MODULE 9

ECONOMIC VALUATION OF NATURAL RESOURCES AND THE ENVIRONMENT

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9.1 ECONOMIC VALUES AND VALUATION

9.1.1 Total Economic Value

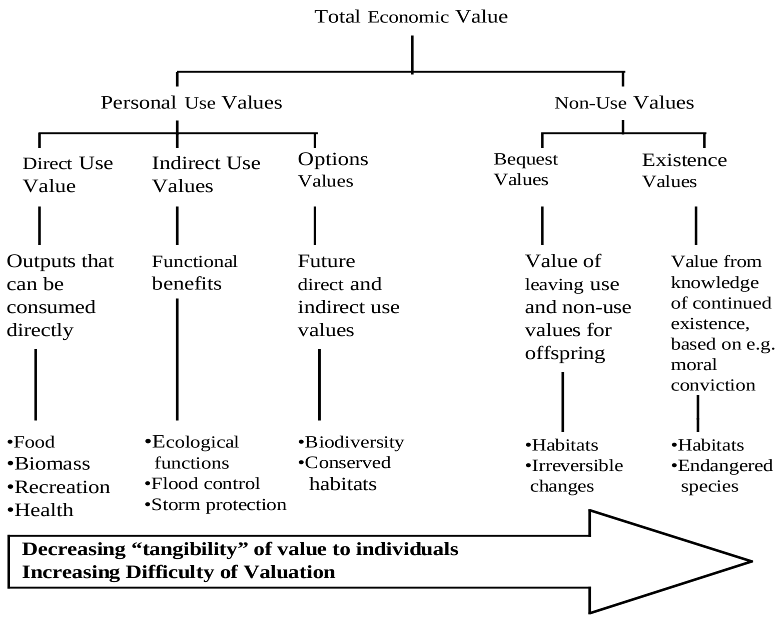
Economists use a taxonomy of values for natural resources and the environment. Total economic value encompasses both use value and non-use value (Figure 9.1). Use values not surprisingly, are those derived from the benefits people gain from using the resource and environment. These are classified into direct and indirect use values. Direct use values arise from the consumption of the resource, for example fuelwood or recreation. Indirect use values refer to the functional or ecological service benefits generated by the environment. People benefit from these but do not directly consume them. Values include recreation and flood control function provided by a forest.

Non use values are important to people even though the resource is not directly or indirectly used. One component is the bequest value, which is preserving the resources and the environment for other generations. People may value being able to pass on certain natural resources or environmental function to their children. Another component is existence value where people value just knowing that a natural resource or environmental function exists, even though they may never see or use it. A good example is the campaigns in the west to raise money for Black Rhino protection programmes in southern Africa. People donate money to save the species even though they may only see it in books or on television.

The last component, option value, cuts across both use and non-use values. This is the value of keeping options open to generate use and non-use values in the future. A development project could destroy unique habitat that has high potential tourism and ecological service functions (use values) that can be passed on to future generations (non-use values). A decision to not approve the project could be based on the option values at risk. By not proceeding with the project, society maintains the option of generating other use and non-use values in the future.

It should be noted that the values represented by use value in the left-hand side of Figure 9.1 are more easily derived and tangible. Policy makers can understand the value of forest production, or water quality. Direct use values in particular are also fairly easy to estimate. Moving towards the right-hand side of Figure 9.1, values become more difficult to grasp and measure. In theory, valuation should strive for total economic value, however in practice, economists have to settle for a partial measure.

Figure 9.1: Total economic value



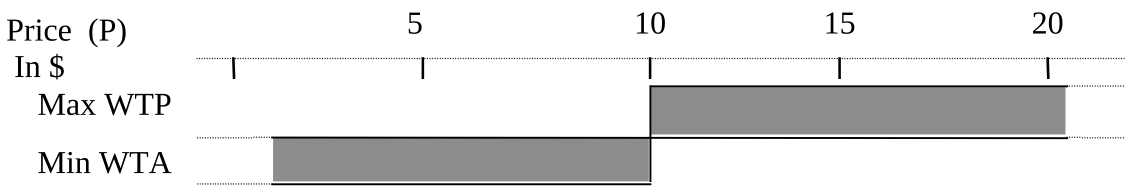
9.1.2 WTP/WTA[1] as a Measure of the Economic Value

The valuation of a natural resource or environmental service is usually based on the monetary value individuals place on it. The maximum amount of money an individual is willing to pay for obtaining a benefit or avoiding a loss in most situations reflects the preferences for such a benefit or loss[2]. Preferences are based on the values he or she attaches to the goods or services in question. The maximum willingness to pay (WTP) can be considered therefore an expression of the individual's values. Analogously, the minimum Willingness To Accept (WTA) an amount of money as compensation for giving up a benefit or for receiving a loss reflects the value of such a benefit or loss. As an example, we might be interested in estimating the aggregate WTP of people to maintain the environmental quality and amenity benefits of Victoria Falls in Zimbabwe. Alternatively we could estimate the WTA compensation where a development project might compromise these values, by changing the water flow upstream or damaging the rain forest along the Falls.

[1] WTP = Willingness to pay, WTA = Willingness to Accept.

When an individual buys an asset at the market price, the price paid directly reveals a lower bound of his maximum willingness to pay. Our willingness to pay for such an asset is "at least" equal to the price paid. For example, if we observe an individual paying 10 dollars for a kilo of sugar, this means that he or she was willing to pay at least that much, otherwise they would not have bought it at that price. When someone sells an asset at the market price, the amount of money received directly reveals an upper bound for his or her minimum willingness to accept for giving up such an asset (Figure 9.2).

Figure 9.2: Price as lower bound maximum WTP and upper bound minimum WTP



A kilogram of sugar is traded at P=$10. It means that the lower bound to Max WTP to get a kilo of sugar is $10. Besides, $10 is the upper bound to Min WTA to give up a kilo of sugar.

Where an asset has no market, obviously there is not a market price that reveals the lower bound of individual's maximum WTP and the upper bound of the minimum WTA. When evaluating WTP or WTA for obtaining a money measure of the value individuals attach to non-marketed assets, we have to get this information in alternative ways. These "alternative ways" are the techniques presented in the following sections in this module.

9.1.3 Classification of Valuation Techniques

a) Background

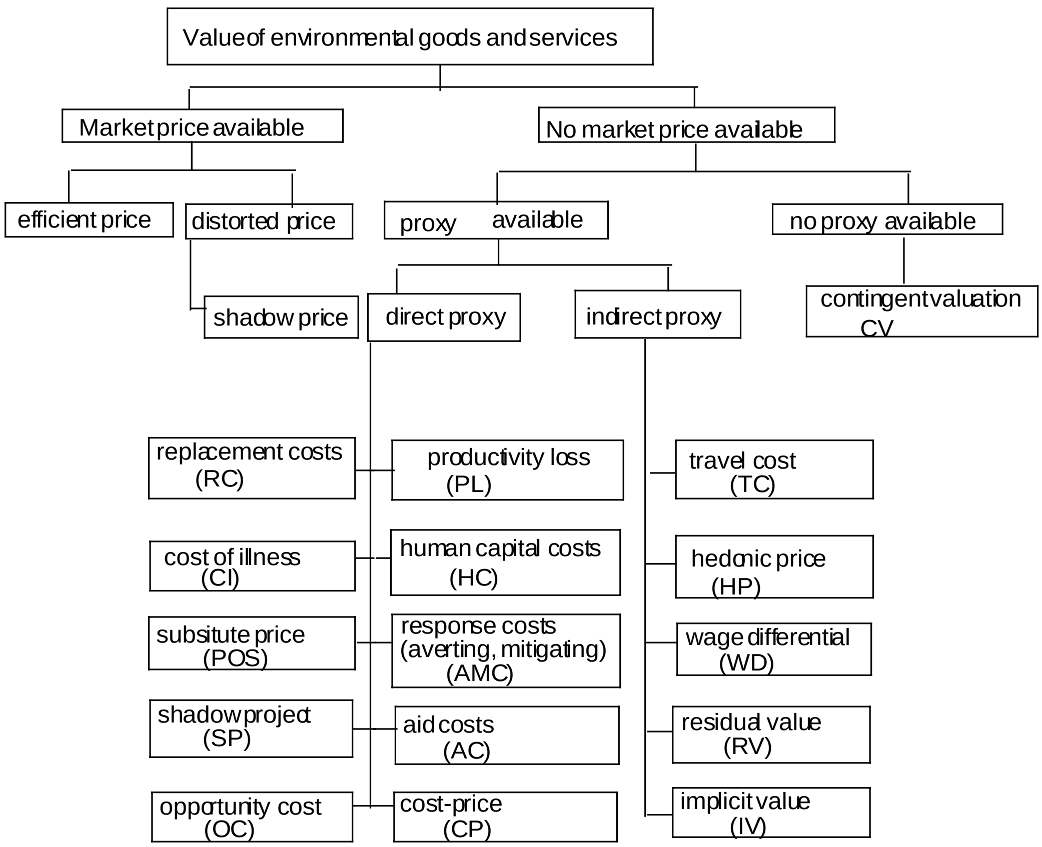
All valuation techniques attempt to get at WTP/WTA but some are better than others in terms of results. A number of techniques for placing a value on non-marketed environmental goods and

[2] It is common sense to say that if we are willing to pay more for the asset A than for the asset B, then we prefer A to B.

services are available. A simple taxonomy is provided in Figure 9.3 based on whether or not a market price is available. As with Figure 9.2, the complexity of the method increases as one moves to the right. The CV method, for example, is placed at the extreme right because it is the most complex method. But, it is also the only method that allows incorporates non-use values, thus providing the closest estimate of total economic value.

Were a market price exists, this must be the basis of valuation. If markets are distorted, shadow pricing might be required to improve the measure of value. This concept was described in module 8. Where no market price exists, a proxy value may be available. Alternatively, where no proxy is available, a measure of value will have to be derived using more complex methods.

Figure 9.3: Taxonomy of valuation methods



b) Direct proxies[3]Direct proxies to estimate environmental impacts do not reflect the full WTP/WTA. These methods involve cost or price information, which approximate values of environmental assets. The advantage of using costs or market prices as proxies for WTP/WTA is that they are easily observable. Market equilibrium prices are an acceptable base for applying these techniques if markets of the goods and services involved are competitive and for small changes in their demand and supply. The actual costs incurred as a result of environmental degradation can represent the minimum benefits from avoiding environmental impacts.

Examples of direct proxies include:

- The loss of agriculture productivity from soil erosion (productivity loss);
- Medical expenditure due to air pollution (cost of illness);
- An ill person or premature death from air pollution (human capital cost);
- Averting or mitigating environmental impacts (response/preventative cost);
- Replacing environmental goods or services (replacement costs);
- An environmental aid project such as grants and donations (aid costs) ;
- The reconstruction of an environmental good (shadow project);
- Cost per unit of output (cost-effectiveness); and
- A close substitute (substitute costs).

All these proxies can be considered opportunity costs of environmental assets Furthermore, different costs of the same impact can also value different functions of an environmental good or service. For example, the cost of illness, human capital and productivity loss, are often complementary in that each reflects a specific aspects of a healthy life. If all three approaches are used to value the different facets of human health impact, one has to be cautious not to double count.

c) Indirect proxies Indirect proxies for environmental goods and services are based on the observed behaviour of individuals with respect to related markets. The **Travel Cost Method** (TCM) derives the value of a recreational site from revealed information on the time and costs

[3] All these methods will be discussed in more detail in subsequent sections in this module.

people spent to get there. **Hedonic** prices infer the value of an environmental attribute from the price of a related market good. For example, the noise associated with a particular residential area will be reflected in lower land and real estate value, everything else being constant. The wage in a safe and quiet factory is expected to be lower than in a dangerous and noisy factory producing the same quantity and quality products. The **residual value** method derives the net price of a natural resource by deducting all the costs from the finished product price. An **implicit value** is obtained from a reverse analysis (bottom-up analysis) similar to the residual approach but for a project instead of a specific good or service. For example, a project to establish sustainable forestry management for charcoal production may have a negative net present value. The value of environmental benefits associated with the project to make the NPV positive or equal to a desired rate is the implicit value.

While the indirect proxy methods involve more calculation they will not necessarily provide better estimate of WTP for environmental goods and services than the direct proxies. They have the advantages however, of relying on observed behaviour and existing market prices directly related to the environmental attribute being valued. These valuation methods are more costly, time consuming and require skilled analysis. Yet, if information is available and the analysis done properly, these methods should provide a better approximation of WTP than the direct proxy approaches.

d) No proxies Where no proxies are available, the **Contingent Valuation Method** (CVM) is the best valuation approach. It consists of asking people directly, via a questionnaire or experimental techniques, what they would be willing to pay for a benefit or what they would be willing to receive as compensation for a deterioration of their environment. The questionnaire simulates a hypothetical (contingent) market of a particular environmental good in which individuals (demand side) are asked to state their WTP/WTA for a change (improvement or deterioration) in the provision (supply side) of the good in question. The questionnaire has to provide the institutional context in which the good would be provided and on the payment vehicle. CVM may apply equally to changes in public goods such as air quality, landscape or the existence values of wildlife, as to goods and services sold to individuals, like water supply and sanitation. It may apply to both use and non-use values which was not the case for the "proxy" techniques.

A challenge in developing countries is to modify the technique for cases where people have little income to base a WTP question on.

9.1.4 Choice of Valuation Techniques

The choice of the proper method will depend on each situation, the information readily available, the time and budget available, and level of expertise. Many different environmental issues may exist in a country. Most environmental impacts can trigger further impacts on the following four welfare relevant issues: productivity of economic activities, health, amenity, and existence. Soil erosion will decrease agriculture productivity. Deforestation may affect not only soil productivity but also amenity and existence values by destroying the landscape and habitat of endangered species. Air pollution can have an impact on productivity (impact on trees and crops, and corrosion of buildings), health (morbidity and mortality), and amenity (dirt, visibility). Table 9.1 relates the environmental impacts with the welfare issues. It then suggests the appropriate valuation methods for each welfare-related issue.

Table 9.1: Environmental impacts, welfare issues, and relevant valuation methods

	Welfare Related	Issues		
	Productivity	**Health**	**Amenity**	**Existence**
Environmental Impacts ⇗				
Green (natural resources)				
Soil erosion and fertility	x			
Land degradation	x		x	x
Desertification	x			x
Salinisation	x			
Deforestation	x		x	x
Loss of habitats (inc. wetlands)	x		x	x
Wildlife	x			x
Depletion of finite resources	x			
Brown (pollution)				
Air pollution	x	x	x	
Waste disposal	x	x	x	
Hazardous waste	x	x	x	
Congestion, noise	x	x	x	
Blue (water-related)				
Groundwater depletion, and pollution contamination	x	x	x	
Surface water pollution	x	x		x
Marine environment	x		x	x
Overfishing	x			x
Red (Social aspects)				
Resettlement	x		x	x
Community disruption	x	x		
Indigenous threat				x
Global				
Global warming, ozone layer	x	x	x	x
Biodiversity, species loss	x		x	x
	⇩	⇩	⇩	⇩
Possible Valuation Methods	productivity change (PC) response costs (AMC) shadow project (SP) replacement costs (RC), Substitution price (POS)	human capital (HC) or cost of illness (CI) response costs (AMC)	contingent valuation (CV) travel cost (TC) hedonic pricing (HP)	contingent valuation (CV)

9.2 DIRECT PROXIES

9.2.1 Productivity Change

In this approach, the environmental attribute (soil stability, water quality, and so forth), is considered as an input in the production function which relates the output of a particular marketed good or service (for example agricultural production, fishing catches) to the inputs necessary to produce it.

The production function will be of the type: $Q = f(X,v)$

where: X is the environmental attribute

v indicates the other inputs and factors.

The change in Q due to a small (unit) change in X is approximated by $\vartheta Q/\vartheta X$. The valuation of this change at the market price of the good Q can be assumed as an approximation of the value of the unit change in the environmental quality X.

This consideration holds only if:

- No other cost of production is incurred by the producers; and
- No change in the price of the good X are induced by the change in the quantity of the good (the producers are price takers).

Let us relax the first assumption by considering that some additional costs are incurred. In this case the output price will not be changed but the supply curve will shift downward and the benefit will accrue to the producers. Benefits can be measured by observing the changes in profits and fixed factor incomes, in other words, the variation of output net of additional costs incurred for its production. If the second assumption on price constancy is relaxed, the supply curves of the producers (the aggregate supply curve) will shift downward causing a fall in the prices and an increase in the output Q. The benefits will accrue certainly to the consumers and only eventually to the producers. In this case the appropriate methods to value the environmental change are those based on Consumer Surplus estimation.

Consider for example, a soil protection project where it is expected that the reduction of soil erosion will increase the crop production. Two possible scenarios can be considered here:

- The farmers can react to the reduction in the soil erosion situation by modifying cultivation practices or by applying lower quantities of organic and inorganic fertilisers. Supplies of agricultural crops may increase as a consequence. Moreover the prices of agricultural crops may decrease because of changes in crop supplies. In this case, the change in the environmental attribute will have an effect on the market equilibrium price and, as a consequence, on the consumers' welfare and producers benefits.

- The changes in crop production determined by the reduction of soil erosion do not affect the market equilibrium prices. In this case only the producers' welfare will be affected and the environmental benefit of the project is the additional net benefits in terms of crop production generated by the reduction of soil erosion.

The use of the production function approach can be very complex in the first scenario in that it implies the knowledge of the effects of changes in the environmental good or service on the cost of production, the supply of outputs, the demand for Q, and factor supplies. The second scenario is the one usually assumed when productivity change method is used. An example of how productivity change has been applied in real life projects is provided in Box 9.1[4].

The soil erosion example in Mali illustrates the use of the USLE as a dose-response and the use of a damage function. Soil erosion is valued from crop response. In the USLE, estimates of soil loss (Sl) is a function of rainfall erosion intensity (R), the erodibility of soils (K); the slope of land (S); a crop factor (C) which measures the ratio of soil loss under a given crop to that from bare soil, and conservation practice (P) with a value of 1 where there is no conservation.

Box 9.2 illustrates how productivity change can be quantified in practice by a simple with-without project analysis.

[4] Refer to Annex 1 for a detailed example of productivity change valuation

Box 9.1: Mali: The On-site Cost of Soil Erosion

This study attempted to put a value on the topsoil used up in agricultural production. The authors used the Universal Soil Loss Equation (USLE) to predict erosion and to estimate its effects on crop yields, before working through farm budgets into money values.

Mali is an African state located in the semi-arid Sahelian zone. Most of the population depends on various forms of agriculture and livestock, and the signs of ecological deterioration (reduced rainfall and river levels, loss of forest and pasture, reduced soil fertility and loss of plant and animal species) are potentially very serious.

Soil loss, in tons per ha, was assumed to be a reliable predictor of changes in soil nutrient content, soil pH and moisture retention, which account for almost all the annual variation in yields of maize and cowpeas. Data on the physical characteristics of land was obtained from a detailed atlas based on satellite images, containing data on soil, vegetation, rainfall, groundwater and land use on which detailed land categories were established to provide the essential information to the soil loss equations.

