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# Draft Guideline for Cost-benefit Analysis of Environmental Management Actions

## Economic Valuation as a Tool for Environmental Decision-making: Theory and Practice of Cost-benefit Analysis of Environmental Management Actions

## Yellow Sea Large Marine Ecosystem (YSLME) Project

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# Economic Valuation as a Tool for Environmental Decision-making: Theory and Practice of Cost-benefit Analysis of Environmental Management Actions

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**Economic Valuation as a Tool for Environmental Decision-making: Theory and Practice of Cost-benefit Analysis of Environmental Management Actions**

# 1 Introduction

## 1.1 Background

Marine and coastal ecosystems suffer from serious environmental degradation which is attributable to various anthropogenic causes. The Yellow Sea ecosystem, a water area adjacent to China and the Korean Peninsula, has experienced for a long time a range of problems such as water quality degradation, declined fish stock, and biodiversity loss (Yellow Sea Large Marine Ecosystem Project [YSLME], 2000). The loss of opportunities for recreation and tourism is also a major concern (YSLME, 2005a, Annex IV, p. 9). Anthropogenic activities such as fishing, mariculture, and tourism might cause those problems (YSLME, 2005b, Annex IV, p. 3). To mitigate those environmental problems, the UNDP/GEF Project on “Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem,” known as the YSLME Project, was launched in 2004.

Bordering three countries: Democratic People’s Republic of Korea (DPRK), People’s Republic of China (China), and Republic of Korea (ROK), the Yellow Sea ecosystem is the semi-enclosed body of water with an area of about 400,000 $km^2$. The floor of the Yellow Sea, submerged post-glacially, is unique geologically. The seafloor has an average depth of 44 meters with the maximum depth of about 100 meters. The slope of the seafloor is gentle near the Chinese continent while the slope is steep toward the Korean Peninsula. The Yellow Sea is connected to the East China Sea in the south, forming a linked circulation system. With its high primary productivity, the Yellow Sea ecosystem supports substantial populations of fish, invertebrates, marine mammals, and seabirds. In addition, people in the coastal countries have benefited for hundreds of years from those abundant gifts from the Sea (YSLME, 2000).

The Project aims to develop a Transboundary Diagnostic Analysis (TDA) and a Strategic Action Programme (SAP) - guides to assist in alleviating Yellow Sea’s environmental problems. Analysing historical data and trends in the region, the TDA prioritises environmental problems which have a transboundary nature; then, it identifies major causes of the problems. The SAP outlines management actions to solve the priority problems. With the endorsement from the Project’s participating countries (i.e., China and ROK), the management actions will be implemented.

The SAP development process includes feasibility studies of suggested management actions. The actions are examined in terms of their technical, economical, and political suitability and viability. Cost-benefit analyses are employed as a tool to assess the actions’ economic feasibility.

## 1.2 Topics

This Guideline provides practitioners of marine and coastal environmental protection with a set of instructions on how to conduct cost-benefit analyses on management actions to mitigate ecosystem degradation. The Guideline presents the basics of environmental economics, explaining valuation techniques and analytical procedures. To compose the Guideline, a number of literature were reviewed, including: Boardman, Greenberg, Vining, and Weimer (2006); Grigalunas, Opaluch, Diamantides, and Brown (1995); and Lipton, Wellman, Sheifer, and Weiher (1995). Those texts constitute the foundation of the Guideline.

What makes this Guideline unique is its focused and detailed description. There are a number of literature available for cost-benefit analyses of environmental commodities. The existing literature introduces a variety of valuation methods, summarising earlier researches as case studies. However, those texts do not provide enough details for those who have a limited knowledge of economics to conduct the analyses. Practitioners need more detailed information on methods: What data should be collected specifically? How should those data be analysed econometrically. This Guideline is composed to meet such a need by focusing on a few most important methods and by describing necessary data and statistical techniques in detail.

First, the Guideline focuses on the following valuation methods which are the most appropriate in the context of the Yellow Sea: the empirical technique (referred often as the market price method or the productivity change method), the travel cost method, and the contingent valuation method. Other methods such as the hedonic property value method are not discussed in this Guideline due to their limitation in data availability in the Yellow Sea region, though the methods are frequently used in other regions, especially North America and Europe. "Benefit transfer," using values or functions estimated by existing studies, is not also discussed in this Guideline for similar reasons.

Second, the Guideline specifies the selected methods, describing their necessary procedures step by step. It discusses required data categories and basic statistical techniques—regression analyses—employing commonly-used spreadsheet programmes. The use of spreadsheet software is described in detail to calculate the net present value of the benefits and costs of environmental management actions. Following the Guideline's instructions, an analyst could easily conduct necessary numerical analyses.

The Guideline describes logistic regression analysis for the contingent valuation method. To conduct logistic regression, a statistical package is necessary. Devoting more space to this method than others, the Guideline explains the basics of logistic regression as well as the use of statistical software to conduct the analysis. To fully understand and apply the presented methods and statistical techniques to the evaluation of management actions, especially if they are complex, readers are recommended to consult literature cited in this Guideline.

### 1.3 Target audience

This Guideline targets a wide range of audiences, including not only economic researchers of marine and coastal environmental protection, but also policy-makers, development planners, and natural scientists. For practitioners, the Guideline provides a handy guide to conduct cost-benefit analyses of environmental management actions. For decision-makers, the Guideline offers an easy reference to assess, interpret, and apply analytical results to marine and coastal management. The Guideline focuses on the Yellow Sea ecosystem; however, most concepts and techniques that are discussed in this Guideline may be applicable to other marine and coastal ecosystems in different regions.

To understand the contents of the Guideline, it is useful, though not necessary, to have a good understanding of basic applied microeconomics and statistical analysis. Computer skills of operating spreadsheet programmes are a minimum requirement for researchers to prepare the economic analyses presented in this Guideline; however, the skills are not required for those who mainly use the analytical results.

## 1.4 Organisation

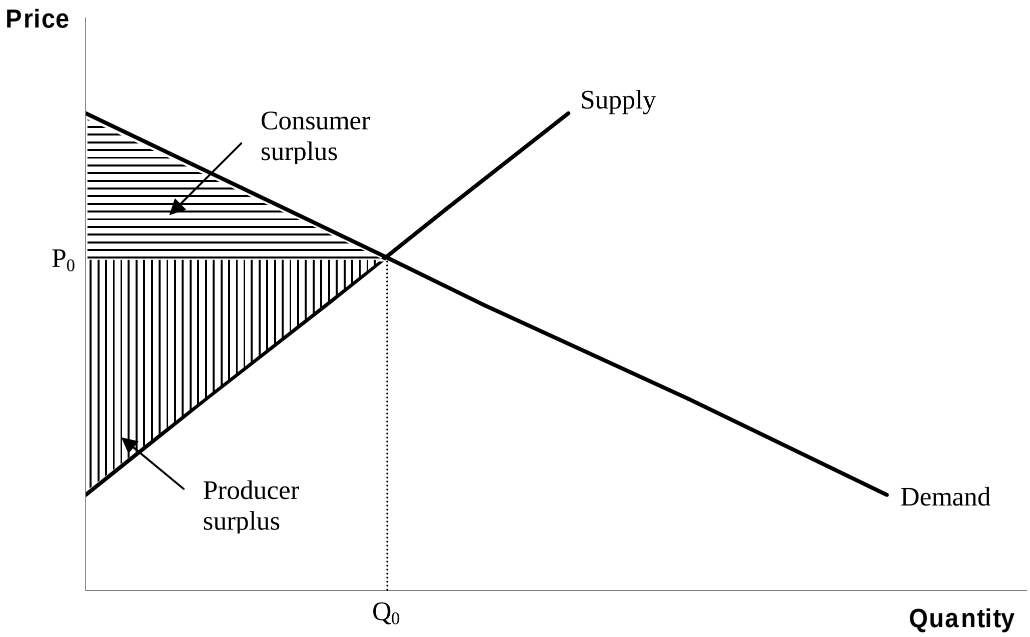
The Guideline mainly deals with two topics: (i) environmental valuation and (ii) cost-benefit analyses. Chapter 2 describes the basics of environmental valuation, defining the "value" of environmental goods and services in terms of economy. The concept of consumer and producer surpluses is introduced, which forms the economic value. The concept of externalities is then introduced; the chapter explains negative externalities as a cause of welfare loss for the society as a whole because they reduce the economic value of concerned commodities. Finally, the chapter presents detailed explanation about valuation techniques, providing hypothetical cases with numerical examples.

