to public goods, large differences in actual values can exist among people enjoying the same non-market attribute. This is both because people value the same public goods differently, and also because there is no easy way to determine non-market prices — as previously discussed, public goods are not traded, so "market-clearing" prices do not emerge. Further, a sunset viewed from a mountaintop will have a different value than one seen at the beach, both for a single individual and between two individuals. As a result, use of a single value for an environmental amenity or a health attribute in all situations is inappropriate.

Natural resources have several dimensions of value which can be derived using different methods:

Market price, traded commodities: To the extent that the resource has a value in an ongoing market — lumber, fish, minerals — it can be assigned a price based

PAYING TO PRESERVE A RESOURCE OR BEING COMPENSATED FOR ITS DEMISE?

A problem in determining the appropriate value for public goods stems from the difference between willingness to pay (WTP) and willingness to accept (WTA) values. WTP represents what an individual would be willing to pay to protect a resource from being destroyed. WTA is the flip side, or what an individual will accept as payment in return for giving up the resource. Under traditional economic theory, WTP and WTA should be equivalent — as they are for private goods. However, the empirical evidence on public good valuation has found significant differences between the two approaches.

In fact, a close examination of the underlying compensation principles in economic theory finds that if a "public" good has no substitutes, a consumer can not be fully compensated for its loss with "private" goods (i.e., money). In this vein, WTP reflects a tradeoff among a portfolio of goods and is constrained by available income; WTA is made in the context of a willingness to part with a single good *unconstrained by income*, and theoretically could be infinity. Thus, WTA typically will be higher than WTP for preserving natural resources. For example, a homeowner near a stream full of debris and junk may not be willing to pay much to clean up the stream, but if that same stream was pristine, the homeowner may demand a substantial price to allow dumping of the same material at the site.

The implication for policymakers is that a "wedge" exists between the value associated with the compensation necessary to pay for the damage imposed on a publicly-owned good versus the value of the private good if the polluting firms hold the property rights and those wishing to preserve the environment have to purchase the land. The asking price in the former case will be higher than the bid price in the latter. In this situation, simply assigning property rights does not lead to a "socially optimal" outcome and the wedge can not be eliminated through some form of government policy short of a subsidy. Instead, the government must choose whether it will act as the owner of a preserved locale or compensate developers for their lost ability to utilize the resources.

upon its traded value. In the case of a redwood forest, this price would reflect the future worth of the timber produced. Market-based valuation requires an assessment of the future value of money, as well as other variables that could affect the future price of a commodity, but in general is a fairly straight-forward technique using common economic assumptions.

Non-market values, non-traded, direct-use resources (use values): Some natural resources are utilized by the public, but not traded in an economic marketplace. For instance, people expend resources to visit national parks and forests, but generally do not pay an admission fee that reflects a true market-set price. In these cases, the economic value of the natural resource — equivalent to a "market-clearing" price — can be derived by evaluating the public's "revealed preferences," or actual **willingness to pay** to enjoy the resource. Such an analysis may include an assessment of travel time and opportunity costs, as well as admission fees, if estimated with the so-called **travel-cost method.** The travel cost method can work well for natural resources which are visited frequently, but is less accurate for valuing remote wilderness with few "consumers."

Non-market values, non-traded, unused resources (non-use values): Neither of the first two values capture the worth of the simple <u>existence</u> of some resources to society. A remotely located, old-growth redwood forest has intrinsic value, whether used or not. This value has been subdivided by economists into four different categories, depending on what motivates the value, as follows:

- **Existence value** reflects society's willingness to pay for the existence or preservation of a natural resource. Values for natural resources exist—and may be quite high—even in cases in which people may never visit, or even see, the resource.
- **Bequest value** reflects society's desire to ensure the existence of a resource for future generations. For example, the Nature Conservancy considers its land purchases "a legacy for future generations." This value is considered to be essentially concurrent with existence value for analytical purposes.
- **Option value** reflects society's willingness to pay to protect a resource from **irreversible** development or demise (e.g., not harvesting a stand of old-growth redwoods, thereby retaining the option to use the resource at a later date). Option value may be thought of as an insurance premium for uncertainty about future preferences, incomes, and technologies that may make the present value of future alternative uses for the resource greater than the present value of its current or proposed use.
- **Quasi-option value** is related to option value, but is a **risk-free** measure of the **expected value** to society of information gained from postponing an irreversible development. Quasi-option value is based on the concept that a resource's

value and appropriate uses are discovered through time, and that irreversible development that destroys the resource cuts short this discovery process. Quasi-option value is the amount society is willing to pay to guarantee that this learning process continues.

Non-market values for, say, a unique old-growth forest may by higher than the market value of cut board because the total worth to society to protect the forest may be higher than its product value. However, non-market resources are not traded in any marketplace for two predominate reasons. First, property rights for existence values are absent — the owner can not simply charge people for the pleasure of knowing the forest exists. Similarly, people can not be excluded from enjoying the existence of the resource. Second, the **transaction costs** — the costs of putting together buyers and sellers — are quite high, due to the non-exclusivity and lack of clearly defined property rights for both use and non-use values. Although the market does not recognize these values, numerous indications say that they are real, such as the regular passage of parks bonds.

The notion that natural resources have non-use values has played a role in American political thought for over a century, and has been a part of economic theory for over three decades. The loss of a species or the disfigurement of an unique scenic area can cause acute distress and a sense of genuine relative impoverishment to society. A large portion of the millions of dollars in fees and voluntary contributions paid by members of environmental groups, and the willingness of environmental activists to volunteer their time to lobby for such legislation such as the Endangered Species Act can be cited as evidence for the reality of non-use values. Economists consider the existence of unique and fragile natural resources a significant part of the real income of many individuals.

Society's belief in non-use values is also reflected in various natural resource laws and regulations (e.g., the federal Endangered Species Act of 1973, and state-specific programs to insure the continued existence of farmland). These programs have real costs to both private sector firms and society in general, costs which represent one measure of existence values. Moratoria on timber harvesting on private lands, though rarely reimbursed by the public, also represent the value society places on the risk of losing a unique resource.

Since no market data exists on the non-use values attributed to natural resources other means must be employed to determine these values. **Contingent valuation methods** (CVM) offer one of the best means of quantifying existence and bequest values. Other possibilities include assessing revealed political choice through actual ballot measures (initiatives or referendums) to purchase natural resources, or the estimated cost society pays as a result of legislative and regulatory action to protect the environment.

Studies have shown that non-use values can be twice to almost ten times as great as the recreational or use values of a resource. The magnitude of non-use value tends to depend on the unique characteristics of the resource, and whether the perspective is to estimate a willingness to pay to preserve the resource or a **willingness to accept** its destruction. For abundant goods, such as a sea gull, the existence value is likely to be quite small. Some unique resources, such as the Grand Canyon, may be "priceless." (See "Paying to Preserve a Resource or Being Compensated for Its Demise?" textbox.)

While valuing environmental assets with economic methods is attractive from a policy-making perspective, critics have argued that current techniques are inadequate for the job. Reducing the value of a single element in a complex ecosystem to "price metric" can result in abandoning information that may be important to stakeholders in weighing the significance of the entire system. In addition, valuation techniques generally rely on exploring the value of an environmental asset to individual consumers. This approach has two problems. The first is that most of us have little experience with attaching values to natural resources. The ability to determine values for various commodities and assets is developed through participation in markets—not a common activity for "buying" environmental assets. The second problem is that values for these public goods are contextual and developed from social norms. That is, consumer preferences are not independent of the setting or the moral values attached to the asset. Environmental debates are as much about establishing new social norms as about ordering preferences within the existing order.

4.4.1 NON-MARKET GOODS VALUATION METHODS

Methods to value public goods have been developed over the last thirty years, with significant progress made in the last decade. These methods can be divided into two broad categories: environmental resource valuation and pollution-based valuation.

Environmental resource valuation includes the following methods:

- **Revealed preference or market-good unbundling.** The premise of this approach is that while people do not directly purchase a public good, they do buy associated market goods, incorporating the value of the public good into their willingness to pay. For example, one might value a view of the mountains by looking at the difference in price between two otherwise identical houses, one with the view, the other without. Two primary revealed preference methods have been developed:
  - Hedonic valuation; and
  - Travel cost method (TCM).

- **Direct inquiry or contingent valuation method** (CVM). This approach relies on directly asking people in a survey to make trade-offs between goods, non-market and market, in such a way that it reveals their inherent preferences. A common technique is to formulate the question as a referendum and ask what is the willingness to pay different tax levels to carry out a policy option. The direct inquiry method which has become most widely used is the *contingent valuation survey method.* This approach uses carefully structured surveys to ask impacted individuals about the value that they put on an environmental amenity. This approach allows for valuation of non-use aspects such as existence values.

Pollutant-based valuation includes the following methods:

- **Politically revealed preference or control costs method.** This method assumes that the choices made by political decision makers reflects the values of the voting public, and therefore these values can be determined from the compliance costs associated with the relevant regulations and laws. Emission control costs, as listed in the California Energy Commission's *1992 Electricity Report*, or the prices paid for permits under a tradeable permits program (e.g., South Coast Air Quality Management District's RECLAIM program) represent indicators used in this approach.
- **Damage functions.** This approach assesses the economic losses or avoidance costs associated with pollution based on scientific relationships between the source and impacted resources. This technique can draw on information from both the revealed preference and direct inquiry methods for valuation measures.

Detailed descriptions of each of these methods is provided in the sections that follow.

4.4.2 HEDONIC PRICING

Hedonic pricing is based on a fundamental economic principle that an analyst should be able to "unbundle" the value inherent in a good by examining how individuals weigh the various characteristics of that good. To do this, the hedonic pricing method takes the difference in prices for two similar market-traded goods, identifies differences in characteristics of the goods — such as environmental quality — and attributes the variation in market price to the value associated with the characteristics of interest. For example, if two identical houses in two different locations differ only in the degree of visibility allowed by air quality, the value of improved visibility is assumed to be the difference in property values. This difference is the implicit market price for the characteristic.

Data Requirements: Most hedonic pricing studies of environmental amenities rely on differences in property values. Thus, the key piece of data is information on sales prices for comparable homes or buildings. Information on other factors which may influence house prices, such as location relative to the workplace, quality of government services, other neighborhood characteristics, as well as measures of environmental quality, is also necessary. Differences in the **socioeconomic** status of home buyers are frequently used in the analysis.

Common Applications: Hedonic pricing can be used to estimate "use" values associated with owning property in specified locations. Non-use values, such as those for existence, obviously can not be determined this way because the value being derived represents an implicit market price for a good being "consumed."

Hedonic pricing was first developed to determine how much consumers would be willing to pay for options on automobiles, such as an automatic transmission. Economists have since used it to value differences in government services such as education and public safety. Hedonic pricing has recently been used to value variations in air quality in Southern California and water quality in the San Francisco Bay.

Strengths and Weaknesses: The fundamental theory of hedonic pricing is well understood, in a large part because the basic approach is used in demand analysis of market-traded goods. Hedonic pricing analysis is done in a wide range of settings and applications so that the literature is rich with methodological discussions.

Hedonic pricing can be limited in its applications because of the difficulty of obtaining the data needed to conduct the analysis. For environmental valuation, it is difficult to find data to compare market-driven prices with comparable fixed assets. Housing sales are the typical comparable asset employed in the analysis, but due to market volatility, the time frame for these sales must be consistent for the data to be of use. Likewise, it may be difficult to find comparable houses sold to similarly situated buyers in locations with different environmental quality. For example, large opulent homes are more likely to be located in higher quality environments. Even getting accurate house sale prices can be difficult because of the recording processes in various localities. Due to property tax law changes (e.g., Proposition 13) and the tendency for downward bias in property assessments, county tax rolls are also frequently not an accurate measure of property value. Finally, other factors, such as neighborhood or local schools quality, can have a large influence on housing prices. Often the estimation error in these other factors overwhelm the environmental values imbedded in the property through **multi-collinearity**. In addition, differences in assumptions about housing supplies and the income and preferences of those purchasing homes can influence the interpretation of the results of hedonic analysis. For example, differences in household socioeconomic traits may prevent comparison of values between individuals.

Hedonic analysis has recently been used to assess how much people value life's amenities, such as enjoying a sunset, a good meal, or a beautiful day. The hedonic method relies on **benefits transfer** from other studies on how people value different amenities. While this approach holds promise, it is fairly new and has not been fully developed yet.

4.4.3 TRAVEL COST METHOD

Description: The concept behind the **travel cost method** (TCM) is that recreators incur travel costs to reach a site, and that these costs can serve as a proxy for the market price of the site. Site use would be expected to decline as distance and travel costs rise —the classic economic assumption about prices and demand. By observing people's recreation choices — site visits — the TCM traces out the prices paid by recreators in terms of travel costs to reach their chosen recreation site. As recreators travel to a selected site from diverse origins, their different travel costs trace out the price/quantity relationship known as the **demand curve**. Through application of this data, the **"use" value** for a resource can be measured.

Travel costs are based on both direct out-of-pocket costs — fuel, hotels, entrance fees — and the **opportunity cost** from giving up work income to travel to the site. This latter component generally is the larger of the two, but also is the most difficult to measure. Usually, the analyst assumes that the opportunity costs of travel time equals some portion of the average hourly **wage** (e.g., one-third to one-half). Unfortunately, however, these estimates are derived from commuter surveys and may be unreliable for use in weekend recreation. The travel costs from the survey are then statistically extrapolated to the target population to derive estimated "user" values.

The shape of the demand curve for any particular resource and the value of any changes to the resource's recreational or aesthetic quality are sensitive to the presence of **substitutes, alternatives** and **complements**. The incremental value for a change in quality will be larger for resources with fewer **substitutes** or alternatives, that are located near other **complementary** resources (e.g., two neighboring national parks), that are closer to large population centers, and that serve higher income user groups.

Data Requirements: Three types of TCM studies are usually done. The first approach uses surveys of individuals at the recreation sites to determine visitor's characteristics, including place of residences. These results are then used to **statistically** infer demand for a larger population group, including those who have not travelled to the site. This type of study requires in-depth surveys of a large number of recreators and the application of rather sophisticated statistical techniques.

The second approach uses a "gravity" model. This model takes a population with an expressed or known demand for various recreational opportunities and distributes this demand among the various recreational options based on the relative costs and characteristics for each option. Demand can be estimated from a household survey (rather than a site survey). The exact characteristics of those actually visiting the sites need not be known, but the total number of visitors to all facilities must be equal to the number of individuals who indicated that they visited the sites in the household survey. Otherwise, demand becomes insensitive to changes in travel costs due to the need to force total demand to equal a particular visitation level.

A third approach relies on **time-series** analysis of a particular site. In this case, site visits are statistically compared to factors which might affect demand, such as changes in income, out-of-pocket costs per mile, the size of relative population centers, and key characteristics of the site. The difficulty with this approach is gathering enough observations to be **statistically valid.**

Common Applications: TCM measures only the "use" values associated with a resource, because the method enquires only about the costs expended by those visiting a resource. Non-use values can not be evaluated with this approach. This acts to limit TCM's applicability to resources which are not altered substantially by a policy option — that is, will not be destroyed or irreparably harmed — but rather are being managed in concert with other goals (e.g., timber harvesting or water supplies).

TCM has been used mostly to estimate the value attached to recreational opportunities such as fishing or hunting. For example, the values attached to salmon fishing in the Pacific Ocean and on the Sacramento River have been assessed in several TCM studies.

Strengths and Weaknesses: The travel-cost method has been used extensively by several federal agencies to evaluate the recreational benefits under their management. The method is probably the most widely reviewed of the non-market valuation approaches. The analytic steps are well understood, including the statistical estimation techniques.

The main weakness in the analysis, other than its limited applicability, is its reliance on the **opportunity cost** associated with travel and time spent at the location as the major indicator of value. These estimates often are based on analyses of commuter preferences from transportation studies which may not have been designed for use in measuring recreational activity. Travellers may attach a value to the trip itself, or may visit multiple sites, thus diminishing the opportunity cost of visiting a single site. Finally, the reliability of extrapolating values from visitors to non-visitors depends on determining why people do not visit a site, a difficult task to accomplish.

4.4.4 CONTINGENT VALUATION METHODS

Description: Although it can be used to estimate both use and non-use values, the primary goal of the contingent valuation method (CVM) is to create a simulated market for natural resource non-use values. Through a questionnaire format, the physical change to be produced by the proposed policy (e.g., public protection of an old-growth redwood forest), as well as how the policy would come about, and how payment would be extracted from each household if the policy is implemented, is described. In some cases, various protection levels based on different prices are also characterized. The questionnaire is administered to a sample of individuals who would be affected by the proposed public policy to determine what they would be either **willing to pay** or **willing to accept** in order to have the policy adopted. The survey instrument typically is implemented only after several focus group meetings and pre-tests have been conducted. In general, in-person interviews are preferred over telephone interviews, as they allow researchers to better educate respondents about the characteristics of the resource in question.

Data Requirements: CVM analysis is based on survey results. Thus, the analysis requires a well-designed survey instrument applied to a representative population that fully understands the implications of the questions being asked. The questions must be constructed so that the respondents give truthful answers, not ones based on "gaming" the questionnaire. The survey sample must be large enough to be **statistically valid** — typically in excess of 100 individual responses. The response rate itself should be high enough so that it adequately represents the target population. A response rate of 25 to 40 percent is common on these types of surveys.

Common Applications: CVM has been used in many of the most visible environmental policy issues. Perhaps the best-know application was to assess damages in the *Exxon Valdez* Alaskan oil-spill case. While the actual damage evaluation done for the State of Alaska was not revealed, the lower bound estimate was reported to be $3 billion. Exxon ultimately agreed to a settlement of $900 million paid out over a nine-year period in addition to the clean-up costs already expended. Other applications include evaluating visibility in the Grand Canyon to determine whether pollution controls on a coal plant were needed, and estimating a value for preserving the Northern Spotted owl through timber-harvesting restrictions. Damages from numerous maritime oil spills also have been determined using CVM.

Strengths and Weaknesses: Since the mid-1980s, CVM has been increasingly adopted by economists, public agencies, and the courts as a valid methodology for determining the non-use values associated with environmental goods. For instance, the District of Columbia Circuit Court of Appeals affirmed both the importance of non-use values in estimating the costs of damages to natural resources and the use of CVM as the "best available technique" to quantify these values. CVM is now a widely accepted method, is recommended by the U.S. Water Resources Council for use by federal agencies for benefit-cost analysis, and by the U.S. Bureau of Land Management, the U.S. Army Corps of Engineers, the U.S. Forest Service, and the U.S. Department of the Interior for valuing resource damages. Environmental groups also generally have been supportive of CVM. (See "The Blue Ribbon Panel and Contingent Valuation" textbox.)

