Guideline for Economic Analyses of Environmental Management Actions for the Yellow Sea

UNDP/GEF Project entitled
"Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem"

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UNDP/GEF PROJECT ENTITLED "REDUCING ENVIRONMENTAL STRESS IN THE YELLOW SEA LARGE MARINE ECOSYSTEM"

Guideline for Economic Analyses of Environmental Management Actions for the Yellow Sea

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Abstract

This guideline describes how to assess the economy of management actions to conserve marine and coastal resources. The guideline discusses the basics of environmental valuation, explaining economic value, negative externalities, and valuation techniques. The methodology of cost-benefit analyses is then discussed with the actions' benefits and costs defined and with the multiple-step analytical procedure explained. The guideline focuses on the Yellow Sea ecosystem, although most concepts and techniques that are discussed here may be applicable to other marine and coastal ecosystems in various regions. The relevant information for this guideline came from books, articles in periodicals, government documents, and publications by international organisations.

Table of Contents

List of Figures

List of Tables

Foreword

This Guideline was prepared under the UNDP/GEF Project entitled "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem," known as the YSLME Project.

The YSLME Project aims to promote the sustainable development of the Yellow Sea, reducing human-induced stress on its ecosystem. To achieve this goal, the Project takes an ecosystem-based approach, conducting a number of activities, including scientific research, policy planning, capacity building, and awareness campaigns.

The Project facilitates environmentally-sustainable management and use of the Yellow Sea by developing the Strategic Action Programme (SAP), a regional environmental strategy with management targets and actions. Given government endorsement, the SAP will contribute to not only conserving the Yellow Sea ecosystem, but also enabling people to continue benefiting from the abundant gifts and services that the Yellow Sea provides.

Economic analyses play an important role in the ecosystem-based management of marine and coastal resources in the Yellow Sea. The analyses help in ensuring that environmental policies and management actions are economically efficient and, therefore, that those actions could attain expected results in a cost-effective manner. The analyses will greatly contribute to improving ecosystem management. It is expected that the economic analyses, in particular the cost and benefit analyses, would become important management tools to evaluate the impacts of management actions to be implemented in the marine and coastal areas of the Yellow Sea.

I believe that this Guideline will be useful for all those who deal with marine and coastal development and management in the Yellow Sea as well as in other regions.

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Guideline for Economic Analyses of Environmental Management Actions for the Yellow Sea

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 these problems (YSLME, 2005b, Annex IV, p. 3). To mitigate these environmental problems, the UNDP/GEF Project entitled "Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem," known as the YSLME Project, was launched in 2004.

Bordering three countries: the Democratic People's Republic of Korea (DPRK), the People's Republic of China (China), and the 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,[1] 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 the suggested management actions. The actions are examined in terms of their technical, economical, and political suitability and viability. Cost-benefit analyses are employed as tools to assess the economic feasibility of the actions.

1.2 Topics

This Guideline provides practitioners of marine and coastal environmental conservation 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 books and articles from the

[1] Primary productivity is the amount of carbon fixed by photosynthesis. In the oceans, this is mainly due to the growth of micro-algae or phytoplankton.

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 writings available for cost-benefit analyses of environmental commodities, that introduce a variety of valuation methods and summarise earlier research 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 methodology: What steps should the analyses take? What data should be collected specifically? How should those data be analysed econometrically? How should analytical results be used for ecosystem management? This Guideline is composed to meet such a need by providing the step-by-step procedure of the analyses and by focusing on a few most important valuation methods.

1.3 Target audience

This Guideline targets a wide range of audiences, including not only economic researchers of marine and coastal environmental conservation, 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.[2] 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 use mainly the analytical results. 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 the literature cited in this Guideline.[3]

1.4 Organisation

The Guideline deals mainly 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 a detailed explanation about valuation techniques, providing hypothetical cases with numerical examples.

[2] Pindyck and Rubinfeld (1995) concisely explain the basics of multiple regression analysis, a means to fit economic relationship to observed data (pp. 659-667).

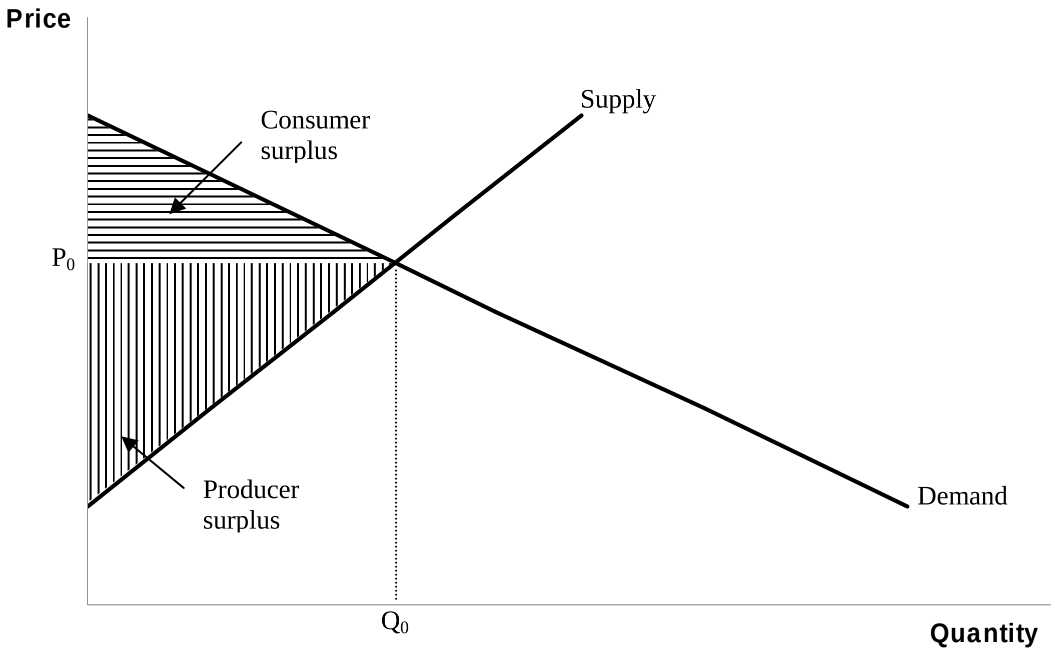
[3] Ecosystem Valuation, a website designed for non-economists, provides the basics of environmental valuation comprehensively (http://www.ecosystemvaluation.org/). The website also provides a useful link to a number of relevant websites.