The USLE was used to predict erosion. Most climatic and soil data collected recently in West Africa were intended for use in the USLE and data available in Mali were easily adapted for this. Because of the positive benefits of deposition, soil loss on catchments known to receive significant alluvial deposits was discounted. The relation between erosion and crop yield was estimated using experimental data from Nigeria. Crop yields were, in turn, translated into farm incomes using farm budgets published by ICRISAT for comparable conditions in Burkina Faso. Farm income foregone from erosion was projected forward ten years and discounted at I 0 per rent results were grossed up for the whole of Mali.

The loss of soil on cultivated land was estimated to be an average of 6.5 t/ha/year for the whole study area, the highest loss being 30 t/ha/year in the southern zone where rainfall is high and the soil more erodible. The mean present value of farm income foregone over ten years as a result of one year of soil loss ranged from CFAF 2 000-8 000 per ha (average net annual farm revenues, excluding rice, were about CFAF 9 700 per ha). The sacrifice of future revenues from erosion was 2-9 percent of current farm income or $31 M (4 percent of farm GDP).

These losses were compared with the costs of various kinds of simple water harvesting measures, such as the construction of bunds and ridges, which conserve the soil and help conserve rainfall. The discounted total cost of these techniques was in the range CFAF 40 000 - 100 000. In many cases the present value of farm income foregone through erosion was greater than the cost of the cheapest conservation technique.

This very systematic study used a technique (the USLE) for which local data can be used, and for which erosion-yield relationships and farm budget data were obtained in neighbouring countries. No account was taken of off-site or wider environmental effects (though some adjustment was made for the positive effects of deposition on certain fields). The scale of soil erosion losses is becoming significant to the national economy, and justifies some conservation investment in the worst affected areas.

Box 9.2: Valuing the benefits of a Nepal hill forest development project

Several market values are adopted to value the effects of the project. The project was concerned with improved land-use planning, the improvement of 7000 hectares of timber stand, management of 16,000 hectares of scrubland, additional fencing to stop livestock damage, and 4000 hectares of afforestation for fodder, fuelwood and fencing timber. Its 'outputs" were increased fuelwood and fodder, higher land productivity and reduced soil erosion. To find the incremental productivity arising from the management progranune it was necessary first to estimate the value of output from land without the project. As an example, grazing land produces two products, milk and animal dung, which is used as fertiliser. Each animal produces 15 kg of nitrogen-equivalent and 2 kg of phosphorus - equivalent per year. Nitrogen is valued at 6 rupees/kg and phosphorus at 18 Rs/kg, so that one animal produces:
((15x6) + (2x 1 8)) Rs of fertiliser per year = 126 Rs. One hectare supports 0.0857 of an animal, so fertiliser production per hectare is 0.0857 x 126 = 11 Rs/hectare.

Output for Total Land Area (Rs million)

		With Project	Without Project	With - Without
Year	1	12.5	7.5	5
	2	5.3	7.2	-1.9
	3	10.8	6.9	3.9
	4	5.8	6.6	-0.8
	5	9.9	6.4	3.5
etc				
	40	21.7	1.6	20.1

The forest management project involved changes in land use. Hence the need was to value the output from each land use, and then to see what changes arose from (a) differences in value due to differences in land use, and (b) increased productivity on a given land use. The discounted value of the net benefit streams shown above was then compared to the discounted value of costs. The result was expressed as an internal rate of return of 8.5%.

Source: Dixon et al. (1994)

Scrubland and unmanaged forest produce fertiliser, milk and fuelwood. Fuelwood was valued in three different ways. First, it is sold on the market and the market price net of collection costs was 280 Rs per cubic meter. Second, the substitute for fuelwood would be animal dung. Dung could in turn be valued in several different ways, but the method chosen was to look at crop responses. Thus, I cubic meter of wood = 0.6 tons of dried manure -= 2.4 tons of fresh manure. Maize yields were estimated to rise by 15% because of applications of. 6 tons p.a. of fresh manure to **a** 0.5 hectare plot. Productivity of 1.53 tons of maize per hectare would rise to 1.8 tons/hectare, and maize output is worth 1200 Rs/ton, so the productivity gain is (1200 x (1.80 - 1.53)) = 324 Rs. Hence the value of a cubic meter of wood is: (324 Rs x 0.5 hectares)/6tons = 27 Rs/hectare for fresh manure = (27 x 2.4) Rs per cubic meter = 65 Rs/cubic meter . The third way fuelwood can be valued is at the time taken to collect it. Each family collects 7.92 cubic meters per year and spends 132 days doing this. At 5 Rs per day as the alternative income from other activity, each cubic meter of wood costs: (132 x 5)/7.92 = 83 Rs/cubic meter .

So by looking at each type of land, output can be calculated. When project interventions are envisaged, it is necessary to estimate output with the changed land use under the project, and compare it with output without the project.

9.2.2 Substitute Cost

In this method, the environmental attribute “X” is assumed to be a perfect substitute for a marketed input in the production function, at least over some range of the input use. In this case, an increase in X (the environmental good or service) will determine a reduction in the use of other inputs. If the technical rate of substitution is known, the valuation of the decrease in the use of the other input is straightforward. The reduction in the total cost of production can then easily calculated.

If the decreased use of input does not affect its market price or, if the effect on it is very small, the money saved using the environmental good instead of the factor input is the true measure of the benefits of the environmental good or service. Conversely, the effect on output and prices should also be accounted for. The procedure may vary according to the specific context of the project but the main steps are mostly those listed below[5] (Box 9.3).

Box 9.3: Steps in evaluation using substitute approach

1. Choose the closest market substitute **Xm** to the non-marketed good **Xn** on the following grounds: a) Consumer preferences (if the output is a final consumption good), and b) Technical relationships and observed habits of producers (if the good is an intermediate good).
2. Calculate the price of the traded good in the project area, **Pxm** either adding to the border price transport costs and margins to dealers (case of import substitute) or subtracting to the local market price the same component (case of locally tradable substitute).
3. Identify the differences between the two goods in terms of their substitutability, considering both their technical features and other characteristics, such as location, availability, and constraints.
4. Estimate the rate of substitution **Rs** of the non-marketed good with the marketed one, (value of the non-traded good in terms of the traded good) taking into account the technical features (inputs; e.g.: fodder - digestible energy content) or consumer preferences (final products, e.g. fresh milk) individuated in the previous step.
5. Multiply the price of the marketed good in the project area times the substitution rate:
   Pxn = Pxm ∗ Rs

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[5] Further case studies for this technique can be found e.g. in: "The Economics of Project Analysis. A Practitioner's Guide". Ward H.W. et al. Economic Development Institute of the World Bank, Washington D.C. 1991.

Annexure 2 provides a detailed case study of substitute analysis where the value of non-marketed forage is derived by estimating the market value of sorghum based on equivalent nutritional quantities.

9.2.3 Cost of Illness

Environmental pollution can affect health through mortality, morbidity or lower human productivity, and less perceived and subtle effects, such as the effects of vehicle exhaust lead on the IQ of children. Economic valuation implications of the various types of effects and categories of effects will vary. For example, environmental alterations leading to chronic physical effects will be valued differently from acute diseases or mortality effects. Morbidity or illness effects can be valued using two main approaches: the individual willingness to pay or accept for compensation, and the damage function approach or health production function.

This approach assumes that the effects of environmental change on health status can be valued in five main steps:

- Estimate the dose-response relationship between health status and environmental attribute;
- Measuring the effects of health on physical productivity;
- Placing a monetary value (market or shadow price) on the physical productivity change;
- Adding the ex post costs for medical care; and
- Adding the cost of averting measures (measures for reducing the probability of illness such as shots against flu) and of mitigation measures (measures for alleviating the impact of illness on productivity).

The dose-response model linking environmental attribute with health status has to be established first. This relationship is usually based on toxicological, micro epidemiological or epidemiological studies and in its simplified form will be of the following type:

$$R=r(P,V) \qquad (1)$$

where: R= days of illness; P= exposure to pollution; V= treatment and other mitigating activities that can be undertaken to reduce the health impact of any exposure to pollution[6]. Yet, exposure to pollution "P" depends on the concentration of pollution "C" and on averting activities "A" to avoid or reduce exposure (e.g., staying indoor on days of high pollutant levels. It follows that:

$P = p(C,A)$ (2)

and by substitution of "P" in function (1)

$R = r(C,A,V)$ (3)

with: $\partial R/\partial C > 0$ and $\partial R/\partial V, \partial R/\partial A < 0$

The dose-response model is usually estimated from regression analysis of illness on all the independent variables entering the function, such as pollution, averting and mitigating activities, plus other determinants of health status like socio-economic characteristics of individuals. Once the dose-response function is established[7], the other four steps illustrated in section will be undertaken to place a value on the environmental change. An example of application of this method is provided in Box 9.4.

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[6] The introduction of this variable in the function has been suggested by Freeman (1993) on the ground that mitigating activities can be chosen by the individual so as to maximize utility, and represents an extension of the Harrington and Portney model in which medical and treatment costs were assumed to be determined by the number of days spent sick.

[7] If the dose-response function R = f(C,A,V) is assumed to be linear, the model is specified as follows: $R = \alpha_1 C + \alpha_2 A + \alpha_3 V$ ...where the coefficient $\alpha_1 = dR/dC$ expresses the cause-effect relationship between pollution and the human health (measured e.g. in days of illness). If the model is assumed to be logarithmic, it is specified as follows: $\ln R = \alpha_1 \ln C + \alpha_2 \ln A + \alpha_3 \ln V$ ....and the coefficient $\alpha_1 = (dR/R)/dC/C = dR.C/R\ dC$ expresses the elasticity of the human health to pollution, i.e. the percentage increase in damage caused by each percentage point increase in pollution.

Box 9.4: Morbidity and air pollution

Ostro (1983, uses data from the Health Interview Survey of the US National Centre for Health Statistics, a database covering 50,000 households. The health data is then matched to pollution data and other information from other sources. Morbidity was measured by days off work - 'work loss days " (WLD) - and "restricted activity days' (RAD), i.e., days in which activity was restricted because of ill-health. Then WLD and RAD are regressed on various variables: indicators of chronic disease, race, marriage, temperature, population density, rainfall, cigarette consumption and work status. There were no variables for air pollution other than sulphur oxides and suspended particulates, nor anything for water quality or diet. The results, showing just the estimates for the two air pollution variables, were:

RAD = -0.83 + 0.00282 TSP - 0.00008 SULF...........

and WLD = -0.47 + 00.00145 TSP - 0.001 SULF............

In the equations, the sulphur coefficients were not significant, which means that sulphur concentrations are not implicated in morbidity. This bears out some earlier studies. The coefficients for TSP were significant and can be translated into 'elasticities', showing the percentage increase in morbidity for each percentage point increase in air pollution. The coefficients were 0.45 for WLD and 0.39 for RAD when expressed as elasticities. Thus, a 1% improvement in air quality would reduce working days lost by 0.45%.

The cost-of-illness method includes only the direct monetary costs associated with illness. These consist primarily of medical expenditures and income lost from the illness due to the environmental alteration and may incorporate averting and mitigation costs. It does not capture discomfort, physical and psychological and other costs, which can only be accounted for using the contingent valuation method. Moreover, it does not refer to chronic illness, which is a condition for which the human capital approach is deemed more appropriate. Back-of-the-envelope calculations of the economic costs of air and water pollution in Mexico were prepared for Mexico City (Box 9.5).

Box 9.5: Environmental Damage Costs In Mexico

A 1991 World Bank study on the cost arising from various environmental problems in Mexico employed the cost-of-illness approach to estimate air pollution costs. The study used damage functions - derived from both laboratory experiments and epidemiological studies done in the US - for air pollutants, including suspended particulate manner, ozone and lead, combined with local data on ambient concentrations and exposures to arrive at ballpark estimates of US$ 1.1 billion annually as likely costs of air pollution in Mexico City. This figure tends to be a lower bound estimate because it only includes direct costs such as medical expenses and lost wages, and not indirect costs of individual disutility (for example, discomfort, suffering, and the opportunity cost of time).

The study used a three-step procedure consisting of:
(i)determining the ambient concentrations of various pollutants;
(ii) given these concentrations and the age distribution of the population, using dose-response relationships to determine the incremental incidence of disease, including both morbidity and mortality, in the population; and
(iii) estimating the costs of the increase in morbidity and mortality, as measured by treatment costs, loss of wages and loss of life.

The costs associated with suspended particulate matter relate to restricted activity days (RAD) and increased mortality. The RAD in Mexico City due to suspended particulate matter is estimated at 3 days per person per year. If concentrations of total suspended particulates (TSP) were reduced to the legislated standard, RAD would be reduced by 2.4 days. This figure was calculated by applying US dose-response relationships to Mexican conditions. Thus, the cost of not meeting the legislated standards can be estimated by valuing the RADS. With an estimated population of 17 million (55 percent adult), and assuming that one-half of the RADs were also days of lost work, the total number of lost work days caused by not meeting air quality standards for suspended particulate matter in Mexico City is 11.2 million days (1 7 million people x .55 adults x 2.4 RAD x .5 LWD/RAD). Multiplying this by a typical wage of $4 per hour yields an estimated cost of US$ 358 million annually from lost work days by adults alone, not to mention the costs due to sickness of children and discomfort that does not result in lost work days.
In the case of excess mortality from exposure to suspended particulate, , dose-response relationships (also from the US literature) estimate that 6,400 lives are lost by not meeting legislated standards in Mexico City, and these lives are estimated to be cut short by an average of 12.5 work years. Using a human capital approach to value these lives, the discounted value of lost earning per person totals US$ 75,000, for a total cost from mortality at US$ 480 million. The total annual cost caused by excess concentrations of suspended particulate matter in Mexico City is thus estimated at US $850 million. The major health consequence of ozone pollution is related to RAD. A calculation for RAD caused by ozone (using the same methodology as for particulate matter) yields an annual cost associated with ozone pollution of US$ 102 million.
Lead pollution is associated with high blood levels in children, which can cause neurological damage, and with high blood pressure in adults which can cause cardiovascular disease. Since local data on these costs were not available, hospital, medication and treatment costs for children were assumed to be 1/15 of similar costs in the US. These unit cost estimates were multiplied by the number of cases predicted by the dose-response function to yield an estimated cost for children's treatment of US$ 60 million per year. Children with high blood lead levels also have slowed cognitive development and require compensatory education. Assuming that three years of supplemental education would be required for the estimated 140,400 children with high blood lead levels, and, with average annual education costs of US$153 per child in Mexico City, yields a total cost in compensatory education of US$ 21.5 million.
It is estimated that elimination of lead in Mexico City's air would also lead to a reduction of 70,422 cases of adult hypertension, and 498 cases of myocardial infarctions. The total costs associated with the hospitalisation and treatment of this illness and the value of lives lost is estimated at $48 million. The annual estimated health costs associated with lead atmospheric pollution above zero concentration levels in Mexico City are thus about US$ 125 million, with total costs of the three major air pollutants in Mexico City (TSP, ozone, lead) of roughly US$ 1.1 billion.

Source: Margulis, Sergio (1991)

9.2.4 Human Capital

The Human Capital approach estimates the value of the increased risk of chronic illness and mortality to one individual, due to environmental hazards. The valuation basis is usually the discounted present value of that individual's earnings over the remainder of his or her expected life [8]. The human capital approach is controversial because it attempts to place a monetary value to human life, which is not acceptable to many on ethical grounds. The value of life obtained with this method is based on the statistical estimation of a change in the probability of death due to an environmental change. In this sense, economists talk about the value of a "statistical life". Suppose that an envisaged industrial plant would increase the risk of mortality due to air pollution from 0.002 % to 0.003% in one year, over a zone where 1 million people live. This means that 1 more person over 100,000 would die within one year or 10 more deaths per year in the whole area. For project analysis purposes, the value of these lives could be obtained by discounting the flow of earnings (netted out of personal consumption expenditures) of these people over the remainder of their expected lives. Of course, to determine these flows, the analyst will take into account the labour participation rate, the average age and the average wage, gross of income taxes.

The same approach would hold in case of chronic diseases affecting the working capacity of individuals. Some examples of environmental hazards that can generate chronic diseases are: 1) lead in the air or drinking water impacting on the nervous system and intelligence quotient, which in turn translates into decreased earnings; and 2) air pollution causing asthma which in turn causes diminished productivity.

The Cost of Illness and Human Capital are generally used together, and both are based on the following steps:

- Determine the type and volume of emission for both point and non-point sources of pollution;

[8] The Human capital approach extends the use of the loss of earnings, already discussed as a component of the cost of illness method, to long term or chronic illness and mortality.

- Determine ambient concentration based on dispersion model or affective monitoring;
- Define the population at risk detailed by age, income and gender;
- Establish the dose-response function (mostly of non-linear type with exponential behaviour of responses);
- Establish the effects of morbidity and mortality on lost output and the requirements medical treatment; and
- Place a monetary value on lost output and add the cost of medical treatments.

An example is provided in Box 9.6 for both methods using air pollution damage in Jakarta, Indonesia.

Box 9.6: Air Pollution and Health in Jakarta

Jakarta, the capital city of Indonesia, has a population of 8-9 million and suffers serious air pollution. The component of air pollution that is studied in this case is particulate matter (PM). Two types are distinguished - total suspended particulates (TSP) and the more harmful finer particles PM10 (so called because it is particulate matter less than 10 microns in size). Pollution exposure is measured in micrograms of PM per cubic meter (m^3) of air. A TSP level of 100 converts to a PM 10 of 55.

No dose-response functions are available for Indonesia, hence the researchers use those estimated for developed countries, and assumed that the same relationships could be carried over. The coefficients were applied to local estimates of PM concentrations, and local data on mortality, admissions to respiratory hospitals, emergency room visits, RADS, respiratory illness of children, asthma attacks and chronic disease.

The central purpose of this study was to estimate the economic benefits of reducing TSP levels in Jakarta, currently ranging from 100 to 350 Mg/M3 in various parts of the city, to the national standard level 190 mg/m^3) and the WHO standard (75 Mg/M3). Using coefficients derived from USA and Canada, it as estimated that reducing PM to the national Indonesian standard level would avoid 1 200 premature deaths, and would save 2 000 hospital admissions, 40 000 emergency. room visits, and 6 million RADS.

The original study did not place economic values on these results. However, the information is presented in a form that can readily be converted into economic values, on certain assumptions. Both loss of working days and RADs are costed with reference to average wages, which are readily available The cost of medical care for different types of illness should also be available locally.

More contentiously, standard estimates of the cost of illness developed in the USA could be adopted, suitably scaled down, as a last resort. For instance, in the USA each respiratory hospital admission (RHA) is valued on average at $28 000, made up of a cost of medical care of $26 900 plus a wage rate for each of the 10 days lost of $125. If these data were used, considerable allowance would have to be made for the high medical costs in the USA and the much lower wage rates in Indonesia.

The same goes for the use of US "value of life" estimates. It is now quite common to use peoples' willingness to insure themselves against the risk of illness or death as a proxy for the value of life. Thus, if people would be willing to pay $300 to reduce their risk of death by a factor of 1 in 10 000, it can be inferred that they would value a death avoided at $3 million. Although widely used, this is nevertheless a controversial technique because (i) arbitrarily extends marginal valuations; (ii) the transfer of empirical values from countries as different as the USA and Indonesia is problematic.