Chapter 3 presents the essentials of cost-benefit analyses, using the concept and techniques discussed in Chapter 2. Benefits and costs are defined in the context of assessing the economy of management actions. Providing simple decision criteria, the chapter explains how to use the results of economic analyses for environmental decision-making. An eight-step procedure of cost-benefit analyses is presented with examples. The procedure includes important components of economic analyses, such as the net present value calculation and the sensitivity analysis. This Guideline explains the concept of discounting, suggesting a specific rate for its calculation, to incorporate the time factor if benefits and costs accrue over time.

# 2 Basic environmental valuation

## 2.1 Economic value of goods and services

The economic value of goods and services is defined as the sum of consumer surplus and producer surplus. (For convenience, hereinafter, the term "good[s]" includes both "good[s]" and "service[s]".) The "consumer surplus is the difference between what a consumer is willing to pay for a good and what the consumer actually pays when buying it" (Pindyck & Rubinfeld, 1995, p. 113). The producer surplus is "the difference between the cost of producing a commodity [good] and the revenue received by selling the commodity [good]" (Grigalunas et al., 1995, p. 25). Graphically, the consumer surplus is an area between the demand curve and the market price for the good. Meanwhile, the producer surplus is an area above the supply curve up to the market price for the good (Figure 2.1).




Source: Pindyck & Rubinfeld, 1995, p. 278

**Figure 2.1 Economic value of goods and services**

The downward demand curve is derived from consumer behavior: Consumers are willing to buy more goods as their price becomes lower. The upward supply curve is derived from producer behavior: Producers (e.g., firms) are willing to produce more goods as their price becomes higher. The supply curve shows the information about firms' production cost (i.e., marginal/incremental valuable cost).

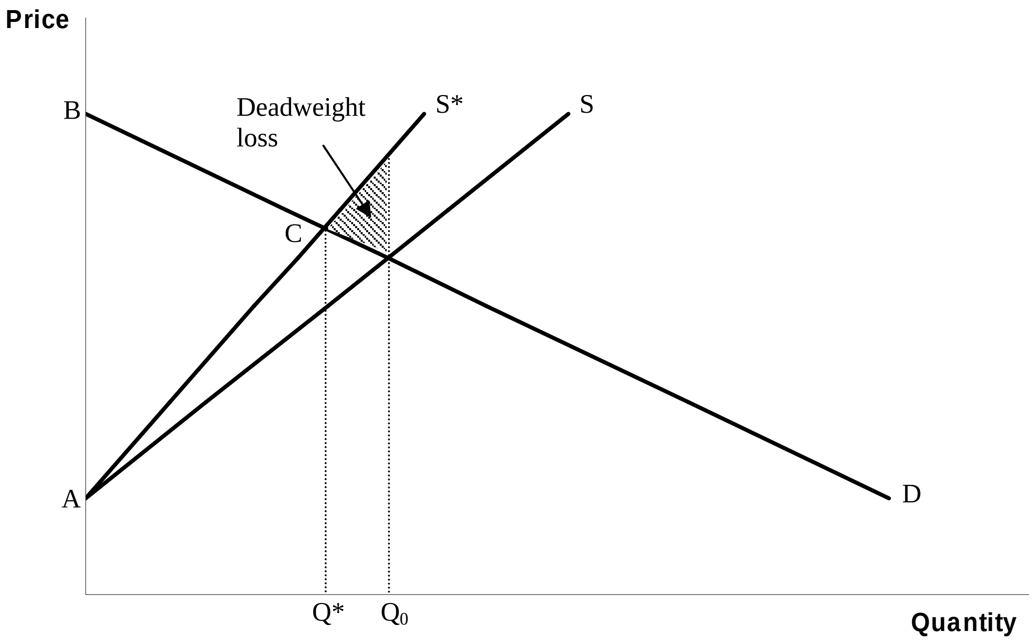
The economic value is maximised if goods are provided at the price and quantity when the demand curve and the supply curve for goods intersect; Figure 2.1 depicts such a condition. When the economic value is maximized, a society is well-off; in other words, social welfare is maximised, at least in terms of economy.

### 2.2 Welfare loss due to negative externalities

The economic value of goods or the social welfare is not maximised when negative externalities exist. The negative externalities are defined as a condition such that "the agent responsible must not take account of the effect that it has on the other party" (Markandya, Perelet, Mason, & Taylor, 2001, p.94).

To understand the concept of the negative externalities, consider water pollution caused by steel production. (This example is adapted from Pindyck and Rubinfeld [1995, pp. 624-626].) Suppose that a company produces pollutants as it produces steel, discharging pollutants through wastewater into a river without treating them. As a result, fish die or disappear; fishermen operating downstream suffer from catching fewer fish. This hypothetical example shows that river pollution costs not the steel company, but the fishermen. The fishermen pay "cost" by losing the income from catching fish because the company does not shoulder the cost of treating wastewater. That is the case of negative externalities: An action taken by one party (the steel company) negatively impacts other party (the fishermen). Those externalities, as mentioned below, should be incorporated or "internalised" so as to maximise costs to the other party (or society) by avoiding excess production of goods, and therefore pollutants.

Figure 2.2 shows negative externalities, following the above example. The company produces steel at $Q_0$ when the supply curve, *S* (that describes the company's production cost), intersects with the demand curve, *D*, for steel. The supply curve *S* does not reflect the cost of controlling the pollution. However, such a cost actually exists; recall the "cost" paid by the fishermen in the example. The supply curve *S** represents the actual cost of supplying steel (i.e., the cost of both producing steel and treating pollution). From the perspective of a society, steel should be produced at *Q** when the supply curve *S** intersects with the demand curve *D*; it is when the economic value for the society as a whole is maximised. Note that *Q** is less than $Q_0$. That is, without considering the pollution treatment cost, the company produces more than it should from the perspective of the society. When the company continues to produce steel at $Q_0$, a loss called "deadweight loss" arises which the society has to bear. The area marked with diagonal lines in Figure 2.2 represents the deadweight loss due to the negative externalities caused by the excess steel production (i.e. the difference between $Q_0$ and *Q**). The economic value for the society as a whole is lessened by the deadweight loss. The total economic value of producing steel at $Q_0$ without the company including the cost of controlling the pollution is the difference between the area marked by ABC and the deadweight loss. The society would not suffer from this loss if the pollution cost were internalised, and therefore the company produced less steel in the amount of *Q**.




Source: Pindyck & Rubinfeld, 1995, p. 625

**Figure 2.2 Deadweight loss due to negative externalities**

### 2.3 Valuation techniques

One can estimate the economic value of goods, using their demand and supply information. An idea behind the value estimation is straightforward, although implementing the idea may not be easy. To estimate the economic value, first, one should estimate the demand and supply curves of concerned goods by using methods described below in this section; then, one can calculate the area of the consumer and producer surpluses of consuming/producing the goods.

If the goods are traded in the market, one can use the goods' market prices and trading volumes to estimate the demand and supply curves. If the goods are not traded in the market, however, one should use either the market information of relevant goods or the information collected by surveys about consumer preference for the goods concerned. It should be noted that if a target is market goods, one should consider both the demand and the supply for the goods. However, if a target is non-market goods, one can consider only the demand for the goods because non-market goods such as recreational opportunities (e.g., scenic views) and biodiversity have "no producer, or the consumer is both the producer and consumer" (Lipton et al., 1995, p. 42). The following sections discuss methods and procedures to estimate the demand and supply for goods according to their nature of being traded in the market or not. Table 2.1 summarises the techniques and their applications described below.

**Table 2.1 Techniques for valuing environmental goods**

| Target goods | Valuation technique | Procedure | Necessary data | Reference |
|---|---|---|---|---|
| Market goods (e.g., commercial fish) | Empirical technique | 1. Collect empirical data on market data<br>2. Analyse data statistically<br>3. Calculate consumer surplus | • Market price and trading volume of target good | • Statistical technique: Regression analysis |
| Non-market goods (e.g., scenic views) | Zonal travel cost method | 1. Collect data on tourists<br>2. Analyse data statistically<br>3. Calculate and aggregate consumer surplus | • Cost information associated with trip to target site<br>• Wage information of visitors<br>• Number of visits per person<br>• Local government districts<br>• Population statistics | • Statistical technique: Regression analysis |
| | Contingent valuation method (dichotomous choice method) * | 1. Collect data on willingness to pay<br>2. Analyse data statistically<br>3. Calculate and aggregate consumer surplus | • Individual's willingness to pay | • Statistical technique: Logistic regression analysis<br>• Survey via interviews |

Notes: *Applicable to a wide range of environmental goods, including biodiversity

### 2.3.1 Market goods and services

A procedure to estimate the demand and supply for market goods such as commercial fish consists of the following four steps:

(1) Collect empirical data on the market prices and trading volumes of concerned goods;
(2) Collect empirical data on the marginal variable costs of producing the goods;
(3) Analyse statistically the market data collected in Step 1 to estimate the demand curve; and
(4) Analyse statistically the cost data collected in Step 2 to estimate the supply curve.

