pacts on human health (cost of illness). All these deal with physical changes that can be valued using market prices, and all are included in the objectively based set of techniques. These approaches are discussed in the following section. (For more detailed information on these and the other techniques, see Dixon et al. 1994.)

Loss in Productivity

A project may raise or lower the productivity of another system. In these cases the valuation is fairly straightforward. For example, in Fiji conversion of a coastal wetland to an industrial site resulted in lower catches in a coastal fishery that was partly dependent on the wetland. The monetary value of the reduced catch was an economic externality attributable to the industrial development project and hence an economic cost of the project. The loss in production had an assessable market value. Because the lower production was accompanied by lower costs of production, the change in net benefits yielded the net impact of the externality. Box 1 illustrates the use of the change-in-production approach in a geothermal project in the Philippines.

In some cases, the impact of the project is not on the level of production but on the costs of production or consumption. For example, buildings may require more frequent painting as a result of emission of pollutants by a nearby factory. The higher maintenance costs should be included as a cost of the factory in the economic analysis.

Dose-Response Relationships and Health Outcomes

Some investment projects yield important health benefits from reduced mortality and morbidity; examples are an increased potable water supply, improved sewage collection and treatment, and reduction of vehicular pollution. Some investments however, may have unintended but important negative impacts on health. For example, expanded industrial production or new thermal power plants produce important economic benefits but also result in some undesirable environmental externalities. These health impacts should be identified and incorporated in the economic analysis, either qualitatively or quantitatively.

For air pollution, a dose-response relationship (DRR) is commonly used to link changes in ambient pollution levels to health outcomes. The DRR is a statistically estimated relationship between levels of certain pollutants in the air and different health outcomes—illness, lost workdays, and so on. Although the DRR approach was developed in the United States and Europe, there

Box 1. Assessing Disposal Alternatives for Geothermal Wastewater in the Philippines

The change-in-production approach was used to assess the impacts of various means of disposing of toxic geothermal wastewater from a geothermal power development project on the island of Leyte in the Philippines. The analysis considered seven different disposal options, including reinjection of geothermal wastewater, untreated disposal in local rivers, and use of ocean outfalls. It estimated the economic costs of these options for irrigated rice production and an offshore fishery.

Pollution of surface water would prevent its use for irrigation of 4,000 hectares in the dry season. Rainfed crop production would continue during the wet season, but with lower average yields. The net return per hectare was estimated at 346 pesos (P) for irrigated rice and P324 for rain-fed rice. The economic cost of the loss of agricultural production on 4,000 hectares would therefore be the difference between the net return from two irrigated crops (4,000 hectares × 2 crops × P346/hectare = P 2,768,000) and the net return from one crop of unirrigated rice (4,000 hectares × 1 crop × P324/hectare = P1,296,000). The difference represents an annual loss of about P1.47 million.

The change-in-production approach was also applied to a coastal fishery. Various disposal options that did not include treatment of wastewater would cause heavy-metal pollution of coastal waters and lead to closing of the coastal fishery. The cost of this loss was calculated by multiplying the value of the annual catch (P39.4 million) by the net return to fishing, estimated at 29%, for an annual loss valued at P11.4 million.

Both of these annual costs were then capitalized to represent the economic damage to rice and fishery production from environmental pollution. Other environmental costs were also calculated (some qualitatively), and this information was used to help assess the total benefits and costs of the various wastewater disposal management alternatives.

Source: Balagot and Grandstaff 1994.

Box 2. Using Dose-Response Relationships to Estimate Health Outcomes in Jakarta

This case study illustrates the use of dose-response relationships (DRRs) to estimate the health impacts of reducing air pollution. The health impact can be estimated by the following relationship:

$$dH_i = b_i \times POP_i \times dA$$

where dH_i stands for the change in population risk of health effect i; b_i for the slope from the dose-response curve for health impact i; POP_i for the population at risk of health effect i; and dA for the change in ambient air pollutant under consideration.

Foreign dose-response functions were applied to local conditions in Jakarta to assess the benefits of reducing airborne pollution to meet both Indonesian standards and the more stringent WHO standards. The estimated numbers of lives saved and illnesses avoided per year in the population of 8.2 million are shown below.

Health effect	*Medium estimate*
Premature mortality (deaths)	1,200
Hospital admissions	2,000
Emergency-room visits	40,600
Restricted-activity days	6,330,000
Lower-respiratory illness (cases)	104,000
Asthma attacks (cases)	464,000
Respiratory symptoms (cases)	31,000,000
Chronic bronchitis (cases)	9,600

Source: Ostro 1994.

is increasing acceptance of its transferability to other countries. Recent Bank work in Jakarta (Ostro 1994) and Chile (Ostro et al. 1995) illustrate what can be done (see Box 2).