Source: Dixon *et al*. (1994), Ostro (1994).

9.2.5 Replacement and Response Costs

Once a damage function has been established because of environmental changes, the costs incurred to put the environment back to its original state (as far as possible) are the replacement costs. This can occur either by recreating the lost environment on the same site or elsewhere (relocation costs). If the damages have not occurred yet (averting costs) or if it has already occurred (mitigation costs) and each person affected undertakes some defensive expenditures, these aggregated costs are called Response Costs. These costs are based on a subjective assessment of the environmental damages. As such, it can be seen as a surrogate demand for environmental value.

The replacement costs are usually a lower-bound estimate of the value of changes of the environment. The costs do not necessarily equal the benefits of preventing environmental degradation because individuals may hold a higher WTP for the environmental services restored than the actual costs reveal. The social costs of remedying an impact that have already occurred (replacement cost) are not the same as the costs of preventing the damage or loss in the first place. A soil erosion example is used to illustrate this method in Box 9.7.

Box 9.7: Case Study: Soil Erosion in Zimbabwe

An intensive erosion research programme in Zimbabwe was instituted during the period of the Federation of Rhodesia and Nyasaland between the years 1953 and 1964. The database is drawn from this source and covers 400 plot years of experiments conducted at the Henderson Research Station. A new model of soil loss estimation, SLEMSA (a modification of tie Universal Soil Loss Equation) was constructed for the specific field conditions of Zimbabwe.

The raw data consisted of sludge measurements taken from the collecting tanks on the erosion plots. This gave records of nutrient concentration in percent for nitrogen (N) and organic carbon, and parts per million for phosphorous (P). These three nutrients represent the major quantitative impact of erosion on soil chemistry. Predictions were made of the losses of nutrients under given levels of erosion on different kinds of plots, and the cost of replacing these nutrients estimated from current market prices. Soil loss was found to be correlated with losses of nitrogen, phosphorus, and organic carbon from experimental plots. In turn, variations in losses of soil nitrogen, organic carbon, and phosphorus were dependent on soil type, crop, and year. The two most important variables in explaining this effect were the rainfall pattern and the crop type. It was discovered that erosion is selective in removing nutrients from the soil. The ratios were highest in areas where run-off was highest, an important finding in evaluating physical conservation measures that are designed to detain soil but allow run-off. Specifically, it was found:

- on average, 1.6 million tons of nitrogen, 156 million tons of organic matter, and 0.24 million tons of phosphorus are lost annually by erosion. The arable lands alone lose 0. 15, 1.5, and 0.02 million tons respectively;
- these nitrogen and phosphorus losses from arable land were about three times the level of total fertiliser application in Zimbabwe in the 1984-85 season, and they do not include losses of nutrients dissolved as runoff water;
- the equivalent cost of fertiliser containing these nutrients would have been US$1.5 billion per year (at 1 985 market fertiliser prices and rates of exchange). For the arable lands alone, where there is the greatest investment in terms of food production and fertilisers, the financial cost amounted to US$150 million;
- on an annual per hectare basis, the financial cost of erosion was found to vary from US$ 20 to $50 on arable lands, and US$ l0 to $80 on grazing lands, according to the level of erosion;
- if the cost of replacing nutrients amounted to US$50 per hectare this would represent between 13 per cent to 60 per cent of the gross returns per hectare of arable land under maize production; and
- the costs of soil erosion from arable land alone in Zimbabwe could exceed 16 per cent of agricultural GDP and 3 per cent of total GDP.

A slightly different approach to the valuation of environmental damages is the relocation cost approach. The actual costs of relocating a physical facility because of damages to the environment are used to evaluate the potential net benefits of preventing the damage. Examples include relocating people because of a dam construction project, or when a waste water pipe is extended to avoid contaminating a source of drinkable water.

The averting behaviour approach examines the expenditures (such as water or air filters) people make to avoid damages they perceive to themselves. These expenditures are used as subjective valuations of the minimum benefits of avoiding environmental damages. The costs are made in anticipation of a negative impact occurring. Different people will have different level of expenditures following their perception of the damages involved.

The mitigation approach examines the expenditures people make to correct a problem after the impact has occurred. In this case, people are better informed about the damages and their expenditure to protect themselves will reflect that. If city water is not up to standard, people in developing countries may have other sources such as door-to-door sales, private wells, filtration systems, boiling water and bottled water depending on income and WTP. A survey would provide the mix and aggregate costs, which could be taken as an estimate of the benefit of an improved urban water supply. However, preventive expenditure in developing countries is more commonly constrained by income than by demand.

These response costs can be considered as the minimum estimate of the benefits of averting or mitigating environmental damages. The benefits derived from avoiding damages are usually assumed to be higher than the costs incurred in avoiding them. Such expenses are seldom related to market forces and so do not reflect the potential environmental benefits.

9.2.6 Other Methods for Direct Proxies

The shadow project is a useful approach that can be used systematically for practically all valuation of environmental impacts. It is an application of the with-without project analysis. The with project in this case should include a component, another (shadow) project, that fixes whatever environmental damage exists or takes into account whatever positive environmental opportunities arise from the main project under appraisal. Sometimes it has the narrower definition of an approach which attempts to recreate an ecosystem with its many goods and services, such as, wetland for example.

The **Aid-Cost** is a proxy value for a change in an environmental attribute derived from the WTP by some donor for the preservation or restoration of an environmental attribute. A NGO could buy land to preserve its biodiversity. The price they pay for the land would be the minimum value of preserving that biodiversity. The actual value may be much higher, especially if some preserved genes would find a market in the future. However, these approaches must be used with caution because they reflect the values of only a subset of the relevant population and in many cases they do not provide an indication of WTP of the individuals directly affected by the project.

The **Opportunity Cost** method of valuing environmental impacts, measures the forgone benefits of using the same resource for other alternative uses. Preserving a forest as a national park instead of harvesting timber would be valued at the forgone income from selling timber. The approach measures what has to be given up for the sake of preservation. In practice, this method is not different from a classic with-without analysis. It is also the same concept as the opportunity cost for shadow pricing in the economic analysis of projects.

The **Cost-Price** method is a cost-effectiveness method[9]. There is no attempt to value the benefits. Instead, one estimates the least-cost way of reaching a certain physical goal or standard. The analyst will calculate all the costs of producing a unit of material resource or to reach a certain level of pollution emission for instance. It is appropriate when a certain standard

[9] Refer to module 8 for more details on this approach as applied to general project appraisal.

of pollution has been established by decision-makers. The goal is to meet the standard by the lowest cost method.

9.3 INDIRECT PROXIES

9.3.1 Travel Cost

a) Background

This method is usually applied to three valuation problems:

- Recreational services flows of an existing site;
- Ex-ante value of a new recreational site; and
- Change of the environmental quality of a recreational site.

By observing how visitation rates to a site change as the environmental quality of the site changes, the method also provides values for environmental quality itself. In order for this to be true, a weak complementary relation is assumed between the environmental good (such as scenery) and the private good (such as visits to forests)[10]. In this case the method measures how the demand curve for the market good shifts if the associated environmental attribute changes.

The fundamental insight that drives this model is that if a consumer wants to use the recreational services of a site he has to visit it. The travel cost to reach the site is considered as the implicit or the surrogate price of the visit, and changes in the travel cost will cause a variation in the quantity of visits. Observation of these variations across individuals will permit the estimation of demand functions and the derivation of the welfare measure.

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[10] Weak complementarity defines a situation where the environmental attribute "q" is a characteristic of the market good "x". This situation entails that if "q" increases, the demand for "x" will also increase. For example, water quality is a characteristic associated with visits to lakes, or scenery is a characteristic associated with visits to forests. In both cases an increase of the environmental quality will increase the demand for visits. Weak complementarity requires that the marginal utility of "q" be zero when the quantity demanded of the complementary private good "x" is zero. This happens for price levels equal or above the choke price, i.e., that price which makes the demand of "x" equal zero.

Two main approaches are used, a zonal TC and individual TC. With the former, visitors to sites are invited to provide information on the trip (cost, length, purpose, other sites visited, etc.) as well as on other socio-economic features (income, age, sex, etc.). The entire area from which visitors originate is divided into a set of visitor zones. The analyst then defines the dependent variable as the visitor rate (the number of visits made from a particular zone in a period, divided by the population of that zone). With the individual TC, the analyst defines the dependent variable as the number of site visits made by each visitor over a specified period (Box 9.8 and 9.9).

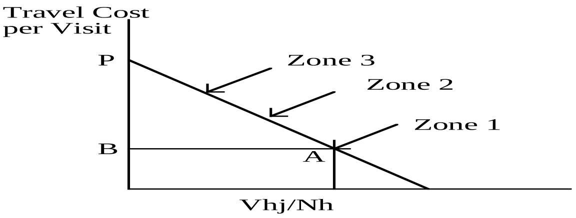
Box 9.8: Basic model of ZTCM

In mathematical terms the trip demand curve will be defined as:
Vij/Ni = f (Ci,Xi)
with: V_{ij} as the total number of trips by individuals from zone i to zone j per unit of time; N_i as population of zone i; C_i as visit cost from zone i to zone j[11]; X_i as socio-economic explanatory variables in zone i[12]. The visitor rate Vij/Ni is generally calculated as visits per 1,000 population in zone h. In each zone the household consumer surplus for all visits to the site is calculated by integrating the equation of the type:

Vij/Ni = a + b C_i

between the price (cost) of visits actually made from each zone and the price at which the visitor rate would fall to 0 (that is the vertical intercept of the demand curve at point P in the Figure:

$$C.S. = \int_{Ch=B}^{P} (a + bCh)dCh$$



Annual total consumer surplus for the whole recreation experience can be estimated in each zone by first dividing total household consumer surplus by the zonal average number of visits made by each household to obtain the zonal average consumer surplus per household visit. Then the result can be multiplied by the zonal average number of visits per annum to obtain annual zone consumer surplus. Finally, cumulating zonal consumer surplus across all zones gives the estimate of total consumer surplus per annum for the whole recreational experience of visiting the site.

[11] Travel cost is the sum of expenditures incurred for petrol, opportunity cost of time for travelling and for visit on-site.

[12] These include factors such as income levels, spending on other goods, the existence of substitute sites, entrance fees, quality indices of n substitute sites, etc.

Box 9.9 Basic model of ITCM

The demand curve in this model relates individual's annual visits to the costs of those visits. That is:

Vij = f(Cij,Xi)
where:
Vij = number of visits made by year by individual i to site j;
Cij = visit cost faced by individual i to visit site j;
Xi = all other factors determining individual i's visits (income, time, and other socio-economic characteristics)
The previous equation can be extended to allow for specification of a number of explanatory variables such as individual "i", estimate of the proportion of the day's enjoyment, which was contributed by the site visit to site j; individual i's estimate of the availability of substitute sites; size of individual's household; size of individual's party; whether individual i is a member of an environmental organisation as well as other socio-economic data.

The demand curve for the site is defined by _Vij/_Cij. Integrating under this curve gives us the estimate of the consumer surplus per individual. The consumer surplus for the site is obtained by multiplying by the number of individuals visiting the site annually.

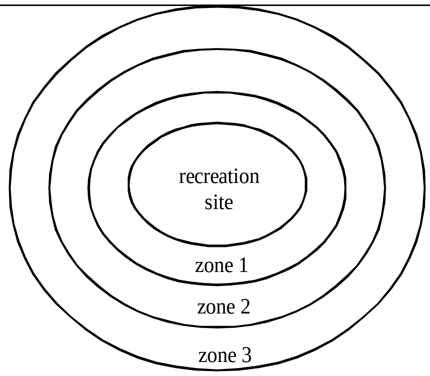
$$C.S = Nj \quad f(Cij, Xi).dCij$$

where: Nj = number of individual visits to site j per year
(Cij,Xi) = defined as above

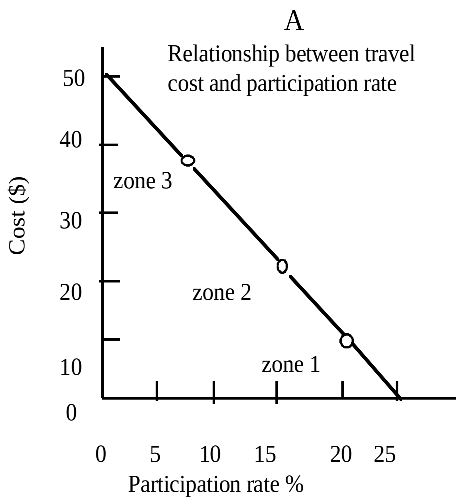
An example of a ZTCM is shown in Box 9.10, which illustrates how the demand curve is derived and a consumer surplus (area under the demand curve) is calculated. In estimating consumer surplus for the on-site recreation experience, one assumes that people would react to increase in admission price in the same way as they would react to an increase in their travel costs and uses this information to estimate their response to an access fee. The second (right) graph in the box uses the relationship derived from the left graph to estimate the reduction in the number of visitors to the site that would result from adding on access fee or price of \$5 or \$10. The relationship in the left graph gives the lower participation rate that could be expected from each zone when the price is added to the travel cost. That rate is then applied to the total population of the zone to yield the number of participants who could be expected at that price. These estimates are then used to plot the demand curve for the recreation site as in the right graph.

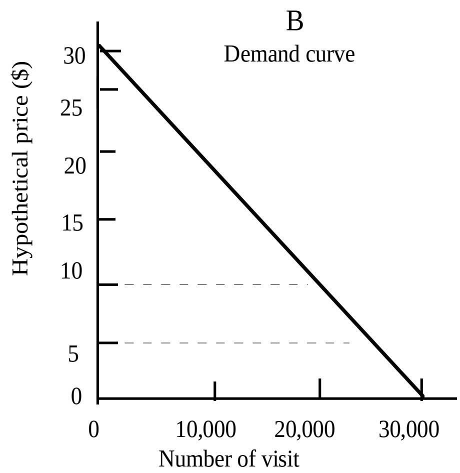
The total CS is $\frac{\$30x29500}{2}$ or \$442,500.

Box 9.10: Example of ZTCM



	Population (number)	Travel cost ($)	price = 0 (observed) Participant rate (%)	Participant (number)	price = $5 (hypothetical) Participant rate (%)	Participant (number)	price = $10 (hypothetical) Participant rate (%)	Participant (number)
Zone 1	50,000	10	20	10,000	17.5	8,750	15	7,500
Zone 2	100,000	20	15	15,000	12.5	12,500	10	10,000
zone 3	60,000	35	7.5	4,500	5.0	3,000	2.5	1,500
Total				**29,500**		**24,250**		**19,000**





In practice the ITCM is usually preferable because:

- The ZTCM approach yields value estimates for the whole recreational experience of the entire day trip to a non-priced recreation site rather than a valuation of the site alone;

- The dependent variable of the ZTCM does not account for individual explanatory variables which may be highly significant in the determination of the choice of visitors;
- Concentric circles around the recreational site do not necessarily mean that the cost and time of travel will be the same on the same circle; and
- The various zones are defined arbitrarily and consumer surplus estimates can differ widely depending on the zones specified.

ZTCM demand estimations always produce upwardly biased R^2.

In the basic model of ITCM described, several assumptions are made, which deserve careful attention when the method is applied.

- The basic method assumes the case of a pure visitor, i.e. that the trip to the site is for the sole purpose of visiting the site. This case is only one possible situation of the real life. Other possibilities are that the visit to the site is only part of the trip program or that the visit is explained with other interests (e.g., visit of relatives). The travel cost and time should in this case be allocated among different purposes.
- It is also assumed that driving to the recreational site produces neither utility nor disutility. In fact it may happen that the trip itself produces some benefits to the driver. In this case the travel cost would be overestimated
- The opportunity cost of the time spent on-site and for travelling is generally assumed to be the wage rate. No general consensus exists on this point[13]
- The basic model assumes that there is only one site to visit. In the real world visitors often have the possibility to choose among substitute sites. In this case, the number of visits that consumers make to the site surveyed will depend not only on its implicit price but also on the implicit prices of any substitute. If these are not accounted for, the parameters will be biased

[13] Some studies maintain that it is necessary to include the opportunity cost of the journey and visit time in the computation of the total travel cost. However, others feel that the value (utility) of time can be either positive or negative but there is not definite a-priori notion about whether travel time utility is positive or negative. Anyway, even assuming the possibility of estimating the sign of the value of time, the problem remains of how to estimate its price. Though various operational approaches have been proposed to place a value on time. There is not yet unanimous consensus on their capacity to overcome the risk of over or underestimation.

Despite the above mentioned difficulties, the method is a useful aid for policy decisions on: setting the level of entry fees to national parks and recreation areas, allocating resources between different sites, preserving a site or changing its land use. In developing countries, TC can also be useful in valuing fuelwood and water entailing significant outlays of time and cost.

b) Method of Research

The methodological framework for conducting a proper TCM survey is as follows:

1. *Identification of the environmental good/service to be valued*: this activity is based on information provided by preliminary studies, which will define exactly the good/service to value. The method is usually applied for the valuation of recreational sites, services/attributes of the site (i.e., walking, fishing, and so forth), or change in the quality/quantity of the environmental attribute.

2. *Preparation of the questionnaire/scenario*: particular care should be devoted to the identification of the variables required for the valuation. An introductory part should explain the purpose of the survey. Then the questionnaire should carefully analyse the main features of the visit: (i.e., the area of origin of the visitor, length of stay at site, number of other possible sites visited in the same trip experience, number of visits/year to the site in question, motive of visit, travel time, etc.); and the socio-economic characteristics of the visitors (i.e., age, sex, educational level, income, member of an environmental organisation, possible substitute sites, activities carried out in the site, and so forth.

3. *The survey*: before the survey is carried out it is suggested that: (i) the enumerators be trained to avoid risks of misinterpretation of the questions and responses and to collect the requested information without influencing the respondents' answers; (ii) a pre-test be conducted to check the goodness of the questionnaire; (iii) a plan of action be formulated stating the number of interviews to be undertaken per day, how the interviews should be distributed over the days, the weeks, the months, and where the enumerators should interview the visitors. Often budget constraints do not permit a pre-test. In this case a simulation exercise can be carried out with the enumerators acting as both interviewers and interviewees. The survey can

be carried out in various ways: mail, telephone, on-site face-to-face, and outside the site face-to-face. It is recommended to use on-site face-to-face interviews. The sample of respondents can also be determined in many ways. Each visitor should have the same known probability of being selected. To get a random sample of the visitors interviewed on-site, visitor statistics from previous years should be used to determine how many interviews to conduct each month of the season. The same percentage of visitors should be interviewed each month. Often, however, a random sample of visitors during the peak season is sufficient in so far as it can be considered as representative of the total visits undertaken in one year. The sample size is also a very important point to address for a proper and reliable estimation of the economic value. In general it is recommended that the number of respondents be at least 200.

4. *Collection of data and validation of the questionnaires*: at this stage invalid questionnaires are eliminated and a database is created. Sometimes new variables can be constructed on the basis of the information collected. The analysis of data is mainly aimed at describing the behaviour of specific variables and checking their consistency and suitability through appropriate crossed comparisons and statistical analysis.