Regression analyses are commonly used to estimate the demand and supply curves. One can obtain functional forms of the curves, regressing the data by ordinary least squares. (For more details on regression, see Pindyck and Rubinfeld [1995, pp. 659-667].) Widely-used spreadsheet programmes have a function to conduct regression analyses. To illustrate how to estimate the demand and supply for market goods, consider coastal commercial fisheries as an example. Suppose that market information are collected as shown in Table 2.2. (This example is adapted from Lipton et al. [1995, pp. 33-40].)

**Table 2.2 Demand and supply for commercial fish**

| Price (USD per kg) | Demand (kg per day) | Supply (kg per day) |
|---|---|---|
| 1 | 21,300 | 0 |
| 2 | 16,000 | 3,200 |
| 3 | 10,600 | 6,400 |
| 4 | 5,300 | 9,600 |
| 5 | 0 | 12,800 |

The price in USD and the demand in catch rate per day are those which generally prevail in the market (i.e., the price and quantity that prevail "on average" or when market conditions are "normal"). The supply is a quantity that is produced corresponding to the price or the industry's marginal variable cost that results from producing one extra unit of goods. In this example, the marginal variable cost is the incremental cost to supply fish by one additional kilogram. (See Pindyck and Rubinfeld [1995, pp. 42 and 198].)

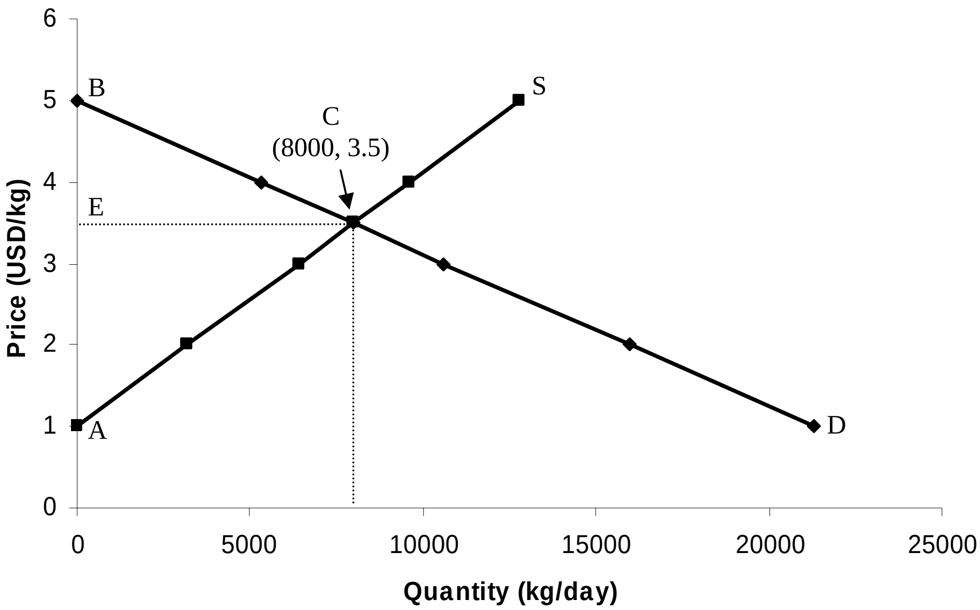
Regression analyses provide the estimated demand and supply functions as follows. (For simplicity, linear regression analyses are used.)

$$Demand: P = 5 - 0.000188Q$$

$$Supply: P = 1 + 0.000313Q$$

*P* and *Q* represent price and quantity, respectively. See Appendix XX for more information on how to estimate those functions.

It is common practice for this kind of economic analysis to check with t-statistics whether estimated coefficients are statistically significantly different from zero. As a rule of thumb, a coefficient is different from zero if its t-statistic exceeds 1.96 in absolute value; then, one can claim that there is an association with 95 percent confidence between a response variable and an explanatory variable(s). Conventionally, t-statistics are presented with an estimated function to indicate the significant level of estimated coefficients. In the example, the t-statistics of the coefficients for the quantity in the demand and supply functions are more than 1.96 in absolute value: -533 and 65535, respectively. The reason why the significant level of those coefficients is very high in the example is simply that the demand and supply data are prepared purposely in such a way that there is a strong (linear) correlation between the price and quantity. Even if the estimated value of coefficients is not significantly different from zero at the 95-percent confidence level, the value should be used for the purpose of cost-benefit analyses because those coefficients may be the best estimate of the true value with given samples. For more details on the statistical significance of estimated coefficients, see Boardman et al. (2006, pp. 328-329) and Pindyck and Rubinfeld (1995, pp. 662-663). Figure 2.3 shows the estimated demand and supply curves that fit the data. (In reality, data would not all lie exactly on estimated lines.)




Source: Lipton et al., 1995, p. 38

**Figure 2.3 Fitting linear demand and supply curves to data**

According to the solution of the simultaneous equations of the demand and supply, the intersecting point, *C*, is where the price is USD 3.5 per kg and the trading volume is 8,000 kg per day. Given that, one can geometrically calculate the economic value as follows.

$$
\begin{aligned}
&\textit{Economic value of commercial fisheries} \\
&\quad = \textit{Area ABC} \\
&\quad = \textit{Consumer surplus (Area EBC) + Producer surplus (Area AEC)} \\
&\quad = (5-3.5)\times 8{,}000\times 1/2+(3.5-1)\times 8{,}000\times 1/2 \\
&\quad = \textit{USD } 16{,}000 \textit{ per day}
\end{aligned}
$$

Suppose that the total number of fishing days is 100 days a year; then, the economic value of the commercial fish is USD 1.6 million per year (USD 16,000 x 100 days).

### 2.3.2 Non-market goods and services

If there is no available market information (i.e., price and trading volume) of target goods, one should use either the information of other relevant market goods or surveyed information about consumer preference for the target goods. In economics, it is common to call the former way of using relevant good data as "revealed preference methods" and the latter way of using survey data as "stated preference methods" (Freeman, 2003, p. 24). This section discusses the travel cost method, a commonly-used revealed preference method; then, the section describes the contingent valuation method, a commonly-used stated preference method.

#### 2.3.2.1 Travel cost method (zonal travel cost method)

The travel cost method (TCM) uses the cost information on how much people spend to consume environmental goods as a proxy variable for their economic value. The method is often applied to measure recreational services that environmental goods provide, such as scenic views. The section below introduces the TCM, particularly the zonal TCM which uses surveyed data of actual visitors with their departure points recorded and divided into areas or "zones." The zonal TCM consists of three steps:

(1) Collect data on the travel cost information of visitors to a site;
(2) Analyse the collected data statistically to estimate the individual visitor's demand curve; and
(3) Calculate and aggregate the consumer surplus for visitors from different zones.

First, to reveal the environmental value of a recreational site, such as a beach, one should collect the following information about visitors to the site (this example is adapted from Boardman et al. [2006, pp. 354-361]):

- Travel distance;
- Travel time;
- Operating cost of vehicles (e.g., gasoline cost);
- Opportunity cost of the travel time (e.g., forgone time wage);
- Admission fee of the recreational site, if any (the above information give the average total cost per person); and
- Average number of visits per person per year.

Suppose that a visitor who lives 2 km away from a beach (the target site to value) spends half an hour each way to get to the beach, driving to the site, park her car, and walk to the entrance. She drives her car which consumes 15 cents per km of gasoline. She pays USD 10 for the entrance fee to the site. Her hourly wage is USD 9.4; she would get the salary of that amount if she uses her traveling time for work. She visits the beach 15 times per year. Then, the total travel cost of the visitor would be USD 20 per trip, as calculated in Table 2.3.

**Table 2.3 Travel cost to a hypothetical recreational site (a sample visitor)**

| | Cost (USD) | Reference |
|---|---|---|
| Opportunity cost | 9.4 | USD 9.4 x 0.5 hour x 2 trips |
| Operating cost | 0.6 | USD 0.15 x 2 km x 2 trips |
| Admission fee | 10 | One-time fee per trip |

| **Total travel cost** | **20** | Visits 15 times per year |
|---|---|---|

Suppose that the information of other four visitors are also collected as shown in Table 2.4. Each visitor is categorised by zone according to distance to the beach. In practice, it is common to use local government jurisdictions as zones. The (average) total cost per person is calculated in a similar way as described in Table 2.3.