THE BLUE RIBBON PANEL AND CONTINGENT VALUATION

Issues related to the reliability and quality of contingent valuation studies have recently been raised in the assessment of natural resources damages. Since 1989, two federal agencies — the Department of Interior (DOI) and the Commerce Department's National Oceanic and Atmospheric Administration (NOAA) — have been in the process of issuing guidelines for the evaluation of environmental damages associated with oil spills and releases of other hazardous substances, as provided for by CERCLA (DOI) and the 1990 Oil Pollution Act (NOAA). In response to questions about CV techniques raised by various industry groups, NOAA appointed a Blue Ribbon Panel to review the measurement of non-use values and the role of CV in their measurement. The Panel was headed by Kenneth Arrow and Robert Solow, Nobel Prize winners in economics; the other members were economists Roy Radner, Paul Portney, and Edward Leamer, and sociologist and survey expert Howard Schuman.

The Panel held public hearings and received voluminous comments during the summer and fall of 1992. Its report, issued on January 12, 1993 and subsequently published in the Federal Register, concluded that "CV studies can produce estimates reliable enough to be the starting point for a judicial or administrative determination of natural resource damages" as long as they adhere to certain guidelines. The guidelines cover various aspects of sample design, survey construction and survey administration. Any studies done assessing environmental resources should be assessed in light of these guidelines.

Although widely accepted, CVM has its problems. As a result of the difficulty in conducting an accurate CV, a large number of flawed CVM studies have been published. Unless adequate numbers of focus groups and pre-tests are conducted to accurately determine people's perceptions of the resource under consideration, there is no assurance that the survey respondents will understand, or believe, the characteristics of the resource they are "buying" or "selling." It is also difficult to get people to think about unfamiliar non-market goods in the same way as they think about goods they actually buy in the marketplace. This is a particular problem since a CVM study occurs in a much shorter time frame than a more typical experience with marketplace goods.

CVs must address the need to distinguish individuals' overall environmental concerns from their interest in a specific resource (i.e., "aggregation"). For example, some studies have found that values expressed by individuals for preservation of an entire ecosystem may be substantially less than the aggregated values for preserving certain species of plants and animals in that ecosystem. Whether this occurs because of a theoretical flaw or mis-designed surveys has not yet been determined.

Individuals also may engage in strategic behavior when answering a CV survey. If the respondent believes that they will not actually have to pay their reported "price," they may overvalue the resource, while if they believe a tax or fee may be assessed based upon what they say, they may strategically underprice the resource. However, research suggests that strategic bias in CVM studies is not a major problem.

Another consideration in estimating non-use values is the size and scope of the paying population (i.e., what geographic scope of people should be charged the estimated payment to cover preservation of the resource). For example, an old-growth redwood forest in California also may have an existence value to the population of the Pacific Northwest, the entire United States, or even other nations. Many environmentalists believe that protecting old-growth forests is a global issue. Typically, this question has been dealt with by assessing the nearby population (i.e., California in this case), the full cost, and discounting the expected payment as the populations become more geographically distant. Alternatively, people in distant locations could be surveyed to determine their willingness to pay for protection of a resource far away from them. This was the basis of the analysis done for the State of Alaska in the *Exxon Valdez* case.

Recent analyses have uncovered various inconsistencies in CV results. For example, responses are frequently unrelated to the respondents' income—an implausible result under the **willingness to pay** formula, which suggests that, all other things equal, higher-income individuals are willing to pay more for desired goods and services (see discussion ***"Paying to Preserve a Resource or Being Compensated for Its Demise?"*** textbox). A more serious problem are the differences in values individuals place on resources versus how the household they represent values the resource. In some cases the sum of individual values is greater than the sum of household values from two identical surveys.

Another problem with CV is that biases in responses may occur as the survey questions change. This phenomenon is called *starting-point bias*, and results in valuations by individuals that differ only because the initial values that the survey-taker offers as a starting bid for the resource changes. So, for example, a higher initial bid value can cause a higher final valuation by the individual. Although a technique called the *double-bid* method has been developed to solve this problem, whether this method will work in all cases is still untested.

4.4.5 POLITICALLY-REVEALED PREFERENCES OR CONTROL COSTS

Description: The politically-revealed preferences (PRP) method assumes that society reveals its priorities about how to use various resources through the political process. These priorities, in the case of reducing pollutants, are manifested through varying levels of pollution control costs. In other words, the political forum becomes the equivalent of the marketplace in setting values on environmental resources. Polluters must pay a price, through controls, for using environmental resources, such as air quality or stream flows. As in a marketplace, economists assume that the **marginal benefits** to society are equated to the **marginal costs** in setting pollution control levels. In an efficient society, the control costs would be equal to the benefits garnered from reducing pollution at the margin (see Figure 5-1 in Section 5.2 "Benefit-Cost Analysis").

Data Requirements: The control cost method relies on three types of data. First are the air quality regulations set through the political process. This determines the target level for pollutants. The second is the required amount of pollution reductions to achieve these standards, broken down by source of emissions or effluent. And third is the engineering, financial and economic costs for each control measure required to achieve the required reduction. These values can come from either a centralized planning process, such as the South Coast Air Quality Management District's (SCAQMD) Air Quality Management Plan, or the market price for tradeable permits, such as those for sulfur dioxide (SO_X) under the 1990 U.S. Clean Air Act Amendments.

Common Applications: The politically revealed preference method can be used in many settings where information about control costs is readily available. The California Energy Commission (CEC) used values derived from SCAQMD analyses in its *Electricity Reports* until the CEC decided to rely on a **damage function** approach.

Strengths and Weaknesses: The politically revealed preference method relies on readily available data that is relatively noncontroversial compared to other non-market good valuation methods. Virtually all jurisdictions have relevant environmental regulations, and control cost data usually is not difficult to find. This method also has the benefit of giving back to policy makers the answer that they have already derived themselves about what are the important priorities, thus making the results politically palatable.

Using the PRP method raises three serious issues. The first is in its inability to distinguish exercise of political power from societal values. Policy makers often will choose the most politically attractive option without seriously considering the associated economic consequences of their decision. Likewise, control costs reflect all of the various factors — many of them non-economic — which influence policy making, including institutional relationships, cultural influences, and interest group organization. As a result, control costs may not accurately reflect the aggregated economic choices that individuals would make. Conversely, some advocacy groups that believe that economic estimates should include equity and other concerns favor the PRP method because these values are embodied in the estimate.

The second problem with PRP is that the world is far from ideal, and decision makers do not possess perfect information about the true marginal costs and benefits associated with controlling pollutants. This makes moving sequentially from low cost to high cost options and equating marginal costs and benefits difficult. It can also lead to inconsistency in decisions among and even within jurisdictions about the relative value of pollution control. What may appear to be a difference in control costs may simply reflect variations in information availability among locations or even time periods. Because of the financial and political commitments necessary for most controls, a regulator is unlikely to reverse a past decision if a measure is found to be too costly relative to other options in the future. As a result, control cost results may be distorted.

These two problems can create a situation where certain polluting sources are over-controlled, while others are under-controlled. The former sources may be more easily identified (e.g., a large industrial plant) or less politically influential. The latter sources are often less identifiable (e.g., non-point sources) or politically valuable. Control measures may be imposed in the absence of adequate information based on a short-term public perception of large risks associated with the pollutant. The use of the control cost approach tends to perpetuate values despite changing information and attitudes because the political process and societal infrastructure are slow to change.

The third problem with the politically-revealed preference method is that by definition it may not give policy makers any new information. The values are derived from the policy-makers' own actions in balancing benefits and costs. However, decision-makers may not be fully aware of the cost implications of their choices, and the PRP can make these costs explicit. And finally, control costs are frequently defined by geographically broad—federal or state—legislation and applied equally to all localities. However, differences in geography, population, and other characteristics may make the actual benefits differ by area, an effect that would not necessarily be captured by the PRP method.

4.4.6 DAMAGE FUNCTIONS OR AVERTING EXPENDITURES

Description: Damage functions measure the ***marginal benefits*** associated with the relationship between pollution reduction and improvement or deterioration in health, cleanliness, and aesthetics. Damage functions provide an overarching measurement technique that incorporates valuation of resources from both the revealed preference and direct inquiry methods, as well as market-based measurements of economic losses associated with degraded environmental quality. The damage function approach examines how a pollutant impacts a large environment rather than focusing on a single resource and assessing its value given all of the environmental "stressors."

To estimate the ultimate economic effect of a particular environmental hazard, a series of relationships must be specified that trace the pollutant from its source to the damaged location ("receptor") and, finally, determine its associated value. First, the amount, location and time of the pollutant are identified. Next, the impacts of the pollutant on environmental quality are assessed. This must be done with an understanding of how the pollutant interacts under various environmental conditions, such as weather, terrain, season, biological setting and other pollutants. Third, the physical responses by humans or other biological resources are measured based on changes in environmental quality. This is known as the **dose-response** relationship. These responses include health effects (morbidity and mortality); ecological damage to vegetation and animals; damages to economic resources such as agriculture, timber or minerals; material damages to buildings, fixtures or vehicles; and aesthetics (visibility or odors). Dose-response functions assess the increased risk to the exposed population and those among them that are most susceptible. Finally, the physical responses are converted into economic values to society, usually denominated in dollars.

Damage function values can be derived both from measured income losses (e.g., crop losses due to ozone exposure) and imputed individual valuations (e.g., differences in house values from variations in visibility). Various market valuation techniques can be used to estimate direct economic losses — the revealed preference and direct inquiry methods are used to derive imputed valuations for

CAN VALUES FROM ONE SETTING BE APPLIED TO ANOTHER?

Because of the paucity of studies on valuing environmental and health attributes, a number of analysts have tried to generalize these values from a few reports. Several problems arise from such ***benefits transfers*** —the use of study results from one problem or geographic area applied to a similar situation that differs in context or location—not least of which is that the original studies are often context- and location-specific. Also, many studies, particularly those for **non-use values**, evaluate large environmental changes, such as the demise of a species or an ecosystem. Applying these values to the small impacts created by a single project or regulation is generally inappropriate.

The problems associated with benefit transfers depends on the amenity at issue. Generalizing health benefits may be appropriate in some cases, but the values are usually dependent on the characteristics of the affected population. As a result, a benefit transfer requires adjusting for demographic differences. Transferring recreational values is more problematic because the studies are almost always site specific.

In addition, two fundamental mathematical problems arise with regard to applying values from one situation to another:

- The possibility of **nonlinearities** in the valuation of particular outcomes or attributes; and
- **Nonadditivities** in the valuation of multiple items resulting from these nonlinearities and the shape, or "curvature," of the estimated benefits function.

Nonlinearity refers to the fact that the marginal value associated with an increment in some outcome variable may not be a constant. Nonlinearity can cause values to change dramatically for small incremental shifts in the variable. For example, a loss of 1,000 salmon out of a run of two million fish does not have the same value as the same salmon loss out of a run of 2,000 fish. This may reflect a "threshold" effect.

Nonadditivity refers to the fact that the value associated with a given increment in one outcome variable may be affected by the levels of *other* outcome variables. As a consequence, the value associated with a change in, say, two outcome variables may be *more or less* than the sum of the values associated with a change in each separately.

health impacts, ecological resources and aesthetics.

Data Requirements: The damage function approach is probably the most complex type of analysis in assessing non-market goods. It requires a scientifically tractable and well-understood relationship between a pollutant and the associated environmental impact. These relationships always have a degree of uncertainty that should be identified and discussed in the analysis. The method requires an extensive effort to identify and value the range of features which are impacted by the pollutant. This means that significant consequences for market resources could be usefully modelled (e.g., accelerated paint deterioration requiring more upkeep, crop yield losses). Also, non-market resource valuations (e.g., respiratory ailments from air pollution) should be appropriately scaled to the pollutant impacts. For example, using **contingent valuation** results for the entire loss of a salmon run are not applicable to a situation where a small portion of a similar run might be lost. In most cases, damage function analyses rely on data from other studies to determine economic values in a process called **benefits transfer.** (See "Can Values From One Setting Be Applied to Another?" textbox.)

Common Applications: Because of the complexity of damage function analysis, it is usually reserved for situations where pollutants have a large and wide ranging impact on the environment. In California, the damage function approach has been used both in setting air quality regulations in the South Coast Air Quality Management District and in determining air quality values associated with electricity generation at the California Energy Commission.

Strengths and Weaknesses: The damage function approach is the next logical step in taking scientifically-estimated environmental impacts and applying these estimates to economically-estimated environmental values to calculate expected damages from specific contaminants, hazards or actions. Creating a damage function is a necessary step in developing an economic analysis for controlling particular pollutants or establishing various standards.

Damage functions focus on **marginal** changes in the environment from reducing or increasing pollution. This is in contrast to the focus on entire environmental assets embodied in **hedonic pricing, travel-cost models,** or **contingent valuation methods** (e.g., an old-growth forest, not on an *incremental* change in that asset such as harvesting ten percent of an old-growth stand). Damage functions evaluate incremental impacts by measuring the **marginal value** of changing an environmental asset. This is the preferred theoretical approach in economics.

While the damage function approach *per se* is theoretically sound, there are some reasons for concern as to whether the existing literature is adequate to support all of the specific dose-response and damage functions that are embedded in a model. In particular, two sets of questions arise:

(1) Are the studies used as the basis for the valuation functions of sufficiently high quality that they are reliable for this purpose?

(2) Is it valid to extrapolate from these studies when formulating model equations, and is the methodology **robust** enough to shift from one type of exposure application to another?

An important consideration in assessing whether to use linearly-adjusted economic values — the typical method — associated with pollutant exposure is to determine whether the economic-loss function is non-linear (i.e., it accelerates in intensity as the level increases) or if it is discontinuous (i.e., it achieves a certain threshold after which damages increase at faster rates). In the latter case, the issue is the ability of the system (e.g., a human body or the air quality of an air basin) to absorb and adjust to the stress of the effect. This can be measured in part by whether the peak incident approaches or exceeds the carrying capacity of the system.

The applicability of different dose-response studies also is important. For example, most economic studies of values associated with air quality levels have focused on average ambient levels over some period of time, or at best daily maximums. This limitation is a result in part from a lack of scientific studies that attempt to measure the impact of peak exposures, the usual focus of regulatory action. Studies of peak exposure require either laboratory experimentation or a focus on a region in which large fluctuations in air quality can be predicted with some certainty. Symptoms manifested by prolonged exposure are likely to be different from those associated with acute episodes.

Another problem with the damage function method is the large uncertainty associated with both the scientific data and the economic valuations. Health and ecological impacts usually are based on applying laboratory results to theoretical environmental conditions. The inability to precisely measure environmental conditions can lead to large ranges in the estimated effects. The confluence of several environmental factors complicate this further. The uncertainty in economic valuation techniques, particularly those for non-market resources and amenities, likewise accentuates this problem. Thus, any damage function analysis can usefully include a range of possible valuation estimates, and if possible, a distinction between the scientific and economic uncertainty.

4.5 VALUING A LIFE

A "statistical" life represents the probability that a certain event or action will cause the loss of a life. This might be measured as the number of deaths per million population or the percent probability of death each year for the exposed population. Three different techniques to value a statistical life are used most commonly today. These techniques draw on the non-market valuations previously discussed. The first, called the *human capital* approach, uses the expected future earning of an individual to estimate the value lost from their death. The second, called *willingness to accept*, relies on pay differentials for various occupations that have different types of risk. The third, called *hedonic valuation*, tries to value all aspects of the quality of life through various methods. This latter method is not yet well formulated or widely applied. (See "To Be or Not To Be, That Is the Question" textbox.)

The *human capital method* takes the net present value of an individual's expected future earnings and assumes that this sum reflects how much that individual valued the remaining years of their life. This method is still commonly used in wrongful-death lawsuits. While this approach may be useful for determining direct compensation for the death of a particular individual, it has three serious problems for policy applications. First, it values the life of a wealthy person more than a poor one, and when younger individuals are considered, it can not address the issue of unknown potential earnings due to a lack of knowledge about a person's abilities or goals. Second, it tends to value the life for a hypothetical "average" person, one which may not be representative of the type of person a specific policy might impact. And third, the human capital approach views the value of life solely in terms of income generated by an individual. The life of an impoverished artist or activist, such as Van Gogh or Mother Teresa, would have a low value despite the fact that the person might be making a significant contribution to our quality of life.

TO BE OR NOT TO BE, THAT IS THE QUESTION

What is the value of life? Philosophers may ponder this question, religious leaders may deliver sermons on the subject, but economists believe they have the answer. Economists assume that individuals prefer leisure activities over work, and to give up their diversions, people must be paid a wage. Economists extend this concept to assert that individuals will also undertake more risk if they are paid an amount equal to how much they value the chance that they may die.

Decision-makers continually put implicit values on life when they make choices about health and environmental safety. And decision-makers frequently must trade-off one risk against another (e.g., allowing the sale of poisonous fungicides to prevent even more highly carcinogenic wheat fungi). Economists attempt to make these values explicit so that they might be debated more readily.

A more popular approach to valuing a life is based on the *willingness to accept* certain risks for extra compensation in various occupations. The willingness to accept method uses the same principles as **hedonic pricing** for non-market goods. First an analyst chooses a set of occupations which have different death and injury rates, but which includes similar **socio-economic** groups, for example, firefighters and carpenters. Then the analyst compares the differences in wages between these occupations, calculates the difference between the expected death rates for each occupation, and divides the income difference by the death rate difference. The resulting sum theoretically equals the value each worker puts on his or her own life. For example:

Occupation	Annual Wages	Probability of Death
Firefighter	$40,000	2%
Carpenter	$30,000	1%
Difference	$10,000	1%

The value of a life would be $10,000/0.01 or $1,000,000 in this case. One can do a similar study examining the differential in automobile prices based on their level of safety.

To the degree that the increased risk can be isolated to the difference in occupations, this analysis captures the full economic valuation an individual places on the higher risk. This is true because the analysis focuses on a **marginal** change in risk levels rather than a total change in risk. Because people derive satisfaction both from goods and services purchased with income and from leisure, the human capital method can not capture the value of leisure time. The willingness to accept method assumes that everyone's value for leisure is the same at the margin, and any change in wages is due solely to changes in risk levels. Thus, the value of leisure is separated from the problem.

Generally, estimates of the value of a statistical life derived from willingness to accept analyses range from $2 to $8 million. However, a recent U.S. EPA analysis found that the Agency placed an implicit value of between $45 and $100 million per life.

Beyond these wide ranges, willingness to accept has several other problems. First, it glosses over important factors which influence how people choose their jobs. Some people are thrill-seekers and enjoy risky jobs, and others say "it can't happen to me" (also known as **cognitive dissonance**). A firefighter, police officer or skyscraper construction worker is probably attracted to the nature of the job, not the pay level. Others may view the higher income potential as the only way out of their economic poverty. A certain amount of tradition dictates job choices as well – sons tend to follow fathers into the coal mines.