5. *WTP estimation*: in this phase the selected models of monetary valuation are implemented. The results obtained can be expressed in per capita values (WTP/per capita) or in total value (total annual value of the environmental service under consideration). Moreover, the flow of net benefits generated by the environmental services can be cumulated using the appropriate discount rate. This phase can be broken down further to illustrate the various steps necessary for the calculation of the WTP.

A detailed step-by-step approach for the calculation of the WTP is provided in Figures 9.4 and 9.5 for the ZTCM and the ITCM respectively[14]. An example is provided in Box 9.11.

[14] Refer to Annexures 3 and 4 for detailed examples of ZTCM and ITCM respectively.

Figure 9.4: Step by step procedure for ZTCM.

Steps	Assumptions and Notes
1. Sample selection and survey running (**p** observations)	Random sampling is appropriate but seasonality must be considered to obtain representative sample
2. Collection of the annual visits to the site (**V**)	Unavoidable information. Source : Existing records
3. Subdivision of visitor origins in zones of increasing distance.	Zones must be chosen such as data of the total population is available
4. Determination of the number of visitors by zone (**pj**) and zone sample share (**pj/p**)	This step is required if information about annual visits by zone is not directly available.
5. Calculation of the number of annual visits by zone (**Vj = V*pj/p**)	The sample share of visitors from each zone is assumed as the total visits' share of each zone.
6. Collection of data on population by zone (**Pj**)	This data can be obtained either from direct questions to respondents or from recorded data.
7. Calculation of the average visit rate by zone (**Rj = Vj/Pj**)	Ratio of the "quantity" of the service demanded on the average consumer by zone, given the travel cost.
8. Calculation of the zonal average travel cost to the site (**Cj**)	Source: questionnaire, published air and train fares, or car costs.
9. Estimation of the (direct) demand function of the recreational service **V/P = f(C)**	Assumption: individuals have the same behaviour independently of the zone of origin.
10. Calculation of the average per visitor Consumer Surplus by zone (**CSj**)	Formulas of CS depend on the specific functional form selected for the demand in the previous step.
11. Calculation of the zonal CS (**CSZ**j)	Product of average per visitor CS times the population of the zone.
12.a Aggregation of CSZj (**ATCS**) / 12.b Further elaboration of CS	
13. Interpretation of results: Presentation	

Figure 9.5: Step by step procedure for ITCM

Steps	Assumptions and Notes
1. Sample selection and survey running (**p** observations)	Random sampling is appropriate but seasonality must be considered to obtain representative sample
2. Elaboration of calculated variables and statistical description of the sample.	Descriptive statistics allow to get a first idea of the collected data.
3.Choice of the functional form for the individual demand curve.	Double log forms give constant price elasticities. R2 should not be used for discriminating log independent w.r.t. double log. functional forms
4. Estimation of the demand function of the recreational service **V/P = f(C,S)**	Assumption: individuals with the same (modelled) features behave in the same way.
5. Calculation of the individual CS observation by observation.	Formulas of CS depend on the specific functional form selected for the demand in the previous step.
6. Collection of data on population by zone (**Pj**)	This data can be obtained either from direct questions to respondents or from recorded data.
7. Calculation of the average sample CS.	I.e., the average of individual CS.
8.a Aggregation of sample CS / 8.b Further elaboration of CS	Sample CS per visit must be multiplied by the total annual number of visits.
9. Interpretation of results: Presentation	WTP for specific social groups can be calculated.

Box 9.11: Case Study - A Tropical Rain Forest in Costa Rica

The site examined in this study is the privately owned Monteverde Cloud Forest Biological Reserve (MCFR), which straddles the continental divide in Costa Rica. The reserve consists of 10,000 ha of rugged terrain, the vast majority of which is virgin rain forest. Tourism to the reserve has increased markedly over the 18 years of its existence, both in terms of domestic and foreign visitation rates, despite the relatively remote locality and difficulty of accessing the site. The data set used in this study was collected at MCFR headquarters by the reserve management, which offered those who gave their names and addresses the opportunity to win wildlife photographs. A total of 755 of approximately 3,000 domestic visitors entered the drawing in 1988. The sample shows a similar distribution, with respect to sites of origin, as a smaller data set collected independently over 3 months during the summer of 1988. The sample was assumed to be representative of the true domestic visitor population.

Visitation rates (number of visits per 100,000 residents) were calculated for each canton by dividing observed numbers of trips by census populations. Populations, densities, and illiteracy rates for each canton by dividing observed numbers of trips by census populations. Populations, densities, and illiteracy rates for each canton were taken from a 1986 census. Distance is converted into currency using average cost per km estimates. We estimate that US$0.15 per km is a reasonable measure of the travel costs in Costa Rica in 1988. This estimate includes out-of-pocket costs, a fraction of fixed costs, and the value of travel time.

Since the semilog functional form could not be used because some district had a zero visitation rate, a linear demand functions was estimated: Vz/Nz = a + (distance) + C (population density) + d(illiteracy). The coefficient on price (distance) b was negative and statistically significant. The linear demand functions estimated in the study suggest that visitation would drop to zero only at distances of 330-350 km. At the presumed US$0.15 per km, this implies a maximum price (PM) per visit of US49-52. Domestic visitation would drop off to zero only if the price per visit exceeded US$50. After calculating this consumer surplus for each canton, the results are summed across all cantons yielding an annual consumer surplus estimate of between US$97,500 and US$116,200, depending on the precise form of the demand equation. Assuming the real value of this recreational flow remains the same over time and using a real interest rate of 4 percent, the present value of domestic recreation at this site is between US$2.4 and US$2.9 million. Given that there are about 3000 Costa Rican visitors per year, the site is worth about US$35 per domestic visit.

This study provides the first published estimate of the ecotourism value of a tropical rain-forest reserve. The travel cost method reveals that Costa Rican citizens place a value of about US$35 per visit upon the MCFR. Tropical rain forests can generate large economic values through recreation. Domestic recreation alone represents an annual value of between US$97,500 and US$116,200 at MCFR.

This US$100,000 per year estimate does not include foreign visitors. Foreign visitors outnumbered domestic visitors by four to one in 1988. Assuming foreign tourists place the same US$35 per trip value on MCFR as domestic users do, foreign visitation would represent an additional US$400,000 to US$500,000 of international recreation value annually. In fact, foreign visitation is likely to be worth far more since foreign tourists probably value the site more than domestic visitors due to their higher income and lack of nearby substitutes.

At current visitation rates, the net present value of domestic and international recreation is about US$2.5 million and US$10 million, respectively, assuming a 4 percent real interest rate. Given that the Reserve comprises 10,000 ha, the combined domestic and international recreational value averages about US$250 per ha. Given that visitation has been growing at 15 percent a year for the past five years, this present value estimate is probably far too low. Nonetheless, the price that the reserve currently pays to acquire new land is between US$30 and US$100 per ha. This suggests expansion of protected areas near this reserve is a well-justified investment, both from an economic and social perspective.

Source: Tobias and Mendelsohn (1991).

9.3.2 Hedonic Price Method

a) Background

The Hedonic Price Method (HPM) attempts to evaluate environmental goods or services by estimating their effects on certain market prices such as property and land. It is based on the assumption that the prices of marketed goods such as houses are affected by the numerous characteristics including size, location, neighbourhood, etc. Environmental attributes such as trees, aesthetic views, etc will also influence market price. By explaining the price of the houses with these features using a multiple regression model, it is possible to isolate and value the effects of environmental characteristics on property prices. From the multiple regression model of the price, one can infer how much money individuals are willing to pay for certain environmental attributes. The value of the change in the environment is therefore given by the private property price change. The underlying concepts of the HPM are summarised in Box 9.12.

b) Method of Research

In general, the Hedonic Price Method (HPM) includes two major actions:

i) Collection of relevant information and data

The collection of data focuses on the price of the asset associated with an environmental good, their environmental features (e.g. the quality of air, level of noise, coverage with trees, etc), structural features (size of house, number of rooms, etc.), and the socio-economic features of their owners. The collection of data about prices and houses features is done following these steps:

- Resident households are randomly extracted from the council directory of resident households;
- The price of the house is determined looking at the estate agencies bulletins and recent transactions. Expert advice for some properties may be required; and
- The collection of information on the socio-economic features of the household is done looking at the recent council census data.

ii) Calculation of the value of the environmental quality (asset). Once the data have been collected, the calculation procedure follows the steps listed below:

1. Estimation of the **House Price Function;**
2. Calculation of the **Implicit Marginal Price** of the environmental good (first derivative of the house price function with respect to the environmental quality) for each observation;
3. Estimation of the **Implicit Inverse Demand Function** for the environmental good (implicit price as function of the environmental good and socio-economic features of individuals); and
4. Calculation of the **Consumer Surplus** (Riemann Integration of the implicit inverse demand function between the observed level of environmental good and the new level).

Box 9.12: Hedonic pricing theory

A price function of housing is of the following type: $P_a = f(S, N, E)$

where: a = unit of housing;
S = structural characteristics;
N= neighbourhood characteristics; and
E = environmental characteristics.

The equation can be specified as a logarithmic form:

$$\ln P_a = a \ln Sa + b \ln Na + c \ln Ea$$

where: c tells us by how much property prices vary if we alter the value of the environmental variable. Figures below show the relationship between environmental changes and property prices.

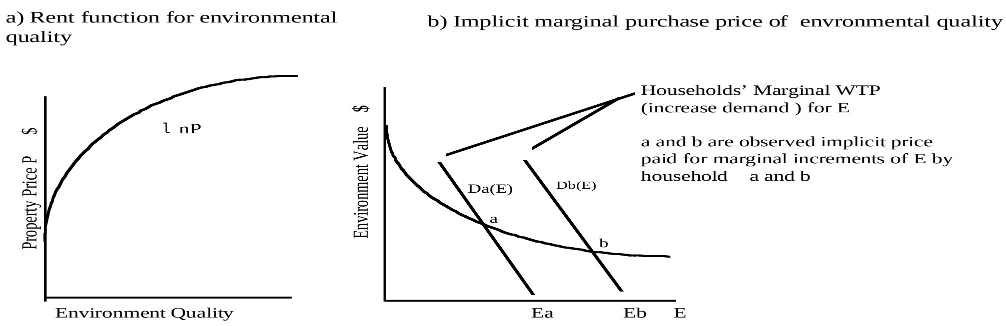


Figure (a) shows that property prices increase with environment improvement at a diminishing marginal utility. Differentiating the equation above with respect to Em gives the implicit marginal purchase price of the environmental good: ƒP / ƒE = c x P/Em. Figure (b) plots the slope of the implicit marginal purchase price of the environmental good or the amount by which property values would increase if landscape (environment) were to be improved Assuming that the only explanatory variable is given by the environmental attributes, the hedonic price function would be In Pa = c In Em. Using the integral log-log rule: 1/x dx = ln x + d, we can rewrite the function : ƒP/P = c ƒE/E or ƒP / ƒE = cP/E. However, the marginal purchase price function does not necessarily correspond to the household demand curve for E. That is, it is unlikely that it corresponds to the household marginal willingness to pay for E. This non-correspondence can be demonstrated intuitively by considering an individual's decision about whether or not to buy an additional unit of E. At a low level of E the individual/household may be more than willing to pay the marginal purchase price for an additional unit of E (MWTP>implicit marginal price). At high levels of E that same household may not be willing to purchase an additional unit (MWTP<marginal implicit purchase price). Yet, there will be an intermediate level of E where the household is just willing to pay for the incremental Em unit (MWTP = marginal implicit price). Figure (b) illustrates the relationship between household WMTP and implicit marginal purchase price for two households.

As shown in figure (b), each household will choose a location where its marginal willingness to pay for one more unit of E equals the marginal implicit price of E. But as it can be observed, this amount is only a single point on the household's inverse demand function for the environmental good. What this demonstrates is that the slope of the estimated l n P is a locus of points on the demand curves of many households. Yet, the question is if the curve ƒP / ƒE of figure (b) can be interpreted as an inverse demand function for E. If all individuals were identical, the demand curve for landscape would correspond to ƒP / ƒE insofar as all households would have identical demand functions. But since individuals do not have the same preferences for landscape quality and differ in income, the HPM should be complemented by estimations of how the marginal WTP varies with income and other individuals characteristics, and should take into account the supply side of housing market. Once the demand function has been estimated, the area under the demand curve between two values of the landscape quality determines the change in consumer surplus caused by the change in "quantity" of this attribute. By aggregating all individuals' CSs we obtain the overall value of landscape improvement.

The general steps in HPM steps are illustrated in Figure 9.6.

Figure 9.6: Step by step procedure for the HPM

Steps	Assumptions and Notes
1. Collection of data on prices and houses features	Various methods exist to collect these data. For complex studies this data must be complemented with information on the socio-economic characteristics of households investigated.
2. Estimation of the **house price function**	It relates the price of houses to the characteristics explaining the house price.
3. Calculation of the **implicit marginal price** of the environmental good for each observation	This is the first derivative of the house price function w.r.t. the environmental attribute
4. Estimation of the **implicit inverse demand function** of the environmental attribute	The price paid is explained by the quantity/quality of the environmental attribute but also by the socio-economic characteristics of households
5. Calculation of the **CS**	Riemann integration of the implicit demand curve between the former level of environmental quality/quantity and the new one.

A functional form must be selected for estimating the price function of houses[15]. The first derivative of the price function with respect to the environmental feature(s) shows how the price of the houses changes for changes of the environmental quality associated. This derivative is expected to be positive, signalling that, other things equal, increasing environmental quality is associated with increasing prices of houses[16]. The first derivative of the house price function can be interpreted as the **Implicit Marginal Price Function** for the environmental good. "Implicit" means that the price of the environmental good is embodied in the value of the house that ceteris paribus, would have a different value if the associated environmental quality were at a different level. "Marginal" refers to the last unit of environmental quality purchased, being the value of first derivative at a specific point an approximation of the change of the house price for unit changes in the environmental quality.

[15] Refer to Annexure 5 for details on mathematical derivation of functional forms.
[16] Obviously, this is true when the environmental attribute is a good (not a bad).

The second derivative of the house price function is expected to be negative, signalling decreasing implicit marginal prices for increasing environmental quality units. This means that the implicit price of a unit of environmental good when the environmental good is largely available is less than the price of one unit when the availability of the environmental good is limited.

To some extent the marginal price function could be considered the inverse demand function for the environmental good (inverse because the price of the good is expressed as function of the quantity). This is however correct only if some restrictive conditions on the shape of individual utility functions hold (identical utility functions). Estimated implicit prices for different houses refer to different individuals. Every estimated implicit price is only one observation of the true individual demand curve and corresponds to the individual willingness to pay (WTP) for a marginal unit of environmental good only for that specific level of environmental good purchased.

Instead of using the implicit marginal price function for directly estimating the change in the individual consumer surplus, it can be better utilised for calculating the implicit marginal price paid by every household. A second stage estimation of the inverse demand curve can be obtained regressing the implicit marginal price on the quantity of environmental good purchased and other socio-economic features of individuals[17].

The variation of the Consumer Surplus (CS) due to a change of an environmental service is calculated as the definite integral of the inverse demand function with respect to the quantity of the environmental good between the initial level of the environmental good and the final level.

Graphically, CS is represented in Figure 9.7, where Q0 is the initial level of the environmental service Q and Q1 is the final level.

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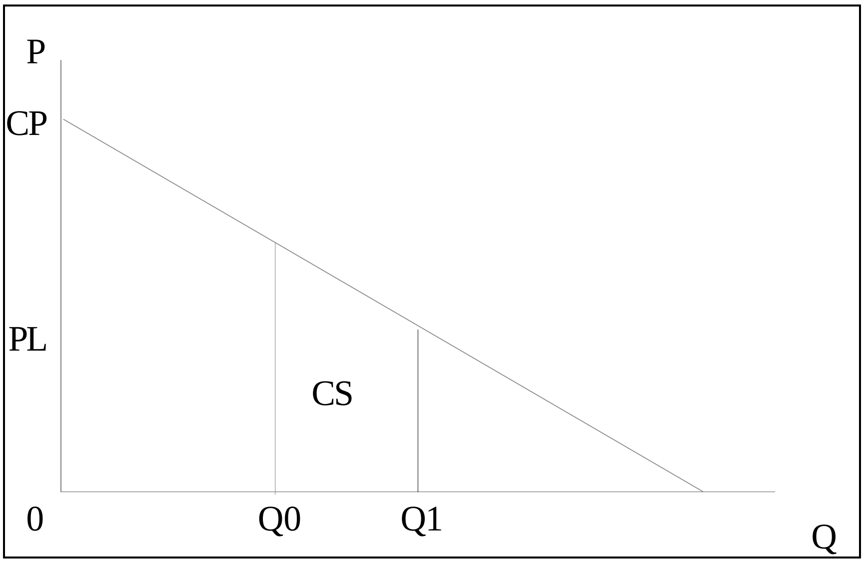
[17] Problems in the identification of the supply and demand functions occur. A possible assumption is that the system is supply constrained, i.e. the supply of the environmental good fixed irrespective to the price (inelastic supply). This allows to regress the (estimated) price Pe on the quantity E and other socio-economic variables to obtain the Inverse Demand curve.

Figure 9.7: Consumer surplus in HPM



Notice that the variation of the surplus can be allocated entirely to the consumer, i.e. the house owners only if the price they pay for obtaining the improvement is zero. Despite these distributional issues, the improvement of the environmental service generates a WTP roughly represented by the area CS. However, CS cannot be considered a net gain as in the case of the CS for a marketable good, where CS is net of the price paid for the good and the price reflects the production costs of the good. In this case, if a measure of the net benefit of the environmental improvement is required, the costs of producing the environmental improvement must be considered.

In conclusion, the HPM relies on a number of assumptions, which can be restrictive in its use. Among the most important are the following:

- Property markets exist and are competitive;
- Data on property is available cross-sectionally or through time; and
- The environmental variable is measurable and clearly perceived by individuals.

Some shortcuts in their practical use are that

- The required data is seldom recorded in official statistics both in terms of quality and quantity, particularly in developing countries;
- Data may be unreliable. Housing prices, for example, are often distorted and owners of houses frequently accept to sell or rent at lower prices than the true market price, therefore the observed price does often not correspond to the marginal WTP; and
- Finally, as for the TCM, this method does not capture the full WTP.

An example on the use of HPM to estimate the benefits of neighbourhood improvement schemes in poorer cities is illustrated in Box 9.13[18].

[18] Refer to Annexure 6 for a detailed example of the Hedonic Pricing method.

Box 9.13: Visakhapatnam slum improvement program (SIP)

Visakhapatnam lies on the East Coast of India, midway between Calcutta and Madras. Between 1971 and 1991, its population trebled from 360,000 to 1.05 million. This rapid increase reflected the city's industrial growth as a major naval base and manufacturing centre, the poverty of the surrounding rural areas from which many migrate, and the high natural birth rate. However, there is an acute shortage of land in the city, which is bounded by hills and sea. Population density is high, with 30,000 persons per km over much of the city. Despite some industrial prosperity, over 200,000 people (40,00 households) live in nearly 200 officially designated slums with an average annual household income of 13,00 rupees ($400). Half the adults in the slums are illiterate. Few slum households have private tap water and only half of the slums have public tap water. Under one in five slum houses has a toilet and 60 percent of slum dwellers practise open defecation. Not surprisingly, health problems are rife.