**Table 2.4 Travel cost to a hypothetical recreational site (five sample visitors)**

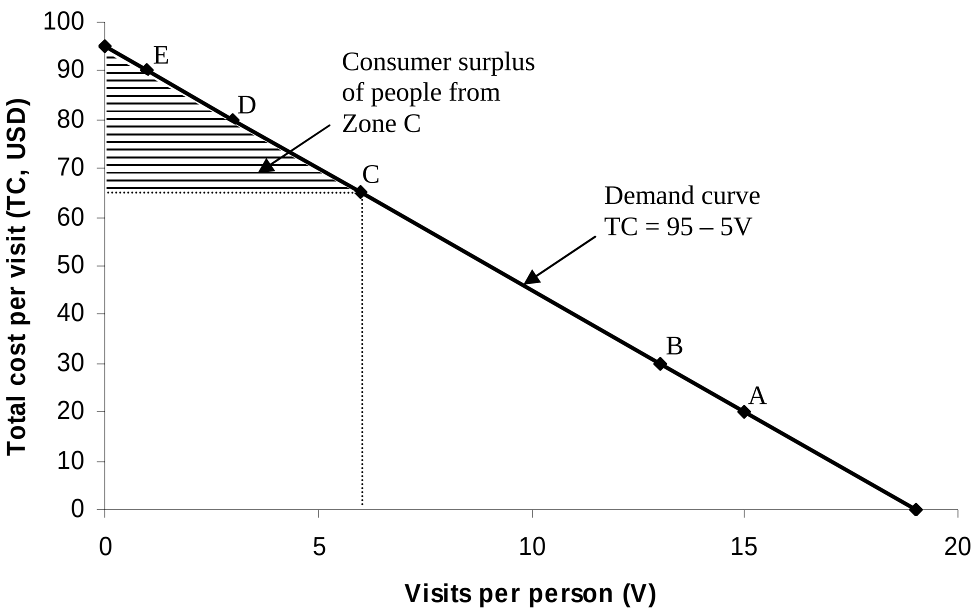
| Zone | Travel time (hours) | Travel distance (km) | Average total cost per person per visit (USD) | Average number of visits per person per year |
|---|---|---|---|---|
| A | 0.5 | 2 | 20 | 15 |
| B | 1.0 | 30 | 30 | 13 |
| C | 2.0 | 90 | 65 | 6 |
| D | 3.0 | 140 | 80 | 3 |
| E | 3.5 | 150 | 90 | 1 |

Source: Boardman et al., 2006, p. 356

Second, regressing the data on the average total cost per person and the average number of visits per person reveals the (representative) individual's demand curve for visits to the beach as follows.

$$TC = 95 - 5V$$

where *TC* and *V* represent the travel cost per visit and the visits per person, respectively. See Appendix XX for more information on how to estimate this demand curve. Figure 2.4 shows the estimated demand curve. (For simplicity, the above data were prepared so that they would all lie exactly on the estimated line.)



Source: Boardman et al., 2006, p. 357

**Figure 2.4 Estimated demand curve for a hypothetical recreational site**

Third, using the Figure, one can geometrically calculate consumer surplus for people from different zones as Table 2.5 shows; for example, the consumer surplus for those who are from Zone C is USD 90 per person ([USD 95 - USD 65] x 6 visits / 2).

**Table 2.5 Travel cost to a hypothetical recreational site (five sample visitors)**

| Zone | Average number of visits per person per year (1) | Consumer surplus per person per year (2) | Population (3) | Consumer surplus per Zone per year (USD thousand) (4) = (2) x (3) | Trips per Zone (thousand) (5) = (1) x (3) |
|---|---|---|---|---|---|
| A | 15 | 562.5 | 10,000 | 5,625 | 150 |
| B | 13 | 422.5 | 10,000 | 4,225 | 130 |
| C | 6 | 90.0 | 20,000 | 1,800 | 120 |
| D | 3 | 22.5 | 10,000 | 225 | 30 |
| E | 1 | 2.5 | 10,000 | 25 | 10 |
| **Total** | | | | **11,900** | **440** |

Source: Adapted from Boardman et al., 2006, p. 356

If population statistics are provided, one can estimate consumer surplus in each zone by multiplying the consumer surplus per person in each zone by corresponding population (for example, the consumer surplus of Zone C is USD 1.8 million [USD 90 x 20,000 people]). Then, an analyst can estimate the total consumer surplus for the visitors by summing those products: The total consumer surplus in this example is USD 11.9 million per year.

#### 2.3.2.2 Contingent valuation method (dichotomous choice method)

The contingent valuation method (CVM) estimates the economic value of environmental goods, using survey results from an individual's willingness to pay (WTP) for the goods. Providing plausible hypothetical scenarios (i.e., carefully describing the current and future status of concerned ecosystems with and without conservation efforts), this method asks respondents how much they would pay or whether they would pay a certain amount of money to prevent environmental degradation. The CVM is applicable to a wide range of environmental goods, including the goods that people have not yet used and/or will not use (e.g., biodiversity) (Mitchell & Carson, 1989, p. 90).

According to Boardman et al. (2006), the CVM mainly consists of two groups of sub-methods: the direct elicitation (nonreferendum) method and the dichotomous choice (referendum) method (pp. 370-374). The former method, includes the open-ended willingness-to-pay method, the closed-ended iterating bidding method, and the contingent ranking method. Those methods, at one time commonly used, are no longer in use due to various limitations. The latter method was recommended as the method of choice in most circumstances by a blue-ribbon panel of social scientists, that was convened by the National Oceanic and Atmospheric Administration (Boardman et al., 2006, p. 370). The section below, adapted mainly from Boardman et al. (2006) and Loomis (1988), illustrates how to use the dichotomous choice method to measure the economic value of environmental goods.

Suppose that a coastal site faces serious environmental problems. A local government that has jurisdiction over the site decides to develop rehabilitation plans. The government also decides to implement a study to understand the environmental value of the site, expecting that the study results will contribute to developing the plans. To measure the value of the site, one can employ the dichotomous choice method as follows:

(1) Collect data on individual's WTP for environmental goods (in the example, the coastal site);
(2) Analyse the collected data statistically to estimate the individual's WTP; and
(3) Calculate and aggregate the WTP to reveal the consumer surplus of having the goods for the society as a whole.

First, one should collect data on individual's (e.g., city residents and visitors who use the site) WTP for rehabilitating the site. Using a questionnaire, interviewers can ask respondents whether they would pay a certain amount of money to prevent environmental degradation. Given one randomly drawn price, referred to as "bid prices," a respondent is asked to state whether he would be willing to pay the price (Boardman et al., 2006, pp. 371-372). The following is a simplified sample question:

> The site you are visiting is deteriorating due to lack of management and maintenance. [Here, interviewers provide the detailed information about the site and the environmental problems it faces.] Let us assume that the local government is planning to rehabilitate the area and that, due to budget constraints, it is also considering asking visitors to contribute to investment costs by paying an entrance fee for a visit. [Here, interviewers provide the detailed information about not only the rehabilitation plans but also the consequences of implementing or not implementing them.] Would you be willing to pay the following fee? [Here, interviewers offer the respondent one bid price.] (Markandya, Harou, Bellu, & Cistulli, 2002, p. 453)

See Appendix XX for a sample survey questionnaire with detailed information and specific questions.

The data from the example survey are shown in Table 2.6 . In this example, there are 12 respondents who are suggested different prices ranging from USD 5 to USD 60. If a respondent replies "yes," that is recorded as *1*. If he replies "no," that is recorded as *0* (Loomis, 1988, pp. 209-213).

**Table 2.6 Sampled individual's willingness to pay for coastal site rehabilitation**

| Bid price (USD per visit) | Response (1 = "yes," 0 = "no") |
|---|---|
| 5 | 1 |
| 6 | 1 |
| 7 | 1 |
| 9 | 1 |
| 10 | 1 |
| 11 | 0 |
| 25 | 1 |
| 30 | 0 |

| | |
|---|---|
| 35 | 0 |
| 50 | 0 |
| 55 | 0 |
| 60 | 0 |

Source: Loomis, 1988, p. 210

Second, one should analyse the data statistically to estimate the individual's WTP for the site. The logistic regression, using the logit model, helps in estimating the relationship between bid prices and responses, although there may be a number of other possible models applicable. The logit model is defined as:

$$L_i = \ln\left(\frac{P_i}{(1-P_i)}\right) = \beta_1 + \beta_2 X_i$$

where $P_i / (1 - P_i)$ is the ratio of the probability that an event occurs to the probability that it does not occur; this ratio is called the "odds ratio." *L*, called the logit, is the log of the odds ratio (Gujarati, 1995, p. 555). *X*, an explanatory variable, represents bid prices, while $\beta_1$ and $\beta_2$ are coefficients. Taking the exponential of *L* gives:

$$\exp(L) = \exp\left(\ln\left(\frac{P_i}{(1-P_i)}\right)\right) = \exp(\beta_1 + \beta_2 X_i)$$

$$\frac{P_i}{(1-P_i)} = \exp(\beta_1 + \beta_2 X_i)$$

$$P_i = \frac{\exp(\beta_1 + \beta_2 X_i)}{1+\exp(\beta_1 + \beta_2 X_i)}$$

where $P_i$ is, as defined above, the probability that respondents would be willing to pay or reply "yes" at given bid prices, *X* (Taromaru, 2005, p. 176).