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 analyses. The 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 1).



Source: Pindyck & Rubinfeld, 1995, p. 278

Figure 1: Economic value of goods and services

The downward demand curve is derived from consumer behaviour: Consumers are willing to buy more goods as their price becomes lower. The upward supply curve is derived from producer behaviour: 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).

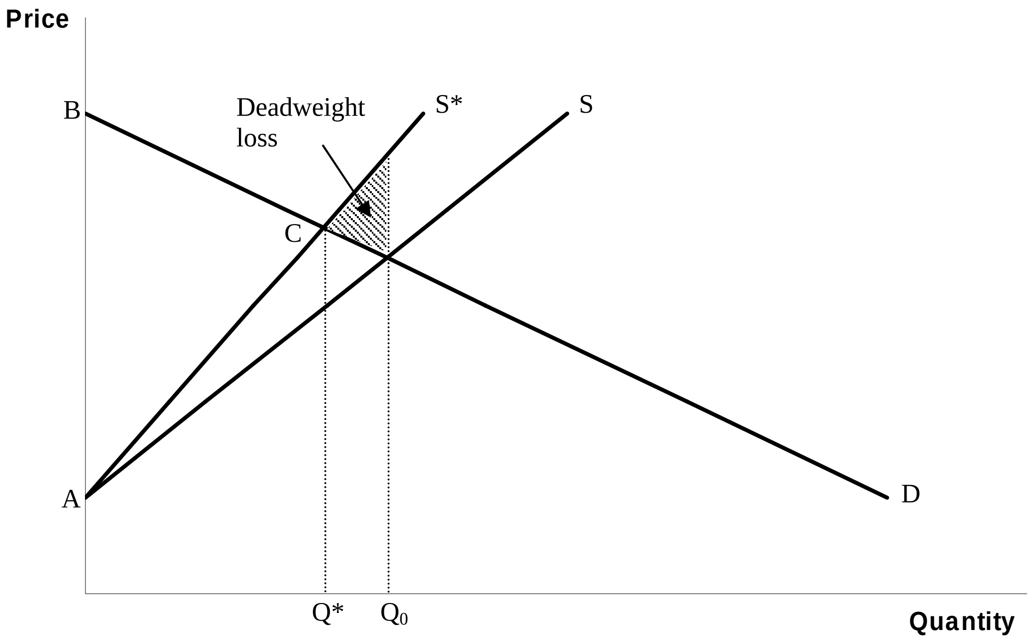
The economic value is maximised if goods are provided at the price and quantity when the demand curve and the supply curve for goods intersect; Figure 1 depicts such a condition. When the economic value is maximised, a society is well-off; in other words, social welfare is maximised, at least in terms 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 and so 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 not to cost the other party (or society) by avoiding excess production of goods, and therefore pollutants.

Figure 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*; then, 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 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 when the company does not consider 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 the company produced less steel in the amount of *Q**.



Source: Pindyck & Rubinfeld, 1995, p. 625

Figure 2: Deadweight loss due to negative externalities

2.3 Valuation techniques

Various techniques are available to measure the economic value of environmental goods. Table 1 summarises common techniques, classifying them into four categories: direct observable, direct hypothetical, indirect observable, and indirect hypothetical. All those techniques require collecting and analysing field data (i.e., primary information source). Meanwhile, there is an approach known as "benefit transfer" which uses "existing valuation information for one good or service to estimate the value of a similar good or service" (Abt Associates Inc. [AAI], 2005, p. 1-1). Unlike other techniques, the benefit transfer uses the findings of other existing studies (i.e., secondary information source); therefore, the benefit transfer requires less costs and time than other techniques.[4]

Table 1: Techniques for valuing environmental goods

Methods	Observed behaviour	Hypothetical
Direct	Market price Simulated markets	Contingent valuation
Indirect	Travel cost Hedonic property values Hedonic wage values Avoidance expenditures	Contingent ranking

Source: Tietenberg, 2003, p. 39

[4] This is part of the reason that the benefit transfer is widely practiced (AAI, 2005, p. 1-1). However, as Pagiola, Ritter, and Bishop (2004) point out, this approach is extremely controversial because it has often been used inappropriately (p. 22).

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 the 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. The focus is on the most appropriate techniques in the context of the Yellow Sea: the empirical technique (referred to often as the market price method or the productivity change method), the travel cost method, and the contingent valuation method.[5] Table 2 summarises those suggested techniques and their applications as described in detail below.

[5] Other methods such as the hedonic property value method are not discussed in detail 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. The detailed discussion of the benefit transfer, using values or functions estimated by existing studies, is also not provided in this Guideline for similar reasons.

Table 2: Suggested 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 good on the market 2. Analyse data statistically 3. Calculate consumer surplus and producer 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 2. Analyse data statistically 3. Calculate and aggregate consumer surplus	• Cost information associated with trip to target site • Wage information of visitors • Local government districts • Number of visits per person • Number of visitors	• Statistical technique: Regression analysis
	Contingent valuation method (dichotomous choice method)*	1. Collect data on willingness to pay 2. Analyse data statistically 3. Calculate and aggregate consumer surplus	• Individuals' willingness to pay • Population statistics	• Statistical technique: Logistic regression analysis • Survey via interviews

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

2.3.1 Empirical technique for 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 is collected as shown in Table 3. (This example is adapted from Lipton et al. [1995, pp. 33-40].)