Second, willingness to accept can not adequately account for all the different factors that make jobs more or less desirable due to non-wage issues, such as responsibility, flexibility, other types of challenges, and impacts on leisure time. Third, people view risks that they believe they have some control over differently from risks that are "uncontrollable" or can not be seen. For example, despite the better safety record for airplanes, most people feel less anxiety when they are behind the wheel of a large automobile.

Fourth, willingness to accept tends to lump an impacted population together as though it is represented by an "average" person. For policies that affect a broad population, this method may be appropriate, but if the focus is on certain socio-economic groups or localities, the values may be inappropriate. And finally, the **value for a statistical life** (i.e., the probability that an additional life is saved from an action) is generally derived from accidental deaths rather than environmentally-related mortality. However, individuals are just as likely to put a value on *how* they die as *whether* they die.

4.6 GETTING THE MEASUREMENTS RIGHT

While policy analysts prefer using economic-based measurements even in cases where non-economic attributes are of key concern, as discussed in Section 4.4, both economic and non-economic measurements are used in **decision analysis.** (See Section 5.4 "Decision Analysis.") However, combining economic and non-economic attributes raises the issue of **commensurability** — the ability to compare across dissimilar attributes. In general, if attributes are to be quantitatively combined within an **objective function,** they must satisfy the following conditions:

- **Cardinality:** Cardinal scaling of an attribute implies that the attribute can be measured in real numbers. It is not enough to be able to say that alternative A is better than alternative B which is better than alternative C. Such a ranking represents an **ordinal scaling.** Instead, it must be specified how *much* better: for example A is 1.2 times better than B which is 3 times better than C. The later example constitutes a **cardinal scaling.** (See "Addition of Rankings: A Cardinal Sin" textbox.)
- **Common time frame:** Time frame refers to the interval over which the attribute is being measured. If attributes are to be commensurable they must be compared over the same time frame. And any accounting made for the **time value of money** — such as **discounting** — must also be applied consistently in and across analyses which compare alternatives (see Section 4.3.1). Time frame-related assumptions also affect estimates of how firms behave in the short- and long-terms, as follows:
  - In the short-term, or in a truly **competitive market,** an analyst might assume that output levels and prices are fixed. In this case, the firm tries to maximize profits within the constraints, such as prices and input levels, at play. In the long term, however, the firm may maximize profits given *flexible*

input and output levels. As input or output prices change, the firm is allowed to change the input mix or production levels to maintain optimal profitability.

- **Common accounting stance**: An accounting stance refers to the spatial — geographic — and temporal — time horizon — boundaries of the analysis. These boundaries define what will be included in the analysis and what will be left out. For example, the population of interest must be identified. This is particularly important for state-based policies, in which California may benefit, but at the cost of Nevada. Likewise, in **benefit-cost analysis**, benefits and costs must be accounted for equally. The **baseline** conditions used in the analysis have critical implications to analytical findings, particularly when comparing outcomes between two policies or across time.

ADDITION OF RANKINGS: A CARDINAL SIN

It is not uncommon to find decision-makers using the following inappropriate procedure for selecting the preferred alternative in a multi-attribute decision process:

(1) Rank each alternative within each attribute (i.e., best equals 1, next best equals 2, etc.).

(2) Add up the attribute scores for each alternative.

(3) The preferred alternative is the one which has the lowest total score.

This procedure violates the need for cardinality in two ways. First, by adding rankings within an attribute, one implicitly assumes that the differences among the ranks are equal, which may not be the case. If alternative A saves ten lives, alternative B saves two lives, and alternative C saves one life, the ordinal rankings would be A = 1, B = 2, C = 3. This mistakenly implies that it is just as important to move from C to B as it is to move from B to A. This faulty procedure only properly works in cases in which each ordinal interval happens to be equally important.

The second fallacy of this method is introduced by adding rankings among alternatives. This action reflects the assumption that each attribute has equal weighting. Assume the second attribute is cost, where A costs $3,000, B costs $2,000 and C costs $1,000 (in the case discussed above). The rankings are A = 3, B = 2 and C = 1 for this alternative. When the ranks for each alternative are added together, all three alternatives are tied at 4 points each. This suggests that the misguided decision-makers are indifferent between saving one life at a cost of $1,000, two lives at a cost of $2,000, or ten lives at a cost of $3,000.

Clearly, a cardinal measurement error has been made here.

5 ANALYTIC DECISION-MAKING METHODS

Analytical decision-making methods use the measurement techniques described in Chapter Four, combined with the systematic approach discussed in Chapter Three, to develop comprehensive assessments of proposed public policies. There are numerous analytic decision-making methods available to environmental decision-makers. A fairly complete — but by no means comprehensive — list of applicable approaches include the following:

- Cost-Effectiveness Analysis
- Benefit-Cost Analysis
- Least-Cost Planning
- Decision Analysis
- Risk-Related Analysis

Each of these techniques is described in the subsections that follow, including the method's theoretical basis, its data and modeling requirements, common applications, and strengths and weaknesses.

Ignoring environmental externalities can lead to unpleasant and dangerous consequences. For example, according to Alfred Kahn: "Our cities are clogged and decaying in large measure because automobiles are not charged their full marginal costs, including congestion costs. We confront the possibility of a new world energy shortage in large measure because we have not priced energy at its full marginal costs. We have become increasingly concerned about the destruction of our environment by a market system which fails to reflect marginal external costs in prices."

The need for analytic methods for environmental decision-making in part stems from the existence of environmental externalities. These externalities arise when individuals make resource allocation decisions without taking into consideration the impacts of their choices on society (see "Environmental Externalities" textbox). Each of these methods is described in order of increasing complexity, and required analytic resource needs and level of effort.

5.1 COST-EFFECTIVENESS ANALYSIS

Description: Cost-effectiveness analysis is a very straight-forward and direct means of comparing alternative methods of solving a particular problem. A cost-effective solution is defined as the lowest-cost alternative which accomplishes a specified purpose. Cost-effectiveness can also be viewed relatively. For example, it can be determined whether one measure is less costly than another in achieving a desired level of environmental protection.

Theoretical Basis: Cost-effectiveness analysis is chiefly a matter of common sense. After all, common sense strongly suggests that it is economically **efficient** to use the least-costly method to achieve a given purpose. However, economics dictates that to achieve efficiency **utility** must be maximized within a budget constraint. To satisfy this condition, goods and services must be obtained for the lowest possible price. Cost-effectiveness analysis enables policy-makers to identify a "frontier," or group of efficient policies, thereby allowing decision-makers to consider the trade-offs between means of achieving a goal.

ENVIRONMENTAL EXTERNALITIES

Environmental regulation focuses on minimizing damages to human health, welfare, and the environment. Another way to think about these damages is as societal costs. Economists call the unreimbursed costs imposed on the environment by human activity "environmental externalities." These costs are "external" in the sense that those imposing the damages are not required to pay for them.

Externalities arise when individuals make resource allocation decisions without taking into consideration the impact their choice has on the rest of society. Environmental externalities may engender the need for public regulation. However, even after complying with government laws, private firms might still create externalities if permissible pollution levels cause damage to others.

Data Requirements: Cost-effectiveness analysis follows the steps outlined in Chapter Three: a goal is defined; a range of alternatives identified; and data collected to examine the alternatives. As with **benefit-cost analysis** (see below), benefits and costs must be accounted for equally and are usually defined in common terms.

Common Applications: Cost-effectiveness analysis is frequently used in environmental policy evaluation. For example, the California Air Resources Board (CARB) estimates the costs per ton of reducing polluting air emissions associated with different air pollution control methods. Based on this analysis, CARB has determined that, if a pound of oxides of nitrogen can be reduced for $5, it is not efficient to require the expenditure of $10 per pound to obtain like emission reductions.

Strengths and Weaknesses: The main strength of cost-effectiveness analysis is that it is simple to apply. The main drawback to this technique is that it assumes that the goal being examined is worth achieving. That is, cost-effectiveness does not test whether a particular policy's benefits exceed its costs; it takes that as a given and simply seeks the least-cost method of obtaining the chosen objective. This limitation is especially troublesome in cases where decision-makers do not fully understand the difference between benefit-cost and cost-effectiveness analysis, and where even the least-costly option is expensive.

*To make behavioral models tractable, economists have developed a set of simplifying assumptions, including **transitivity**. Transitivity is essentially a logic-based formula that states that if A is preferred to B, and B is preferred to C, then A is preferred to C. This technique makes choosing among alternatives through indirect comparison possible.*

An additional weakness of cost-effectiveness analysis arises when the cumulative effect of policies adopted based on cost-effectiveness analysis acts to significantly impact the economy in unforeseen ways. In other words, policy-specific cost-effectiveness tests do not necessarily protect a state or region from being overburdened by environmental regulations.

AVOIDED COSTS: HOW DO THEY MEASURE UP

Avoided costs are used to compare the ***cost-effectiveness*** of two alternative investments, one being the current standard practice for which cost information is readily available and the second being a new innovation. The first investment represents a cost that could be avoided by choosing the second one. The avoided-cost rate provides a ceiling on potential costs associated with alternative management solutions.

The avoided-cost concept was first introduced in electricity resource planning in the 1970s. During this period environmentalists and private power developers began to ask utilities to consider using conservation, cogeneration or renewable energy instead of the usual fossil-fueled sources to generate electricity. Utilities and regulators responded by telling these groups that these alternative resources would be chosen if they could beat the "avoided costs" for new natural gas or coal-fired plants. The result was rapid development of conservation and cogeneration opportunities that cost less than traditional generating facilities.

The avoided-cost method is now being applied in other environmental forums. In solid-waste management, for instance, recycling expenses are compared to the avoided costs of expanding landfills due to diversion of the waste stream. Water conservation efforts are measured against the avoided costs of building new dams. Avoided costs are usually measured in a standard unit, such as cents per kilowatt-hour of electricity, dollars per ton of waste, or dollars per acre-foot of water.

5.2 BENEFIT-COST ANALYSIS

Description: Although its use is limited at Cal/EPA and its associated boards and departments, benefit-cost analysis (B/C) is the analytic decision-making technique most widely used by public sector agencies. It is also the most frequently *misused* technique. In concept, B/C analysis simply seeks to determine whether an action's benefits will exceed its costs. The use of B/C analysis is intended to promote economic efficiency. In practice there are many variations on what is meant by B/C analysis, and even more interpretations of how benefits and costs should be measured.

BENEFITS AND COSTS: WHAT'S THE DIFFERENCE, AT THE MARGIN, WHETHER A RATIO IS USED?

B/C is variously defined as a **ratio**, a **difference** or a **marginal value**. Historically ratios have been used to evaluate water projects. Generally, a B/C ratio greater than one justifies the adoption of a water project or environmental policy. Under this method, project costs and benefits are tallied, and a B/C ratio — dollar benefits divided by dollar costs — is calculated. This same application can be used for environmental control measures, except the cost is usually born by the polluter, while the benefits accrue to all of society (and vice-versa: the costs of the pollution are born by society, and the benefits of polluting go to the polluter, as well as to the consumer in the form of lower prices). Regardless of who bears the costs and who reaps the benefits, a policy is considered to be economically efficient if costs do not exceed benefits.

Differences — defined as benefits minus costs — convey more information than B/C ratios because they take into consideration project scale. If there is a budget limitation — which there generally is — differences allow decision-makers to rank all potential projects where benefits exceed costs in order of greatest net benefit. That is, in general it is net benefits that should be maximized, not the B/C ratio. A similar strategy using more approximate ratios would result in lower economic efficiency.

Perhaps the best use of B/C analysis is to estimate marginal, or incremental, benefits and costs. Under this framework it is economically efficient to increase environmental expenditures until the incremental costs of doing so equals the incremental benefit. **Least-cost planning** reflects this principle (see Figure 5-1).

Theoretical Basis: Economic activity engenders pollution. According to economic theory, the optimal pollution level is the level that would result under the following conditions:

(1) The marginal, or incremental, cost of controlling emissions is equal to the marginal benefit of control (see textbox above).

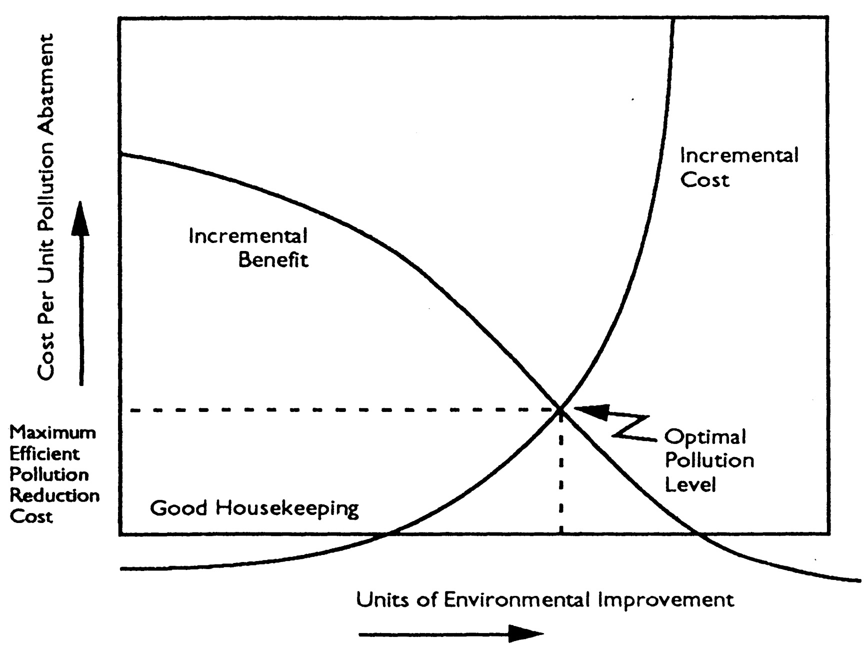
(2) Control is achieved by the least-costly method available (cost-effectiveness).

(3) Environmental control restrictions are equal over all emission sources. That is, no firm would be willing to pay another firm to reduce its pollution further to satisfy the first firm's requirements. This last condition is derived from the Kaldor-Hicks efficiency criterion.

Figure 5-1 illustrates a generalized pollution control situation: marginal costs trend upward while marginal benefits decline. The socially optimal pollution level is at the intersection of the marginal cost and benefit curves. Said differently, the costs to control each successive unit of pollution go from perhaps less than zero — implementing good housekeeping procedures — to greater and greater costs as more sophisti-

All of the methods described in this chapter combine measurement techniques discussed in Chapter Four into environmental decision-making methods. These methods do not purport to mechanize or automate decision-making, nor do they obviate the need for judgement and discretion. Use of these methods will, however, make what would otherwise be implicit decisions explicit; provide a logical and consistent framework for incorporating available technical data with subjective judgement; and create an orderly decision-making procedure with a documentable record.

Figure 5-1
OPTIMAL LEVEL OF ENVIRONMENTAL IMPROVEMENT



cated methods are employed. Finally, these costs become almost infinite as it becomes technologically or physically impossible to reduce pollution further.

Data Requirements: The precise data requirements of B/C analysis depend on how it is being applied. However, in general deriving marginal cost — and especially marginal benefit — curves can be a very data-intensive undertaking. The analytical methods described in Chapter Four are used to estimate benefits and costs. Defining the **accounting stance** of the analysis is critical to this process. It is also important to clearly identify to whom the benefits and costs will fall. For example, some policies have statewide consequences, while others focus on particular groups. Whatever accounting stance is used must be applied consistently to benefits and costs, and to all alternatives being considered (see Section 4.6).

Common Applications: Although public sector agencies have relied on B/C analysis to evaluate resource projects for over a half-century, its application to environmental policies and programs has been slow to develop. Most of the applied B/C work done to date has focused on water and air quality issues, including comparing the costs of air quality compliance controls with the benefits from reductions in polluting air emissions. Academics have conducted substantial research on the use of B/C analysis in environmental problem-solving, but this work is frequently of limited use to policy-makers because it does not always focus on topical issues and often relies on inadequate data.

Strengths and Weaknesses: B/C analysis provides a consistent framework for organizing information and evaluating trade-offs. Likewise, the method defines what is an "efficient" outcome based on the economic assumptions discussed

THE COSTS OF OBTAINING BENEFITS

B/C analysis can be conducted in a strictly monetary sense, or it can be understood from a broader perspective. From a stringently economic perspective, benefits and costs tend to be tallied in monetary terms. However, it is almost always more difficult to estimate the benefits of environmental polices than the costs. Costs are borne by individual polluters who tend to be well aware of their compliance costs. Benefits accrue to all of society, and come in the form of cleaner air, reduction in health care costs, longer lives, greater productivity, and increased well-being. While all of these attributes are clearly worth something, their dispersed nature and lack of "tradeability" makes their value difficult to measure. Further, it is difficult to tie benefits to a particular control action — visibility in Los Angeles may not improve on a given day because of South Coast Air Quality Management District actions so much as due to weather changes. While economists are developing methods to address all of these problems, they continue to present problems to analysts.

elsewhere in this handbook. In addition, the technique increases the objectivity with which decisions are made, and as a result adds to the credibility of governmental decision-making. However, B/C analysis has distinct limitations. These weaknesses do not act to debilitate the method as a decision-making tool, but should be kept in mind when using B/C analysis. Key deficiencies include:

- B/C — and other economic and financial — analysis tends to emphasize easily monetized costs, and inadequately addresses more complex benefits. This is a

WHAT IS "SOCIAL WELFARE"?

Defining and measuring "social welfare" is the "Holy Grail" of economics. Although a single measure of social welfare has never been developed, economists make many recommendations to improve societal well-being based on presumed measures, which most often reflect changes in total tangible wealth (i.e., income and material goods). This wealth-based approach has been criticized for excluding less tangible amenities, such as the environment and public health, and for ignoring how the distribution of economic gains and losses affects the social fabric.

A recent study done as part of the California Comparative Risk Project defined several dimensions of social welfare that should be considered in policy analysis. These include: economic well-being; environmental and aesthetic well-being; physical well-being; peace of mind; future well-being; equity; and community well-being. An analytical framework can be applied to each of these dimensions to help define and measure them as applied to a particular problem. For example, *economic well-being* can be measured both through changes in aggregate wealth and how that wealth is distributed. *Environmental and aesthetic well-being* can be measured using techniques developed to value ecological and aesthetic resources, and quality of life. *Peace of mind* can be represented both through analysis of uncertainty and potential health impacts. Evaluating *future well-being* requires a correctly structured study with a long time horizon and explicitly stated assumptions about growth and discounting of future costs and benefits. Analysis of *equity* issues involves distribution of economic and political assets and power, both of which are the focus of much analytical work. *Community well-being* can be evaluated through several indicators, such as property values and impacts on human resources (e.g., the number of individuals in prison).