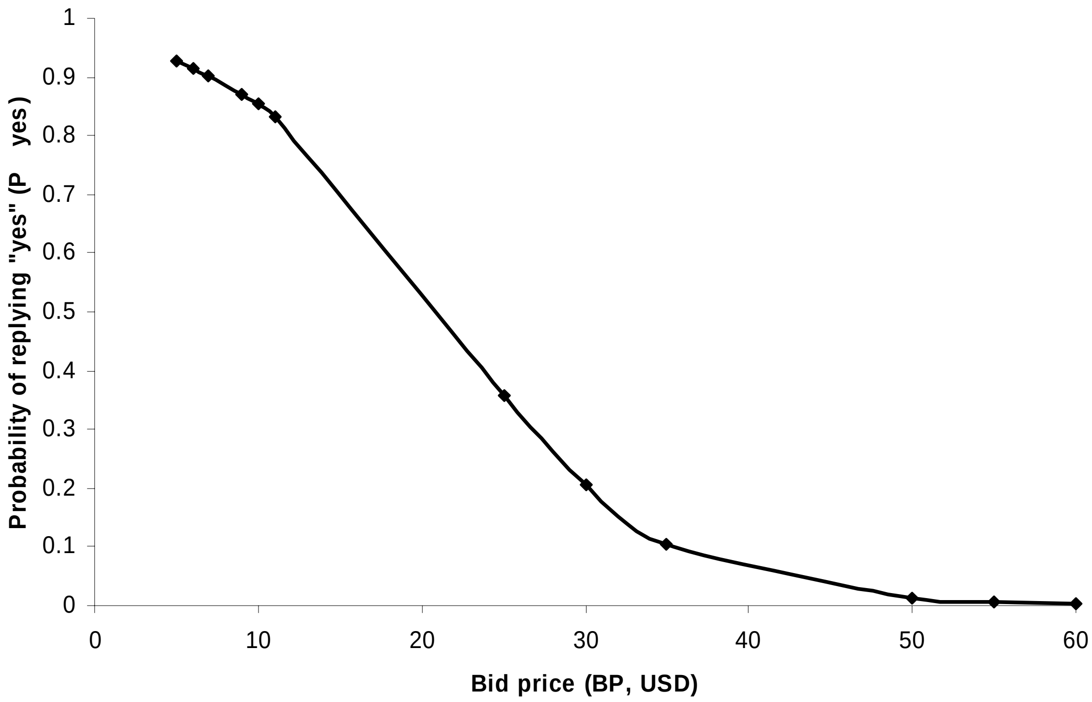
Using the logit model with the raw data in Table 2.6, one can estimate the individual's WTP function as follows (Loomis, 1988, p. 211).

$$RY = \ln\left(\frac{P_{yes}}{(1-P_{yes})}\right) = 3.321 - 0.156BP$$

*RY* is the log of the odds ratio or the ratio of the probability that respondents would reply "yes" at given bid prices, *BP*, to the probability that respondents would reply "no." To estimate this equation, a statistical package is necessary. See Appendix XX for more information on how to use a statistical software to estimate logistic regression. Taking the exponential of *RY* gives:

$$P_{yes} = \frac{\exp(3.321 - 0.156BP)}{1+\exp(3.321 - 0.156BP)}$$

This estimated function explains the relationship between the bid prices and the probability for an individual to reply "yes" to pay for rehabilitating the coastal site. For example, when the bid price is 11 (i.e., *BP* = 11), the probability of an individual agrees to pay that amount is approximately 0.83 ($P_{yes}$ = exp(3.321 – 0.156 x 11) / (1 + exp[3.321 – 0.156 x 11]) = 0.832). Figure 2.5 shows the estimated logistic regression based on the data.




Source: Adapted from Loomis, 1988, p. 212

**Figure 2.5 Estimated relationship between the bid prices and the probability for an individual to reply "yes" or accept the prices**

Third, considering the estimated logistic regression function as the demand curve for the coastal site concerned, one can estimate consumer surplus for the site. The area under the function approximates the individual's mean maximum WTP or the individual's consumer surplus for the site (Loomis, 1988, p. 212). According to Boardman et al. (2006), the area can be calculated by the following five procedures:

> First, divide the range of *X* [*BP* in the example] into equal segments of width *n*. Second, calculate the probability of acceptance at each of these points. Third, find the average acceptance value for adjacent pairs of points. Fourth, multiply each of these averages by *n*. Fifth, sum all these products to get the estimate of the area (pp. 397-398).

With the above procedures followed, the estimated individual's consumer surplus for the site is approximately USD 21. See Appendix XX for more information on how to calculate the individual's consumer surplus. Then, one can estimate the aggregate consumer surplus or the economic value of the site for the society as a whole by multiplying the individual's consumer surplus by the number of relevant individuals or households (Grigalunas et al., 1995, p. 88; Lipton et al., 1995, p. 54). Assuming that there are 300,000 people concerned in our example and that everybody visits the site at least once a year, one would estimate the economic value of the site at approximately USD 6.3 million per year (USD 21 x 300,000 people x 1 time per year).

# 3 Cost-benefit analysis of environmental management actions

## 3.1 Basic framework of cost-benefit analysis

### 3.1.1 Change in economic value due to environmental degradation

The economic value of environmental goods decreases because of environmental resource degradation. For example, consider the decline in landings of commercial fish due to the decline in fish stock, which is attributable to the overexploitation of the fish. The size of fish catch depends on both the size of fish stock and the amount of fishing efforts (Tietenberg, 2003, p. 310). If the fish stock declines, fishermen have to increase fishing efforts (e.g., employing better equipment or more people) to maintain fish catch at the same level as before: That costs fishermen. Put simply, reduced stock size increases fishing cost. As a result, the supply curve of catching fish shifts to the left (Lipton et al., 1995, p. 37); recall the supply curve of producing goods is modeled as a function of a producer's marginal variable cost (see Section 2.1). Figure 3.1, using the example discussed in Section 2.3.1 in this Guideline, illustrates the shift in supply for commercial fish due to the decline in fish stock.

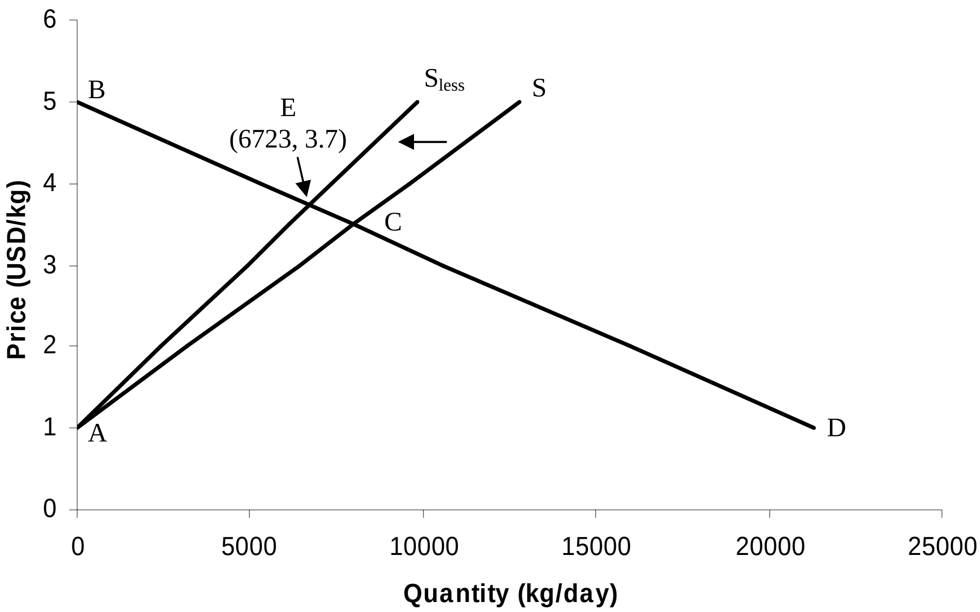



**Figure 3.1 Shift in supply for commercial fish due to the decline in fish stock**

$S_{less}$ represents the supply for commercial fish when less stock is available due to overexploitation, assuming that the cost of catching fish increases by 30 percent as an example. The estimated function of the new supply curve, $S_{less}$, is as follows.

$$Supply_{less} : P = 1 + 0.000407Q$$

Note that the coefficient for the quantity in demand in this new supply function with less stock is 30 percent more than that in the original supply function with more stock (0.000407 = 0.000313 x 1.3). The demand and supply curves intersect at *E* where the price is USD 3.7 per kg and the trading volume is 6,723 kg per day. (Solving the simultaneous equations of the two functions—the demand function [*D*] and the new supply function [$S_{less}$]—gives the intersecting point. For the demand function, see Section 2.3.1.)