Table 3: Demand and supply for commercial fish

Price/Cost (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

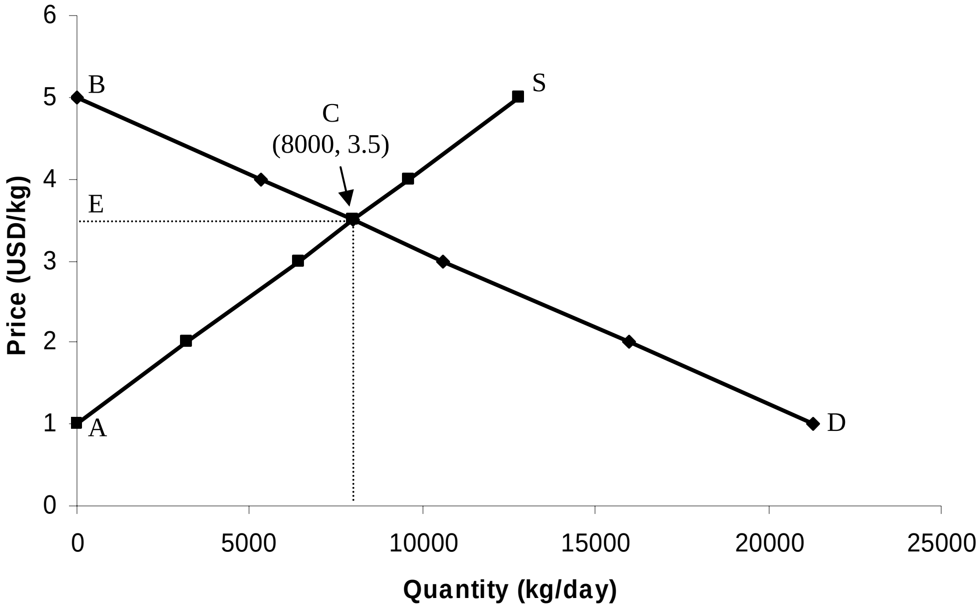
The price in USD and the demand in catch rate per day are those which generally prevail in the market (i.e., the price and quantity that prevail "on average" or when market conditions are "normal"). The supply is a quantity that is produced corresponding to the industry's marginal variable cost that 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.[6] 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). That is, there is an association with 95 percent confidence between the fish price and the quantity in demand for fish and between the marginal variable cost of fishing and the quantity in supply for fish. The reason that the significant level of those coefficients is high in this 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. Figure 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 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.

Economic value of commercial fisheries

= *Area ABC*

= *Consumer surplus (Area EBC) + Producer surplus (Area AEC)*

$$= (5-3.5)\times 8{,}000\times 1/2+(3.5-1)\times 8{,}000\times 1/2$$

[6] 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. 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).

$$= USD\ 16{,}000\ per\ day$$

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 Techniques for 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 (i.e., the travel cost of a sample of visitors);
(2) Analyse the collected data statistically to estimate an individual visitor's demand curve; and
(3) Calculate and aggregate the consumer surplus for visitors from different zones (i.e., extrapolate the consumer surplus for the sample to the entire population of the visitors).

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 gives the average total cost per person per visit.)
- Average number of visits per person per year; and
- Average number of visitors 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 (e.g., driving to the site, parking her car, and walking 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 travelling 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 4.

Table 4: 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 four other visitors is also collected as shown in Table 5. 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 4.

Table 5: Travel cost to a hypothetical recreational site (five sample visitors)

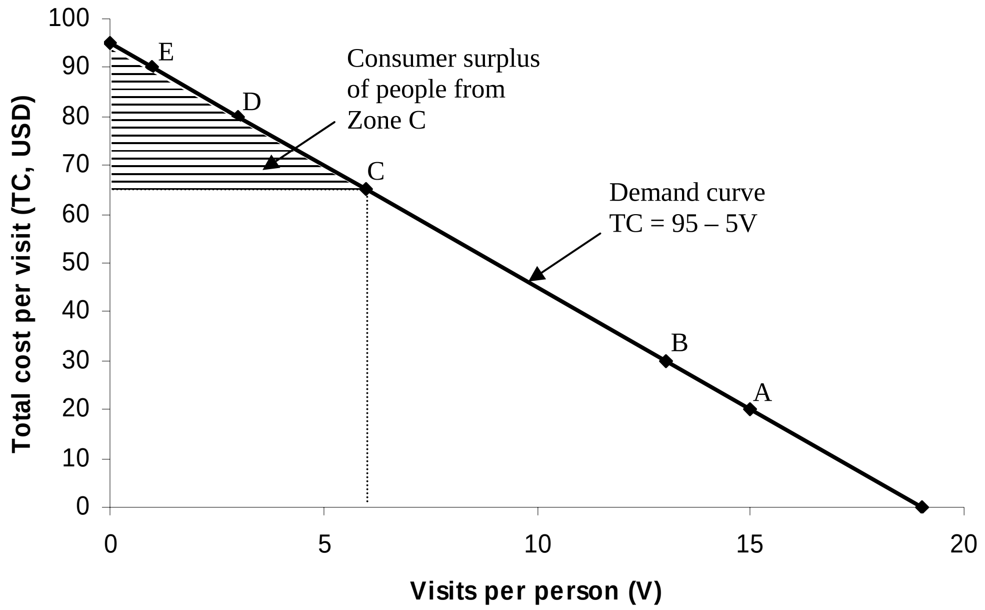
Zone	Travel time (hours)	Travel distance (km)	Average total cost per person per visit (USD)	Average number of visits per person per year
A	0.5	2	20	15
B	1.0	30	30	13
C	2.0	90	65	6
D	3.0	140	80	3
E	3.5	150	90	1

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. Figure 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 4: Estimated demand curve for a hypothetical recreational site

Third, using this figure, one can geometrically calculate consumer surplus for people from different zones as Table 6 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). (See Column 2 in Table 6.)