Policy analysts must consider other factors, such as institutional and organizational relationships, demographic trends, and issues of social justice, to fully evaluate progress toward social welfare goals. Economics can inform this analysis by rigorously defining and quantifying many of these dimensions. Claiming that these issues are too "fuzzy" to be rigorously examined ignores the many analytic tools available to an analyst.

particular problem for environmental policies, which are typically oriented towards generating broad social benefits that are not easily measured (See "The Costs of Obtaining Benefits" textbox.)

- B/C and **cost-effectiveness** analytical results are typically sensitive to a number of basic assumptions — including the **discount rate** and **price elasticities** used. As a result, sole reliance on a single B/C estimate can result in misleading counsel.
- By expressing values in monetary terms, B/C — as well as cost-effectiveness — analysis tends to focus attention on efficiency issues, neglecting considerations of **equity** and **risk**. As a result, when using B/C analysis it is important for decision-makers to separately and comprehensively weigh such concerns where applicable. While B/C analysis may indicate that a policies' aggregate benefits may exceed its costs, this does not mean that each individual is necessarily better-off under the policy. (See "What is 'Social Welfare'?" textbox.)
- When not carefully applied, benefits can be double-counted in benefit-cost analysis. For example, agencies may treat transfer payments from one entity to another as a benefit, when in fact the transfers cancel one another out.

5.3 THE "LEAST-COST" PLANNING APPROACH

Description: In least-cost planning (LCP) the costs (or savings) per unit of pollution (weighted by relative environmental damage) are calculated for each policy alternative. This process is derived from **cost-effectiveness analysis**. The benefits of reducing environmental damage are also estimated with economic valuation techniques to derive a societal "demand" for environmental improvement. The options are then ranked by relative cost and the implementation level chosen through the planning process to the point where the cost equals the total economic benefit of adding the last option.

LCP was originally designed as an approach to minimize the total cost of electrical generation, including environmental damages. Utility companies who have many possible alternatives for meeting demand, each of which has a different set of capital and operating costs, use LCP to decide how to expand their system capacity to meet rising demand at the lowest cost. Government regulators use LCP to ensure that required utilities provide the lowest-cost energy to their customers. Utility companies also use the related short-term decision models, called dispatch models to decide which units to operate at any given time.

Theoretical Basis: The least-cost planning methodology is based on a fundamental assumption of standard economic theory: *that the results of least-cost planning by a central authority should be equivalent to the market-driven outcome if prices*

POLLUTION PREVENTION: NEGAWATTS VERSUS MEGAWATTS

The goal of pollution prevention is to limit the use of toxic and polluting materials in production processes so as to reduce the ultimate amount of pollutants and waste. This principle is the same that guides energy conservation, where the amount of energy consumed is reduced through changes in the production process, choices of inputs, and types of products. The argument is made that pollution prevention should be done to the maximum extent possible. However, such an assertion implies the total cessation of economic activity unless an economically-defined stopping point is chosen. While pollution prevention is an important method in achieving a better environment, it is not a goal by itself, just as energy conservation is one of several tools in managing energy costs and waste.

Many of the same analytic tools used to decide if energy is best conserved or produced can be applied to pollution prevention analysis. Analysis of energy conservation has evolved over the last 20 years since the first energy crisis, and much has been learned about what the right and wrong approaches are to the problem. In the case of conservation, energy use is reduced up to the point where the costs of conservation—"negawatts"—equal the avoided costs of producing the energy—"megawatts." Once it becomes more cost-effective to build, say, a new electric power plant, conservation is no longer a preferred option, and the power plant is built. This fundamental principle guides decision making at the California Public Utilities Commission and Energy Commission.

In the same way, pollution prevention can be evaluated using economic tools. The costs of reducing use of offending materials can be compared to the **avoided costs** of damaging the environment and producing goods using a polluting process. Once the costs of pollution prevention exceed the avoided costs or "benefits," pollution prevention is no longer the preferred management option.

fully reflected social costs. The benefits of reducing one more unit of pollution is balanced against the cost of reducing that unit of pollution until the marginal benefits and costs are equal. In a hypothetical market, this is the theoretical price equilibrium.

In the case of electricity, when social or environmental costs are ignored, least-cost generating decisions inefficiently allocate generation capacity to polluting generation units. By including the full cost to society of the pollution from each unit, as well as its conventional operating costs, externalities are internalized.

Data Requirements: Two data sets are necessary when using least-cost planning for environmental regulation. The first data set includes the normal market-valued information on capacity, capital and operating cost and reliability and availability constraints for each production technology. These data are readily available and comprise the inputs normally used in conventional least-cost

A TALE OF TWO GENERATING UNITS

Least-cost planning relies on site-specific data on environmental and conventional costs. For example, consider an evaluation of two physically identical electric generating units. Both units have similar polluting emissions. However, one is located in an urban area, close to electrical load centers, and the other is in a remote rural area. The urban unit would have greater conventional economic benefits because its location near its load center would enhance its transmission reliability. The rural unit would impose lower environmental costs, because fewer individuals would be exposed to its emissions, but it would contribute less to system reliability. Given accurate site-specific data on the marginal benefits of system reliability and pollution abatement, least-cost planning analysis could be used to assist policy-makers in choosing between the two plants.

Short-term timing could also be a factor. For example, suppose the two plants described above were both available to the system. During an inversion-induced air quality emergency, the importance of emission reductions may favor idling the urban plant, even if it was the least-costly resource under normal conditions. Conversely, when planned or unplanned outages degrade system reliability, it might be optimal to fire the urban unit, despite its environmental costs.

planning models. The second data set includes the environmental costs associated with production from each unit. These include costs for each contaminated media — air, water, and hazardous waste. Functions relating emissions by output and the associated external costs of these emissions need to be calibrated for each unit. This second data set is at present quite difficult to obtain.

Common Applications: Least-cost planning, including environmental consideration has thus far been applied mainly to electrical generation. Many state commissions, including the California Energy Commission and the California Public Utilities Commission have used some form of this method to determine a relative ranking of fossil-fuel, renewable and demand-side management generating resources. A similar approach has been advocated for addressing the effects of global warming on the world economy. In California, urban water agencies are planning to use LCP to assess future needs and supplies. And during 1993 and 1994, CARB had several studies under review that could lead to the use of least-cost planning methods as part of air quality regulations (see "Pollution Prevention: Negawatts versus Megawatts" textbox).

Strengths and Weaknesses: The strength of least-cost planning is that it clearly identifies and ranks the available policy options on a common cost basis. It also represents the planning method that most closely approximates the market in balancing costs and benefits to achieve a policy goal.

However, least-cost planning has several drawbacks. First, the method's underlying assumption is that economic efficiency is the sole goal of the planning process. Other goals can only be accommodated if they are explicitly recognized. Second, least-cost planning is based on the assumption that the planner is all-seeing and all-knowing ("omniscient") (i.e., that all costs, availability and ramifications of each option are known and can be correctly incorporated into the model). To be comprehensive, the planner must know all affected parties' preferences and be able to properly weigh these preferences among individuals.

Common Pitfalls: While engineering or program costs are calculated and compared to existing technologies and behavior in least-cost planning, other important economic factors should also be considered in the analysis, as follows:

- How consumers and producers will react to new processes (e.g., assuming people will not, for example, cool their house to a greater extent if it is cheaper to do so ignores the basic economic principle borne out in the empirical literature on energy conservation and the "rebound effect").
- How demand for products and services depend on the counterbalancing effects of rising prices which depresses demand, and rising incomes which increase demand.
- Shifts in the sharing and spread of risk — central planning tends to dissipate the advantages of risk spreading from having a diversity of decision-makers (i.e., consumers) in the marketplace.
- The path of innovation adoption, and the turnover in aging stock which leads to natural improvements in efficiency.
- The effect of businesses making multi-objective investments, in which pollution control or energy efficiency is but a small part.
- The institutional relationships between individuals and organizations in society and the market.

In LCP analysis technical potential for alternative energy sources should be distinguished from the economic potential, and a supply curve created for these technologies so that a resource plan can be developed. However, estimates of benefits and expected technological developments should be viewed skeptically in any analysis. The *economic* potential for alternative technologies, (e.g., renewable generating resources), is substantially less than *technical* potential, as developing, for example, each additional megawatt of wind power becomes more expensive than the previously added megawatt. Eventually, additional development is no longer cost-effective, although some available resources technically remain.

5.4 DECISION ANALYSIS

Description: Decision analysis (DA) is a formal and systematic means of evaluating a set of policy alternatives. The primary tool of DA is the development of quantifiable **utility functions.** Through such functions complex information can be organized so as to provide insight to decision-makers. DA can be distinguished from other analytic decision methods both by its reliance on quantifiable utility functions, and by the fact that it addresses both objective information (technical data) — and subjective preferences — (normative inputs). Use of DA does not guarantee "correct" decisions, but rather encourages rational outcomes given the identified goal, specified alternatives and available information.

In DA the roles of the decision-maker — whether an individual, group or committee — the decision analyst and the technical analyst are clearly defined as follows:

BOOTLEG DECISION MAKING

Although decision analysis mixes **positive** and **normative** values, the roles of the different parties engaged in the analysis must be clear, and treated with respect.

Example One. A prominent decision analyst who worked for a major environmental consulting firm was hired to analyze a controversial U.S. Department of Energy (DOE) program for siting nuclear power plants. The technical consultant amassed a large amount of objective information on site-specific impacts and the risks associated with various siting alternatives. The decision analyst then requested that DOE staff provide a list of their subjective concerns, including how to balance trade-offs between health risk levels and cost implications. However, DOE declined, and instead requested that the consultant rely on technical experts to develop normative inputs. The resulting decision was represented as reflecting the decision-maker's judgements, and became part of national policy.

Example Two. A technical assessment was made of alternatives to reducing the risks of petroleum product spills associated with marine transportation. In addition, the decision-maker was asked to develop a ranking of his preferred alternatives. The resulting analysis indicated that the optimal alternative was the development of a marine transit station. However, the decision-maker was not happy with this recommendation, and instructed the analysts to reconstruct the assessment using a different set of constraints. This revised analysis was ultimately adopted as policy.

Both of these examples reflect a misuse of decision analysis. The first example illustrates the point that subjective choices must be made by decision-makers, not by technical experts. In the second example, although the decision-maker did his job (i.e., provided subjective input), he did not treat the resulting analysis with respect. In this case it is apparent that the goal of the analysis was to legitimize a decision that had already been made, rather than to independently identify the appropriate alternative.

- Either the *decision-maker* or *stakeholders* are in the best position to specify what factors — or **attributes** — determine a better or worse policy outcome. Decision-makers or stakeholders must also specify how combinations of different attributes should be ranked as part of an **objective function.** In this sense the decision-maker and the stakeholders are responsible for making all the necessary value, or normative, judgements.
- The *technical analyst's* role is to estimate what outcomes will result from various policy decisions. The technical analysts' judgements are limited to those which are **positive** — observable or theoretical— in nature.
- The *decision analyst's* role is to organize and facilitate the process. For example, the decision analyst assists the decision-maker in selecting a comprehensive and discrete set of preferred attributes, and in organizing these attributes into an objective function. The decision analyst should essentially make no judgements, but rather serve as a neutral facilitator.

Theoretical Basis: Decision analysis derives its theoretic basis from a combination of **multiattribute utility theory** and **probability theory.** Utility theory describes how individuals make choices within **budget constraints.** According to this theory, people strive to "maximize their utility" by selecting the combination of goods and services that provides them with the greatest amount of satisfaction within their budget limits.

DISCRETE, CONTINUOUS, OR DETERMINISTIC ASSESSMENT?

There are three different types of probability estimates: **discrete, continuous,** and **deterministic.** A discrete probability consists of mutually exclusive alternatives. For example, if a single bottom oil tanker loses its main engine, there is a 5 percent chance it will run aground, and a 95 percent chance of power being restored or of the ship making it to a safe harbor without further difficulties. This is a discrete probability distribution because it is comprised of mutually exclusive alternatives. Under a continuous probability there is an infinite number of possible outcomes. For example, if the oil tanker runs aground, the amount of oil that is likely to be spilled follows a **normal distribution,** with a **mean** of 1,000 barrels and a **standard deviation** of 300 barrels. Deterministic analysis assumes that actions will result in a certain outcome. For example, if the tanker runs aground, 1,000 barrels of oil *will* spill.

In general the choice of probability type to employ in a specific analysis is left to the analyst. Use of a deterministic model tends to make the ensuing analysis easier to develop and to understand, but at the cost of losing some information about the range of potential outcomes.

Probability theory is a branch of mathematics which addresses the likelihood that an event will occur. Methods for addressing conditional probability— the likelihood one event will occur simultaneously with another — and sequential chains of events are encompassed within this theory. Probability theory is used in DA only when **uncertainty** is an explicit part of the analysis. However, outcomes are frequently probabilistically related to actions. (See "Discrete, Continuous or Deterministic Assessment?" textbox.)

Data Requirements: Decision analysis necessitates the same pattern of information as discussed in Chapter Three. The method can incorporate the results of the analytic methods discussed in Chapter Four. However, DA's greatest strength is to structure problems. For this process most important "data" comes from values expressed by decision-makers and stakeholders.

Common Applications: Decision analysis can be aptly employed in almost all policy analysis. In general, it is most useful in evaluating complex policies that, because of the nature of benefits involved, may not be good candidates for **benefit-cost analysis.**

Strengths and Weaknesses: Decision analysis has a large number of strengths, including the following:

- Decision analysis focuses decision-makers' attention on the key attributes and alternatives of a policy outcome.
- Through decision analysis a rational decision can be developed, thereby adding credibility to the policy.
- When skillfully applied, decision analysis can provide a vehicle to achieve consensus, or at least reduce differences, within a decision-making group. Decision analysis can move decision-makers past divisive discussions of alternatives by focusing attention on defining the key attributes, and evaluating outcomes. A decision-making group — even one consisting of diverse stakeholders — can typically reach consensus on important attributes, enabling remaining differences to be resolved through some type of trade-off mechanism.

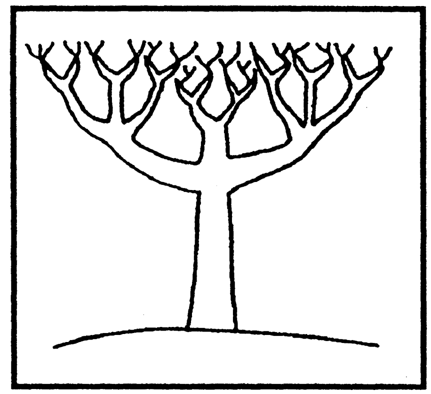
Decision analysis' primary weaknesses are as follows:

- Decision analysis at times forces policy-makers to express their preferences in quantitative terms, even in cases where important considerations are essentially qualitative in nature.
- The technique may require significant time investment, particularly on the part of decision-makers.

5.5 RISK-RELATED ANALYSIS

Description: In addition to the analytical methods described above, several other techniques are used in environmental decision-making to address issues of risk. Methods that fall into this category include: **risk-cost-benefit; comparative risk;** and **decision-tree** and **fault-tree analyses.**

- *Risk-cost-benefit* analysis is essentially a subset of B/C analysis, with the addition of specific consideration of the costs of risk mitigation.
- *Comparative-risk analysis* focuses on comparing the relative probability of harm associated with different risk factors. Comparative risk is a new concept, and does not as yet have a complete definition. In general, this technique refers to a comparison of one risk factor with another, rather than a risk versus cost or benefit comparison. For example, the risks of leaving contaminated soil in place can be compared with the risks associated with transporting the soil over public highways to a disposal site.



- *Decision trees* provide a means of evaluating the probability of an event occurring as a result of a chain of events. Through the decision tree each event on the chain is assigned a probability of occurrence. At each event point the tree branches, depending on the incident outcome. The probability of each possible outcome can then be calculated as the product of the probabilities of each branch point.
- *Fault-tree analysis* is a special case of decision tree analysis in which the event whose probability is being calculated is a failure of a safety system.

Theoretical Basis: As with **decision analysis,** probability and statistical theory provide the basis for all risk-related techniques. Although probability and statistical theories are well-established, their application to complex environmental risks necessitates the use of considerable judgement. This is because environmental risks are composed of the complex interaction between the environment at issue and humans.

Data Requirements: Depending on the specific issue being examined, the data requirements to conduct risk analysis can be formidable. Scientists frequently reduce their data needs by focusing their analysis on extreme — or polar — cases. For example, rather than modeling how an air pollutant affects every single individual in an air basin, regulatory analysis is often designed to protect the most susceptible populations (e.g., children, the elderly) at the highest exposure rates. Similarly, safety systems for nuclear power plants are generally designed to protect the environment in the event of a worst-case combination of events.

Common Applications: Risk-cost-benefit analysis is frequently used to establish priorities for action on environmental issues, such as protection from the risks associated with radon and asbestos. Comparative risk evaluation projects have been undertaken by the U.S. EPA and a number of states, including California. Fault-tree analysis is frequently used in engineering and management to determine minimum allowable safety standards.

Strengths and Weaknesses: The greatest strength of risk-based methods is their ability to provide an orderly structure with which to examine uncertain — and frightening — environmental hazards. The greatest limitation to these techniques is the difficulty of predicting the risks associated with the complex interaction between humans and their environment.

5.6 SELECTION OF APPROPRIATE ANALYTIC DECISION-MAKING METHODS

Determining which of the methods described in this chapter is appropriate for a given environmental decision-making situation requires good judgement and some familiarity with the techniques. However, limited generalities can be made. Cost-effectiveness and benefit-cost analysis apply best to situations in which economic efficiency is the sole factor of concern. Cost-effectiveness and least-cost planning are only appropriate in selecting the least-costly means of achieving a specified goal, <u>not</u> determining whether a goal is worthwhile. Benefit-cost and decision analysis are the appropriate methods to be employed to determine whether or not a goal is worthwhile.

Benefit-cost and least-cost planning have difficulty incorporating non-monetary environmental attributes, and special care must be made to ensure those qualities are considered. Decision analysis has the broadest application. Risk-related analysis can be incorporated into all of the other methods whenever outcomes can be expressed as probabilities.

6 KEY TERMS

Accounting costs are the out-of-pocket expenses, depreciation, and historical costs that are used in bookkeeping entries.

Accounting stance refers to the spatial and political framework within which a decision is made. Applying a consistent accounting stance to all alternatives under evaluation is critical to rational decision-making. The appropriate accounting stance will vary with the objectives of the **decision-makers** and **stakeholders.**

Ad hoc defines a decision-making processing that is not systematic or can not be duplicated.

Adverse selection is when buyers and sellers have differing levels of information about a market transaction (e.g., the competence of a worker) so that when a trade actually occurs the participant with the better information has the advantage.

Anecdotal analysis is the reliance on a single incident or a collection of "stories" to infer cause and effect.

Arbitrage is the simultaneous purchase *and* sale of the same good or service in two different markets to take advantage of the price differential between the markets.