Given the above information, one can calculate the reduced economic value by taking the difference between the economic values of goods before and after environmental resource degradation. In our example, the economic value of commercial fisheries before environmental degradation is USD 1.6 million per year (see Section 2.3.1). Meanwhile, the economic value of commercial fisheries after environmental degradation is approximately USD 13 thousand per day as calculated below, or USD 1.3 million per year on the assumption that the total number of fishing days remains the same at 100 days a year (USD 13,446 x 100 days).

*Economic value of commercial fisheries with less fish stock*

$$= \textit{Area ABE}$$
$$= (5-1)\times 6{,}723 \times 1/2$$
$$= \textit{USD } 13{,}446 \textit{ per day (Area AEC)}$$

The reduced economic value of commercial fisheries is about USD 300 thousand per year, that is the difference between USD 1.6 million and USD 1.3 million.

Environmental resource degradation also reduces the economic value of goods by affecting the demand for them; for example, people might decide not to visit a beach where the water is polluted. Suppose that the number of tourists to the beach in our example decreases by 10 percent as water quality degrades. Table 3.1 illustrates that change as the 10-percent decline in the number of visits per person per year. For example, the average number of visits per person from Zone B decreases by 10 percent from 13 times to 11.7 times.

**Table 3.1 Decline in the number of visits to a hypothetical recreational site due to environmental resource degradation**

| Zone | Average total cost per person per visit (USD) | Average number of visits per person per year (before degradation) | Average number of visits per person per year (after degradation)* | Consumer surplus per person per year (after degradation) | Population | Consumer surplus per Zone per year (after degradation) (USD thousand) |
|---|---|---|---|---|---|---|
| A | 20 | 15 | 13.5 | 506.3 | 10,000 | 5,063 |
| B | 30 | 13 | 11.7 | 380.3 | 10,000 | 3,803 |
| C | 65 | 6 | 5.4 | 81.0 | 20,000 | 1,620 |
| D | 80 | 3 | 2.7 | 20.3 | 10,000 | 203 |
| E | 90 | 1 | 0.9 | 2.3 | 10,000 | 23 |
| Total | | | | | | 10,710 |

Notes: *10-percent decline in the number of visits assumed

Figure 3.2 shows the shift in demand, due to water degradation, for recreational opportunities that the beach provides. *D* represents the original demand for the site, *TC* =

95 – 5*V*; whereas, $D_{low}$ represents the reduced demand for the site due to low water quality, *TC* = 95 – 5.56*V*, estimated by ordinary least squares regressing the reduced number of visits on the total cost per visit (the t-statistics of the coefficients of this estimated function are more than 1.96 in absolute value).

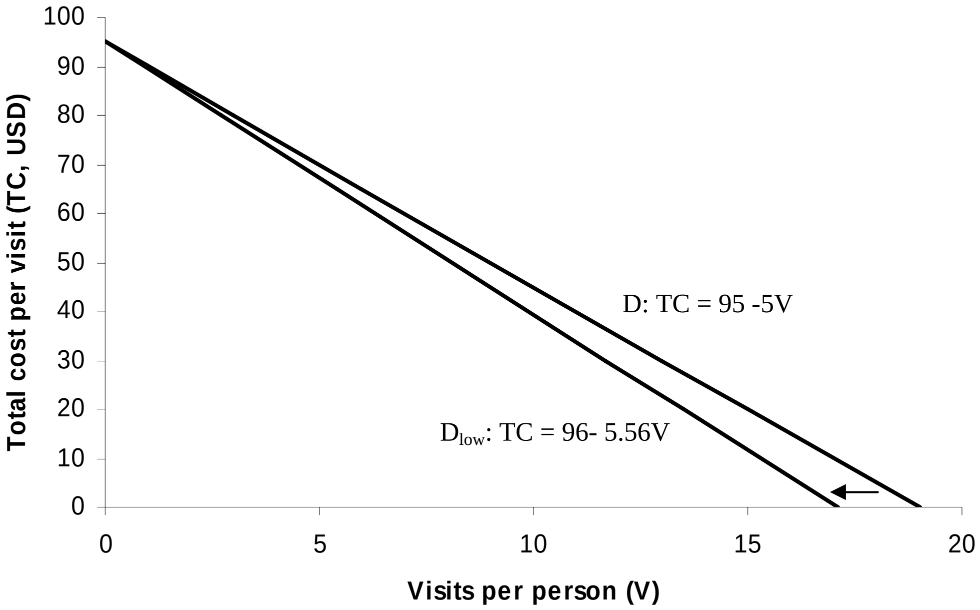



**Figure 3.2 Shift in demand for a hypothetical recreational site due to water degradation**

One can calculate the annual consumer surplus per zone in the same way as described in Section 2.3.2.1. For example, the annual consumer surplus for those who are from Zone A is approximately USD 5 million ([USD 95 - USD 20] x 13.5 visits / 2 x 10,000 people = USD 5,063 thousand). The total consumer surplus for the visitors with the reduced demand is USD 10.7 million per year, that is the sum of all the consumer surplus per zone. Then, the reduced economic value of the beach is about USD 1.2 million per year with the difference taken between the economic value under the original demand, USD 11.9 million, and that under the reduced demand, USD 10.7 million.

### 3.1.2 Benefit of management actions as prevented loss in economic value

The benefit of management actions to mitigate environmental problems can be defined as the prevented future loss measured in economic value. Recall in the example that the reduced economic value of the commercial fisheries is about USD 300 thousand per year. Suppose that a management action will be taken to prevent the decline in fish stock by controlling overexploitation of the fish (e.g., reducing illegal fishing) and that the action will reduce fishing cost so that the supply curve of catching fish will shift to the right. For simplicity, assume in Figure 3.1 that the supply curve shifts from $S_{less}$ to *S*; then, the benefit of controlling overexploitation is USD 300 thousand per year, that is the prevented future loss in commercial fisheries.