Table 6: Consumer surplus for a hypothetical recreational site

Zone	Average number of visits per person per year (1)	Consumer surplus per person per year (2)	Number of visitors per year (3)	Consumer surplus per Zone per year (USD thousand) (4) = (2) x (3)
A	15	562.5	10,000	5,625
B	13	422.5	10,000	4,225
C	6	90.0	20,000	1,800
D	3	22.5	10,000	225
E	1	2.5	10,000	25
			Total	11,900

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

If population statistics are provided (i.e., the number of visitors), one can estimate consumer surplus in each zone by multiplying the consumer surplus per person in each zone by its corresponding population (for example, the consumer surplus of Zone C is USD 1.8 million [USD 90 x 20,000 people]). (See Column 4.) 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. It is possible to estimate the total consumer surplus by deriving the market demand curve for the site. For more information about that, see Appendix 1 in this document.

2.3.2.2 Contingent valuation method (dichotomous choice method)

The contingent valuation method (CVM) estimates the economic value of environmental goods by using survey results on individuals' willingness to pay (WTP) for the goods. Providing plausible hypothetical scenarios (e.g., 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 consists mainly 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 individuals' WTP (i.e., the WTP of a sample of respondents from the population) for environmental goods (in the example, the coastal site);
(2) Analyse the collected data statistically to estimate the individuals' WTP; and
(3) Calculate and aggregate the WTP to reveal the consumer surplus of having the goods for the society as a whole (i.e., extrapolate the WTP for the sample to the entire population).

First, one should collect data on individuals' (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 a “bid price,” each 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 day 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)

The data from the example survey are shown in Table 7. 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 7: Sampled individuals' 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 individuals' 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. For more information about the logit model, see Appendix 2 in this Guideline.

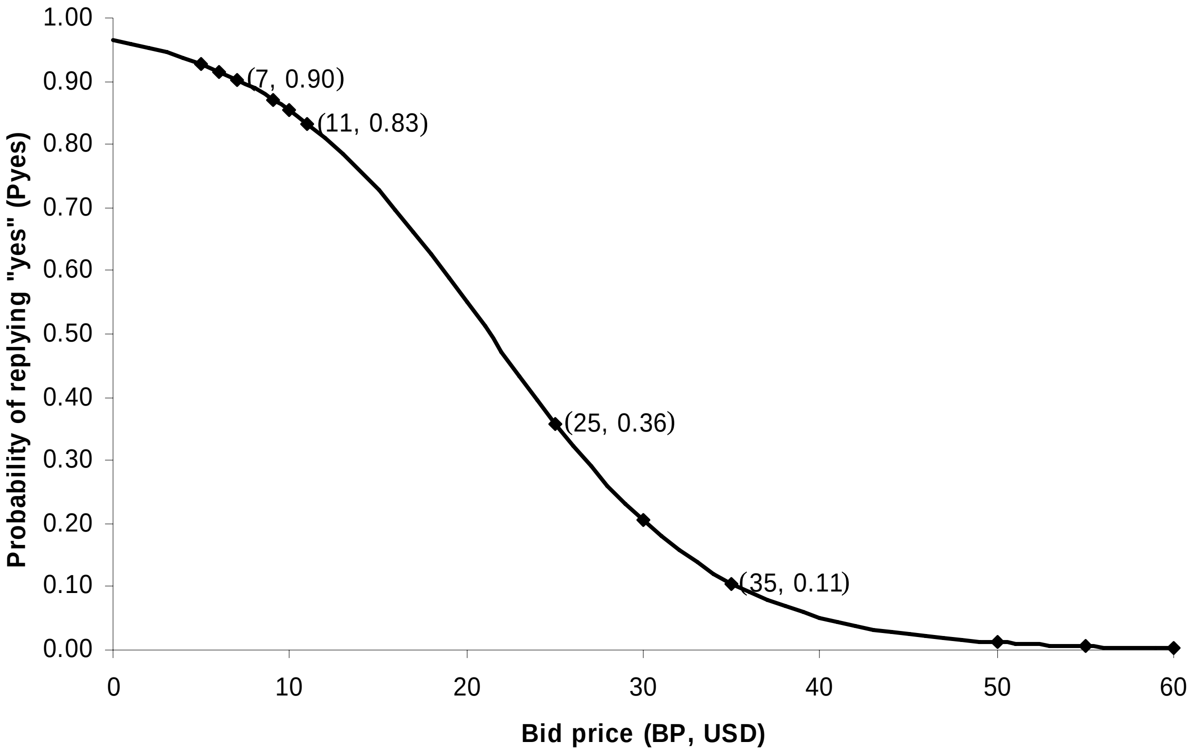
Using the logit model with the raw data in Table 7, one can estimate the individuals' WTP function as follows (Loomis, 1988, p. 211).

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

RY is the log of the odds ratio or the ratio of the probability that respondents would reply "yes" to given bid prices, *BP*, to the probability that respondents would reply "no." To estimate this equation, a statistical package is necessary. 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 individuals 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 individuals agreeing 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 5 shows the estimated logistic regression based on the data.



Source: Adapted from Loomis, 1988, p. 212

Figure 5: Estimated relationship between the bid prices and the probability for individuals to reply "yes" to 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 individuals' mean maximum WTP or the individuals' 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 individuals' consumer surplus for the site is approximately USD 21.5. See Appendix 3 for more information on how to calculate the individuals' 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 individuals' 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 the example, one would estimate the economic value of the site at approximately USD 6.5 million per year (USD 21.5 x 300,000 people = USD 6,450 thousand).

3 Cost-benefit analyses of environmental management actions

3.1 Basic framework of cost-benefit analyses

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., employ 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); one can recall that the supply curve of producing goods is modelled as a function of a producer's marginal variable cost (see Section 2.1). Figure 6, 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.