Asset rental price is the lease price that an **asset** would receive in a hypothetical market. This price changes from year to year to reflect **depreciation** and market conditions. The asset rental price differs from **levelized annual payments,** which reflects a constant price regardless of the condition of the asset or the market. For example, a homebuyer might have purchased a house for $100,000 at a 13 percent mortgage rate under a 30-year loan. The levelized payment scheme results in a monthly payment of $1,000 that does not change over time. However, using asset rental pricing, if the market price appreciates at 8 percent per year, the initial monthly payment would be $711 per month and would escalate at 8 percent per year, so the payment would be $768 the second year and so on. The asset rental price better reflects the value of an asset in the market.

Assets are a useful or valuable resource, good, person or quality. Assets may be tangible, such as cash or a forest, or intangible, such as client goodwill or the knowledge that a species exists.

Assumptions are aspects of a problem which are taken for granted as a basis for a line of reasoning or course of action. Assumptions are used to either make a complex problem tractable with available analytic methods or to fill gaps in **empirical data.** Assumptions generally derive from a **theory** about how a process works. Assumptions may be stated *explicitly,* particularly if they are specific to a situation, or be *implicit* in the approach being used. The use of implicit assumptions is inherent in relying on sophisticated analytic methods such as engineering economics, and other social sciences or decision analysis.

Asymmetric information is the situation where one party has more or better information than another party.

Attributes are distinctive characteristics that can bring value to an **asset**.

Average is a number used to describe in a single value the middle or the central tendency of a set of numbers. **Mean, median** and **mode** are types of averages.

Avoided cost is the cost for a current standard practice or facility that could be *avoided* by choosing an alternative strategy or investment.

Baseline conditions are defined as (1) the expected conditions into the future if no policy change is adopted, (2) the conditions in the initial year of the study, or (3) the "no-action" alternative in which no policy or strategy is in place. Baselines are an artificial construct about future conditions based on a set of **assumptions**. The baseline conditions provide the standard against which costs and benefits of policy proposals are measured.

Bayesian analysis involves incorporating objective **empirical** and **theoretical** analytic results with **decision-makers'** subjective prior beliefs about likely outcomes (called a *prior distribution*) to evaluate the desirability of various choices. Bayesian analysis is commonly used in **decision analysis**.

Benefit-cost analysis (B/C) generally describes a method used by public agencies to determine whether a proposed action is in the public interest by weighing expected costs against potential benefits. Normally in **economic** analysis, when benefits exceed costs or the ratio of benefits to costs is greater than one, the action is considered beneficial from the standpoint of **efficiency**.

Benefits transfer is the use of study results to value **nonmarket goods** — environmental or health attributes — based on values derived from one problem or geographic area for a similar situation that differs in context or location. This method is most commonly used in **damage function** estimation, but also is applied in specific policy-making situations where budget or time resources are insufficient to develop original research on the problem.

Bequest values derive from the desire to leave a resource to future generations (e.g., that no development will occur on a distant lake) although a concerned individual may not visit the resource in their lifetime. While this concept is different cognitively from **existence value**, it has the same mathematical representation. Bequest values are typically derived in analysis through **contingent valuation methods**.

Biased estimates misestimate the "true" **expected values** of the population as a whole because the chosen **statistical** or **econometric analysis** method violates certain **theoretical** criteria. The problem of biased estimators can be addressed by either (1) redressing the original analytic problem or (2) identifying the direction and magnitude of the bias and adjusting the resulting estimators.

Binding constraints are **constraints** that limit the number of **feasible solutions** to an analytic or policy problem.

Bond ratings are an indicator of the creditworthiness of a specific bond issue. These ratings often are interpreted as an indication of the likelihood of default by bond issuers.

Budget constraint limits the resources available to acquire a good or provide a service. Budgets can be constrained by not only income and wealth, but also by time and other available resources.

Bureaucracy is a formal hierarchical organization with many levels in which tasks, responsibilities and authority are delegated among individuals, offices or departments, and tied together by a central administration. Bureaucracies are characteristic of many large organizations, for both **governments** and **corporations**.

Business sectors (See **economic sectors**.)

Calibration is the process of matching the results of a simulation model to real-world data. This is done by adjusting **parameters** within the model after the initial formulation and estimation process.

Capital Asset Pricing Model (CAPM) is an **equilibrium** model of asset pricing which states that the **expected** return of an **investment** is a positive linear **function** of the investment's sensitivity to changes in the return for the entire **market portfolio** (i.e., all available investments of a similar nature.)

Capital gain (or loss) is the difference between the **value** of an **asset** when sold or exchanged and the original cost of the asset adjusted for improvement or depreciation.

Capital goods are used in the production of commodities; also known as *producers'* goods.

Capital-intensive is a term that describes industries that employ relatively few laborers or energy units in comparison to the amount of **capital goods** or equipment they use.

Cardinal scaling is a measurement which can be expressed in real numbers (i.e., one, two, etc.) that represent absolute measurement or intensity, and can be thus be manipulated using arithmetic operations. A cardinal measurement which is twice as good will be exactly twice as high. This contrasts with **ordinal** measurements, which do not have this property (see **ordinal scaling**).

Cartels is an association formed by producers or consumers to limit output or purchases so as to control the price of a good in a market as a means of increasing their profits or consumer surplus. Producer cartels find it difficult to limit output because rival firms inside the cartel have trouble allocating the reduced output among themselves (each wanting a larger share of the output and profits), enforcing the limitation, and keeping other firms out of the market who are attracted by the higher profit potential. Cartels are easiest to maintain where entry into the market is difficult and the market has just a few firms.

Case studies are the application of **theory** and **empirical** findings to a specified situation to determine the validity of the findings under particular circumstances. Case studies can be used to illustrate the application of an analytic method or as a screening method to determine if an action might have a significant effect on a specified population.

Certainty-equivalent return is the return on a risk-free investment which makes an investor indifferent between the risk-free investment and an investment with a particular risk level.

Ceteris Paribus is the Latin term for the assumption "all other things equal," (i.e., all relevant factors in an analysis are held constant except for the variable or variables of interest).

Churning is the *gross* change in jobs or other resource use in an economy induced through an event, action or policy. Churning differs from the *net* change in jobs in that it measures how many individuals will lose their current jobs and how many new hires will be required. For example, a policy analysis may show that one million jobs are lost and another million created in different **economic sectors** through a policy. While the expected net job loss equals zero, the level of churning indicates that significant social dislocation may occur.

Coase Theorem states that an efficient allocation of resources can be attained in the presence of **externalities** through reliance on bargaining among the parties involved, if a series of strict **assumptions** hold. It is based on an article by Ronald Coase, "On Social Cost" (1960). Most important of the assumptions is the one stated by Coase that bargaining costs must equal zero, and that the parties value the externality the same whether they are paying for or accepting compensation.

Cognitive dissonance occurs when an individual ignores information that might affect their behavior and acts in opposition to the implications of that information. For example, a smoker might have a cigarette even though he knows the consequences of doing so. Cognitive dissonance leads to the belief "it can't happen to me."

Commensurability is the ability to be measured by a common standard or in units which have the same dimensions. Properly defining the **accounting stance** in an analysis aids in developing commensurability of report analyses.

Comparative-risk analysis is a procedure for ranking environmental problems and hazards by their seriousness or "relative risk" for the purpose of assigning them priorities for regulatory action. Comparative risk analysis is done by a team of experts who first list and sort the problems by types of risk–cancer, mutagenic, ecological. This list is then weighed based on legal and institutional requirements, the technological and economic feasibility of addressing each problem, and the level of public concern for each issue.

Competitive markets create the situation where the product and input prices are not influenced by the behavior of an individual firm. Competitive markets arise because either the number of firms and consumers is so large that the actions of a single individual are inconsequential, or the threat of entry by other firms or consumers forces firms or consumers in the **market** to accept the available prices.

Complements are two goods which relate in such a way that if the price of one rises, consumption of the other will fall. For example, if the price of bread increases, less bread will be purchased—ceteris paribus—and the consumption of butter will decline. (See also **substitutes.**)

Confidence intervals measure the likelihood that an observed estimate falls within a set range and, thus, that the confidence interval includes the actual value being sought. If the analysis was repeated a number of times, the percent of confidence is the proportion of times that one would expect the real value to be included within the confidence interval. (See **statistical significance**).

Constant dollars are an economic convention that is used to measure industrial output and consumption over time while controlling for changes in prices owing to **inflation**. The use of constant dollars allows for a more accurate comparison across periods.

Constraint equations used in **mathematical programming** describe the **technologies** or management techniques available to reach the **objectives** and calculate how costs vary with input levels.

Constraints are limits on either the resource use or range of possible outcomes in a policy decision. Constraints can be described either mathematically or in qualitative terms.

Consumer goods are those that satisfy human wants and needs through their consumption or use, such as food and clothing.

Consumer Price Index is the cost-of-living index which tracks the prices for a representative market basket of goods and services purchased by U.S. consumers. CPI is one of the most common indicators of the **inflation** rate.

Consumer surplus is the difference between the total value consumers receive from using a particular good or service and the total amount they pay.

Contingent valuation method (CVM) relies on directly asking people in a survey to make trade-offs between **non-market** and **market** goods, in such a way that their inherent preferences are revealed. CVM uses carefully structured surveys to ask individuals about the value that they put on an environmental asset, such as a forest or an animal. CVM enables analysts to value non-use aspects, such as **existence values**.

Continuous functions follow a path over time or space that have no breaks or sudden changes in direction. For example, continuous-time **discounting** means that the **present discounted value** changes every single second and that change is calculated and measured by the discount function. Compounded **interest** is based on this concept.

Corporations are business organizations owned by a group of stockholders, each of whose liability for any losses incurred by the business is limited to the amount invested in the corporation's stock.

Correlation coefficient is a statistical measure of the degree of mutual variation between two variables with random characteristics. The coefficient is bounded by the values of -1 and +1, with negative values indicating that the variation is in opposite directions, and positive values indicating variation is in the same direction.

Cost-benefit analysis (see Benefit-cost analysis)

Cost-effective refers to an action which is the lowest-cost plausible means of achieving a specified end. An action which is cost-effective is an **efficient** means of achieving a goal, but this does not imply that the goal is always worthwhile. Cost-effective does not encompass comparison of the benefits to the cost (that would be **benefit-cost analysis**).

Cost of capital or funds rate is the return that investors or lenders expect from investment in a firm.

Costs are payments or opportunities forsaken by an economic actor to gain use of a resource.

Cross-sectional analysis looks for patterns of cause-and-effect across a spatial (e.g., geographic) or **socio-economic**, dimension. Cross-sectional analysis assumes that the **dependent variable** is **commensurate** across localities at the same time. In **economics**, such analysis can be used to discern how differences in certain conditions (e.g., prices, local **attributes** or other factors) can lead to changes in consumption or production. This makes this approach useful for comparing alternative options. Cross-sectional analysis produces estimates of *long-term* impacts without any reference to how the impacts might evolve over time.

Culture is the sum of attitudes, customs and beliefs that distinguish one group of people from another. Culture is transmitted from one generation to the next through language, objects, rituals, art and institutions.

Decision analysis (DA) is a formal, structured approach to decision-making which relies on multi-attribute **utility** theory and the laws of **probability**. Decision analysis accounts for different decision rules (e.g., **minimax** or **Bayesian analysis**), the likelihood of certain outcomes, and the weighing of the relative importance of **constraints** and **objectives**.

Decision analysts are individuals trained in structured formal decision making. The decision analyst does not make decisions, but merely structures the information to assist the **decision-maker** in making an informed, rational decision.

Decision-makers are the individuals or groups responsible for making a choice from among alternative courses of action and who are accountable for the consequences of that decision. It is the decision-makers and **stakeholders** who make subjective **value judgments** about the desirability of an outcome, rather than the technical or **decision analysts** whose purpose is to provide and organize information.

Decision tree analysis is a method of evaluating the probable outcomes of actions which have several intermediate steps, each with a defined **probability**, upon which the final outcome depends.

Demand curve or function is a graph showing the relationship of potential prices and the amounts demanded at each price per unit of time, other things given. Demand curves usually slope downward from the left to right, indicating the most important property of the demand curve: the incentive to demand less as prices rise. The point at which the quantity demanded is equal to the quantity supplied—where the demand and **supply curve** intersect is the market-clearing price in **economic theory**. (See also **elasticity of demand or supply**.)

Depreciation is an accounting procedure that allocates the cost of an **asset** or **durable good** over the estimated useful life of the asset. In economics it can be thought of as the cost of continuing possession of the asset (e.g., the longer we keep an automobile, the less its resale value is likely to be).

Deterministic functions are influenced only by variables contained in the equation with no **random variables** causing unpredictable fluctuations. As a result the path of deterministic functions can be predicted at any point in time with complete certainty.

Diminishing returns to investment is the proposition that additional investments in a particular asset or policy will ultimately produce increasingly smaller additional or **marginal** returns.

Direct costs or impacts are imposed on individuals or firms who must respond directly to an action, event or policy. These costs can then create **induced** and **indirect** effects in the economy.

Discount rate is used to calculate the **present discounted value** of future benefits and costs. Benefits received in the future are not as valuable as the same benefits received today because they provide less utility or satisfaction, and, therefore, they have to be discounted. For example, if air pollution is reduced today, more lives will be saved than the same reduction at a later date—pollution reduced today is more valuable. The farther in the future benefits are received, the less value they have compared to receiving the same benefits today. The discount rate reflects the **time-value of money**, and the riskiness associated with future benefits and costs. Discounting is based on the principles that (1) people prefer receiving benefits now rather than later; (2) benefits received now can be reinvested to produce greater benefits in the future; and (3) technological progress will make future generations better off than today's. The discount rate can be derived several ways, including from a representative **market interest rate**; a time preference for an affected individual or firm; or a measure of the social value of deferring consumption to **invest**. (See **interest and rate of return**.)

Discrete or discontinuous functions change values at intervals in time or space in a single jump. These are often known as "step" functions. For example, discrete-time **discounting** calculates the **present discounted value** in each year on the assumption that a cash outlay is made once a year. Simple **interest** is based on this concept.

Dispatch models are used to determine which combination of electrical generating resources (or other productive resources) to use in order to most efficiently meet short-term system demands. When environmental impacts are considered in addition to direct cost, it is said to be an *environmental dispatch* model.

Diversification is the process of adding investments to a portfolio in order to reduce the portfolio's **idiosyncratic** or unique (unrelated to the market) **risk** and, thereby, the portfolio's total risk.

Dominant solution is one which is superior to all other alternatives with respect to *all* criteria. Dominant solutions are unusual; most often solutions are better in terms of some criteria and worse in terms of others. As a result, **decision-makers** usually must trade-off among criteria when making a decision.

Dominated solution exists when at least one other alternative is found to be at least as good or better than all other solutions with respect to *all* criteria.

Duality is an **assumption** used in **economics** that in the short-term or in a truly competitive market, **profit maximization** implies that a firm also minimizes costs. Duality occurs when one assumes that output levels and prices are fixed, implying the only way the firm can maximize **profits** is to minimize inputs. Duality is a useful analytic tool because the analyst can ignore the **revenue** portion of the profit function by assuming it remains constant, thus simplifying the analysis. Duality is also used in **mathematical programming** to find the **shadow values** for adding inputs or relaxing **constraints.**

Dummy variables can be used to represent **explanatory variables** that have **discrete** or dichotomous (i.e., "either/or") properties in **statistical analysis.** Typically, a dummy variable is used to assess the importance of a yes/no characteristic on the **dependent** variable (e.g., is an individual a male?) Typically, the variable is set at 1 if the answer is yes; 0 if no.

Durable goods are manufactured goods designed to have a long life or utilization periods, such as automobiles or appliances.

Dynamic analysis takes into account that economic, technological, institutional, and social relationships may change through time, in part through feedback effects or outside influences, and that **equilibrium** conditions may change over time as well. This is in contrast with **static analysis,** which holds the current situation constant over time.

Economic life is the **expected** remaining life for an **asset** given operating and maintenance costs versus the costs and benefits of replacing the asset. When the **net present value** of expected operating costs exceeds the net costs of purchasing a new asset the current asset should be retired for economic reasons. This differs from **accounting costs.**

Econometrics is the application of mathematics and statistics to economic analysis. A major role of econometrics in ennvironmental economics is to provide numerical values for the parameters in the formal mathematical equations used by analysts. These parameters can replace qualitative judgements, and allows for easier testing of environmental theories, as well as providing more exact information.

Economics does not have a standard definition which is accepted by all economists. In general, it is the study of how people choose to satisfy their wants and needs given that they have limited time and resources and constraints imposed by technology, institutions and nature. In analytical terms it can be thought of as a mathematical optimization problem (i.e., selecting instruments—variables—from an opportunity set so as to maximize an **objective function).** Economics provides analysts with a method of ordering and arranging knowledge so as to allow for better decision making. In environmental analysis economics is often used to place dollar values on selected elements of the environment as a means of standardizing diverse benefits and costs that otherwise could not be added together. In the economists' theory of value, the value of goods and services is not intrinsic, but rather is revealed by market-clearing prices. In environmental economics the value of **non-market goods,** such as health and morbidity, are estimated by non-market means.

Economic sectors are portions of the overall economy that are related to the production or consumption of goods and services. Broadly, economic sectors are usually divided into households (or consumers), producers (or firms), and the government. Within the production sector, the U.S. economy is analyzed by Standard Industrial Classification (SIC) code.

Economy of scope occurs when it is less expensive to produce two goods or services simultaneously than separately. For example, cattle are raised to produce beef, hide and milk. Economy of scope is characterized by the use of common inputs to produce multiple outputs.

Ecosystems are collections of living things and the physical environments in which they live.

Efficiency in broad terms means the absence of waste, or obtaining the maximum benefit from the available resources. It is often expressed as the ratio of output to input (engineering efficiency) or the value of output to the value of the input (economic efficiency). The higher the value of the ratio the greater the efficiency. For example, one outcome is more efficient than an alternative outcome if it (1) creates more benefits at the same cost or (2) yields the same benefits at less cost. (See also **cost-effective** and **efficient allocation.**)

Efficient allocation in a market economy occurs when exchange takes place to the point where no individuals can make themselves better off without making someone else worse off. (See also **Pareto Optimality and Kaldor-Hicks criterion.**)

Elastic demand or supply (see **elasticity of demand or supply.**)

Elasticity is the responsiveness of one **variable** to a change in another variable, measured as the percentage change in one variable caused by a one percent change in another explanatory variable. Elasticity is used most often to derive how much the quantity demanded or supplied changes with a change in price (i.e., price elasticity.)