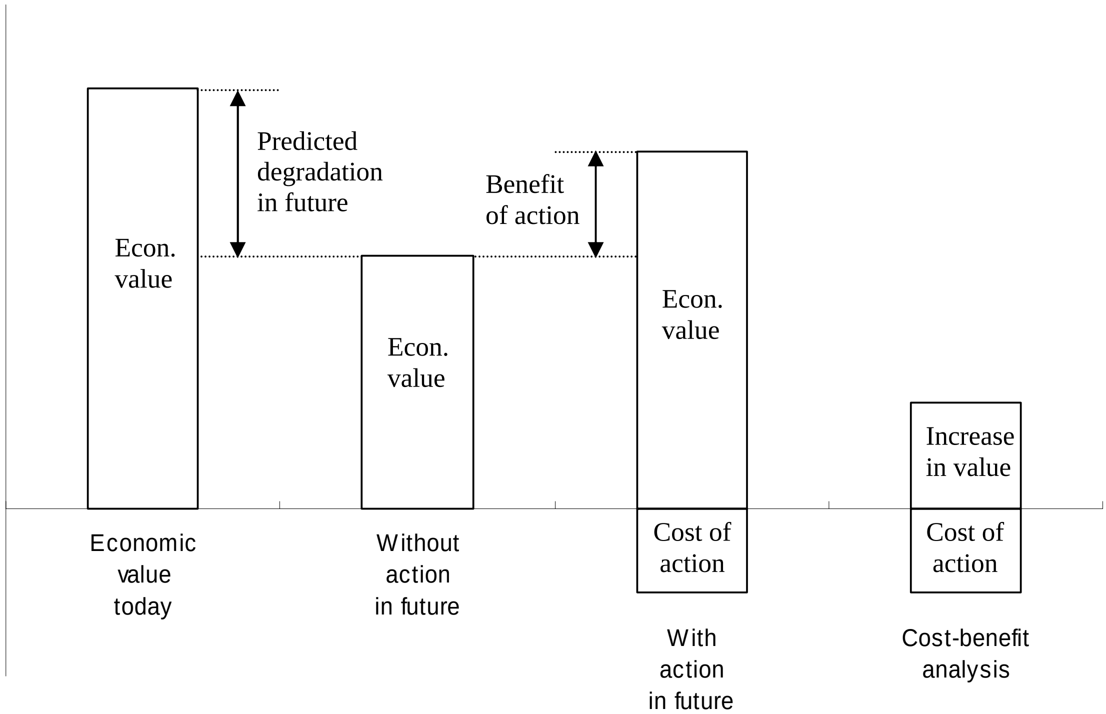
### 3.1.3 Cost of management actions

The cost of management actions is relatively straightforward; it is defined as the cost incurred to implement proposed actions. The cost consists of "both the direct costs of implementing conservation measures, and the opportunity costs of foregone uses" (Pagiola, Ritter, & Bishop, 2004, p. 7). Direct costs may be divided into the following two categories: (i) the cost to establish and initiate proposed management actions (installation cost); and (ii) the cost to operate and maintain the actions (O&M cost). The opportunity costs are forgone future benefits, which otherwise would be realised through other benefits, due to the implementation of the actions. For example, the opportunity cost of preserving mangrove forests is the forgone profit from deforesting and converting the land for commercial use. If one protected mangrove forests, he would give up future revenues from the sale of agricultural crops, for instance, that were cultivated in the deforested area (Markandya et al., 2001, p. 144). In our example of the commercial fisheries, the cost of management actions may include the following: the direct costs of establishing and enforcing laws and regulations, that include monitoring costs.

### 3.1.4 Cost-benefit analyses for decision-making

Analysing the benefits and costs of proposed management actions helps decision-makers decide whether to implement the actions. Comparing the net benefits (i.e., the difference between [gross] benefits and costs) of management actions under two scenarios, with or without the actions, cost-benefit analyses address a research question: "What would happen if conservation measures [management actions] were implemented to what would have happened if they were not" (Pagiola et al., 2004, p. 19). The analyses then use a simple yet effective decision criteria: Comparing the gains (benefits) with the losses (costs) of an action, if the former exceeds the latter, support the action; otherwise, oppose it (Tietenberg, 2003, p. 19). With analysis results given, it is logical for decision-makers to accept the proposed actions if the net benefits are positive, or to decline the actions if the net benefits are negative.

Figure 3.3 illustrates the concept of a benefit-cost analysis under with or without scenarios. Properly measured, the economic value of goods today may be illustrated as the leftmost column in the figure. Suppose that these benefits will decrease in the future because of environmental degradation; then, the benefits would be as shown in the next column to the right. This situation with decreased benefits is a "baseline," which is defined as the "reality in the absence of the regulation [management actions]" (U. S. Environmental Protection Agency [U.S. EPA], 2000, p. 21). The difference in the amount of the economic value between today and the future is the scale of predicted degradation. With management actions implemented, however, this degradation might be less (third column from the left). Comparing the results of the two scenarios, with or without management actions, would reveal the benefit of the actions. In the subsequent cost-benefit analysis (the rightmost column), the benefit of implementing the management actions is compared with the cost of implementing them. The cost might consist of both direct costs and opportunity costs. If the benefits exceed the costs, it is reasonable to support the management actions.




Source: Adapted from Pagiola et al., 2004, pp. 13-21

**Figure 3.3 Cost-benefit analysis of environmental management actions**

It is important to note that the cost-benefit analysis should compare the benefit and cost "with and without" the management actions, rather than "before and after" implementing them. In other words, the analysis does not compare the economic value today and that in the future with the actions. This is because many other factors may have changed in the period of intervention (i.e., between today and sometime in the future); it is difficult to see whether the increase in the economic value is attributable to the concerned management actions or other unaccounted factors (Pagiola et al., 2004, p. 19).

## 3.2 Procedure of cost-benefit analysis

The procedure of a cost-benefit analysis consists of the following eight steps (adapted from Boardman et al. [2006, pp. 7-17]):

(1) Specify management actions to analyse;
(2) Predict future environmental degradation;
(3) List expected benefits and costs of the actions;
(4) Predict the benefits and costs quantitatively;
(5) Monetise the benefits and costs;
(6) Calculate the net present value of the benefits and costs;
(7) Conduct a sensitivity analysis; and
(8) Make recommendations.

To explain each step specifically, image a hypothetical case as follows. There is a coastal development plan to convert a wetland into various industrial usages. The development is expected to bring economic profits to a local community. However, there is a concern about the adverse impact of the development on the ecosystem in the proposed development site and on the local economy near the site, such as coastal fisheries and tourism. The site provides habitat for unique marine wildlife, including those in danger of extinction. The wildlife would disappear if the plan were materialised. Additionally, the development might pollute the seawater and cause decline in coastal fish stock and catch, and in beach bathing areas. Considering the above situation, the local government decided to take management actions to both reduce the converted wetland area and control pollutants from the industries on the reclaimed land. The government also decided to conduct a cost-benefit analysis of this action to see whether it would be justifiable economically. Using the above hypothetical case, the following sections explain the eight steps for the cost-benefit analysis.

**Step 1: Specify management actions to analyse**

First, one should specify a set of management actions to analyse. In our hypothetical example, the management actions are to reduce the reclaimed land area and the pollution. As mentioned above in this chapter, cost-benefit analyses compare the net benefits of taking management actions (with scenario) with that of taking no action (without scenario).

**Step 2: Predict future environmental degradation**

Second, one should predict likely environmental degradation in the future if no action is taken. An estimated environmental value of goods with the predicted future loss is then considered as a baseline to be compared with an estimated increased environmental value of goods as a result of management actions. The prediction might require scientific knowledge (e.g., environmental modeling).

**Step 3: List expected benefits and costs of the actions**

Third, one should identify expected benefits from and costs of taking proposed actions. The benefits of the actions are the difference between the economic value of goods under a without-action scenario (baseline) and that under a with-action scenario. The costs of the actions are all expenses incurred to install, operate, and maintain the actions. Those costs might include opportunity costs caused by taking the actions.

In this example, the anticipated benefits of reducing the reclaimed land area and the pollution may be an increase in the number of marine wildlife, coastal fish stock, and beach tourists. Meanwhile, the anticipated costs may include not only the direct costs of administering regulations to reduce the reclaimed land area (e.g., compliance monitoring and enforcing the regulations) and of installing, operating, and maintaining pollution control devices, but also the opportunity cost of forgone future benefits that would be realised if the reclaimed area were not reduced. Table 3.4 summarises the benefits and costs expected as a result of taking the actions.

**Table 3.4 Categories of expected benefits and costs of management actions to reduce hypothetical reclaimed land area**

| Benefit | Cost |
|---|---|
| Increase in the number of:<br>• marine wildlife<br>• coastal fish stock<br>• beach tourists | Direct cost:<br>• regulation cost (e.g., compliance monitoring and enforcing cost)<br>• installation, operation, and |

| | |
|---|---|
| | maintenance cost of pollution controlling facilities<br><br>Opportunity cost:<br>• forgone future benefits if the reclaimed land area are not reduced |

**Step 4: Predict the benefits and costs quantitatively**

Fourth, one should quantitatively predict at this stage the benefits and costs of management actions in terms of their magnitude, not monetary value. On one hand, as was the case in Step 2, predicting the benefits may require environmental modeling as well as socio-economic survey to reveal cause-and-effect relationships between the actions (cause) and the benefits of them (effect). On the other hand, to estimate the costs, there are three approaches: survey approach, engineering approach, and combined approach with the above two approaches (Tietenberg, 2003, pp. 47-48). The survey approach is to ask those who know the most about the proposed management actions; the engineering approach is to use general engineering information. The combined approach collects information on possible technologies as well as special circumstances; then, it derives the actual costs of those technologies with the special circumstances considered. The combined approach is preferable because it provides balanced information while minimising the problems of the other two approaches.

In the example, an analyst should estimate the benefits by predicting how much marine wildlife, coastal fish stock, and beach tourists would increase as a result of reducing the reclamation area and pollution. Environmental modeling would help in estimating those increases by predicting the relationship not only between the wetland area as habitats and the marine animals, but between the pollution caused by the industry located on the reclaimed land and the fish stock. Socio-economic survey is necessary to reveal the relationship between the pollution and the number of tourists, predicting how many tourists would visit the beach if the pollution were to decrease. The cost estimation in the example requires interviews with those who know the most about administering the regulations and developing the reclaimed land for industrial use. It is also necessary to evaluate specific pollution control technologies by collecting information on possible technologies as well as special circumstances facing firms or areas where the technologies are introduced. The information source may include the following: local government agencies which deal with coastal management and development, land developers, manufacturers of pollution control devices, operators of existing pollution control facilities, technical people of local coastal industries, and universities with expertise in relevant fields.