In the 1988, the Visakhaptnam Municipal Corporation, supported by the UK Overseas Development Administration, started a major program to improve 170 slums. This program included physical infrastructure improvements (roads, drainage, paths, street lighting), improved water supply, public toilets, community centres, primary health care services, and educational and training services. Concurrently, the Municipal Corporation provided subsidised housing loans to slum residents to improve their dwellings. When slum improvements are formally evaluated, benefits are almost always based on estimated increases in land values or rent. Under certain conditions, nearly all private benefits (including health, productivity and amenity benefits) would be reflected in increased land prices or rents, and in house prices, in the slums. These conditions are:

i) all private benefits accrue only to residents of the slum area;
ii) all SIP benefits (including health benefits, reduced flood and fire damages, etc) are fully perceived by people inside and outside the slum areas;
iii) slum property prices are not controlled; slum residents can sell or rent their properties to outsiders as well as to other slum residents; and
iv) property transactions are costless.

Visakhapatnam has an active housing market. Official land valuation data were collected for typical properties in 24 slum areas which were improved in 1988 or 1989 and valued (to the nearest R 50 per square yard) in 1987 and 1990. Between these two years, mean land values in the sample slums increased from R 256 to R 441 per square yard. Elsewhere in Visakhapatnam land values rose by an estimated average 20 percent except in commercial development areas where land values rose by another 10 to 20 percent. Allowing for an overall increase in land values in Visakhapatnam of 25 percent, average slum land values would have risen to R 320 without the SIP and the difference between R 411 and R 320 is attributable to the SIP. Applying a benefit of R 121 per square yard to 36,500 houses with an average 50 square yards per house (a total of 825 million square yards) produces a total increase in land values of R 221 million in 1990 Rs or about R 254 million in 1992 Rs.

The estimated benefits from the land value and house price approaches are reassuringly close and give one some confidence in the results. Alternatively, in competitive markets, increased rents could be a measure of improved living conditions. Between 1988 and 1991, the average rent of Visakhapatnam slum tenants who pay rent increased from R 114/month to R 145/month in 1992 prices. Applying a notional annual rent increase of R 372 to 36,500 slum households, total rent increases would be R 13.6 million per annum. With a 10 percent discount rate, the capital equivalent would be R 136 million. This figure is well below the estimated increase in land values or house prices and cannot be considered relevant to evaluation of the SIP. The relatively low rate of return can be explained partly by the unrepresentative nature of the rental market: only 13 percent of households are tenants and they mostly rent in the lower to middle end of the slum housing market. Also, restrictions on tenant evictions substantially reduce market rents.

In conclusion, the Visakhapatnam Municipal Corporation has spent about R 300 million on improving 170 slums. An additional R 20 million or more per annum will probably be required to maintain this capital program. The SIP brings benefits to slum and non-slum households, and savings to the government.

In short, most slum household benefits are reflected in increased land and house prices, although some benefits may not be fully capitalised into property prices. We estimated that the SIP increased total land values in the 170 slums by R 254 million and house prices by R 285 million. Allowing for some slum householder surpluses, private non-slum benefits and government savings (equivalent in total to about one-quarter of SIP costs), there is a clear surplus of social benefit over capital expenditures.

9.3.3 Wage Differential

a) Background

The wage differential is similar to HPM in that the benefits of environmental improvement (decreasing mortality and morbidity) to human health can be deduced from variations in wages across different work settings and localities. It is assumed that an individual can make trade-offs between income and health, thus revealing the value of health and the work place. Both the supply side and the demand side of the labour market define a job and the corresponding wage rate (hedonic wage rate) by a bundle of characteristics or attributes such as , age, skill level, education, and so forth, including exposure to environmental or occupational risk. There is a relationship between wage level and environmental/risk characteristics. The analysis of these relationships is called wage risk study.

b) Methods

Most of the applications of this method have dealt with the valuation of risks of death or injury due to accidents on the job. However, the same approach can be used to value adverse environmental effects on morbidity and mortality.

A wage risk study involves four steps:

- To estimate earning function, W = f(J, S, R) where the wage (W) depends on job (J) related characteristics (occupation, union, working conditions, number of weeks/year, location....), the individual socio-economic characteristics (S) (income, age, education, experience ...) and the job risk (R) of accident (mortality or morbidity);
- Collect cross-sectional data;
- Derive the coefficient on risk or the implicit value of the risk of an accident $\Delta W/\Delta R$ using multiple regression analysis; and
- Derive the value of the benefits of reducing the risk of damage to human health in terms of probability of death or injuries i.e. for extra 1 in 100,000 homes, the Value of Life = $100{,}000 \times \Delta W/\Delta R$, or if logarithm function is used VoL = 100,000 x average wage x Δ .....W/ΔR. An example is provided in Box 9.14.

Strong assumptions for this technique to work are that:

- Labour markets functions freely. In developing countries, labour markets are highly imperfect and are characterised by important surplus of labour and uneducated workers who do not have a good perception of job risk. This leads to situations where low wages may coexist with poor environmental conditions;
- Labour is mobile;
- It is possible to isolate the exclusive impact of risk on wages;
- Perfect comparability between different types of risks; and
- Good quality of information on risks.

Box 9.14: Example of a wage risk study

This study looked at data on deaths classified by occupation for the period 1970-1972. The risk variable used is the excess death rate due to accidents.

An earnings function is estimated using data on household information combined with the risk data. The earnings function has the general form:

$$\ln(Y) = f(S, EX, EX^2, \ln(WEEKS), RISK, UNION, OCC, UNIONxRISK)$$

Where, In refers to logarithms; Y is annual earnings; S is a measure of education; EX is years of experience in the labour force (the square of EX is to take account of non-linearity); WEEKS is the number of weeks worked in the year; RISK is the risk variable above; UNION is a measure of the degree of unionisation; OCC is a measure of the desirability of the occupation; UNION x RISK indicates any possible interaction between unionisation and risk.
Linear multiple regression is used to estimate the coefficients of the equation. The estimated equation was found to be:

$$\ln(Y) = 1.95 + 0.058[S] + 0.046(EX^2) + 1.13[\ln(WEEKS)] + 0.229[RISK] + 0.002\,[UNION] + 0.008[OCC]$$

The coefficient on UNION x RISK was dropped from the equation because it was found to be insignificant. The other coefficients were all significant.

Risk of death is expressed as X per 1000 workers. Now if a sum of £Z per worker is required to compensate for an increased risk of death of 1 in 1000, then the value of life is £1000xZ for the 1000 workers affected. Now Z is given by the change in earnings for a given change in risk ($\Delta Y / \Delta RISK$). Now since $\Delta Y = Y(\Delta \ln(Y)$, then the value of life is: $VOL = 1000 \times Y \times (\Delta \ln(Y) / \Delta RISK)$

But since the term in brackets in the above equation is the coefficient on RISK in the estimated equation (= 0.229) then the value of life can be found if we know average income.

Source:Marin and Psacharopoulos (1982).

9.3.4 Other Methods for Indirect Proxies

a) Residual value

The Residual value or derived price method estimates the value of particular goods or services from the prices of goods and services established later in the production - distribution process. For some goods, there is sequence of several markets from the raw material origin up to the final consumer. The value of the product produced at each stage may be in part a residual of the value at the next stage and ultimately will depend upon the final product market. For example, the value of Brazil nuts in the Amazon Forest depends in part on the price paid by local intermediaries, which depends in part on the price paid by traders/exporters who depend on the wholesalers who sell to candy manufacturers and then to the final consumers.

Residual values for commercial timber are derived by deducting all costs (beginning with harvesting logs through processing and marketing) from finished wood products such as lumber or pulp. The approach could also be used as a simplified HP approach if used to estimate environmental values of a property for instance. Some studies equate this value with economic rent or stumpage.

b) Implicit value

Implicit value or reverse (bottom-up) analysis method does not calculate value or use proxies. Instead, the analyst works backward from a desired IRR or NPW to determine what the level and value of environmental improvement would need to be in order to justify the investment. As an example, an irrigation project may have a NPV of -$250,000 USD but will generate environmental benefits that are difficult to quantify. The implicit value of the environmental benefits can be assumed to be $250,000 if the objective is to break-even on the investment. The implied values can then be benchmarked against literature based value. Then, decision-makers have to evaluate the implicit values in relation to the overall project investment. If the desired NPV were $500,000, then this would become the implicit value of the environmental benefits.

9.4 NO PROXIES – CONTINGENT VALUATION

9.4.1 Introduction to CVM

a) Background

The CVM method is the best approach to get at the WTP/WTA for the total economic value (including non-use values) of an environmental improvement. This is an important consideration since some CVM studies have shown that non-use value in some cases can be 40 percent of total economic value for wilderness preservation and even above 60 percent for water quality project. Basically, people are asked how much they would be willing to pay for a specified environmental quality improvement. If people understand fully the environmental impact and answer truthfully the WTP/WTA question, this approach is ideal because the analysts would get an individual's strength of preference for the proposed environmental change. The values expressed by people in CVM interviews are *contingent* upon such factors as the description of the environmental good, whether it is provided, and the way it would be paid for. The central problem in the application of this valuation method is whether the intentions people indicate before the change will accurately describe their behaviour after the change when people face no penalty or cost associated with a discrepancy between the two.

b) What is to be measured?

The possible environmental changes about which one individual can be asked to express his value judgement about an environmental change are (Figure 9.8):

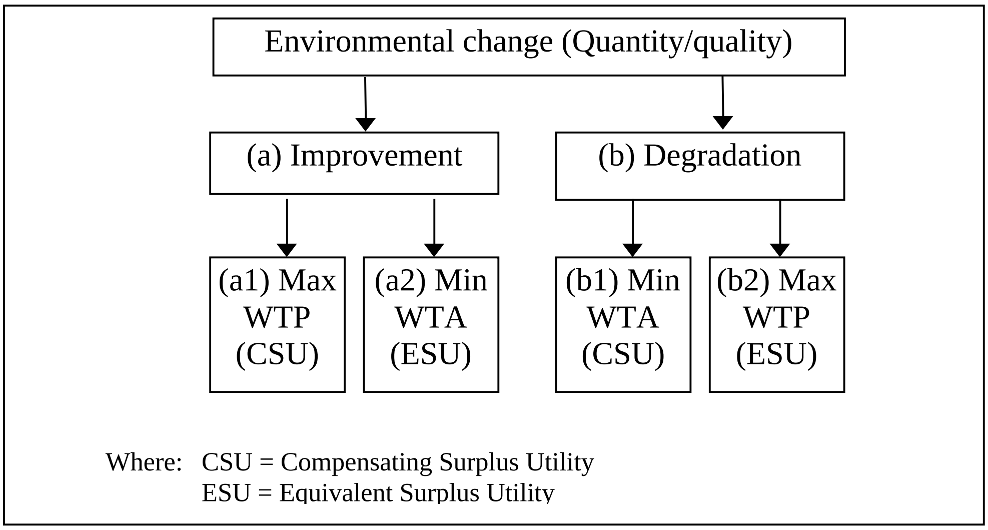
i) Environmental improvement. The value of the environmental improvement in such a situation can be measured either by:

- The individual's Maximum Willingness to Pay (max. WTP) to obtain the environmental improvement;
- The individual's Minimum Willingness to Accept (min. WTA) a compensation to forgo the environmental improvement.

ii) Environmental damage. The value of the environmental damage in such a situation can be measured either by:

- The individual's Maximum Willingness to Pay (max. WTP) to avoid the environmental damage;
- The individual's Minimum Willingness to Accept (min. WTA) a compensation to consent the environmental damage.

Figure 9.8: Environmental changes and the possible measures of their value



c) Willingness to pay versus willingness to accept

One basic issue in CVM studies for the estimation of environmental values is to choose whether to ask individuals their maximum WTP or their minimum WTA for a given environmental change. With an environmental improvement, the individual, currently at a utility level U0, ceteris paribus, is brought to a higher utility level U1. The maximum amount of money the individual is willing to pay to secure this improvement is such that after the payment at most he would be back to U0. In other words, he or she should not be prepared to pay any amount of money such that utility falls below the original utility level U0). This maximum amount of money is the Compensating Surplus - CSU. A reverse situation occurs when dealing with environmental damage. In this case, the individual's utility will fall because of the damage. The individual will then want monetary compensation at last to return to the original level of utility. This is the Equivalent Surplus - ESU.

Randall and Stoll (1980), suggested that the possible differences between the Compensating Surplus and Equivalent surplus are barely significant in most practical situations. For example, an individual might state his or her maximum willingness to pay to obtain an increase of the tree and shade coverage rate in the surroundings of the house from 20 percent to 25 percent. This should not be very differently from the minimum willingness to accept a compensation to consent to a reduction of the tree and shade coverage rate from 25 percent to 20 percent.

Hanneman (1991) showed that this is not always the case. The amount by which WTA exceeds WTP varies directly with the income elasticity of demand for the environmental good/service and inversely with the elasticity of substitution between the environmental good/service and other goods. If the income elasticity of demand for q is zero, or if q is a perfect substitute for a private good, WTP should equal WTA. If, however, the elasticity of substitution between q and marketed goods is zero, the difference between WTA and WTP can be infinite. Carson (1991) also argued that when individuals are asked to state their minimum WTA, they tend to state their expectations about what they could extract as compensation rather than their true minimum WTA. On these grounds also Mitchell and Carson (1989); Pearce and Turner (1990) put forward notes of caution regarding the differences among WTP and WTA formats.

Although WTA is the appropriate measure of value when a good that someone owns is damaged, it is often difficult to measure WTA accurately in contingent valuation surveys. Evidence of this is provided by the fact that willingness to accept compensation for quasi-private goods (hunting licenses) in contingent valuation surveys has been found to exceed actual willingness to accept compensation for the same goods (Bishop and Heberlein 1979; Bishop, Heberlein and Kealy 1983). It is also the case that willingness to pay for a good is usually many times lower than willingness to accept compensation to forego the same good (Bishop and Heberlein 1979; Knetsch and Sinden 1984). When the good is not unique, this is interpreted as evidence that WTA is more difficult to measure than WTP. For these reasons, researchers have focused almost exclusively on WTP as the measure of value in contingent valuation surveys.

9.4.2 Different Elicitation Formats and Related Biases

a) Background

In order to obtain answers that reflect the true maximum WTP, or minimum WTA of the respondent, different formats for eliciting the value judgement have been experienced. The main formats are:

- Open ended questions;
- Bidding Games; and
- Dichotomous choice (referendum) questions.

b) Open-ended format

Simple CVM exercises can be based on the so called "open ended" elicitation format, where the individual is asked to state a maximum WTP or minimum WTA for a described environmental change. In this case, descriptive statistics (such as means and medians) can be used to obtain rough indications about the respondents' value judgements. The main drawback of this approach is that it is easy for the respondent to introduce a "strategic bias", by stating a WTP/WTA lower or higher than the true one to influence the decision making process. A second is that the individual may be unprepared to express a value judgement without any reference point to express his or her value judgement. This reference point is often termed the "bound".

c) Bidding game format

To avoid a high rate of "loose" and/or missing answers caused by the lack of bounds in the open ended format, an iterative technique called "bidding game" can be used. In this case the respondent is asked whether he or she accepts to pay (or to be compensated with) a given amount of money. If they refuse the proposed amount, the question is repeated with a reduced (or increased) amount, by a given percentage (say, 10 percent). The procedure is repeated until the respondent answers "yes". This amount is the maximum WTP (or minimum WTA) for obtaining (or to give up) the environmental improvement. If the individual accepts the initially proposed amount, the procedure continues until the individual answer "no". This amount is also the maximum WTP (or minimum WTA) for obtaining (or to give up) the environmental improvement. This elicitation technique has a main drawback called "starting point bias". It has been observed that the final value judgement is affected by the initial proposed amount.

d) Dichotomous choice

To contain the starting point bias and the strategic bias, the "dichotomous choice" (referendum) format can be used. In this case, a possible range of values for the maximum WTP (or minimum WTA) of individuals is pre-set by the analyst[19]. The sample of interviewed individuals is divided in sub-samples. A value within the pre-set range is assigned to each sub-sample. Each individual within a sub-sample is then asked whether he or she is willing to pay (or to accept) the assigned value to obtain (or to consent to) the environmental improvement (or damage). He or she is not allowed to state an amount as in the case of the open-ended format, or to play with subsequent acceptance/refusal answers as in the bidding game format. Besides, he or she does not know the range of values within which the proposed amount is bounded. In this case however, the outcome of the individual answer it is not the maximum WTP (or minimum WTA) but only the consensus or refusal to pay (or to accept as compensation) a given amount of money. Specific statistical techniques are therefore required to work out the individual's value judgement about the environmental change.

e) Combined approaches

In order to take account of the possible differences in the results due to the use of one, rather than another elicitation format, the three main elicitation formats can be used. The sample is split as in the dichotomous choice approach. A bidding game is proposed for a fixed maximum number of bids and an open ended question is lastly posed to obtain the maximum WTP (or minimum WTA) when the respondent switches from "yes" to "no" either if also the last bid is accepted[20].

9.4.3 Organisation of a CVM Study

[19] Pre-tests may be used to appropriately set the range of values.

[20] Also other elicitation formats exist such as for example: i) "payment cards", which report the likely current expenditure of the respondents on other public goods and services such as security, defence, justice, environmental protection, health. The cards are showed to help the respondent to calibrate his reply. Ii) "Contingent ranking" where the respondent is asked to rank alternative policies or projects in order of preference considering different attributes. When at least one of the attributes is expressed in money terms (e.g. "price" to pay), Contingent ranking can be considered an extension of the dichotomous choice approach.

The general approach to follow for a CVM survey is outlined in Figure 9.9. The most crucial steps are marked in bold and are briefly described below. Most of the actions are the same as for a TCM survey. However, the core of the CVM survey directly focuses on the WTP/WTA for a specific environmental good, rather than on travel costs and number of visits to a specific site. The major elements of a CVM survey are:

- A scenario is described where the impacts of the change in the provision of an environmental good/service are outlined;
- The respondents are invited to consider and to understand the proposed scenario within which the choice concerning the environmental good/service will occur; and
- The respondents are invited to supply their statements concerning their WTP/WTA, from which the value attached to a change in the provision of the good/service in question is inferred.