Elasticity of demand or supply represents the responsiveness of quantity demanded or supplied to a change in price. Elasticity is normally different at each point along the demand or supply curve except in three cases where the elasticity is zero, infinite or one. One, the elasticity is zero or *perfectly inelastic* where there is no change in quantity when the price changes. In this case the demand or supply curve is vertical. A vertical demand curve could be thought of as the demand curve for a "need" where a certain amount is needed regardless of the price (e.g., a new fuse to replace one that has blown and shut down a billion-dollar assembly plant). A vertical supply suggests a fixed stock of goods that the seller is willing to sell at any price to get rid of it (e.g., produce that is about to spoil). Two, the elasticity is infinite or *perfectly elastic* where the demand or supply curve is horizontal. In this case buyers can get all they want at the given price so they will not pay more, and sellers can sell all they want at the given price so they would not sell for any less than the price. This implies a perfectly competitive market place where buyers and sellers are price takers rather than price searchers, for example, the exchange of stocks in the New York Stock Exchange. Three, the elasticity is *unitary* where the demand or supply curve is a rectangular hyperbola. In this case the total revenue from sales does not change as price and quantity change. An example would be if a cartel chooses to control price and quantity so that revenue stays the same.

Empirical data or evidence is observed real-world data, often used in **statistics.**

Endogenous variables are the phenomena being explained by an analytic model. For example, in the analysis of product demand, the endogenous variable would be the quantity of the product demanded. Endogenous variables can be affected by policy choices. For example, a local government might treat its land-use patterns as endogenous from a planning perspective because they can influence these patterns through zoning and fiscal policy choices. An endogenous variable can be an **explanatory variable** for another endogenous variable. (See also **exogenous variables**)

Energy-intensive is a term that describes industries that employ relatively large amounts of energy in comparison to the amount of **capital goods**, equipment or laborers they use.

Environmental equity is "the equal protection from environmental hazards of individuals, groups or communities regardless of race, ethnicity or economic status." *(U.S. EPA, February 1994)* This is a form of **horizontal equity**.

Environmental impact is a discernible human-induced alteration of an environment or ecosystem.

Environmental justice is "the fair treatment of people of all race, cultures, income and education levels with respect to the development, implementation and enforcement of environmental laws, regulations and policies. Fair treatment implies that no population of people should be forced to shoulder a disproportionate share of the negative environmental impacts of pollution or environmental hazards due to a lack of political or economic strength." *(U.S. EPA, February 1994)*

Equilibrium is a situation in balance where there is no tendency for change, such as when supply and demand are in balance (i.e., at an equilibrium price level where the quantity demanded equals the quantity supplied.) In a realistic **dynamic** setting, equilibrium is never actually attained; rather the market is assumed to tend to move in that direction.

Equity analysis is the assessment of the distribution of gains and losses from an outcome across different dimensions, including social, spatial and temporal.

Estuary is a wide body of water formed where a large river meets an ocean. It contains a mixture of fresh and sea water. The San Francisco and Chesapeake Bays are examples of estuaries.

Ethnicity is identification with or membership in a particular racial, cultural or national group.

Ex ante means before the fact or event; looking to the future.

Excise tax is similar to a sales tax, but is selectively imposed on certain goods, such as gasoline or luxury goods.

Existence values come from the knowledge that a resource continues to exist even though the individual may not actually use it (e.g., that a lake in Alaska remains pristine although the person has never visited Alaska). While existence values are different cognitively from **bequest values**, they are the same in its mathematical representation. Existence values are typically derived through **contingent valuation methods.**

Exogenous variables are controlled by events and influences beyond the scope of the policy model and are taken as given. These variables are not affected by policy choices, but are used to explain the behavior of **endogenous variables**. For example, a local government must take the U.S. interest rate as having an exogenous—and significant—influence on new housing starts.

Expected outcomes or value represent a defined midpoint or central tendency of a distribution of possible outcomes that might arise as conditions vary. The expected outcome formally equals the **mean**, but it may be interpreted as the **median** of a **probability distribution.**

Expected utility is the average **utility** expected in an uncertain situation. Expected utility is computed by estimating the **utility** or **preference functions** for each possible outcome and **averaging** the utilities.

Exponential growth occurs when the amount being added to a quantity is proportional to the quantity already present—the bigger the quantity, the greater the absolute amount of growth. For example, if a one billion person population is growing at 2 percent a year, the first year growth will be 20 million. After 35 years at exponential growth the population will increase to 2 billion, with growth of 40 million people in the last year.

Ex post means after the fact or event; with a historical perspective.

Externalities can be thought of as unintended side-effects of an activity. They can be either positive or negative. Externalties are impacts on one or more individuals resulting from an activity of another person or persons for which there is no corresponding compensation to or paid by those creating the impacts. For example, smoke from a factory may degrade the air quality of nearby homes, but the factory owner is unlikely to compensate the residents for damages and the residents are unlikely to pay the factory to reduce its emissions. The **pollution** is an externality because no market exchange mechanism explicitly exists. Externalities are a form of **market failure.**

Fault tree analysis is a special case of **decision tree** analysis in which the occurrence whose probability is being calculated is a failure of a safety system.

Feasible solutions are the set of possible outcomes in which *all* constraints are satisfied.

Final or consumptive goods are those that are sold for consumption and not used in producing another good.

Fixed costs are those that do not change as output level changes over the time horizon being analyzed. These costs include fixed or **capital goods,** land and long-term contract commitments. In the short run, fixed costs do not enter into calculation of marginal costs. In the long run, almost all fixed costs become **variable costs.**

Flow is the measure of the production or consumption or a good, service or resource through time. Flows come from a **stock** of available resources at a particular point in time. For example, *income* is a flow variable that measures the rate at which economic resources are accumulated; *wealth* is a stock variable that measures the amount of economic resources accumulated at a certain point in time. Flows can describe the harvesting of **renewable** and extraction of **nonrenewable resources,** or the use of **capital goods** in production. For example, timber harvesting is flow from the stock represented by a forest.

Functions are a mathematical expression of how one quantity is uniquely determined by another set of quantities.

Futures markets involve the setting of a contract for delivery of an **asset** on a specified date in exchange for either an immediate or promised payment.

General equilibrium analysis is when the operation of many markets is modelled simultaneously.

Goods in economics are anything that gives utility or satisfaction to someone (e.g., clean water, food, clothing, music). An economic good is a scarce good for which a person is willing to pay something to get more of it (e.g., public safety, peace and quiet). What is an economic good for one person—such as cigarettes or rock climbing— may not be an economic good for another.

Government is a complex of institutions, laws and customs created by a group of individuals to, at a minimum, define and protect rights of various kinds within certain geographic boundaries. As governments evolve, they can direct resource allocation, redistribute wealth, or provide education, in addition to other services. To maintain legitimacy, a government must have at least the tacit support of the individuals possessing or controlling the majority of political support in the geographic area.

Greenhouse effect is a term used to describe the heating of the earth's atmosphere due to the presence of carbon dioxide and other gases that absorb infrared radiation. The effect causes the climate to be about 30 degrees Celsius warmer than it would be without the atmosphere. The term is also used to describe the potential warming of the earth's climate above present-day temperatures due to the emission of various gases from human activity.

Hedonic valuation seeks to identify the value placed on a particular characteristic (e.g., air quality) by finding two similar goods which are the same except for the characteristic being considered (e.g., houses of the same size in different cities) and statistically analyzing the different values placed on these goods.

Heuristic analysis is a method of problem solving that relies on inductive reasoning from past experience or "rules of thumb" in the absence of a more rigorous approach.

Horizontal equity states that individuals in similar situations should be treated similarly.

Hypothesis is a proposed explanation for some natural or social phenomenon, made in order to draw out and test its logical consequences. Hypotheses can be tested using **empirical data** and different analytic techniques, such as **statistics, econometrics** or **mathematical programming.**

Identification occurs in **econometrics** when the problem can be specified with a sufficient number of variables to estimate the **parameters.** If the parameters can not be estimated, the model is *unidentified;* if several values can be derived for the same parameters, the model is *overidentified.*

Idiosyncratic risk is the portion of the total **risk** associated with holding an **asset** that is independent of movements in the **market portfolio,** (i.e., the risk is not related to how the market moves). Whereas **systematic risk** involves risk that is common among all assets and thus can not be diversified away, idiosyncratic risk from an asset can be diluted by acquiring a large number of different assets.

Income is in general the rate at which money is earned over time. In accounting, income is the money (revenue) or money equivalent earned or accrued from the assets of the business during an accounting period. Personal income is usually defined as money earned in a year in return for labor or services rendered, or the proceeds from assets. In economics, income can be defined as a stock or a flow. As a **flow** it is either the accumulation or the returns from wealth (assets). The unconserved part of income is either savings or investment. Income as a stock is thought of as the utility or real income received from a basket of goods at a point in time (e.g., your psychic pleasure from knowing the Grand Canyon exists).

Income effect from a change in the price of a good is the amount of a change in the purchase of a good or service caused by a change in the consumers' real income resulting from a price change for that good or service. (See also **substitution effect.**)

Incremental cost is the additional cost incurred from producing an additional increment (i.e., one or more units) of goods. **Marginal cost** is the measure for a single added unit.

Indifference curve is the combinations of goods and services that provide a consumer with an equal level of satisfaction or **utility.**

Indirect effects result from a change in how money is spent by individuals or firms who incur **direct impacts** from an event, action or policy. For example, expansion of an automobile fabrication plant will increased business activity by automobile parts suppliers indirectly through increased supply purchases.

"**Individualism**" is a doctrine underlying neoclassical **economics** that individuals are the decision-making focal point, and for this reason, the public interest is best served by encouraging them to fully recognize all costs, private and social, and to act according to their own self-interest.

Induced effects are changes in an economic system — local, regional or national — caused by changes in spending patterns due to **direct** and **indirect effects**. Induced effects are the third component of the **multiplier effect**. For example, an expanded automobile factory creates a **direct impact** through increased wages, an **indirect** impact through increased demand for parts, and an induced impact through greater general spending in the local economy.

Inelastic demand or **supply** of a product implies that it is relatively unresponsive to changes in prices. If a good is inelastic, a one percent change in its price results in a less than a one percent change in quantity demanded or supplied.

Inflation is the rate of change in a price index (e.g., the **Consumer Price Index**) over a certain period of time that reflects a general increase in <u>all</u> prices so that the relative costs of different goods and services remain essentially the same. Or equivalently, inflation reflects the percentage change in the purchasing power of a dollar over a certain period of time, usually per year.

Input demand is the demand for a good or service required for the production of another good or service. Input demand can be shown as a **function** of the price and productivity of the input and the price and output level of a firm. For example, demand for labor is analyzed as an input demand.

Interest is the cost of borrowing money or the return for lending it. Interest represents the added return on repaying a loan that compensates the lender for the **time value of money** and the risk that the loan will not be repaid.

Interest rate is the price paid to receive goods or wealth at an earlier date. Interest rates reflect individuals' desire for earlier availability, and the productivity of capital, which can be used to increase wealth.

Intergenerational equity addresses the differences in impacts from various policy options on those currently alive versus those yet-to-be-born. A fundamental trade-off assessed in intergenerational equity is whether a portion of the cost of realizing some present benefit will be unfairly or inequitably shifted to future generations, or vice versa. The concern over deficit spending and national debt is largely a concern over intergenerational equity. In questions of natural resource policy, the focus of this inquiry is often on **sustainable development** and **irreversibility** of chosen actions.

Intermediate goods are those that are produced to be used in producing another good or service. (See **input demand.**)

Internal rate of return is the **discount rate** that equates the cost of a particular **investment** to the **present discounted value** of future benefits expected to be received from that investment.

Intertemporal analysis compares impacts between different periods of time and in the aggregate over a long time horizon. The analysis involves modelling **dynamic** processes and weighting values among time periods through use of a **discount rate.**

Investment is the acquisition of property or financial instruments in anticipation that its value will increase over time or it will generate a certain **income** level. Investment reflects the concept of sacrifice of certain (or known) present value for (possibly uncertain) future value.

"Invisible hand" is a phrase coined by **Adam Smith in the** *Wealth of Nations* (1776) to express the notion that a well-functioning market economy, with individuals acting out of self-interest, will direct as though "with an invisible hand" the production of those goods and services that will benefit society as a whole. This concept in concert with philosophers contemporary with Smith led to the doctrine of **individualism**. However, the presence of externalities and other market failures reduces the effectiveness of free markets, and provides a rationale for government intervention into the market.

Irreversibility is when, once a decision is made, other opportunities are foregone and an investment can not be easily undone or dismantled without great cost. While virtually all investments are eventually reversible due to physical deterioration and the passing of generations, the amount of time required to remediate an action can vary substantially. Standard economic models assume that an action or investment generally can be reversed by selling it in the market, an assumption that probably is not valid in large-scale projects or programs.

Kaldor-Hicks efficiency criterion states that if the individuals who benefit from an outcome *could* in the aggregate compensate those who lose based on the measures of benefits and costs, then the outcome is efficient. This principle is the basis of **benefit-cost analysis**.

Keynesian economics is a branch of **macro-economics** that attempts to explain why aggregate demand and supply do not achieve the full employment **equilibrium** conditions predicted by neoclassical **micro-economics**. For example, why does unemployment persist when the wage is set by the **market** at a rate that should be acceptable to all workers? Keynesian economics focuses on the "stickiness" of wages and prices (i.e., the tendency for these value indicators to readily rise but resist downward trends) as the cause for disequilibrium conditions. Keynesian economics leads to the conclusion that a general **market failure** exists that in some cases should be remedied through government intervention, such as stimulus of the economy. John Maynard Keynes first put forth these concepts in the 1930s. Keynesian economics failed to predict or solve the economic crises of the 1970s, and has recently lost much of its support in academic and policy circles.

Labor-intensive is a term that describes industries that employ relatively large numbers of laborers in comparison to the amount of **capital goods** or equipment and energy.

Least-cost planning is a form of **cost-benefit analysis** in which a portfolio of strategies and technologies is selected based on the **cost-effectiveness** of achieving a set goal while incorporating benefits of achieving other social objectives. For example, a least-cost plan for an electric utility might determine the most cost-effective way to generate electricity given that the societal benefits of reducing air pollution are valued and netted from the cost of more environmentally-friendly resources, such as wind power or conservation.

Levelized annual payments represent the constant annual payments required to recover the single, upfront costs of an initial capital **investment**, including **interest** and **principal**. This is the same principle used in determining the mortgage payment on a house. For example, if the initial investment is $1,000, the operating costs are $25 per year, the expected life is 20 years and the interest rate is 5 percent, the investor would want to receive $101 per year to fully recover that investment.

Life-cycle analysis examines the costs of a policy option or technology choice over the entire **expected** lifetime of the technology or strategy. For example, a life-cycle analysis of an automobile would encompass at least the purchase price, fuel, maintenance, and scrapping costs aggregated in **present discounted value**

terms over the typical ten-year life of a vehicle. Environmental and congestion costs might also be included in this example.

Linear functions are composed of a set of variables added or subtracted together in an equation, with each multiplied by a **parameter** and raised only to the exponential power of one. An example of a algebraic linear equation is:

$$y = 2x + 5z$$

If plotted on a graph, a linear equation would trace a straight line or a flat plane.

Linear-programming models are the simplest and most common form of **mathematical programming.** These models find the maximum **feasible solution** for a **linear objective function** given a set of linear **constraint equations.** Linearity allows for larger data sets and faster solutions to large-scale models. Linearity imposes restrictive **assumptions** about the type or form of economic phenomena being modelled. Linear constraints imply that the use of an input is *proportional* to the output that uses it, and the total usage of an input resource is *additive* across all outputs. A linear objective function implies that demand is perfectly "**inelastic**" or is nonresponsive to changes in product prices.

Liquidity is the ability to sell an **asset** quickly in a **market** without having to make a substantial price concession. This translates to the ability of investors or owners to convert an asset to cash at a price similar to the price of the previous trade in the asset, assuming no new information has arisen since the previous trade.

Long-term analysis focuses on a long time horizon over which producers and consumers are able to vary all of the economic factors of interest, such as inputs to production or location. By focusing on the long-term, economists attempt to derive **equilibrium** conditions that result from a policy change.

Macro-economics attempts to explain the behavior of the aggregate economy using broad economic indicators of economic performance, such as the interest rate, unemployment rate, factor output and money supply. Much of this analysis has grown out of the apparent failure to adequately explain the behavior of aggregated individual decisions through neoclassical **micro-economic** analysis. For example, long-run sustainable unemployment should not occur according to neoclassical micro-economic theory. Keynesian analysis is probably the best-known macro-economic approach, but has fallen from favor since the 1970s. Neo-Keynesian, neo-classical and new growth theory are now the main schools of macro-economic theory.

Marginal cost is the additional cost incurred by producing one more unit of output. This concept is similar to **incremental cost.**

Marginal rate of substitution is the rate at which an individual is willing to trade one unit of a good or service for another while remaining equally well off as measured through the **utility function.**

Marginal revenue is the additional revenue received when one more unit of output is sold.

Marginal revenue product is the additional revenue received when the output produced by one more unit of input is sold. For example, if one added hour of labor produces a hundred more units of output, the marginal revenue product is the additional sales revenue from that output.

Marginal tax rate is the amount of taxes, expressed as a percentage, paid on each additional dollar of taxable income, production or consumption.

Marginal utility is the extra **utility** or satisfaction that an individual receives from consuming one more unit of a good or service.

Marginal value product is the **marginal revenue product** when the output is sold in a perfectly competitive market (i.e., the price of the output does not change as supply increases).

Market-based goods are those that are traded in a **market** with explicitly identified buyers and sellers who agree on a mutually-satisfactory price at which they exchange. The **property rights** of market goods are clearly defined so that exchange of possession is not usually disputed.

Market failure occurs when either no **market** exists for a potential transaction, or a transaction results in an outcome distorted from what is predicted by **economic** theory as the most **efficient** result. Market failures lead to a divergence between private individual choices and "optimal" or preferred social outcomes. Externalities are a form of market failure. If the use of a public good reduces its value but this is not captured in the market price of the offending private good, then an externality is imposed on the public. For example, if the cost of polluting the air is left out of fuel prices, this is a market failure.

Market portfolio consists of an investment in all available and relevant assets, most commonly defined as financial securities. The proportion invested in each asset equals the percentage of the total market value represented by the asset. The market portfolio is used as a benchmark for risk and return in the **capital asset pricing model.**

Market power is the ability of a firm to raise and sustain its price significantly above the competitive price level.

Markets are where individuals, firms or other organizations come together to exchange resources such as goods and services. Markets can take many forms, including dealerships, financial asset and stock exchanges, stores, bulletin board listings, and brokerages. How well the market works can affect the level of **transaction costs** involved in consummating an exchange.

Mathematical programming simulates a firm's or organization's decisions to allocate limited resources among competing activities in the "best" possible combination based on prospective costs, revenues and production information. The model is formulated to find the maximum **feasible solution** for an **objective function** given a set of **constraint equations.** A set of technology costs are calculated for a range of outputs and the technology which allows for the highest profit level is chosen through a mathematical search process. The model produces a **normative** analysis of "what should be." Model types include **linear, quadratic or non-linear programming.**

Maximin decision rule is for choosing a strategy in which the minimum payoff or benefit will be as large as possible in all possible situations.