**Step 5: Monetise the benefits and costs**

Fifth, one should place monetary values on the benefits and costs of management actions, using techniques described in the Guideline. To measure the benefits, there are three valuation techniques suggested in Section 2.3: empirical technique, zonal TCM, and CVM. Using those techniques, one can estimate the economic values of goods without management actions, or the baseline. Given the information obtained from Step 4 about the benefits of management actions in “impacts,” then, an analyst can estimate the economic values of goods with the actions. The benefits of management actions in “monetary terms” is the difference between the economic values of goods with and without the actions (see

Section 3.1.2). Monetising the costs of the actions is relatively easy; in fact, in most cases, those costs are already in monetary terms.

**Step 6: Calculate the net present value of the benefits and costs**

Sixth, one should calculate the net present value (NPV) of the benefits and costs of management actions. The benefits and costs might accrue over time. To incorporate this time factor, an analyst assesses the NPV of a stream of net benefits $\{NB_0, \ldots, NB_n\}$ that arise over time, which is computed as

$$NPV[NB_n] = \sum_{i=0}^{n} \frac{NB_i}{(1+r)^i}$$

where $r$ is a social discount rate and $NB_i$ is net benefits—the difference between the present value (PV) of the gross benefits and the PV of the costs—accruing in various timings (Tietenberg, 2003, p. 24). One can easily calculate both NPV and PV using widely-used spreadsheet programmes. The idea of this calculation is to discount future net benefits by interest rates so that they represent today's values.

Setting the discount rates is not an easy task; there is neither a single rate to apply nor a consensus on how to set the rates. However, for practical purposes, Boardman et al. (2006) recommend a discount rate of 3.5 percent for most projects whose main impacts occur within 50 years and whose financing does not "crowed out" other investments (p. 270). U.S. EPA suggests 2 to 3 percent for the intra-generational discounting (a relatively short term, e.g., several decades) based on historical rates of return on relatively risk-free investments such as government bonds, which are adjusted for taxes and inflation (2000, p. 48); Freeman (2003) supports this recommendation (p. 199).

[DISCUSS RATE MANDATED BY THE GOV. IN CHINA AND ROK.]

Considering the rates suggested by literature, this Guideline recommends 3 percent as a social discount rate for the cost-benefit analysis of environmental management actions. The Guideline also recommends conducting a sensitivity analysis with respect to the discount rate. For more information about the sensitivity analysis, see Step 7 below.

In the given example, suppose that the benefits of the management actions as well as the costs of them accrue in various timings as described in Table 3.2. It is assumed that the annual economic value of increased marine wildlife, coastal fish stock, and beach tourists would be USD 6,300 thousand, USD 300 thousand, and USD 1,200 thousand, respectively, following the example discussed in this Guideline. (See Section 2.3.2.2 and 3.1.1 for how to estimate the increase in the economic value.) For example, the increase in the value of wildlife value accrues from the first year soon after taking the actions, while the value of coastal fish stock accrues from the fourth year; there is a time-lag before any effect of the actions on the fish stock is seen. It is plausible to assume that the management actions do not immediately affect "external" goods such as fish stock and beach tourism. (For details about externalities, see Section 2.2.) The total benefit (Column 7, Table 3.2) is the sum of the increased economic values, while the total cost (Column 3) is the sum of direct costs and opportunity costs. The opportunity costs are assumed here to be the forgone future benefits from industries that would be established if the reclaimed land area were not reduced. The net benefit is the difference between the total benefit and the total cost.

**Table 3.2 Benefits of management actions from a hypothetical case (Units: USD thousand)**

| | Cost | | | Benefit | | | | Net benefit | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Direct cost (1) | Opportunity cost (2) | Total cost (3) = (1) + (2) | Marine wildlife (4) | Fish stock (5) | Beach tourists (6) | Total benefit (7) = (4) + (5) + (6) | Undiscounted (8) = (7) – (3) | Discounted (r = 3%) |
| 0 | 1,000 | 0 | 1,000 | 0 | 0 | 0 | 0 | -1,000 | -1,000 |
| 1 | 1,000 | 0 | 1,000 | 6,300 | 0 | 0 | 6,300 | 5,300 | 5,146 |
| 2 | 1,000 | 7,500 | 8,500 | 6,300 | 0 | 1,200 | 7,500 | -1,000 | -943 |
| 3 | 1,000 | 7,500 | 8,500 | 6,300 | 0 | 1,200 | 7,500 | -1,000 | -915 |
| 4 | 1,000 | 7,500 | 8,500 | 6,300 | 300 | 1,200 | 7,800 | -700 | -622 |
| 5 | 1,000 | 7,500 | 8,500 | 6,300 | 300 | 1,200 | 7,800 | -700 | -604 |
| 6 | 500 | 7,500 | 8,000 | 6,300 | 300 | 1,200 | 7,800 | -200 | -167 |
| 7 | 500 | 7,500 | 8,000 | 6,300 | 300 | 1,200 | 7,800 | -200 | -163 |
| 8 | 500 | 7,500 | 8,000 | 6,300 | 300 | 1,200 | 7,800 | -200 | -158 |
| 9 | 500 | 7,500 | 8,000 | 6,300 | 300 | 1,200 | 7,800 | -200 | -153 |
| 10 | 500 | 7,500 | 8,000 | 6,300 | 300 | 1,200 | 7,800 | -200 | -149 |
| **Total** | | | **76,000** | | | | **75,900** | **-100** | **272** |

It is worth noting that the signs of total net benefits are different depending on whether they are discounted or not. Without discounting, the total cost exceeds the total benefits; the undiscounted net benefit is negative. However, discounted with the 3-percent interest rate, the net benefit (i.e., NPV) is positive; that is, the management actions are preferable according to the decision criteria discussed in Section 3.1.4.

**Step 7: Conduct a sensitivity analysis**

Seventh, one should conduct a sensitivity analysis to not only incorporate uncertainties but also check the robustness of analytical results. There might be uncertainties about the impacts—benefits and costs—of management actions, that were predicted in Step 4, or about the discount rates used in Step 6. To incorporate the uncertainty with respect to the discount rates, an analyst should recalculate net benefits, using different rates. If net benefits still remains positive (or negative), one can be confident about supporting (or opposing) the proposed management actions.

For example, consider using different discount rates that are either slightly higher or lower than the original 3-percent discount rate. Table 3.3 shows estimated discounted net benefits or NPVs in the example with the following three different rates used: 1, 3, and 5 percent. In this example, the signs of net benefits for all three discount rates are positive. That is, an analyst can conclude with confidence that the proposed management actions make sense economically.

**Table 3.3. Sensitivity analysis results: Net present value of management actions from a hypothetical case (Units: USD thousand)**

| | Net present value | | |
|---|---|---|---|
| Year | r = 1% | r = 3% | r = 5% |

| | | | |
|---|---|---|---|
| 0 | -1,000 | -1,000 | -1,000 |
| 1 | 5,248 | 5,146 | 5,048 |
| 2 | -980 | -943 | -907 |
| 3 | -971 | -915 | -864 |
| 4 | -673 | -622 | -576 |
| 5 | -666 | -604 | -548 |
| 6 | -188 | -167 | -149 |
| 7 | -187 | -163 | -142 |
| 8 | -185 | -158 | -135 |
| 9 | -183 | -153 | -129 |
| 10 | -181 | -149 | -123 |
| **Total** | **34** | **272** | **474** |

**Step 8: Make recommendations**

Lastly, one should prepare recommendations based on the results of cost-benefit analyses. Following the decision criteria discussed in Section 3.1.4, an analyst should recommend that decision-makers adopt management actions with a positive NPV (or with the largest NPV), or dismiss the actions with a negative NPV (or with small NPVs). Explaining the methodology and data processing used in the analysis, the analyst should also present (as displayed in Tables 3.2 and 3.3) the flow of benefits and costs in addition to a summation of values (i.e., NPV) (U.S. EPA, 2000, p. 48). That would provide decision-makers with an opportunity to examine the validity and reliability of an estimated NPV(s).

## 4 Case studies

[TO BE PREPARED]

Mariculture: Cost-benefit analysis of reducing area for mariculture (change-in-production method)

Reclamation: Cost-benefit analysis of reducing area for reclaimed land (TCM and/or CVM)

## 5 Summary and conclusions

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