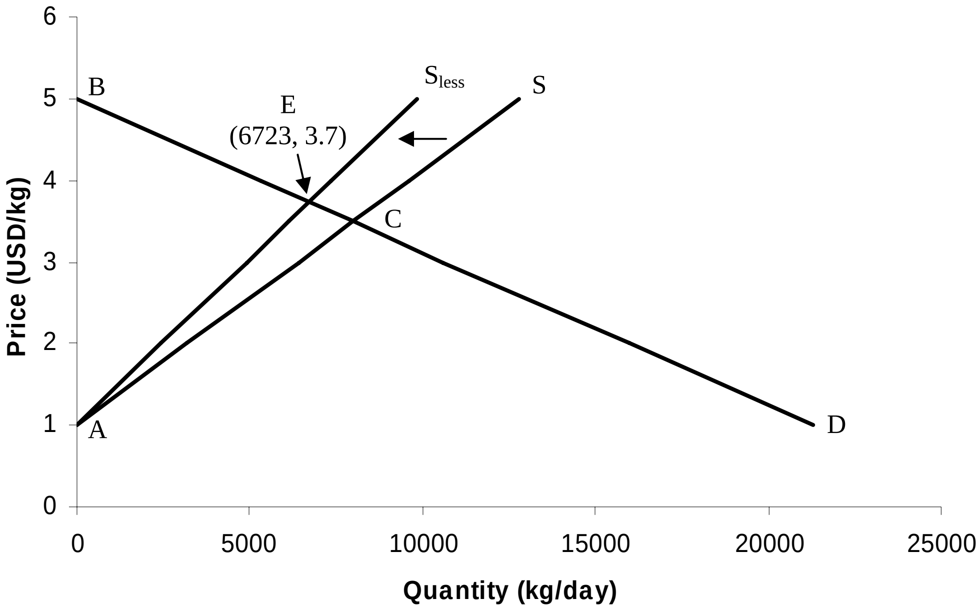


Figure 6: Shift in supply for commercial fish due to the decline in fish stock

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 the 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).

$$\begin{aligned}&\textit{Economic value of commercial fisheries with less fish stock}\\&\quad= \textit{Area ABE}\\&\quad= (5-1)\times 6{,}723\times 1/2\\&\quad= \textit{USD } 13{,}446 \textit{ per day (Area AEC)}\end{aligned}$$

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 the example in Section 2.3.2.1 decreases by 10 percent as water quality degrades. Table 8 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 8: 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)	Number of visitors per year	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 7 shows the shift in demand, due to water degradation, for recreational opportunities that the beach provides. D represents the original demand for the site, $TC = 95 - 5V$; whereas, D_{low} represents the reduced demand for the site due to low water quality, $TC = 95 - 5.56V$, 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).

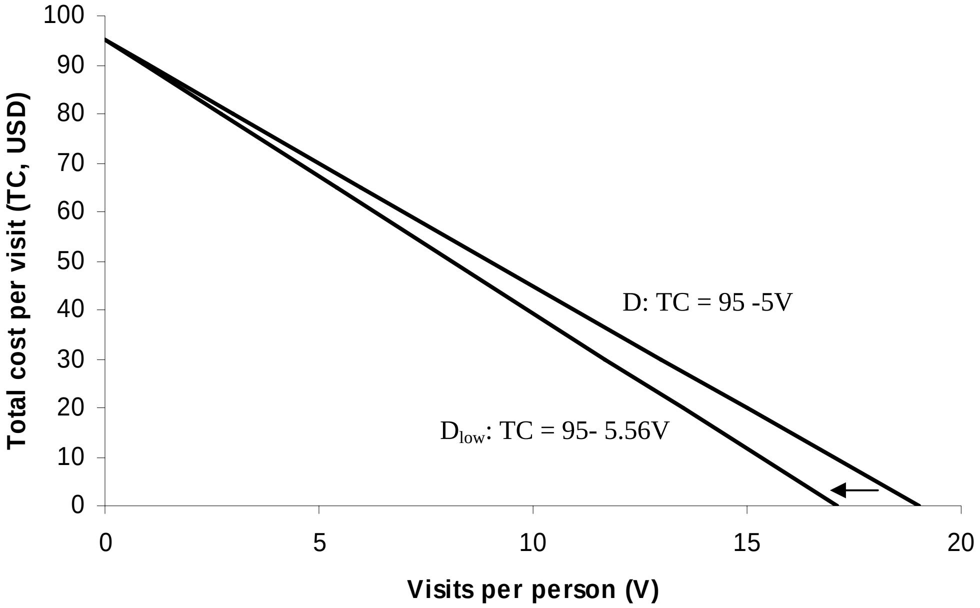


Figure 7: Shift in demand for a hypothetical recreational site due to water degradation

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. (See Section 3.1.1.) 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, seasonal/area fishing ban) 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 6 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.