Whereas everyone breathes the same air in a location, actual exposure to polluted water is the key variable in determining whether a person becomes ill. Individuals can "self-insure" themselves from the effects of contaminated water by, for example, boiling their water or using bottled water. Epidemiologic studies are therefore usually required in order to estimate the impacts of changes in water quality on health outcomes. Such studies take into account the important social and economic factors that determine the links between contaminated water and illness and death.

Once the impacts on health have been identified, they can be quantified in physical terms and, where feasible, assigned a monetary value. Sickness is much easier than death to measure in economic terms. For illness, it is possible to estimate, for example, the costs of medical treatment and hospitalization (doctors' visits, medicine, hospital costs, and lost work time). It is more difficult to estimate the "cost" of pain and suffering to the sick individual, relatives, and others. The measured costs of illness based on direct expenditures (or their appropriate shadow prices) are a minimum estimate of the true costs of illness and, in turn, of the potential benefits from preventing morbidity.

For death, we do not have an equivalent, equally applicable valuation approach. Various methods are used in practice: estimation of willingness to pay to avoid premature death, wage differential approaches, and, although not economically sound, a "human capital" approach that estimates the present value of the future earnings of an individual that would be lost due to premature mortality. The difficulty arises when one compares estimates for different countries, especially countries with very different income levels. For example, a common value for a "statistical life" in the United States s now US$3 million–$5 million or more, as determined by income levels and willingness to pay to avoid premature death (see Box 3).

Clearly this same value cannot be applied directly to another country with a per capita income one twentieth the size of the U.S. economy. Yet, deflating the U.S. value by the relative difference in income levels also ignores important dimensions, including purchasing power parity. In the absence of careful national studies of the value of a statistical life, it is often best to present mortality data in terms of the number of lives lost or saved rather than in terms of dollar value.

Measuring Intangibles

One of the most difficult valuation areas is measuring subtle or dramatic changes in ecosystems, destruction of nonsubstitutable goods (such as biodiversity), effects on historical or cultural sites, and recreational benefits. Although these considerations are seemingly distant from this

Box 3. Use of Statistical Techniques for Valuing Life

The use of loss of earnings to value the cost associated with premature mortality is referred to as the human capital approach. It is similar to the change-in-production approach in that it is based on a damage function relating pollution to production, except that in this case the loss in productivity of human beings is measured. In essence, this method is an ex-post, exogenous valuation of the life of a particular individual using as an approximation the present value of the lost (gross or net) market earnings of the deceased.

This approach has many shortcomings. By reducing the value of life to the present value of an individual's income stream, the human capital approach to the valuation of life suggests that the lives of those with high earnings are worth more than the lives of those with low earnings. As a direct consequence, the lives of residents of rich countries would be rated as more valuable than the lives of people in poor countries. Narrowly applied, the human capital approach implies that the lives of subsistence workers, the unemployed, and retirees have a low or zero value and that the lives of the underemployed have a very low value. The very young are also valued low, since their future discounted earnings are often offset by education and other costs incurred before they entered the labor force. Furthermore, the approach ignores substitution possibilities that people may make in the form of preventive health care, and it excludes nonmarket values such as pain and suffering.

At best, this method provides a first-order, lower-bound estimate of the lost production associated with a particular life. However, the current consensus is that the societal value of reducing risk of death cannot be based on such an estimate. Although most economists do not favor using this method for policy analysis purposes, it is often used to establish ex-post values for court settlements related to the death of a particular individual.

An alternative method of valuing reductions in risk of death—the wage differential approach—uses information on the "wage premium" commonly paid to individuals with risky jobs (e.g., coal miners and steel construction workers) to impute a value for an individual's implicit valuation of a statistical death. This value is found by dividing the wage premium by the increased chance of death; for example, a US$100 per year premium to undertake a job with a chance of accidental death of 1 in 10,000 is equivalent to a value of US$1 million for a statistical death. Information on self-insurance and other measures also gives an indication of an individual's willingness to pay to avoid premature death.

In many cases, a project's impact on the environment is not apparent, but the market value of the externality is assessable, albeit sometimes indirectly. For example, property values decrease with the proximity of houses to a highway. The increased noise from traffic creates a project externality that should be included in assessing the costs of the highway. The exact relationship between the highway and the noise level may be unknown, but the value of quiet surroundings can be assessed indirectly. For example, information from another neighborhood may be used to compare the value of houses that are close to a highway with the value of houses farther away, controlling for differences in other characteristics of the properties.

Handbook's main concern, industrial pollution, in many cases an important benefit from controlling pollution may be the protection or enhancement of a recreational site or important natural habitat. It is possible, although difficult, to estimate economic values for, say, the consumer's surplus of visitors to parks and protected areas, by using the travel cost approach or conducting contingent valuation studies. Recent work in East Africa is incorporating the results of such studies in the analysis of projects (see Box 4). Intangible benefits often include important environmental benefits that are secondary to the primary benefits produced by a project. Air pollution control projects in Santiago and Mexico City, for example, will yield primary benefits from reduced health effects and reductions in damage to buildings, equipment, and other capital goods as a result of pollution. Cleaner air will also improve visibility—an important but unpriced benefit. Ideally, the visibility benefits should also be entered into the economic analysis. Because of data and measurement difficulties, however, these measures are usually entered into the analysis only qualitatively.