Maximum return at minimum risk is a financial analysis paradigm in which a **portfolio** of assets is compiled that first minimizes risk to the investor and then maximizes expected return within the minimum risk constraint.

Maximum sustainable yield is the rate at which a **renewable resource** can continually produce the maximum amount of harvest at a constant level. This rate is dictated by the natural population and reproduction rate. Maximum sustainable yield, unlike **optimal yield,** does not account for human consumption preferences over time.

Mean is one method to calculate an **average.** It equals the sum of all values for a data series divided by the number of values. The **mean** is the **expected outcome** for a **random variable** when calculated from a **sample** of a population. Outlying sample observations may cause the mean to poorly reflect the "true" central tendency of a population, particularly if the sample is small and the distribution of observations large.

Measurement error involves uncertainty about the historic information on which theories are constructed and tested.

Median is one method to calculate an **average.** It equals the middle value for a data series ordered from highest to lowest. This is also known as the "fiftieth-percentile" observation. The median can differ substantially from the **mean** because the influence of "outliers" is reduced to be equal to that of all other observations in a sample. For example, mean income is usually larger than median income because a the income of millionaires carries more weight in calculating the mean than the median.

Micro-economics focuses on decisions made by individual persons and firms in the economy on consuming or producing goods and services in an isolated **market.** These decisions can be then aggregated as the building blocks for analyzing an **economic sector.** Neo-classical, institutional and Marxist economics are the most prevalent schools of micro-economic analysis.

Mode is a method to calculate an **average.** It represents the most commonly observed value in a data set or population. This value need not have any other relation to the rest of the data series and can equal the highest or lowest value in the data series.

Monopoly is where an industry or market sector has only one *seller* of a particular good. That seller can exercise market power and is a "price searcher."

Monopsony is where an industry or market sector has only one *buyer* of particular good. That buyer can exercise market power and is a "price searcher."

Monte Carlo simulations involve starting with a theoretical **statistical** model of a process, generating simulated samples of data consistent with the process, developing estimates of the unknown **parameters** consistent with one or more rules, and analyzing the estimates to determine statistical characteristics. In the simulation, the analyst plays the role of "nature" and assumes that the true **mean** and **standard deviation** of the population is known. A **random** number generator is used to produce several samples. This approach can be used to develop a distribution of forecasts based on the statistical characteristics of historic data. For example, the probability that a future river flow might exceed a certain level can be forecasted using data on past flows and a Monte Carlo simulation.

Multiattribute utility analysis is a type of decision analysis which relies on consumer utility theory to logically combine several attributes into a single figure of merit, so that alternatives can be compared across a number of attributes.

Multicollinearity occurs in **regression analysis** when two or more **independent** or **explanatory variables** are highly (but not perfectly) **correlated** with each other. While multicollinearity does not **bias** the parameter estimates, it does distort the measure of their **statistical significance.** As a result, the relative importance of their cause-and-effect relationship to the **dependent variable** can not be separated.

Multiplier effect estimates how many times an additional dollar of **investment** or spending will be spent as it works it way through the economy. This effect measures the increase in the regional income and consumption **induced** by the initial amount. Typically, this value is estimated at between 2 and 2.5 over the long run.

Myopic literally means "near sighted;" it is used in economics to describe the **assumption** that economic actors consume or produce based solely on today's conditions without looking to how those conditions might change in the future.

Nominal or inflated value or dollars is the value of a good expressed in the terms of currency for the year in which the good is produced or consumed (i.e., the value is not adjusted for **inflation**). For example, when asking the question in 1994 what the nominal price of a good will be in 1999, the inflation rate is estimated over that time and added to the good before examining as how much its **real** price changes.

Nonlinear functions are composed of a set of **variables** in which the **parameters** may be multipliers or exponents and the relationships of the variables are not limited to being additive or subtractive as is the case with **linear functions.** An example of an algebraic nonlinear equation is:

$$y = 2x^2/5z^3$$

If plotted on a graph, a nonlinear equation would trace a curve or an undulating surface.

Nonlinear mathematical programming models, such as **quadratic programming** or **positive mathematical programming (PMP)** use non-linear **constraints** and **objective functions** that allow for more flexible modelling of economic phenomena. For example, quadratic and non-linear models can incorporate demand responsiveness where **linear programming** can not.

Nonmarket goods are **scarce** resources to which people attach value, but due to difficulty in defining the **property rights** are not traded in a **market**. Most often these are a type of **public good.** These goods can include environmental **assets**, such as a vista or a species of animal, or human health and well being. Because these goods are not traded in a market, no explicit price exists that describes their **marginal values** to people; other valuation techniques are required to infer those values.

Nonrenewable resources have a total stock available to humans which is fixed or finite for the foreseeable future. These resources are also considered *exhaustible* (i.e., they can be fully depleted through consumption).

Normal probability distribution is a symmetric "bell-shaped" **probability distribution** of outcomes, that can be completely described by its **mean** and **standard deviation.** The normal distribution is significant because the Central Limit Theorem of statistics states that regardless of the type of probability distribution that describes the underlying population, in the case of sufficiently large samples, the sample mean is distributed approximately normally and equal to the population mean, and the **variance** is proportional to the population's variance. This property allows for simple statistical tests in most cases about the mean or variance of the sampled population.

Normative analysis is when a position is taken on how participants in the economy or society *should* act. Normative analysis is prescriptive in nature, in contrast to **positive analysis**, which analyzes how things *are* rather than how things should be. For example, with regard to an environmental regulation positive analysis might estimate how many jobs are created or lost; normative analysis might suggest whether or not the effects of the regulation are desirable. The reliability of normative statements can not be tested unless some measurable standard of desirability has been estimated. Normative judgements are usually personal views of the world and vary from one person to another.

Objective functions are a means of expressing progress toward a specified goal. The objective function must consist of measurable quantities if it is to support a quantitatively analytic decision process. Objective functions may include economic variables (such as cost), health variables (such as lives saved), environmental variables (such as habitat created) and many other possible considerations. In **decision analysis**, the objective function evaluates the achievement of various policy objectives, and how those objectives might be traded-off against each other. In **mathematical programming**, the objective function measures the net revenues from economic activity, with the objective being to find the largest difference between revenues and costs or to maximize profits.

Oligopoly is where an industry or market sector has only a few sellers of a particular good. Those sellers may be able to exercise market power, particularly if they create a **cartel**.

Opportunity costs are the true costs faced by a **decision-maker**, measured as the highest valued (best) alternative that is foregone when an action is taken.

Optimal solutions in **mathematical programming** are those among the **feasible solutions** that generate the highest value of the **objective function**.

Optimal yield for a resource is the economically **efficient** rate of extraction or harvest, which depends on the **discount rate**. This differs from the **maximum sustainable yield** in that human consumption desires enter into the production decision.

Options are the ability to purchase a specific asset at a specific cost within a specific time period. The value of an option can be evaluated by estimating the **expected value** at the end of the time horizon, the **probability distribution** of possible values, and the value of an alternative asset which can be purchased with certainty over the same time horizon. If the value of the option falls below the value of the alternative asset, then the option is not exercised.

Option value reflects society's **willingness to pay** to protect a resource from **irreversible** development or demise (e.g., harvesting a stand of old-growth redwoods) thereby retaining the option to use the resource at a later date. Option value may be thought of as an insurance premium against **uncertainty** about future preferences, incomes and technologies that may make the **discounted present value** of future alternative uses for the resource greater than the present value of its current or proposed use.

Ordinal scaling applies to measurements which can be placed in relative order, but cannot be measured on an absolute or cardinal scale. Thus an ordinally-scaled measure of 2 is not necessarily twice as good as a 1 (See **cardinal scaling**). Ordinal values are usually expressed as rankings (i.e., first, second, etc).

Ordinary least squares (see **regression**.)

Parameters are the mathematical values that describe the relationship in a model between the **dependent** or **endogenous** variable and the **independent** or **explanatory** variables. The parameters are generally derived either from **econometric** or **mathematical programming** estimation, from theory, or by assumption.

Pareto optimality criterion defines an efficient choice as one where *everyone* is at least as well off after a chosen action as before, and certain individuals are better off—there are no losers from the policy. This is the strongest measure of an **efficient allocation**.

Parity price is the price benchmark used by the U.S. Department of Agriculture in setting its commodity price support levels. It is designed to give American farmers the same purchasing power as they had between 1910 to 1914, a period described as that of agricultural prosperity.

Partial-equilibrium analysis considers only the immediate affects on a portion of the economy from a change in economic conditions, (i.e., it does not consider changes that might occur outside of the affected market in other markets). In other words, the analysis examines how a change in price might affect demand or supply on a single market assuming that all other conditions are held constant and not influenced substantially by the change within that market.

Per capita literally means "by head"; it is used to describe data on a per person basis (e.g., per capita U.S. income levels).

Perfect competition is the assumption that there are a sufficiently large number of buyers and sellers in the market such that no one individual or firm can influence the market price significantly, and thus all are "price takers." Perfect competition is perhaps the most common assumption used in economic modelling.

Perfect information implies that an economic actor has all of the information with certainty about the past, present and future necessary for a market transaction. Economists often assume that information about the future can be conveyed through "rational expectations" by all participants through market prices, thus incorporating perfect information into the **market**.

Poisson distribution describes the **probability** of when an "event" will occur within a certain time interval if the probability of each "event" occurring is independent of the others. For example, the likelihood that a person will join a line often can be estimated with a Poisson distribution.

Pollution is the contamination of a natural environment by waste from human activity. For example, the atmosphere can be polluted by automobile exhaust, or rivers by industrial plant wastes.

Pooled time-series analysis is a combination of **cross-sectional** and **time-series analyses**. It draws data compiled over time from different but comparable settings (e.g., consumer behavior in several states over the last 20 years). Pooled time-series analysis can give important information about both trends and policy alternatives.

Positive analysis seeks to explain and predict actual events and decisions based on observed and **hypothesized** behavior. Positive analysis is descriptive in nature, versus **normative analysis**.

Present discounted value or net present value is the current value in today's dollars of a sum of money that will be expended or received sometime in the future. NPV takes into account the **time-value of money** as measured by the **discount rate**.

Price in economics is what has to be given up to obtain something. "The price of a sunrise is but an hour's sleep." If an individual is unwilling to pay the price for something, that person will not obtain it unless they resort to unlawful means, and pay a price of a different sort. In environmental economics, and according to demand theory, if polluters have to pay a price to pollute, they will pollute less than if they are allowed to pollute freely. One reason given by economists for the massive pollution of the environment is that until recently polluting has been free of charge.

Price discrimination is charging different prices to different buyers of the same product. It occurs whenever a buyer or seller is able to use "market power" to separate related **markets** for the same good or service and to institute different pricing policies in each market. These markets are resistant to **arbitrage**.

Principal is the original amount of a loan that is paid back over time. **Interest** is added as a fee for the use of the principal.

Prisoner's Dilemma is a situation where two individuals each must make choices that affect the other person, but each is **uncertain** about the other's behavior. As a result of a Prisoner's Dilemma, each person may decide to follow the **maximum** course of action which limits potential losses (poses the least **risk**). However, if both individuals choose this strategy, the outcome is less beneficial to each than if they could have coordinated their actions. The classic example is where two (guilty) suspects are brought in for questioning by police. In this situation three outcomes are possible:

(1) If both prisoners refuse to cooperate, they will both be set free;

(2) If both prisoners confess, they will both get moderate-length sentences; and

(3) If one prisoner confesses to the crime, but the other prisoner refuses to cooperate, the first one will get a

light sentence while the second will be locked away for life.

While outcome (1) is the preferred cooperative solution, outcome (3) is the maximin or "Nash" solution. The dilemma is whether to trust the other prisoner to make the best choice.

Probability distribution is a mathematical description of the relative frequency of possible values that a particular **random variable** can take.

Probability theory is a branch of mathematics which addresses the likelihood that an event will occur. The underlying assumption is that the occurrence of random events over time will fall into a general pattern called a **probability distribution.**

Production functions define relationships between inputs and their associated output. They are a mathematical representation of the **technology** of the production process that describes how the maximum product amount can be achieved from different combinations of inputs given current technology at a point in time. They summarize the substitution possibilities in production.

Production possibility frontier is the envelope of all combinations of outputs that can be produced with fixed amounts of productive inputs given available resources and technology.

Productivity is a measure of the output produced by use of an input, particularly labor measured in terms of output per hour.

Profit functions are simple models of a firm's financial and technological traits that relate inputs to output. The profit function includes **revenues** which equal the price of the product or service times the quantity of output; costs which equal the price of inputs, such as labor or investment, times the quantity of inputs; **constraints** on resource availability; and a **production function.**

Profit maximization is the assumption that firm owners and managers are motivated to achieve the highest profit level, which equals **revenues** minus costs of net revenue.

Profits in economics are the difference between the total **revenue** a firm receives and its total economic (or **opportunity**) costs of production (versus **accounting** costs and profits). The economic costs include "normal" returns to investors (i.e., what they could earn if they invested in an alternative activity). The **assumption** under **perfect competition** is that economic profits equal zero. In this case accounting profits would be positive and equal to the normal **rate of return.**

Progressive taxes are those that take a higher proportion of income and wealth as income and wealth increases (i.e., the **marginal** tax rate increases with income and wealth).

Property rights are the legal specification of ownership and the **rights** of owners to specific assets. Weak or non-existent property rights are a major cause of environmental pollution and degradation (e.g., dumping the wastes of industrial production into waterways and the atmosphere or overfishing of the oceans).

Public goods are those which, once produced, are available to everyone on a *nonexclusive* basis, that is, can not be denied (e.g., natural defense). Public goods are often nonrival as well, meaning that consumption by one person does not affect consumption by another individual (e.g., a sunset). With private goods, more for one person means less for someone else (e.g., tickets to the Super Bowl). Some goods have features of both, such as the Super Bowl and the San Diego Freeway. One can be excluded from the Super Bowl, but once in the stadium one's viewing does not reduce the amount left for someone else to view. Although one may not be excluded from the San Diego Freeway, use at 5:00 a.m. may not reduce someone else's use. But during the congestion of the evening rush hour, it does. As a result, at 5:00 a.m. there are no restrictions to limit freeway use, but at 5:00 p.m. there are (e.g., car pool lanes and ramp metering). Private goods are normally rationed by prices in markets. The classic example of a public good is provision of a national army where everyone is made secure within a set of national boundaries whether they pay for the army or not. How many people reside within the nation makes no difference to the security level.

Public utilities are either a government agency or a government-regulated private **corporation** that provides basic services that require an extensive and capital-intensive network, such as water, sewers, electricity, natural gas, telephones and cable television. The motive for government intervention is the belief that these services can be provided **cost-effectively** only through a **monopoly**, which is a classic form of **market failure.**

Quasi-option value is related to **option value**, but is a risk-free measure of the **expected value** to society of information gained from postponing an **irreversible** development. Quasi-option value is based on the concept that a resource's value and appropriate uses are discovered through time, and that irreversible development that destroys the resource cuts short this discovery process. Quasi-option value is the amount society is **willing to pay** to guarantee that this learning process continues.

R-squared (R^2) is the proportion of variation for the dependent or **endogenous** variable of a **regression** that is "explained by" the independent or explanatory variables, which may be **endogenous or exogenous.** R^2 values are between 0 and 1.

Random variables take on alternative values according to chance. Such variables may have part of their behavior explained by other forces, but a portion of the behavior is described by a **probability distribution.**

Rate of return is the rate at which an investment made today can be transformed into income or benefits in the future. For example, a 10 percent rate of return indicates that a dollar of consumption foregone and invested today will yield $1.10 of benefits next year.

Real value or dollars is the value of a good expressed in the terms of the currency for a single **baseline** year (i.e., the value is adjusted for **inflation**). For example, when determining in 1994 what the real price of a good will be in 1999, the inflation rate is subtracted over that time before looking at how much its price changes, in contrast with **nominal or inflated** dollars.

Regression is a **statistical** model of the relationship between **dependent** and **independent random variables** in which the dependent variable is **hypothesized** to be mathematically related to the others. A linear regression, also known as *ordinary least squares* (OLS), estimates this equation by minimizing the sum of the squared deviations between the observed and fitted values of the dependent variable.

Regressive taxes are those that take a smaller proportion of income and wealth as income and wealth increases (i.e., the **marginal tax rate** decreases with income and wealth).

Renewable resources have a **stock** that is replenished on a regular basis. These resources can be biological, as in the case of agriculture, timber and fisheries, or geophysical, as with rainfall or sunshine. If the rate of harvest or extraction is sufficiently high to deplete the stock, the resource can be *exhaustible.*

Rent is the payment to a "factor" of production (e.g., land, equipment or labor) that is in excess of the amount necessary to keep it in its current employment. This means that the factor is being paid more than its **opportunity cost.**

Returns to scale (or scale economies) classifies production functions by how output levels change proportionately as inputs change. *Decreasing returns* are when the costs of producing each additional unit *increase* with total output—each added unit becomes more expensive because more input is required for the same unit of output. *Increasing returns* are when the costs of producing each additional unit *decrease* with total output—each added unit becomes less expensive. *Constant returns* occurs when a unit increase in input translates into a *constant proportional* output unit.

Revenues are the gross monetary returns from selling a quantity of goods at a given price, as measured over a period of time (i.e., total revenue is the price of a good times the amount sold). Revenues are used in calculating **profits**. Maximizing revenues does not imply that profits are being maximized. (See **marginal revenue** and **marginal revenue product**.)

Rights define one person's recognized legal position with respect to the legal positions of all other individuals. A right exists only when all people have a duty or obligation to respect that right.

Risk is the potential loss that could result from an **uncertain** outcome. Risk is driven by the uncertain value associated with an asset or policy.

Risk analysis uses **risk assessment** as a starting point, but adds judgment regarding the significance of the risk, and **risk communication**. Significance determinations place an importance or priority on the social consequences of the risk.

Risk assessment is the technical evaluation of the magnitude of the risk posed by a particular substance, hazard or event in a specified situation. It involves quantifying the amount released, determining the environmental dispersion, measuring the dose received by the receptor, and observing the receptors response to this dose.

Risk aversion is when consumers or producers prefer certainty over risky situations.

Risk communication involves conveying risk-related information from technical experts to public **decision-makers**, **stakeholders** and the public.

Risk management is a further extension of **risk analysis** which involves controlling elements of risk to minimize harm given various **constraints**. Risk management incorporates the results of **risk assessment** with information on technologically-feasible responses and social and **economic** consequences of both the risk and the response.

Risk neutrality occurs when an individual or a firm is indifferent between two choices that have the same **expected outcomes**, regardless of whether one outcome may involve *higher risks* than the other.