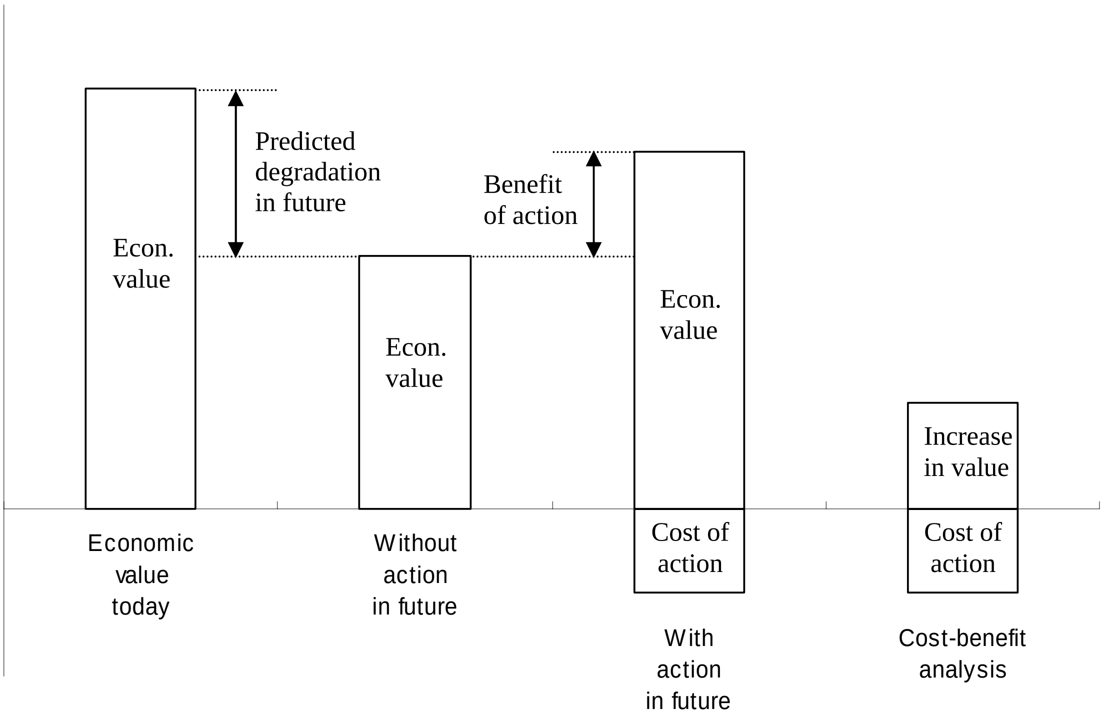
3.1.3 Cost of management actions

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 et al., 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 usages, 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 (Markandya et al., 2001, p. 144). 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. In the example of controlling the overexploitation of the fish (Section 3.1.2), the cost of management actions may include the following: the direct costs of establishing and enforcing laws and regulations, that include monitoring costs, and the opportunity cost of a fishing ban.

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 [compared] to what would have happened if they were not” (Pagiola et al., 2004, p. 19). The analyses then use 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 analytical 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 8 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 the value will decrease in the future because of environmental degradation; then, the value would be as shown in the next column to the right. This situation with decreased value 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 8: Cost-benefit analysis of environmental management actions

It is important to note that the cost-benefit analyses should compare the benefit and cost "with and without" the management actions, rather than "before and after" implementing them. In other words, the analyses do not compare the economic value today and that in the future with the actions. The reason for this is that 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 to other unaccounted factors (Pagiola et al., 2004, p. 19).

3.2 Procedure of cost-benefit analyses

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 sensitivity analyses; 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 a decline not only in coastal fish stock and catch, but also in beach bathing areas/opportunity. Considering the above situation, the local government decided to take management actions both to reduce the converted wetland area and to control pollutants from the industries on the reclaimed land. The government also decided to conduct a cost-benefit analysis of those actions to see whether they 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 the 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) to 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 modelling).[7]

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 9 summarises the benefits and costs expected as a result of taking the actions.

[7] Bioeconomic modelling might be useful to assess the economy of management actions such as fisheries management. Having developed a bioeconomic model for red grouper fishery, Kim (2003) evaluated the effect of management actions to recover fish stock, including a total allowable catch and a five-month closure period.

Table 9: Categories of expected benefits and costs of management actions to reduce hypothetical reclaimed land area

Benefit	Cost
Increase in the number of: • marine wildlife • coastal fish stock • beach tourists	Direct cost: • regulation cost (e.g., compliance monitoring and enforcing cost) • installation, operation, and maintenance cost of pollution controlling facilities Opportunity cost: • forgone future benefits if the reclaimed land area be 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 modelling 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 on 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 modelling 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 on 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 this 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 "crowd out" other investments (p. 270). U.S. EPA (2000) 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 (p. 48); Freeman (2003) supports this recommendation (p. 199).

Considering the rates suggested by the literature, this Guideline recommends 2 to 4 percent as a social discount rate for the cost-benefit analyses of environmental management actions. The Guideline also recommends conducting sensitivity analyses with respect to the discount rate. For more information about the sensitivity analyses, 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 10. It is assumed that the annual economic value of increased marine wildlife, coastal fish stock, and beach tourists would be USD 6,450 thousand, USD 300 thousand, and USD 1,200 thousand, respectively, following the examples discussed in this Guideline. (See Section 2.3.2.2 and Section 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 2, Table 10) is the sum of the increased economic values, while the total cost (Column 1) 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. Supposedly, it would take one year to establish the proposed industries; therefore, the forgone future benefits from them would accrue from the second year and onwards. The net benefit is the difference between the total benefit and the total cost (Column 3 and 4).

Table 10: Benefits of management actions from a hypothetical case

	Cost			Benefit				Net benefit	
Year	Direct cost	Oppor-tunity cost	Total cost (1)	Marine wildlife	Fish stock	Beach tourists	Total benefit (2)	Undis-counted (3)	Dis-counted (r=3%) (4)
0	1,000	0	1,000	0	0	0	0	-1,000	-1,000
1	1,000	0	1,000	6,450	0	0	6,450	5,450	5,291
2	1,000	7,500	8,500	6,450	0	1,200	7,650	-850	-801
3	1,000	7,500	8,500	6,450	0	1,200	7,650	-850	-778
4	1,000	7,500	8,500	6,450	300	1,200	7,950	-550	-489
5	1,000	7,500	8,500	6,450	300	1,200	7,950	-550	-474
6	500	7,500	8,000	6,450	300	1,200	7,950	-50	-42
7	500	7,500	8,000	6,450	300	1,200	7,950	-50	-41
8	500	7,500	8,000	6,450	300	1,200	7,950	-50	-39
9	500	7,500	8,000	6,450	300	1,200	7,950	-50	-38
10	500	7,500	8,000	6,450	300	1,200	7,950	-50	-37
Total	8,500	67,500	76,000	64,500	2,100	10,800	77,400	1,400	1,552

Unit: USD thousand

The total net benefits are different depending on whether they are discounted or not. In this example, both the net benefits (discounted and undiscounted) are positive. Discounted with the 3-percent interest rate, the NPV is approximately USD 1.6 million. In other words, the management actions are preferable according to the decision criteria discussed in Section 3.1.4.