Figure 9.9: Organisation of a CVM study

1 DEFINITION OF THE OBJECTIVES ➡	2 QUESTION NAIRE DESIGN ➡	3 SURVEY OF SAMPLED VISITORS ➡	4 DATA BASE CREATION AND DATA ANALYSIS ➡	5 WTP ESTIMATION
↓	↓	↓	↓	↓
1a THE OBJECT OF THE VALUATION	2a INTRODUCTION	3a SAMPLING TECHNIQUE	4a COLLECTION AND VERIFICATION OF DATA	5a WTP MODELS CHOICE
1b TYPE OF VALUE TO ELICIT AND MEASURE UNIT	2b SOCIO-ECONOMIC INFORMATION	3b HOW, WHEN, AND WHERE TO RUN INTERVIEWS	4 b DATA BASE CREATION	5b ESTIMATION OF ANNUAL INDIVIDUAL AVERAGE MAX. WTP
1c TIME SPAN OF THE VALUATION	2c SCENARIO FORMULATION	3c TRAINING OF ENUMERATORS	4c ELIMINATION OF INVALID QUESTIONNAIRE S	5c ANNUAL NET BENEFITS
1d WHO SHOULD BE INTERVIEWED (DEFINITION OF THE POPULATION)	2d WTP/WTA ELICITATION FORMAT		4d DERIVED VARIABLES BUILDING	5d TOTAL VALUE OF ENVIRONMENTAL SERVICES
	2e PAYMENT VEHICLE		4 e DATA ANALYSIS	

The **first step** concerns a definition of the objectives of the survey.

1a.**What to value**: the purposes of the survey and the object of the valuation exercise must be identified and stated clearly. What is the environmental good or service we want to place a value on? Are we valuing the whole environmental good, one of its attributes, a specific change in the quality/quantity of the good/service?

1b.**Type of the value and measure unit**: Is the analyst eliciting the marginal value or the average value to the individual of the good/service? What is the measure unit?

1c.**Time span of the valuation**. The analyst must decide whether to collect monthly, annual, multi-period WTP/WTA or lump sum WTP/WTA.

1d.**Who should be interviewed**: the relevant economic agents have to be defined, i.e., who is affected by the change in the provision of the environmental good or service(individuals, households, production units).

The **second step** concerns the design of the questionnaire. This activity is of fundamental importance. Indeed, a well-conceived questionnaire is the basis for the success.

2a.**Introduction.** The interviewer explains some likely reasons (not necessarily all of them) of the survey to the interviewee, to make him involved.

2b.**Socio-economic information**. To analyse the answers and to interpret them in the socio-economic context of the respondent, data about the interviewee, his household and his social environment are normally collected (e.g. age, education, marital status, number of members of the household, annual income of the household etc.).

2c.**Scenario design**. The scenario description is of course different for each specific study. The scenario usually provides a clear and careful description of the environmental good/service object of the valuation, its changes under given conditions, the impacts of the change on the users/consumers, possibly the type of policies envisaged to secure (prevent) the change and who will pay for them. The WTP/WTA question must be phrased to present a clear, readily understood and plausible scenario. One important dimension of the scenario design is describing the availability of substitutes for the commodity valued. The value of a malaria vaccine, for instance, should depend on the existence of other methods for preventing the disease. Such methods should be clearly spelled out to respondents in the course of the survey; otherwise people may make different assumptions about the commodity being valued.

It is necessary also to include some final questions to check if the scenario has been communicated successfully (debriefing questions). Failure to communicate a realistic scenario to the respondent is likely to result in the respondent not taking the scenario seriously or replacing it with something of his own invention, either of which may bias WTP.

2d.**Elicitation format**. The elicitation procedure establishes the way the question for obtaining the value judgement is posed. Whatever the elicitation format however, it is important that before asking the individual what he would pay for the commodity valued, he should be reminded that his expenditures on other goods must be reduced by this amount; i.e., he should be reminded of his budget constraint. It is also desirable to follow questions that elicit WTP with questions to determine whether a respondent who says he will pay nothing for the good is stating his true valuation or a protest bid. A respondent may say that he will pay nothing for a good that he in fact values if he believes that he should not have to pay for it or otherwise disagrees with the scenario presented in the survey.

2e.**Payment vehicle**: the choice of the payment vehicle is of utmost importance in the design of a CVM questionnaire. One procedure for determining the most appropriate PV is to carry out a pilot study in which several alternatives are tested. The analysis of the results will allow to identify the payment method the respondents are most familiar with and the most preferred by them. Possible payment vehicles are entrance fees (e.g., National Parks), taxes (e.g., pollution), contribution to funds (e.g., existence values such as protection of endangered species), charges (e.g., water use for agricultural, industrial, or domestic purposes). In rural areas in Africa, the choice of payment vehicle is a major challenge since many people have low incomes in a subsistence society.

The **third step** concerns the management of the survey. Sample selection and choices about how, where, and when to interview are presented.

3a.**Sample selection**. After determining the population whose WTP is to be measured, which, depends on the nature and location of the commodity to be valued, the researcher ideally uses probability sampling procedures to select a sample who will receive the contingent valuation questionnaire. This involves constructing a sampling frame and selecting from the sampling frame in such a way that the probability of each person being selected is known. Cost considerations have sometimes led to the use of convenience samples, i.e. interviewees selected at shopping malls or through newspaper advertisements. Such samples are usually adequate when the goal is testing how certain treatments (e.g., changes in scenario) affect responses, but do not allow WTP values to be generalised for the population.

3b.**How, when and where to run the survey**. The researcher must also determine the method of administering the questionnaire. WTP may be elicited through in-person interviews, or in mail or telephone surveys. The choice of administration method depends in part on the nature of survey. Visual aids can be used only with in-person and mail surveys. Some elicitation techniques (e.g., questions whose wording depends on the response to previous questions) are difficult to administer in mail surveys. Which method is chosen will affect both the cost of conducting the survey and the response rate. Response rates are generally lower for mail surveys and may lead to non-response or sample selection bias. This occurs when people who refuse to answer the survey (e.g., due to lack of interest in the topic) have WTP values that are systematically different from (e.g., lower than) those of respondents.

The **fourth step** (data base creation and analysis) is similar to most socio-economic surveys and will not be discussed here in more detail. Issues concerning the **fifth step** (WTP estimation) are presented in the following section.

9.4.4 Analysis of Contingent Valuation Responses

One goal of a contingent valuation survey is to estimate the population distribution of WTP for the environmental good in question. This is the weighted frequency distribution of responses when the WTP question is open-ended. In the case of a closed-ended question, one can compute the percent of the sample that is willing to pay at least a given value, which provides an estimate of 1 minus the cumulative distribution of WTP.

To compute the total benefits of a policy, one typically computes the mean of the maximum WTP distribution and then multiplies mean maximum WTP by the size of the population (N) affected by the policy. Issues arise concerning the definition of the population (N), the sampling choice, and the time period of the environmental benefits. The careful definition of target population is important and can obviously affect the size of society's aggregate maximum WTP/minimum WTA. For national and global issues with many stakeholders, the choice is difficult. The objective is to choose all those people whose utility will be significantly affected by the action.

As an alternative to mean maximum WTP, researchers frequently estimate median maximum WTP, which provides a robust lower bound for mean maximum WTP and is less sensitive to skewed distributions and the presence of gross outliers. It is also possible to compute α-trimmed means to reduce the influence of extremely large and extremely small reported max. WTP amounts. The α-trimmed mean is computed after deleting the α100 percent smallest and α100 percent largest maximum WTP observations. In addition to estimating the mean of the distribution of maximum WTP, it is of interest to see how mean maximum WTP varies with characteristics of the respondent (income, education). This provides a test of the internal validity of responses and is useful if one wishes to transfer WTP estimates from one population to another. The expression of the maximum WTP as difference of expenditure functions, as illustrated above, imply that maximum WTP can be written as a function of income (Y), prices, other non-market goods, taste variables (T), and the original and final levels of the good in question.

$$\text{Maximum WTP} = f(Y,P,Q,T,q^0,q^1) = X\_\beta$$

If one has a point estimate of maximum WTP for each individual in the sample, then it is a simple matter to append an error term to the maximum WTP function (above) and estimate it by mean of regression techniques. Estimation of the coefficient vector β allows one to test the internal consistency of responses and predict mean maximum WTP for different social groups as a function of respondent characteristics. These analyses can help assess accuracy and reliability of WTP/WTA responses and for policy inferences such as who can pay more and why. The purpose of investigating the determinants of WTP/WTA bids is to help also the next phase of aggregation of sample responses to the overall population under study. Besides, it helps to validate past scenarios of WTP/WTA and forecasts new ones.

When a closed-ended question is used to elicit WTP, it is assumed that the respondent answers yes to the stated amount, z_i, if $\mathbf{X}_i\beta + \varepsilon_i > z_i$, where ε_i is an error term representing variables that affect WTP but are not observed by the researcher. If $\{\varepsilon_i\}$ are independently and identically normally distributed with zero mean and standard deviation σ, the coefficient vector β may be estimated using a variant of the probit model. Specifically, the probability that the respondent will not pay z_i is given by $\Phi(z_i/\sigma - \mathbf{X}_i\beta/\sigma)$ where Φ is the standard normal distribution function. By estimating a probit model with z and **X** as independent variables one obtains estimates of $1/\sigma$ and β/σ. Mean WTP is then obtained as $\mathbf{X}_i\beta$.

When a follow-up dichotomous choice question is introduced, more efficient estimates of β are possible for a given sample size. To illustrate, assume that a respondent is initially queried about his WTP \$30, and assume that the response is “yes.” The same respondent would then be asked whether he would pay a greater amount, say \$50. If the answer is “no,” the respondent’s WTP lies between \$30 and \$50. If the answer is “yes,” the respondent’s WTP lies in the interval (\$50, ∞). Denoting the lower and upper bounds of the interval bracketing the respondent i’s WTP by WTPiL and WTPiU , and assuming for the sake of simplicity that $\{\varepsilon_i\}$ is normally distributed with mean zero and standard deviation σ, the log likelihood function of the sample data is given by:

$$\log L = \sum_{i=1}^{n} \log\left[\Phi\left(\frac{WTP_i^U}{\sigma} - \frac{x_i\beta}{\sigma}\right) - \Phi\left(\frac{WTP_i^L}{\sigma} - \frac{x_i\beta}{\sigma}\right)\right]$$

Estimates of the parameters σ and β are obtained by the method of maximum likelihood. If the researcher is reluctant to make distributional assumptions about $\{\varepsilon_i\}$, non-parametric techniques can be used to estimate β. The procedure for estimating the maximum WTP/minimum WTA depends upon the elicitation format chosen and the resources available to the analyst.

9.4.5 CVM Examples

An example of an "open-ended format" interview for a private water connection in Pakistan reveals the expected effect based on demand theory and common sense; WTP/WTA increases with income and education (Box 9.15).[21]

Box 9.15: Example of cross tabulation of households' WTP/WTA bids and socio-economic characteristics of the Household (Panjab, Pakistan)

	Sweet Water	Zone	Brackish Water	Zone
Socio-econ. Characteristics	% of Sample	Mean WTP/WTA Bid* Rs/Month	% of Sample	Mean WTP/WTA Bid* Rs/Month
Yrs. of education of most educated member of household:				
0-8	44	15	38	36
9-12	41	21	41	40
>12	15	33	21	47
Construction value of house (Rs)				
0-49,000	38	14	9	33
50,000-99,000	40	20	22	36
100,000-149,000	10	21	19	38
≥ 150,000	12	35	50	44
Overall Mean		**21**		**40**

WTP/WTA bids are for a connection to a piped water system.

Source:Bateman I. J. and K.R. Turner (1993).

Box 9.16 provides the regression analysis of WTP/WTA for water connection in Haiti on some socio-economic characteristics. The results again confirm that WTP/WTA increases with income, education, and distance from water source.

[21] Refer to Annex 7 for a detailed example of dichotomous choice CVM

Box 9.16: Example of valuation function estimated with ordinary least squares (Laurent, Haiti)

Dependent variable:

Household willingness to pay for private water connection (gourdes $.2/month)

Independent variable:	Coefficient	t-ratio
Intercept	-1.468	-0.32
Household wealth index (WLTH)	1.280	4.73
Household with foreign income (FINC, = 1 if yes)	-0.654	-0.42
Occupation index (IOCP = 1 if primary occupation is farmer)	-2.463	-1.69
Household education level (HHE D)	0.986	3.83
Distance from existing source (DIST)	0.003	2.24
Quality index of existing source (QULT = 1 if respondent is enthusiastic about the quality of the water)	-0.664	-2.79
Sex of the respondent (RSEX = 1 if male)	0.307	0.25
Adjusted R^2	0.34	
F Value	10.25	
Degrees of freedom	120	

Source:Bateman I. J. *et al*. (1993).

Another example (Box 9.17) illustrates simple open-ended questions concerning the WTP/WTA for water quality for recreation. This example also shows that by distinguishing between users and non-users of the area being valued, use and non-use values can be derived without directly asking about these values.

The last example is from India (Box 9.18) where an iterative bidding process was used. Often, the starting values are obtained from a pre-test, using open-ended type questioning. The respondents are asked if they are WTP/WTA this amount. If they reply positively, the bid is increased, otherwise it is decreased. The offering of a water connection in some Indian villages was related to three dimensions, connection fee, monthly tariff and improved service. The CVM study brought interesting policy conclusions concerning all three dimensions.

Box 9.17: Valuing river-water quality improvements using the contingent valuation method

The Monognahela River is a major river flowing through Pennsylvania, USA. Analysts asked a representative sample of households from the local area what they would be willing to pay in extra taxes in order to maintain or increase the water quality in the river. Three possible water quality scenarios were presented and respondents asked how much they were willing to pay for each:

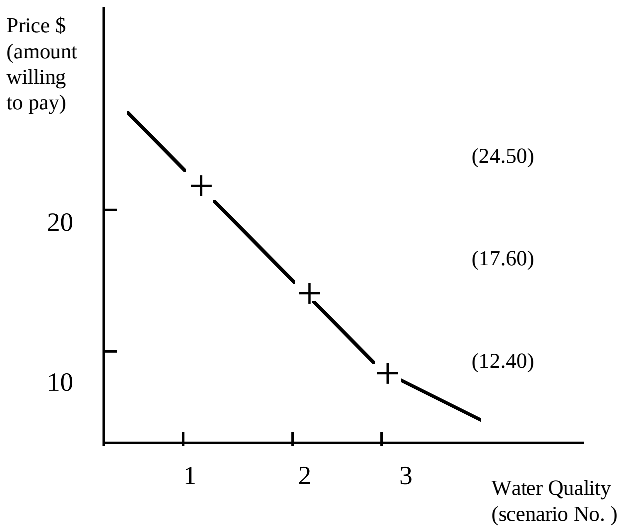
Scenario 1: Maintain current river quality (suitable for boating only) rather than allow it to decline to a level unsuitable for any activity including boating

Scenario 2: Improve the water quality from boatable to a level where fishing could take place

Scenario 3: Further improve water from fishable to swimmable.Among the households surveyed some used the Monongahela river for recreation while others did not. The analysts therefore could look at how much the users were willing to pay compared to the responses of non-users. Results for the sample as a whole were also calculated. The table below presents the willingness to pay, of users, non-users and the whole sample for each proposed river quality change scenario. A number of very interesting conclusions can be drawn from these results. Considering the results for the whole sample, we can see that the stated willingness to pay sums draw out a conventional demand curve for water quality, i.e. people are prepared to pay a relatively high amount for an initial basic level of quality. However, they are prepared to pay progressively less for higher levels of water quality. A demand curve was constructed for the average household.

Water quality scenario of	Average WTP/A of whole sample ($)	Average WTP/A of users group ($)	Average WTP/A of non-users group ($)
Maintain boatable river quality	24.50	45.30	14.20
Improve from boatable to fishable quality	17.60	31.30	10.80
Improve from fishable to swimmable quality	12.40	20.20	8.50

Demand curve for water quality



From this demand curve we could attempt to calculate the total value of environmental quality at the river. More importantly, we could find the value gain experienced by the average household when a water quality improvement is achieved. The total benefit value of a specific improvement could then be estimated by multiplying this average household value by the number of households, which it is thought, would be affected by such an improvement. This benefit can then be compared against the cost of achieving such a quality improvement to see if it was worthwhile.

Source:Desvousges et al. (1987)

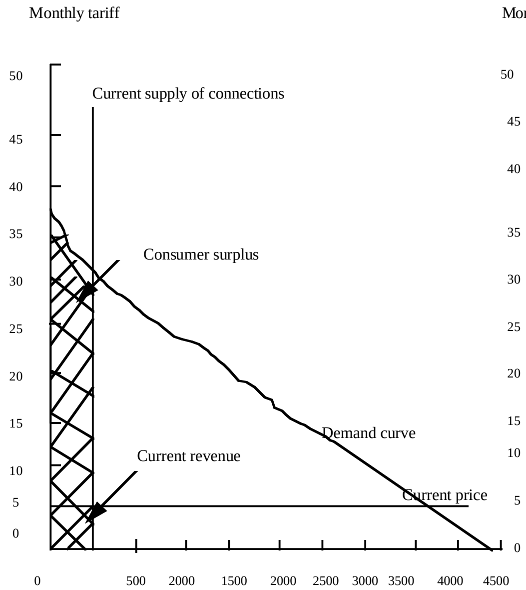
Box 9.18: Contingent Valuation of Rural Water Supply in India

In recent study of the preferences of rural people for different levels of water supply service, the CVM was used to examine willingness to pay for yard taps or house connections in several rural villages in Kerala State, India. Currently, public water systems provide a low level of communal service with few private connections. The service is heavily subsidised and the monthly tariff for water from household connections is quite low. Little revenue is generated by the service, and the water authority cannot afford to maintain the system. Therefore, consumers are forced to supplement their piped water with water from traditional, often low quality, sources such as shallow wells, rivers, ponds, rainwater and vendors. Thus, the water supply is in a 'low-level equilibrium trap' - poor service generates little revenue thereby ensuring continuing poor service.

The use of CVM allowed respondents to consider hypothetical changes in water supply characteristics and to respond to questions about the effect of three variables - the cost of connection, the monthly tariff and improved quality of service - on their decision to purchase a yard tap (to become 'connectors' to the system). The respondents' choice were modelled within a discrete choice random utility framework, in which an individual's response is equal to the indirect utility that the respondent receives from choosing to purchase a yard tap rather than continuing to use existing sources. This choice is influenced by both the hypothesised water source characteristics and household characteristics. Of the variables affecting water use decisions, water policy decision-makers can control only three: the connection charge, the tariff and the quality of service. An iterative bidding process was used, always starting with a pre-selected maximum possible bid. If a negative response was received, the interviewer worked down through a pre-arranged bid schedule.

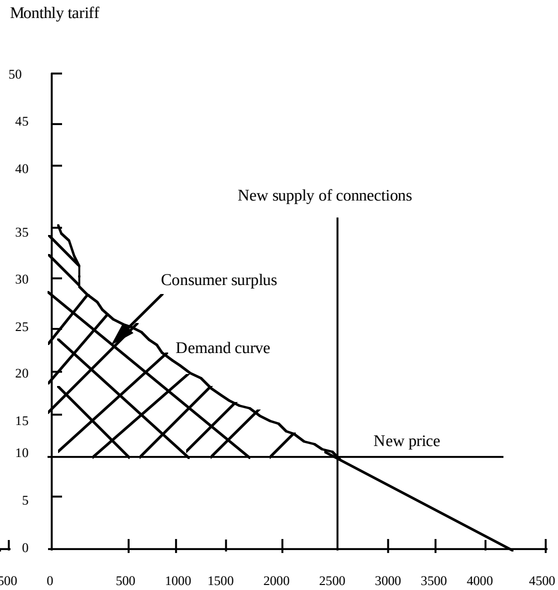
A CVM survey of 1,150 households was carried out, and included both connectors and non-connectors in areas with improved water systems, and those living in areas currently without improved systems. The survey found that the constraint to new connections was the high up-front connection charge in combination with unfavourable credit market conditions. In addition, once connected, there was a high willingness to pay for improved quality of service. Figure (a) below shows the number of connections, revenue and consumer's surplus at the current tariff of 5 rupees per month.