Preventing and Mitigating Environmental Impacts

Sometimes a project can go ahead only if the implementing agency takes measures to prevent or mitigate its environmental impact. If the impact is completely prevented, the costs of prevention are taken into consideration in the

Box 4. Valuing Consumer Surplus of International Tourists in Madagascar

This example presents an application of the travel cost and contingent valuation methods for estimating some of the benefits associated with the creation of a new park in Madagascar. A strong point of the study is that it used questionnaires based on two different valuation techniques to estimate consumer surplus and compared the estimated results.

Questionnaires were prepared and administered to visitors to the small Perinet Forest Reserve adjacent to the proposed Mantadia National Park. Visitors tended to be well off and well educated, with, on average, annual income of $59,156 and 15 years of education. The average stay in Madagascar was 27 days. Data from the visitor survey, supplemented with data from tour operators, was used in an econometric analysis that employed the travel cost approach. To estimate demand by international tourists, traditional travel cost models have to be reformulated because people who travel to a country like Madagascar engage in a variety of activities, of which the visit to the proposed national park would be only one. The travel cost model was then used to predict the benefits to tourists (the increase in consumer surplus) under the assumption that the new national park would result in a 10% increase in the quality of local guides, educational materials, and facilities for interpreting natural areas in Madagascar. The estimation indicated an average increase in willingness to pay per trip of $24 per tourist. If 3,900 foreign tourists visit the new park—a conservative assumption that uses the same number as currently visit the Perinet Reserve—the annual "benefit" to foreign tourists would be $93 600.

The contingent valuation method was used to estimate directly the value of the proposed park to foreign tourists. Visitors to the Perinet Forest Reserve were provided with information about the new park. Using a discrete choice format, they were asked how much more they would have been willing to pay for their trip to Madagascar if in the new national park (a) they saw twice as many lemurs, and (b) they saw the same number of lemurs as on their current visit. Since most of these visitors are expected to visit Madagascar only once, their response represents a one-time, lump-sum payment they are willing to make in order to have the park available. Mean willingness to pay for the park (conditional on seeing the same number of lemurs) was $65. Assuming current visitation patterns, the total annual willingness-to-pay for the park would be $253,500.

The information from these two estimates could be used to help design policies to capture part of this willingness to pay and compensate nearby villagers for income lost when the establishment of the park prevents their traditional activities within the park.

Source: Kramer 1993; Kramer et al. 1993.

economic and financial analysis of the project. If a factory is required to install equipment to *eliminate* air pollution, there is no environmental impact. If the factory is merely required to *mitigate* the environmental impact, the cost of the mitigating action is a direct and identifiable cost of the project, but the value of the residual environmental impact also needs to be considered in the costs of the project. If a dam reduces fish catch downstream, despite mitigating measures, the reduction of the catch is still a cost of the project. Care however, must be taken to avoid double counting. If the favored solution to an environmental impact is to let the damage occur, tax the culprit, and then repair the damage, the cost of the project should include the environmental cost only once—as the cost of repairing the environmental damage or as the tax (if the tax is exactly equal to the cost of repairing the environment), but not both.

References and Sources

Balagot, B., and S. Grandstaff. 1994. "Tongonan Geothermal Power Plant: Leyte, Philippines." Case Study 5 in Dixon et al. (1994).

Dixon, John A., and Paul B. Sherman. 1990. *Economics of Protected Areas: A New Look at Benefits and Costs.* Washington, D.C." Island Press.

Dixon, John A., Louise F. Scura, Richard A. Carpenter, and Paul B. Sherman. 1994. *Economic Analysis of Environmental Impacts.* London: Earthscan Publications.

Kramer, Randall A. 1993. "Tropical Forest Protection in Madagascar." Paper presented at Williams College, Williamstown, Mass.

Kramer, R. A., Mohan Munasinghe, N. Sharma, E. Mercer, and P. Shyamsundar. 1993. "Valuation of Biophysical Resources in Madagascar." In Mohan Munasinghe, ed., *Environmental Economics and Sustainable Development.* World Bank Environment Paper 3. Washington, D.C.

Ostro, Bart. 1994. "Estimating the Health Effects of Air Pollution: A Methodology with an Application to Jakarta." Policy Research Working Paper 1301. World Bank, Policy Research Department, Washington, D.C.

Ostro, Bart, José Miguel Sanchez, Carlos Aranda, and Gunnar S. Eskeland. 1995. "Air Pollution and Mortality: Results from Santiago, Chile." Policy Research Working Paper 1453. World Bank, Policy Research Department, Washington, D.C.