Step 7: Conduct sensitivity analyses

Seventh, one should conduct sensitivity analyses not only to incorporate uncertainties but also to 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 remain 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 11 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 11: Sensitivity-analysis results: Net present value of management actions from a hypothetical case

	Net present value		
Year	r = 1%	r = 3%	r = 5%
0	-1,000	-1,000	-1,000
1	5,396	5,291	5,190
2	-833	-801	-771
3	-825	-778	-734
4	-529	-489	-452
5	-523	-474	-431
6	-47	-42	-37
7	-47	-41	-36
8	-46	-39	-34
9	-46	-38	-32
10	-45	-37	-31
Total	1,455	1,552	1,632

Unit: USD thousand

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 analyses, the analyst should also present (as displayed in Tables 10 and 11) 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 Summary

By analysing the benefits and costs of an action or a group of alternative actions, economic analyses help in deciding whether to implement a specific management action or deciding what management actions should be implemented in order to address environmental problems. As a result, environmental decisions or management actions will be efficient.

To measure the economic value of environmental goods, which is defined as the sum of consumer surplus and producer surplus, various techniques are available, including empirical technique, TCM, and CVM. The selection of the techniques depends on the characteristics of goods to be evaluated. If concerned goods are traded in the market, their market prices and trading volumes are useful to estimate the value of the goods. The empirical technique takes this approach. If the goods are not traded in the market, however, either the market information of relevant goods or the information of consumer preference surveyed for the goods would be applicable to estimate their value. A typical example of the former approach is the TCM; meanwhile, that of the latter is the CVM. The TCM uses the information on how much people spend to consume environmental goods as a proxy variable for their economic value. The CVM uses survey results on individuals' willingness to pay for the goods in order to calculate their value.

Cost-benefit analyses examine the economy or efficiency of a management action(s). The analyses compare the net benefits—the difference between gross benefits and costs—of management actions under two scenarios: with or without the actions. By definition, the gross benefits of the actions are the prevented future loss measured in economic value. The costs of the actions are the costs incurred to implement proposed actions. Given analytical results, it is logical to accept the proposed actions if the net benefits are positive, or to decline the actions if the net benefits are negative.

The procedure of a cost-benefit analysis consists of eight steps, including calculating the NPV of the gross benefits and costs as well as conducting sensitivity analyses. To calculate the NPV, it is recommended to use 2 to 4 percent as a social discount rate. It is also recommended to conduct sensitivity analyses with respect to the discount rate in order not only to incorporate uncertainties but also to check the robustness of analytical results. If the net benefits still remain positive (or negative), as a result of the sensitivity analyses, one can be confident about his/her conclusion to support (or oppose) the proposed management actions.

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Appendixes

Appendix 1: Consumer surplus estimated by market demand curve for the site

The consumer surplus for the recreational site in the example can be calculated by the following two steps (Boardman et al., 2006, pp. 358-359):

(1) Derive the market demand curve for the site, using the representative individual's demand curve; and
(2) Calculate the area under the estimated demand curve and above the admission fee.

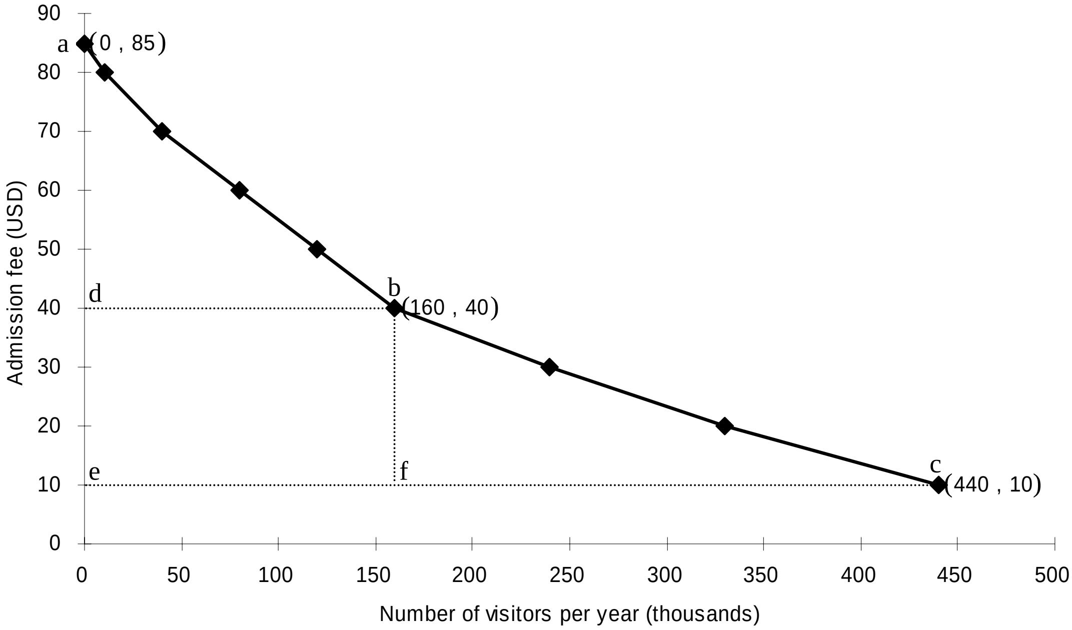
First, according to the individual's demand curve estimated in Section 2.3.2.1, the number of visits per person per year would decrease by 0.2 as $V = 19 – 0.2TC$ (the inverse of $TC = 95 – 5V$). That is, a ten dollar increase in travel cost per visit (*TC*), for example, would reduce the number of visits (*V*) by 2. Since the current admission fee is USD 10, if the fee were USD 20, the number of visits from Zone A would be 13 (15 – 2 = 13). Similarly, the number of visits from Zone B, Zone C, and Zone D would be 11, 4, and 1, respectively. The number of visits from Zone E (1 – 2 = -1) would be considered as 0 because negative numbers of visits are not possible. With the number of visitors by zone considered, the market demand for the site with the 20 dollar admission fee would be 330,000 visits per year (13 x 10,000 + 11 x 10,000 + 4 x 20,000 + 1 x 10,000 + 0 x 10,000 = 330,000). Table 12 shows the market demand for the site with various admission fees. In this example, it is assumed that the fee be raised by 10 dollars. Figure 9 shows the estimated market demand curve based on the information of the fees and the visits described in Table 12.