Figure (a)



Current Availability of Yard Taps & Consumer Surplus

Figure (b)



Simulated Change in Consumer Surplus with a Higher Price & Unconstrained Connections

In contrast, Figure (b) shows the increased connections, revenue and consumer's surplus at an increased tariff of 10 rupees per month. The demand curve was estimated from the survey results and assumed a connection charge of Rs. 100. With increased connection at the Rs. 10 per month charge, those consumers who were already connected suffer a small loss in consumer's surplus (their costs go up from Rs. 5 to Rs. 10 per month). However, this is more than offset by the expansion in consumer's surplus from the large increase in those who now have private connections under the new tariff structure. As seen in figures a and b, the increase in consumer's surplus is roughly 450 percent, from about Rs. 5,500 in figure a to Rs. 25,000 in figure b.

9.4.6 The Validity of the Contingent Valuation Method

Some economists have expressed scepticism of the method because contingent valuation questions are hypothetical and may therefore yield hypothetical answers. Criticism of the method has been also generated by the implausible answers observed in some contingent valuation studies (Hausman 1993). Contingent valuation studies sometimes produce many zero WTP values and/or a few implausibly large values. Zero values may be evidence of strategic behaviour, of attempts by the respondent to misrepresent WTP in order to influence the outcome of the survey. Or, zero values may represent protest bids, indicating that the respondent does not think he should have to pay for the good, even thought he has a positive WTP for it. WTP values that are large relative to the respondent's income and/or the availability of substitute commodities may indicate strategic behaviour, or that the respondent has failed to consider carefully his budget constraint.

In some studies WTP fails to increase very much with the quantity of the good valued. The value of a reduction in risk of death may not increase with the size of the risk reduction (Jones-Lee et al. 1985) or the WTP to save 1,000 birds may not differ significantly from the WTP to save 100,000 (Desvousges *et al*. 1993). This suggests either that the good that is valued is not well understood or that it is a category of programmes that is being valued; i.e., that the value attached to a large class of goods is embedded in the good valued (Kahnemann and Knetsch 1992).

To test whether contingent valuation provides accurate estimates of value, researchers have compared contingent valuation estimates with the results of actual or simulated market transactions. These tests assume that actual WTP measures *true* compensating variation, and is therefore an appropriate criterion to which to compare the contingent valuation method. This is perhaps reasonable for private goods, but is problematic for public goods, where actual WTP may understate compensating variation due to the free rider problem. The results of such comparisons are mixed. In the case of private goods, several experiments comparing hypothetical and actual WTP for hunting permits have found no statistically significant difference between mean values of hypothetical and actual willingness to pay (Mitchell and Carson 1989). Similar results were obtained by Dickie *et al*. (1987) in the case of strawberries. Comparisons of stated v. actual WTP for public goods have generally found that the former overestimates the latter (Kealy *et al*. 1987, Arrow et al. 1993).

A second test of validity compares contingent valuation estimates of WTP with estimates produced by indirect methods, such as hedonic pricing or the travel cost approach, that infer WTP from actual behaviour. To the extent that the two are similar, it is unlikely that people are overstating their WTP in a contingent valuation survey simply because they do not have to pay for the good. A meta-analysis of 83 studies that estimate WTP using both direct and indirect methods found that the mean ratio of the contingent valuation estimate to the estimate produced by indirect methods was 0.9 (Carson et al. 1996). The mean ratio of the two estimates was not significantly different from 1.0 at the 0.05 level.

Comparing contingent valuation to other methods of valuing a good provides important evidence of the reliability of the contingent valuation method, but clearly cannot be applied in all cases. Tests of internal validity attempt to determine whether responses to a given contingent valuation survey are internally consistent. Tests of content validity ask whether the questionnaire describes the commodity to be valued in a meaningful way and avoids biases introduced by failing to mention substitute commodities or encouraging the respondent to consider his budget constraint.

9.4.7. CVM Guiding Principles

Litigation over natural resources damages has led to an upsurge of interest in the CVM method. Following the Exxon-Valdez oil spill. Exxon commissioned a number of CVM studies criticising the reliability and validity of CVM as an approach to value environmental impacts. As a response the US government set a blue-ribbon panel under the joint chairmanship of Kenneth Arrow and Robert Solow to advise on the use of CVM in natural resource damage for oil spills. The panel concluded that CVM studies *can provide estimates reliable enough to be a starting point for a judicial or administrative determination of natural resources damages. To be acceptable to this purpose, though, such studies should adhere closely to the guidelines described in this report*. The following main guidelines, not in ranking order, have been suggested by the panel (Arrow *et al*. 1993).

- For a single dichotomous question (yes-no type) format, a total sample size of at least 1000 respondents is required. Clustering and stratification issues should be accounted for and random sub-sampling will be required to obtain a bid curve and to test for interviewer and wording biases;

- High non-response rates would render the survey unreliable;
- Face-to-face interviewing is likely to yield the most reliable results;
- Full reporting of data and questionnaires is required for good practice;
- Pilot surveying and pre-testing are essential elements in any CVM study;
- Conservative design more likely to underestimate WTP/WTA is to be preferred to one likely to overestimate WTP/WTA;
- WTP/WTA format is preferred;
- The valuation question should be posed as a vote on a referendum, i.e. a dichotomous choice question related to the payment of a particular level of taxation;
- Accurate information on the valuation situation must be presented to respondents, particular care is required over the use of photographs;
- Respondents must be reminded of the status of any undamaged possible substitute commodities;
- Time dependent measurement noise should be reduced by averaging across independently drawn samples taken at different points in time;
- A “no-answer” option should be explicitly allowed in addition to the “yes” and “no” vote options on the main valuation question;
- Yes and no responses should be followed up by the open-ended question: “why did you vote yes/no?”;
- Cross-tabulations: the survey should include a variety of other questions that help to interpret the responses to the primary valuation question, i.e. income, distance to the site, prior knowledge of the site etc.;
- Respondents must be reminded of alternative expenditure possibilities, especially when “warm-glow” effects are likely to be prevalent (i.e. purchase of moral satisfaction through the act of charitable giving); and
- In yes/no elicitation, there should be a “no reply” possibility with a “why” follow-up question.

9.5 SUMMARY

Total economic value includes both use and non-use value. Different valuation methods can be applied for both types of environmental goods and services. These methods span from using market price to using direct or indirect proxies up to the constructed market technique. Which method is used will depend on the importance and type of environmental impacts and the time and budget available to do the valuation. The basis for environmental valuation is the criterion of increased human well being. It is determined as the maximum amount of income the individual affected by the environmental change would be willing to pay (WTP) for a positive change or willing to accept (WTA) a compensation for damages incurred. The methods presented in this module vary in terms of capturing full WTP or WTA.

Ten direct proxy valuation methods were reviewed. These approaches are fairly simple to use and understand but they do not capture total economic value. Their focus is more on direct use values. The most commonly used methods include replacement costs for environmental damage, the effect on productivity of other marketed resources, health costs, expenditure to prevent or mitigate environmental impacts, and general opportunity cost.

Indirect proxy approaches, sometimes called revealed preference methods, are demand curve approaches by opposition to direct proxy approaches. The indirect proxy approaches estimate better the WTP for environmental quality because they relate more directly to a demand curve. Travel cost, hedonic pricing, and wage differential are the three main methods used to derive an indirect proxy. Other methods include residual valuation (similar to deriving forestry stumpage) and implicit pricing where environmental assets are valued equivalent to the amount needed to bring a project NPV or IRR to a specific level.

Where no proxy is available, the CVM method is used. It is theoretically the best way to get at the maximum WTP/minimum WTA, economic measures, which somehow approximate human well-being value judgements. The method covers both use values and non-use values, which none of the other methods could do. Yet the application of the method is not easy even when strict guidelines are followed. Given the possibility of false results and the high costs and time involved, one must carefully weigh the pros and cons before embarking on CVM study and the depth of analysis required. It may be that a simple transfer of values from other similar studies could be as useful. This module presented a number of guidelines developed in the USA to improve the validity of CVM. When adhering to the guidelines, CVM studies can provide estimates reliable enough to be a starting point for a judicial or administrative determination of natural resources damages. This can eventually help assign CVM an important place among valuation methods.

ANNEXURE 1 – Productivity Change Valuation in Djibouti

a) Background

The project area includes:

An area of about 2,000 ha with the highest elevation at 1,800m that includes the Mani Forest. It lies within the 300 mm isohyet and receives the highest rainfall in the country

An area of about 4,000 ha severely desertified, composed of plateaux and hills with altitudes between 900 and 1,400 m. It lies between the 300 and 250 mm isohyets

An extremely rugged area of 20,000 ha (called Karam), with altitudes between 500 to 1,200m. It lies between the 250 and 200 mm isohyets. 75 percent of the rainfall is concentrated in the hot season

The forest plays a central role in the ecological system as well as in the economic activities of the pastoralists living in the area. In years of severe drought, the Mani Forest is considered the last resort for all cattle. The multi-functional role of the forest includes also its use as a source of fuel-wood and minor forest products, besides to its micro-climatic functions and its key role in determining the region's hydrology. Due to overexploitation the forest is suffering irreversible degeneration and will eventually disappear within ten years. Moreover, this, together with rangeland degradation will threaten the livelihood base of subsistence pastoralists. It is therefore of foremost importance to introduce more sustainable resource management practices. To relieve the pressure on the Mani Forest and assist its regeneration, the project aims at a more balanced utilisation of both over-exploited and under-exploited sylvo-pastoral resources. In the meantime it aims at a diversification of the range of income-generating opportunities for the subsistence pastoralists in order to reduce the pressure on the forest resources.

b) Project Components

The project comprises six components:

Sylvo-pastoral management. It consists of the progressive introduction of a system of deferred grazing over 24,000 ha the creation of 750 ha of permanent pasture; establishment of 400 ha of forage plantation and livestock support activities

Forest conservation and regeneration. Toward the aim of conservation and regeneration of the Mani forest, the project would promote the natural and assisted regeneration of juniper procera on various sites, the plantation of 86 ha of community woodlots and the construction of windbreaks around the livestock water points

Water development. The project, with the beneficiary's participation, would construct 39 drinking water storage tanks and 25 livestock water points

Soil and water conservation. Soil and water conservation measures such as stone bunding, gully plugging, terracing and water harvesting, over an area of 900 ha, would enhance the productivity of pasture resources

Income diversification. It would be promoted through charcoal production using excess dead wood, wood carving, aviculture and apiculture

Institutional support. It would consist of the creation of a project management unit, the provision of a core of local and expatriate staff, training and monitoring and evaluation support

c) Problem Set

For the project to be appraised, all the costs and benefits of the project must be priced. The following example demonstrates how the analyst has proceeded to place a monetary value on a nonmarketed good provided by the forest: the forage. The value of the products, notably milk and meat, obtainable with one unit of forage is chosen as a measure of its value. The problem is how to calculate the value of the change in production due to the increased availability of forage. For finding the answer, some further assumptions and data are required.

Table 1 shows the livestock by species existing in the project's area before the project implementation:

Table 1 Existing livestock by specie in project's area

Species	Number
Camels	472
Cattle	1,324
Sheep	1,244
Goats	3,331
Donkeys	218

The feed requirement of a camel is 2.3 metric tons of forage dry matter per year. Table 2 shows the sorghum feed requirements of every species of animal in terms of the sorghum feed requirement of one camel. These values are called "Tropical livestock Standard Units" (TSU).

Table 2 Tropical livestock standard units

Species	TSU
Camels	1.00
Cattle	0.73
Sheep	0.12
Goats	0.12
Donkeys	0.40

Table 3. shows the annual per unit production of milk obtained from lactating females and the production of meat obtained from all animals.

Table 3 Annual productions' parameters

Species	milk (litres/year)	Meat (Kg/year)
Camels	600	14.0
Cattle	400	16.0
Sheep	30	4.7
Goats	40	6.6
Donkeys	0	0.0

Table 4 gives the number of lactating females by livestock species in the project area.

Table 4 Number of lactating females by species

Species	lactating females
Camels	54
Cattle	245
Sheep	87
Goats	473
Donkeys	0

Table 5 gives the average observed price of milk and meat.

Table 5 Price Of milk and meat

commodity	price
milk	150 B$/litre
meat	600 B$/Kg

d) Solution Set

When an input of a production process is not marketed, its value can be elicited from the value of the production obtainable with the use of the input, considering the contribution of the input to the product. In this case the non-marketed forage substantially contributes to the production of milk and meat. The value of a Kg. of forage dry matter can be therefore assumed equal to the value of the production of milk and meat at present obtainable in the project's area with a kg of forage dry matter. The following calculation is done:

looking at the total value of milk and meat obtainable in one year from the existing livestock
calculating the theoretical annual consumption of forage dry matter by the existing livestock
obtaining the value of a Kg of forage dry matter by the ratio: total value of milk and meat/quantity of forage dry matter consumed

e) Calculation of the Value of Milk and Meat Annually Obtainable in the Area

This value is obtained multiplying the total annual production of milk and meat times their average market prices. The annual total quantity of meat is obtained multiplying the annual production of every animal times the number of animals present in the project area by species, then summing across the different species (Table 6).

Table 6 Total meat produced

species	**number of animals in project area**	**meat per animal (Kg/year)**	**Total meat by species (Kg/year)**
camels	472	14.0	6,608
cattle	1,324	16.0	21,184
sheep	1,244	4.	5,846.8
goats	3,331	6.6	21,984.6
donkeys	218	0.0	0
total meat (Kg/year)			55,623.4

Analogously, the total annual quantity of milk is obtained considering the number of lactating females by species and the relative milk production per unit, summing then across the species (Table 7).

Table 7 Total milk produced

species	**lactating females**	**milk (litres/year)**	**milk by species (Litres/year)**
camels	54	600	32,400
cattle	245	400	98,000
sheep	87	30	2,610
goats	473	40	18,920
donkeys	0	0	0
total milk (liters/year)			**151,930**

The total value of the annual production is obtained multiplying the annual quantities times the relative prices (Table 8).

Table 8 Total value of production

commodity	Price	annual quantity	annual value (B$/year)
milk	150* B$/litre	151,930 (litres/yr.)	22,789,500
meat	600 B$/Kg	55,623.4 (Kg/yr.)	33,374,040
total annual value (B$/year)			**56,163,540**

f) Calculation of the Annual Forage Dry Matter Requirements

The total forage dry matter requirement of the existing livestock in the project's area is calculated following these steps:

The different animals are expressed in tropical livestock standard units (TSU) according to their feed requirements and added up across species

The total TSU is multiplied by the annual forage dry matter requirement of the standard animal (the camel), to get the total annual forage dry matter requirements of the existing livestock in the project's area (Table 9).

Table 9 Total TSU by species

species	TSU	animals in project area	total TSU by species
camels	1.00	472	472
cattle	0.73	1,324	966.52
sheep	0.12	1,244	149.28
goats	0.12	3,331	399.72
donkeys	0.40	218	87.20
total TSU in the area			2,074.72

The annual standard animal requirement of forage dry matter is 2,300 kg/year. The existing livestock's requirement per year is therefore:

2,074.72 TSU x 2,300 Kg/year = 4,771,856 Kg/yr.

g) Calculation of the Value of a Kg of Forage Dry Matter

The value of a Kg. of forage dry mater is obtained as the ratio of the total value of annual production divided by the total forage dry matter requirements:

B$/year 56,163,540 B$/yr divided by 4,771,856 Kg/yr = 11.77 B$/Kg.

The value of the forage dry matter, according the change in production approach is therefore 11.77 B$/Kg.

h) Discussion

For supporting from the economic point of view the above analysis, a number of assumptions have been made.

The average product equals the marginal product of forage. This means that the incremental quantity of forage produced leads to a proportional increment of milk and meat

The incremental production of forage leads to an increase of meat and milk sellable at a constant price, i.e. the prices of milk and meat do not fall due to the increase of the supply

All the value of the output (selling price) is allocated to the production input "forage". This is correct only if we assume that the production costs are negligible. For example, if the major production factor is labour, we assume that its opportunity cost is close to zero, i.e. no other output is forgone when additional labour is employed in milk and meat production. By the same token, we should assume that the value of leisure time forgone is zero. This assumption could be not realistic in other projects. In such cases, the remuneration of all other production factors and input costs that allow the production of milk and meat should be deducted from the selling price.

ANNEXURE 2 – Substitute Valuation Method

a) Background

This example focuses on how to derive the value of a non-marketed asset, (forage) looking at the value of a marketed asset (sorghum) that can be its substitute. The project area includes several ecozones; tropical forests, mountainous areas, and severely desertified areas. The forest area and its surroundings are controlled by a tribe of subsistence pastoralists and exploited for pastoral activities. The desertfied area instead is currently under-utilised due to the severe water constraint. The brown tropical soils and fluvisols in the project area offer some potential for pastoral activity if properly managed, but are very vulnerable to erosion in absence of adequate vegetation. In absence of timely intervention to introduce more sustainable sylvo-pastoral resource management practices, the forest will suffer irreversible degeneration and will eventually disappear within ten years. This, together with rangeland degradation, will threaten the livelihood base of subsistence pastoralists.

The project comprises several components, including the sylvo-pastoral management. It involves the progressive introduction of a system of deferred grazing over 24,000 ha.; the creation of 750 ha of permanent pasture; establishment of 400 ha of forage plantation and livestock support activities. In the particular socio-economic context, forage is an important output. Since no market for forage exists, to appraise the benefits of the project its shadow price, i.e. the value to the economy of one unit of forage produced by the project must be estimated. The value of forage is estimated looking at the value of sorghum that can be its substitute for animal feeding. The sorghum is imported from abroad. The price of sorghum (sorghum dry matter) for the final user is composed by FOB price, freight, insurance and transport costs on site, as listed in the Table 1.

Table 1 Imported air-dried sorghum costs

Description	Values
FOB price USD/ton	96
Freight USD/ton	100
Insurance USD/ton	5
local transport B$/ton	5337
Exchange rate B$/USD	156.65

The air-dried sorghum contains 90percent of dry matter and 10percent of moisture[22]. The digestible energy, i.e., the quantity of energy animals manage to obtain from the feed is shown in Table 2, expressed in mega-calories per kilogram (Mcal/Kg) of dry matter of feed:

Table 2 Digestible energy of different feeds

description	Values
sorghum dry matter	3.88 Mcal/kg
forage dry matter	2.40 Mcal/kg

The analyst is interested in evaluating the price of a kilogram of forage dry matter in the project area. Since no market for forage exists, the prices prevailing for a surrogate after appropriate adaptations can be used for assessing the value of forage. The procedure described in section 25.18 will be followed.

b) Steps in Valuation Process

Step 1. Determination of the appropriate substitute. The suitable substitute for forage is sorghum. For eliciting the value of forage from the value of sorghum we have to consider: (i) the price of a kg of sorghum dry matter in the project's area; (ii) the quantity of digestible energy present in a kg of forage dry matter relative to the quantity of digestible energy contained in a kg of sorghum dry matter. For understanding why we have to look at the digestible energy present in a feed it is worth recalling that the value of a feed is roughly determined by its feeding capacity that in turn is closely related to the quantity of digestible energy present in it.