Robust models are not highly sensitive to changes in the underlying assumptions and data, meaning the results stay relatively stable. **Sensitivity testing** can be done either directly or as a side calculation to test a model's robustness.

Royalty is a payment for a right or a privilege to use an asset owned by someone else. For example, a royalty can be paid by a publisher to an author for the right to sell a book, or it can be paid by a mining company to recover minerals from government-held land.

Scarcity occurs when allowing people free access to goods results in more being demanded than can be provided. Scarcity means not having enough, for example, old-growth redwoods, clean air, jobs, adequate health care, or whales. Scarcity implies competition for the limited resources available—redwoods or whales—and hard choices, such as when employment clashes with the desire to protect endangered species. Scarcity drives the fundamental economic problem of what to produce, how much to produce, and who gets what is available. For example, a high price for a scarce good such as water would encourage production and discourage consumption.

Scenario analysis begins with a series of plausible future economic conditions, or "scenarios," estimates the probability of their occurrence, and determines an **expected outcome**, reasonable bounds on outcomes and, possibly, a **probability distribution**.

Second best is the "best" allocation of resources that is achievable when various constraints preclude reaching true economic efficiency. The theory of the second-best states that if constraints within in the economic system prevent some of the **efficiency conditions** from prevailing, it is not always desirable to have the optimum conditions hold elsewhere. For example, if an industry pollutes, economists suggest putting a fee on that pollution to reduce the amount of pollution to the optimal level, where, from an economist's viewpoint, the marginal benefits of a unit of abatement are no longer greater than the additional abatement costs. If an industry which pollutes is also monopolistic, rather than charging a fee or tax on the pollution, the second-best solution may already be in place because monopolists restrict output, and thus pollution, relative to competitive firms.

Sensitivity tests measure how **robust** model results are as **assumptions** change about **parameters** and data. If the model has a "knife-edge" characteristic, slightly altering an assumption may actually reverse the direction of the results, from, for example, positive to negative net benefits.

Shadow values are the increase in the value of the **objective function** when a **binding constraint** is relaxed in **mathematical programming**. The shadow value represents the **opportunity cost** of holding a constraint constant.

Short-run analysis focuses on near-term events and results and assumes that most influential factors remain fixed (e.g., in **economics**, the relative importance of individual inputs to production will be unchanged).

SIC or Standard Industrial Classification is used to classify establishments by type of activity. Typical SIC codes are as follows:

Two-digit SIC	Economic Sector
01 - 09	Renewable resource production and agriculture
10 - 19	Nonrenewable resource production and construction
20 - 33	Raw resource processing
34 - 39	Finished manufacturing
40 - 49	Transportation and utility services
50 - 59	Retail goods
60 - 89	Retail and professional services
90 - 99	Government services

Simulations are experiments on social, physical or biological processes conducted by abstracting the essence of a process to assess its underlying structure and simulating its operation over time. Simulations are used to examine especially complex problems by breaking the problem down into its individual components, identifying those components that have predictable versus random behavior, and specifying the relationship among components. Simulations allow analysts to examine how changes in **parameters** and **assumptions** impact outcomes and to compare **statistically** a set of experimentally-generated data. Simulations can be conducted either on computers, particularly for physical and biological processes, or through various role-playing forums for social analysis.

Sinking fund is a fund into which governments or businesses place money to redeem their bonds and other forms of indebtedness.

Adam Smith is acknowledged as the founder of modern Western economic thought. His book, *Wealth of Nations* (1776) described the basic principles of economic analysis still used today. He advocated reliance on markets as a method to further general social well-being.

Social welfare functions measure aggregate benefits and costs to society as a whole based on assumptions about how well-being can be compared among individuals. Social welfare functions are a hypothetical construct of how society views equity among individuals.

Socioeconomic status is an individual's or group's position within a hierarchical social structure. Socioeconomic status depends on a combination of traits, such as occupation, education, income, wealth, ethnicity and location. Socioeconomic status can be used as a broad indicator of likely behavior in social and economic analyses.

Spot markets involve the immediate exchange of assets for cash, versus a type of futures market.

Stakeholders are parties and individuals who hold a stake in the outcome of a policy decision. Most frequently stakeholders are identified as key interest groups that represent collections of individuals most affected by the potential outcome. Stakeholders may give decision-makers input on how policy analyses should be weighed in the decision-making process based on value judgements.

Standard deviation measures the dispersion of possible outcomes around the expected outcome of a random variable. The standard deviation equals the square root of the sum of the squared deviations from the mean (or the variance) for the observations.

Static analysis assumes that the world is in a "steady-state" (i.e., tomorrow's circumstances will be the same as today because all influential forces are in equilibrium or unchanging). Some economists argue that a static analysis is equivalent to the end result over the long term. If the system is not in a "steady-state equilibrium," then a more complex dynamic analysis may be preferred.

Statistically valid describes whether a particular analysis meets certain statistical criteria, such as sample size, sampling technique, sample-to-population characteristics, and parameters' characteristics obtained from the analysis.

Statistical significance is the expression of the probability that the result of a given analysis represents the "true" results that would be obtained by using a hypothetically perfect data sample. Statistical significance can be expressed as a margin of error, as is done with public opinion polls, or as a confidence interval.

Statistics is the mathematical analysis of the collection, organization and interpretation of numerical and empirical data. Statistics is the analysis of how real-world or simulated events and trends relate to each other given that a certain amount of random chance intervenes. Statistics relies on probability theory to develop measures of the *most likely* explanation of cause and effect for certain events. Statistical applications include analyses of population characteristics or social phenomena by inference from sampling.

Stock is the unused economic value associated with a resource. The stock can grow or fall depending on the flow of resources in and out of the stock. For example, the stock for timber is the stand or forest of trees. Stock can be thought of as the holding of capital goods for the use in production of other goods or services.

Subsidies occur when one party pays (or receives) a price for a good or service that is below (or above) its opportunity cost because another party either makes a transfer payment, or misprices the resource and absorbs the economic loss in value. Many examples of subsidies by the U.S. government exist where individuals or companies have access to natural resources (e.g., forests, developed water supplies or minerals) and pay prices substantially below the true costs of their provision.

Substitutes are two goods such that if the price for one increases, demand for the other increases in response (e.g., public and private transportation. If the price of private transport increases, consumers will look for less expensive alternatives, and the demand for public transportation—ceteris paribus—will increase). (See also **complements**.)

Substitution effect is the change in quantity demanded of a good which results from a change in its price relative to the price of other goods, exclusive of the income effect. Substitution effect gives rise to the standard statement that "when price goes up, the quantity of demand goes down."

Sunk costs are costs that are not recoverable after their expenditure. These costs should be disregarded in making a choice about an asset or policy. For example, if $1 million dollars was spent to unsuccessfully repair a facility, those costs are sunk from the perspective of whether to continue to operate the facility. Only the future expenditures necessary to successfully repair the facility should be considered, because the decision-maker has control over those funds.

Supply curve or function is a graph showing the relationship between a good's price (usually on the left-hand axis) and the quantity provided to the market. Supply curves usually slope upward from the left to right, indicating the incentive to produce more as price rises.

Sustainability is the maintenance of an existing **ecosystem** so that consumption can continue into the future without destroying that system. Younger and future generations do not have equal bargaining strength with the older and present generations, and must rely on the latter's altruism and patience. **Bequest value** as well as **intergenerational equity** are concepts used in analyzing sustainability.

Sustainable development means a constant or growing quality of life based on a social and economic system that enables this rate to be maintained indefinitely.

Systematic risk is the portion of the total risk associated with holding an asset that is related to or correlated with movements in the **market portfolio** (i.e., the value of the asset increases or decreases as the market portfolio increases or decreases in value). This risk can not be diversified away with combinations of assets.

Tariffs are either (1) a government tax on imports, intended to raise revenues and/or to protect domestic industries from foreign competition, or (2) prices set by government regulators for private companies that are either public utilities or transportation common carriers, such as railroads and trucking.

Tax incidence identifies who ultimately bears the burden of a tax, which could be quite different from those charged statutorily with paying the tax to the government. For example, a tax charged to employers on the basis of their labor costs is likely to be borne, at least in part, by workers; thus part of the incidence is on labor.

Technological or production possibility frontier defines the minimum combinations of inputs needed to produce a given output level with available resources and technology. The choice set of available policy options is similarly constrained by the technological possibilities of reaching a set goal. (See **production possibility frontier**.)

Technology in an economic **production function** includes not only the machinery necessary but also the management process, information and knowledge required to produce a good.

Theories derived by scientists, whether natural or social, provide a simplified understanding of the problem. Theories are developed from **hypotheses** using **empirical data** and different analytic techniques, such as **statistics**, **econometrics** or **mathematical programming**. Theories provide the basis for developing and assessing policies in policy analysis.

Timeframe is the temporal period over which an alternative is to be evaluated. It is important to maintain a consistent timeframe within an analysis of alternatives.

Time-series analysis is the **statistical** evaluation of the variations in a single or combination of variables over time. Time-series analysis used in **economics** can estimate how preferences or technology choices change over time and assess the importance of different factors in this transformation. Time-series analysis focuses on **trends**. It can estimate both *short-term* and *long-term* impacts given that a particular development path has been chosen. Time-series analysis assumes that the environment in which a choice is made is most important regardless of the goods or services being studied.

Time-value of money reflects the principles that (1) people prefer receiving benefits from spending money now rather than later, and (2) money received now can be reinvested to produce greater benefits in the future. This concept is used in developing the **discount rate**.

Transaction costs are the costs beyond those simply for production or reflected in the price for a good or service incurred from participating in a **market**. Transaction costs include (1) searching and information gathering, (2) bargaining and decision-making, and (3) monitoring and enforcement of contracts, including gaining legal approval. Examples of transaction costs include searching for a buyer or seller; identifying legal and physical characteristics of the commodity, such as title searches; negotiating the price; financial constraints on the participants; and a regulatory approval process. The existence of high transaction costs reduces the amount of mutually beneficial exchanges. This is particularly true for environmental pollution. For example, if it is costly to negotiate and police contracts with regard to restrictions on emitting pollutants onto private property, there will be fewer restrictions and more pollution. Many of these costs can be reduced through an efficient market structure, but others may be inherent in the laws and regulations defining the **property rights** for a commodity.

Transfer payments are the direct transfer of money or economic value from one party to another without an exchange of goods or services in return.

Transitivity of preferences implies that consumers make well-ordered, consistent choices among goods and services (i.e., if they prefer A over B and B over C, then they prefer A over C). This trait is a basic principle in the development of consumer **utility theory** and **decision analysis**.

Travel-cost method (TCM) assesses how much are individuals willing to expend in time and on transportation to reach a particular destination. This expenditure is used to find the revealed preferences for consumers of public goods, and their **willingness to pay** for those goods.

Uncertainty is a lack of knowledge about potential future outcomes.

Use values are based on direct interaction through recreation (e.g. fishing in a lake), or proximity (e.g. having a home on a lake). Use values can be measured either through revealed **non-market** valuation techniques, such as **hedonic pricing** or **travel-cost modeling**, or direct inquiry, also known as **contingent valuation methods**.

Utility is a measure of the satisfaction that an individual gets from consuming a good or service.

Utility or preference functions are a mathematical representation of the way individuals rank alternative bundles of goods and services based on their preferences. Generally, economists make several restrictive assumptions about utility functions to simplify modelling. The mathematical forms used to estimate the functions also have implications about how people are assumed to rank their preferences. Most often, economists assume that the utility of other people does not enter into an individual's utility function, and that the utility for a single good can be separated from that of other goods.

Value judgement is an assessment of a person, situation or event that either reveals or is based on the values of the person making judgement rather than on the objective characteristics of what is being assessed.

Variable costs can change in response to changes in the output level by a firm. These costs include such things as energy use, hourly labor, and supply purchases. As the time horizon of the analysis expands, more costs become variable.

Variables are composed of data points and included in equations as either explanatory or dependent. Variables are combined with parameters to explain mathematical relationships among the variables.

Variance measures the dispersion of possible outcomes around the expected outcome of a random variable. The variance equals the sum of the squared deviations from the mean for the observations.

Vertical equity states that those in dissimilar or unequal situations are likewise treated dissimilarly, but in a way defined as equal by society.

Von Neuman-Morgenstern utility ranks the outcome of uncertain situations on the basis of individuals' expected utility functions.

Wage is the cost of hiring one worker for hour.

Watersheds are areas drained by a particular water system. Usually, watersheds are divided by high ridges of land so that two areas are drained by two different riverine systems, either on the surface or underground.

Wealth is the current stock of economic goods. It is usually measured by the market value of these goods. The total value of the wealth of a society includes the people and their health, and their environment, but those goods are not measured unless they are bought and sold. This is one reason why the usual measure of a society's wealth—gross domestic product, or GDP—is often criticized as not being a true measure of a society's wealth. GDP is the sum of money values of all final goods and services provided by the economy in a year. (See income.)

Willingness to accept is what an individual will accept as payment in return for giving up a resource, good or provide a service. Willingness to accept need not be constrained by an individual's income level, although it can reflect the opportunity cost of holding an asset, particularly if it is a private good rather than a public good.

Willingness to pay represents what an individual would pay to acquire a resource, good or service. Willingness to pay will be constrained by an individual's level of income, and reflects the opportunity cost of acquiring an asset.

Zero-sum is when the benefits of the gainers equals the losses of the other economic actors.

Acronyms Used in the Handbook

B/C–benefit-cost analysis

CAAA–Clean Air Act Amendments

Cal/EPA–California Environmental Protection Agency

CAPM–Capital Asset Pricing Model

CARB–California Air Resources Board

CARM–California Agricultural Resources Model

CEC–California Energy Commission

CFC–chlorofluorocarbons

CGE–computable general equilibrium

CPI–Consumer Price Index

CVM–contingent valuation method

DA–decision analysis

DCF–discounted cash flow

DOE–Department of Energy

DOI–Department of Interior

DPR–Department of Pesticide Regulation

GDP–gross domestic product

IMPLAN–U.S. Forest Service's Impact Planning

I/O–input-output

IRR–internal rate of return

LA-CBD–Los Angeles Central Business District

LCP–least-cost planning

OLS–ordinary least squares

mph–miles per hour

PMP–positive mathematical programming

PRP–politically revealed preferences

NOAA–Commerce Department's National Oceanic and Atmospheric Administration

NPV–net present value

OMB–U.S. Office of Management and Budget

OPEC–Organization of Petroleum Exporting Countries

PPE–partial pareto efficiency

PVDR–present value discounting rate

RECLAIM–South Coast Air Quality Management District's marketable permits program

REMI–the Regional Economic Modeling, Inc. EDFS Model

RIMS II–U.S. Department of Commerce's Regional Impact-Output Modelling System

SCAQMD–South Coast Air Quality Management District

SIC–Standard Industrial Classification

SOx–sulfur dioxide

TCM–travel cost method

U.S.–United States

U.S. EPA–U.S. Environmental Protection Agency

VMT–vehicle miles travelled

WTA–willingness to accept

WTP–willingness to pay

7 ANALYTIC RESOURCES

In addition to this handbook, readers are encouraged to seek out and use the many analytical guides and information resources that are currently available. One key resource is Cal/EPA's bibliographic database of decision analysis documents. This database contains more than 100 abstracts describing analytical documents that relate to Cal/EPA-regulated issues. Topical articles on environmental issues can be found in *EPA Journal*, published by the U.S. Environmental Protection Agency, and *Resources*, published by Resources for the Future. Other sources of economic data include the following:

- California Employment and Development Department maintains data on tax returns and employment.
- California Department of Finance issues economic and demographic reports.
- California's Franchise Tax Board publishes *Bank and Corporation Franchise Tax Statistics.*
- California's Office of the State Controller publishes data on local government financial transactions.
- California's State Board of Equalization publishes taxable sales data.
- President's Council of Economic Advisors maintains information related to the national economy.
- U.S. Department of Commerce publishes *U.S. Industrial Outlook.*
- U.S. Department of Commerce (DOC), Bureau of the Census, provides a wide range of business statistics, including data on retail and wholesale trade, service industries, transportation, manufacturers, and the mineral and construction industries. DOC also maintains comprehensive demographic data.
- U.S. Department of Commerce, Bureau of Economic Analysis, tracks the nation's leading economic indicators.
- U.S. Department of Labor maintains information related to inflation and employment.

- U.S. Department of Treasury, Internal Revenue Service, publishes *Corporation Source Book of Statistics and Income.*

In addition to these data resources, accessible academic textbooks and articles can provide more detailed descriptions of the analytical methods described in this handbook. Popular textbooks and journal articles which may be useful are listed below.

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"Profiles in Risk Assessment." *EPA Journal.* Vol. 19, No.1 (1993) - [An issue devoted to various risk analysis perspectives.]

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With offices in Oakland, Sacramento, and San Francisco, California, M.Cubed is an economic consulting firm specializing in natural resource and public sector issues. M.Cubed professionals have substantial experience evaluating and recommending local, state and federal policies. M.Cubed staff have worked for the U.S. Congress and the Executive Office of the President and have testified before state legislatures, public utility commissions and other regulatory bodies. Recent notable projects include an estimation of the employment benefits associated with investment in natural gas vehicle technology in Southern California; an evaluation of federal pesticide regulations; and analyses of state and federal water reform proposals.

Steven Moss, M.Cubed partner, served as project manager and principal author for chapters one, two and three. Richard McCann, M.Cubed partner, and Marvin Feldman, a Resource Economist with Resource Decisions, served as lead writers on chapters three, four and five. Mr. McCann was also chiefly responsible for the handbook glossary. Gregory Adams, of the University of California, Berkeley, and Frank Neuhauser were responsible for conducting the analysis of the case studies that appear in the handbook. Alan Dechert and Adam Diamant of KI Associates designed and completed the literature review database from which many of the case study examples were derived. Mr. Diamant also assisted with case study development. Consulting assistance was provided by Robin Gregory of Value Scope; Dallas Burtraw of Resources for the Future; and Michael Hannenman, of the University of California, Berkeley. Duo Studio created the handbook format and graphics. Malcolm Dole provided the photograph for the handbook cover.

In addition, the following individuals provided insightful comments and essential oversight to the project: Chuck Shulock, David Chan, Malcolm Dole, Norm Coontz, June Anderson, Fereidun Feizollahi, Robert Anex, Rick Austin, Arnie Baker, Kimi Klein, Lee Friedman, David Goldstein, Jennifer Jennings, Tony Gonzalez, Dennis Meyers, Steven Monk, Bart Ostro, Don Owen, Pete Price, Perry Shapiro, and Randolph Shipes. Many of these individuals participated in the handbook project's internal and external review committees, which represented the viewpoints of the environmental, business, and academic communities, as well as the six Cal/EPA boards and departments, through the handbook development process.