Note that there would be no demand for the site (i.e., there is no visit) if the admission fee were USD 85. According to the individual's demand curve, the number of visits would be 0 when the travel cost per visit were USD 95. (See Figure 4.) Recall that the travel cost per visit includes the admission fee which is currently USD 10. That is, the representative individual would be willing to pay USD 85 at a maximum for the site (95 – 10 = 85).

Table 12: Market demand for a hypothetical recreational site

	Admission fee	10		20		30		40		50		60		70		80		85	
		Annual visits		Annual visits		Annual visits		Annual visits		Annual visits		Annual visits		Annual visits		Annual visits		Annual visits	
Zone	Population	Per person	Per zone*	Per person	Per zone	Per person	Per zone	Per person	Per zone	Per person	Per zone	Per person	Per zone	Per person	Per zone	Per person	Per zone	Per person	Per zone
A	10,000	15	150	13	130	11	110	9	90	7	70	5	50	3	30	1	10	0	0
B	10,000	13	130	11	110	9	90	7	70	5	50	3	30	1	10	0	0	0	0
C	20,000	6	120	4	80	2	40	0	0	0	0	0	0	0	0	0	0	0	0
D	10,000	3	30	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	10,000	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total			440		330		240		160		120		80		40		10		0

Note: * Thousand per zone



Source: Boardman et al., 2006, p. 359

Figure 9: Estimated market demand curve for a hypothetical recreational site

Second, the market consumer surplus can be measured by calculating the area under the estimated market demand curve and above the original admission fee (i.e., Area *abce*). For simplicity, suppose that the demand curve is linear between points *a* and *b* and between points *b* and *c*; then, the market consumer surplus for the site is estimated at USD 12.6 million per year as follows.

$$\begin{aligned} &\textit{Consumer surplus for a hypothetical recreational site} \\ &\quad = \textit{Area abce} \\ &\quad = \textit{Area abd} + \textit{Area dbfe} + \textit{Area bcf} \\ &\quad = (85-40)\times 160\times 1/2 + (40-10)\times 160 + (40-10)\times (440-160)\times 1/2 \\ &\quad = \textit{USD}\ 12{,}600\ \textit{thousand per year} \end{aligned}$$

In theory, the market consumer surplus estimated above should be the same as that estimated in Section 2.3.2.1. However, in this Guideline, the estimation in this section (USD 12.6 million) is more than that in Section 2.3.2.1 (USD 11.9 million); the former overestimates the market consumer surplus. The reason for the overestimation is that it is assumed in the above calculation in this section that the market demand curve consists of simply two straight line segments (i.e., line *ab* and line *bc*). If the area were summed with more segments assumed, the sum would be USD 11.9 million (D. L. Weimer, personal communication, March 30, 2008).

Appendix 2: Logit model

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 (e.g., respondents would be willing to pay or reply "yes" in the example in Section 2.3.2.2) 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 in the example, while β_1 and β_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 reply "yes" to given bid prices, X , in the example (Taromaru, 2005, p. 176).

Appendix 3: Individuals' consumer surplus estimated by CVM

The individuals' consumer surplus (i.e., the area under the estimated logistic regression function) in the example can be calculated by:

(1) Dividing the range of bid prices into equal segments of width *n* (e.g., *n* = 1) (Column 1 in Table 13);
(2) Calculating the probability of acceptance at each of these points, using the estimated logistic regression function (Column 6);
(3) Finding the average acceptance value for adjacent pairs of points (Column 7);
(4) Multiplying each of these averages by *n* (i.e., *n* = 1) (Column 7); and
(5) Summing all these products to get the estimate of the area (See the last row in Column 7).

According to the calculations, the area or the estimated individuals' consumer surplus for the site is approximately USD 21.5.

Table 13: Estimated individuals' consumer surplus for coastal site rehabilitation

Bid price (USD) (1)	Response (2)	logit(p) (3)	exp(logit(p)) (4)	1+exp (logit(p)) (5)	p^=exp(*)/ (1+exp[*]) (6)	Area (7)
0		3.321	27.688	28.688	0.965	0.962
1		3.165	23.689	24.689	0.959	0.956
2		3.009	20.267	21.267	0.953	0.949
3		2.853	17.340	18.340	0.945	0.941
4		2.697	14.835	15.835	0.937	0.932
5	1	2.541	12.692	13.692	0.927	0.921
6	1	2.385	10.859	11.859	0.916	0.909
7	1	2.229	9.291	10.291	0.903	0.896
8		2.073	7.949	8.949	0.888	0.880
9	1	1.917	6.801	7.801	0.872	0.863
10	1	1.761	5.818	6.818	0.853	0.843
…	…	…	…	…	…	…
55	0	-5.259	0.005	1.005	0.005	0.005
56		-5.415	0.004	1.004	0.004	0.004
57		-5.571	0.004	1.004	0.004	0.004
58		-5.727	0.003	1.003	0.003	0.003
59		-5.883	0.003	1.003	0.003	0.003
60	0	-6.039	0.002	1.002	0.002	
					Total area	21.501

Note: The log of the odds ratio (Column 3) is calculated, using the estimated individuals' WTP function (i.e., $RY = 3.321 - 0.156BP$; see Section 2.3.2.2 in this Guideline).