[22] This is due to a partial drying effect of air, the atmospheric humidity and other causes.

Step 2. Calculation of the price of sorghum dry matter in the project's area. The sorghum is an imported commodity. It is usually transported after drying it. The price of the air-dried (a.d.) sorghum in project 's area is therefore determined by the CIF price plus the transportation cost from the border to the project's area.

The CIF price in U.S. dollars of one ton of the air-dried sorghum is obtained adding to the FOB price the cost of freight and insurance.

FOB price of a.d. sorghum USD/ton	96	+
freight USD/ton	100	+
insurance USD/ton	5	=
CIF price of a.d. sorghum (USD/ton)	**201**	

The CIF price in USD of a ton of air dried sorghum is converted in local currency (B$) using the exchange rate:

CIF price of a.d. sorghum (USD/ton)	201	x
Exchange rate (B$/USD)	156.65	=
CIF price of a.d. sorghum (B$/ton)	**31,486**	

The transport cost from the border to the project area is added to the CIF cost in local currency for obtaining the cost of a ton of air dried sorghum in the project area:

CIF price of a.d. sorghum (B$/ton)	31,486	+
Local transportation (B$/ton)	5,337	=
Local price of a.d. sorghum (B$/ton)	**36,823**	

The cost per ton is converted in cost per kilo:

Local price of a.d. sorghum (B$/ton)	36,823	:
Conversion factor (Kg/ton)	1,000	=
Local price of a. d. sorghum (B$/kg)	**36.823**	

For calculating the local price of the sorghum dry matter we have to consider that a kg of air-dried sorghum contains 0,9 kg of sorghum dry matter.

Local price of a. d. sorghum (B$/kg)	36.823	:
Dry matt. content of a.d. sorghum (Kg/Kg)	0.9	
Loc. price sorghum dry matter (B$/kg)	**40.914**	

The cost of a kilo of sorghum dry matter in the project's area is therefore 40.914 B$[23].

Step 3. Individuation of the differences between forage and sorghum. The main difference between these different kinds of fodder is their digestible energy content. There is to notice that little imported sorghum is used in the project area, despite the technical substitutability of forage with sorghum.

Step 4 Calculation of the substitution rate of forage with sorghum

The substitution rate of forage with sorghum shows how many kilograms of sorghum dry matter we need for having the same digestible energy as a kilo of forage dry matter. The substitution rate is obtained as the ratio between the digestible energy of forage and the digestible energy of sorghum.[24]

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[23] This is equivalent to consider the price of a kg of air dried sorghum as the price of 900 grams of dry matter. The price of a gram of dry matter is indeed (B$/kg) 36.823 / (grams/kg) 900 = (B$/gram) 0,040914 . The price of a kg. of dry matter is obtained multiplying by 1,000 the latter result: (B$/gram)0,040914 x (Grams/kg)1,000 = (B$/kg)40.914

[24] If we have a given quantity of forage, we can obtain the equivalent quantity of sorghum (equivalent on digestible energy grounds) multiplying the quantity of forage times the conversion factor of the forage in sorghum).

Forage dry matter (Mcal/Kg)	2.40	:
Sorghum dry matter (Mcal/Kg)	3.88	=
of forage in sorghum	**0.6186**	

Step 5. Calculation of the value of forage based on digestible energy content. For eliciting the value of a kilo of forage dry matter from the value of a kilo of sorghum dry matter to multiply the value of a kg. of sorghum times the substitution rate of the forage with sorghum.

Price of sorghum dry matter(B$/kg)	40.914	x
Conversion factor of forage in sorghum	0.6186	
Value of forage dry matter (B$/Kg)	**25.308**	

The forage dry matter contains 62percent of digestible energy of sorghum dry matter, therefore, under these assumptions, the value of forage dry matter is 62percent of the value of sorghum dry matter. Alternatively, we can calculate the cost of one unit of digestible energy (one mega-calorie) obtainable from a kg. of sorghum dry matter.

price of sorghum dry matter(B$/kg)	40.914	:
Sorghum digest. energy (Mcal/Kg)	3.88	=
Price of a Mcal (B$/Mcal)	**10.545**	

This calculation highlights the value of a mega-calorie in the project area, when it is obtained by sorghum dry matter. Assuming that a mega-calorie of the sorghum dry matter is equivalent to a mega-calorie of the forage dry matter, to obtain the value of a Kg. of a forage dry matter we can multiply the value of the sorghum mega-calorie times the mega-calories obtainable from a kg. of forage dry matter.

Price of a Mcal (B$/Mcal)	10.545	x
Forage digest. energy (Mcal/Kg)	2.400	=
Price of forage dry matter (B$/Kg)	**25.308**	

ANNEXURE 3 – Zonal Travel Cost Valuation

a) Background

This exercise is the outcome of a simulation developed with the collaboration of trainees during a training workshop held at the World Bank. The participants were assumed to travel to Washington for visiting a national park. A questionnaire survey was carried out among the attendants to collect the information necessary to develop a ZTCM. Data have been adjusted for illustrative purposes.

b) Methodology

To value an environmental asset with the ZTCM the information necessary to estimate the following function must be collected:

$$Vij/Pi = a + b\,C_i$$

The procedure for the calculation of the value of a recreational service can be summarised as follows:

Identification of the site (boundaries, maps, etc.)

Design of the questionnaire. Compulsory items: origin of visitors, vehicle used. Non compulsory travel cost, individual socio-economic features, other attributes (e.g., activities)

Conduction of the survey on a sample of ***p*** visitors

Collection of the number of visits to the site (***V***) in a period (year). Source: statistical records (e.g., tickets sold)

Subdivision of visitor origins into zones of increasing distance. Source: questionnaire

Determination of the number of visitors by zone (***pj***) and the relative shares over the sample size (***pj/p***)

Calculation of annual visits by zone (***Vj=V*pj/p***)

Collection of data on population by zone (**P*j***) and zonal socio-economic features (***Si*). Source: statistical records.

Calculation of average visit rate in each zone (***Rj=Vj/Pj***)

Calculation the zonal average travel cost to the site (***Cj***) with reference to the distance. Source: questionnaire or recorded data (e.g., Automobile Association)

Estimation of the demand function ***V/P = f(C,S)***

Compute the average visitor consumer surplus by zone (***CSj***)

Compute the zonal annual CS by zone (***CSZj***) by multiplying CSj times the resident population by zone (***Pj***)

Aggregate the zonal annual CS to get the total annual CS (***ACST***).

To summarise, in ZTCM the researcher estimates a demand function using the data from each zone. This derived demand curve is assumed to be the same for each zone. The "choke point" where demand is 0 is then calculated. The consumer surplus (per visit) for each zone is then calculated in the usual manner; i.e. by integrating the curve between the choke point and the travel cost (price) paid by residents of that zone. The following exercise applies the proposed procedure.

c) Problem Set

The data collected in the survey about the origin of visitors, their travel costs and the total population of their countries have been inserted in the database shown in Table 1. Besides, also the total number of annual visits to the site as been obtained by recorded statistics (steps 1 and 2 of the procedure above).

Table 1 Zonal travel cost - database.

OBSERV	PAYSXX	COUTVO (Usd)	POPULA(milions)
1	GUINEE	1,029	6
2	CONGO	2,650	3
3	LIBAN	900	3.5
4	SEYCHELLES	4,200	7.5
5	COTE D' IVOIRE	1,037	13.5
6	BENIN	1,064	5
7	ITALIE	1,000	56
8	BURKINA	1,300	10
9	BURKINA	1,300	10
10	MAURICE	4,200	100
11	MAROC	1,000	26
12	COTE D' IVOIRE	1,037	13.5
13	COTE D' IVOIRE	1,037	13.5
14	BENIN	1,064	5
15	TOGO	1,074	4
16	ITALIE	1,000	56
17	MADAGASCAR	5,000	100
18	TOGO	1,074	4
19	TOGO	1,074	4
20	BENIN	1,064	5
21	BENIN	1,064	5
22	CAMERUN	2,600	12
23	SENEGAL	1,000	10
24	MALI	2,000	8.5
25	ZAIRE	2,650	40
26	BELGIQUE	985	10
Total annual visits to the site: TOTVIS (V)			30,000

d) Solution Set

Once the data have been organised in the database, the division in homogeneous zones of origin can be run (Table 2 and step 3 of the procedure). Dichotomous variables are utilised for codifying the different zones.

Table 2 Classification of data by zone

OBSERV	PAYSXX	COUTVO	POPULA	EURMED	SAHELX	AFRWES	AFRCEN	OCEIND
3	LIBAN	900	3.5	1	0	0	0	0
26	BELGIQUE	985	10	1	0	0	0	0
16	ITALIE	1,000	56	1	0	0	0	0
7	ITALIE	1,000	56	1	0	0	0	0
11	MAROC	1,000	26	1	0	0	0	0
23	SENEGAL	1,000	10	0	1	0	0	0
24	MALI	2,000	8.5	0	1	0	0	0
8	BURKINA	1,300	10	0	1	0	0	0
9	BURKINA	1,300	10	0	1	0	0	0
1	GUINEE	1,029	6	0	0	1	0	0
13	COTE D' IVOIRE	1,037	13.5	0	0	1	0	0
12	COTE D' IVOIRE	1,037	13.5	0	0	1	0	0
5	COTE D' IVOIRE	1,037	13.5	0	0	1	0	0
14	BENIN	1,064	5	0	0	1	0	0
20	BENIN	1,064	5	0	0	1	0	0
21	BENIN	1,064	5	0	0	1	0	0
6	BENIN	1,064	5	0	0	1	0	0
18	TOGO	1,074	4	0	0	1	0	0
19	TOGO	1,074	4	0	0	1	0	0
15	TOGO	1,074	4	0	0	1	0	0
22	CAMERUN	2,600	12	0	0	0	1	0
2	CONGO	2,650	3	0	0	0	1	0
25	ZAIRE	2,650	40	0	0	0	1	0
10	MAURICE	4,200	100	0	0	0	0	1
4	SEYCHELLES	4,200	7.5	0	0	0	0	1
17	MADAGASCAR	5,000	100	0	0	0	0	1
TOTAL		43,403	531	5	4	11	3	3
MEAN		1,669	20	0.19	0.15	0.42	0.12	0.12

In Table 3, the number of sample visitors by zone have been calculated (variable SANUVI) and the sample share of visitors from each zone on the sample observations (TOTSAM) is obtained (variable SASHAR, step 4 of the procedure).

SASHAR = SANUVI / TOTSAM

where TOTSAM = number of sample observations.

Subsequently, these shares are used for splitting the total annual number of visits (TOTVIS) and estimating the number of annual visits zone by zone. (variable NUMVIS) (step 5 of the procedure).

NUMVIS = TOTVIS * SASHAR

Table 3 Calculation of the annual visits by zone (Vj)

VARIABLES	bCOUTZO	CONSTA
PARAMETERS	-0.000066	0.288998
ST.ERRORS	0.000056	0.139565
R2/ ST.ERR. Y^	0.317039	0.165798
F-TEST /D.G.F	1.392639	3.000000
T-RATIOS	-1.180	2.071
CHOKE PRICE (Usd)		4,363

In Table 4, the population by region (variable POPUZO) is reported (step 6) . The visit rate (variable TAUXVI) is then obtained as the ratio of the number of visits per year (NUMVIS) and the total population by region (var. POPUZO) (step 7):

TAUXVI = NUMVIS / POUPZO

Besides the zonal averages of the travel costs (variable COUTZO) is calculated (step 8).

Table 4 Population by zone, zonal visit rates, zonal average travel cost

ZONEXX (j)	NUMVIS (Vj = V*pj/p)	POPUZO (,000) (Pj)	TAUXVI (Rj=Vj/Pj)	COUTZO (Cj)
EUROPE	5,769	95,500	0.060	977
SAHEL	4,615	28,500	0.162	1,400
AFRWES	12,692	28,500	0.445	1,056
AFRCEN	3,462	55,000	0.063	2,633
OCEIND	3,462	207,500	0.017	4,467
total (p)	30,000	415,000	0.072	1,669

The estimation of the (direct) demand function has been run regressing the variable TAUXVI (dependent) on the variable COUTZO (independent). (step 9 of the procedure). The linear form for the demand function had been chosen:

TAUXVI = CONSTA + bCOUTZO * COUTZO

The estimated parameters (CONSTA and bCOUTZO , i.e. the constant and the slope respectively) are shown in Table 5. Also some statistics of the goodness of fit (t-ratios, R2 and F test) are reported.

Table 5 Demand curve estimation

VARIABLES	bCOUTZO	CONSTA
PARAMETERS	-0.000066	0.288998
ST.ERRORS	0.000056	0.139565
R2/ ST.ERR. Y^	0.317039	0.165798
F-TEST /D.G.F	1.392639	3.000000
T-RATIOS	-1.180	2.071
CHOKE PRICE (Usd)		4,363

The choke price for the linear demand function i.e. the price that lead to zero visits, was calculated setting the demand function equal to zero:

TAUXVI = 0 implies:

CONSTA + bCOUTZO * COUTZO = 0

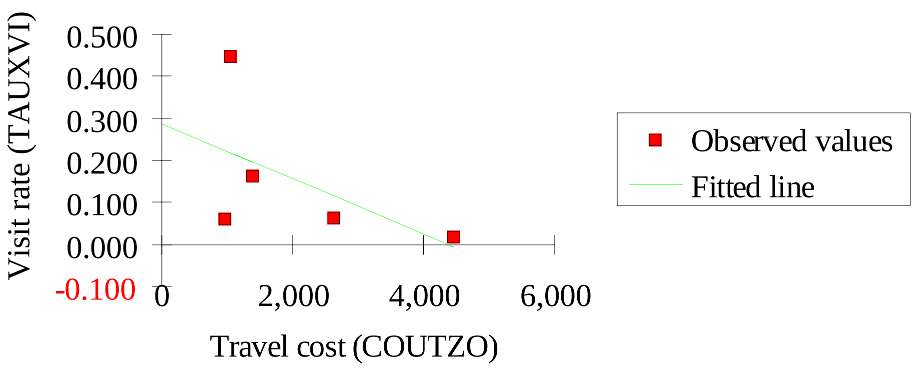
COUTZO° = - CONSTA / bCOUTZO

COUTZO° = CHOKE

CHOKE = - CONSTA / bCOUTZO

The graph in Figure 1 below shows the observations of zonal data (COUTZO, TAUXVI) and the fitted line, graphed using the estimated parameters.

Figure 1 Zonal travel cost - estimated demand curve and CS



In Table 6, the (average individual) consumer surplus was calculated zone by zone integrating under the demand curve between the average travel cost of each zone (COUTZO) and the choke price (CHOKE). (step 10 of the procedure). The formula for the definite integral was worked out integrating the demand curve and substituting inside the bounds of integration:

int (TAUXVI d COUTZO) = (int means integral)

int [(CONSTA + bCOUTZO * COUTZO)] d COUTZO =

= CONSTA*COUTZO + 1/2 bCOUTZO * COUTZO^2

The definite integral between the specific value by zone of COUTZO (<u>COUTZO</u>)and the upper bound of integration CHOKE is therefore:

CONSUR = [CONSTA * CHOKE + 1/2 bCOUTZO * CHOKE^2] - [CONSTA* <u>COUTZO</u> + 1/2 * bCOUTZO * <u>COUTZO</u>^{2}]

The Consumer Surplus (CONSUR) referring to a population unit (one thousand people) was then multiplied by the population of each zone (POPUZO), to obtain the annual CS by zone (variable CONZON, step 11 of the procedure)

Table 6 Consumer surplus estimation

	CONSUR (Usd) (CSj)	POPULA (,000) (Pj)	CONSZON (Usd) (CSz = CSj * Pj)
EUROPE	379.7	95,500	36,264,784
SAHEL	290.8	28,500	8,287,484
AFRWES	362.2	28,500	10,322,252
AFRCEN	99.1	55,000	5,450,553
OCEIND	0.4	207,500	73,589
TOTAL CS (Usd)			60,398,662
AVER. CS PER VISIT (Usd)			2,013

The total consumer surplus is then obtained summing up the zonal consumer surpluses (step 12 of the procedure). Further elaboration can be undertaken, such as the calculation of consumer surplus per visit (division of the total consumer surplus by the number of annual visits), or discounting the annual flows to get the component of the asset value due to the recreational services supplied by the environmental asset under consideration.

ANNEXURE4 – Individual Travel Cost Valuation

a) Background

This exercise draws on a actual study aimed at estimating the total use-value of forests in Liguria Region (Italy)[25]. Liguria Region used to be an important producer of timber and chestnuts in the past. Over the years, the relative importance of these activities has dramatically declined, thus leading to forests abandonment and emigration of its population in the urban areas situated in the coastal zones. Consequently, coastal areas are now suffering of high and unsustainable population densities especially during the summertime, when significant flows of tourists add on the local population. As well, the internal forested areas are progressively deteriorating due to lack of management and maintenance of both forests and historical sites within the forested areas.

From the financial point of view, revenues from forests of these areas are rather low compared to revenues from other uses of land. However, the forests provide other important non valued services such as soil-moisture conservation, open access recreation and hunting, as well as valuable secondary forest products such as berries, mushrooms and litter. Local authorities have therefore undertaken a study for appraising the net social benefits provided by the forested areas in a view of allocating financial resources for the rehabilitation and development of these areas.

This example estimates the benefits of the recreational use of these forests. In Liguria Region, recreation is a non-priced public good, therefore its value could not be assessed with conventional market techniques. The evaluation techniques used were the Individual Travel Cost Method and the Contingent Valuation Method

b) Methodology

The procedure for carrying out a study with the ITCM method is similar, at least in the very first steps to the ZTCM method. The following 11 steps have been used:

[25] This study is published in: Bellù, L.G., Cistulli V., 1997. Economic Valuation of Forest Recreation Facilities in the Liguria Region (Italy). Working Paper GEC 97-08. CSERGE.

Identification of the site: a clear description of the site to be surveyed is essential for interviewees and interviewers to know which is the object they are talking about. It will also help identify the sites where interviews will be done. Maps and photographs of the site will provide a valuable contribution during the interviews. In the particular case of this study, sites have been identified on the basis of the following criteria: suitability of the area for tourism; actual flow of tourists; and the Plans of Liguria Region for creating regional parks.

Definition of the environmental good/service to be valued: the good or service to be valued have been defined so that no misunderstandings occur. Goods or services of a forested area can be the whole area of the site, one of the particular services provided by the forest (i.e., aesthetics, cycling, fishing, etc.), or the change in the supply of one attribute, both in quantity and in quality terms. In the Liguria case, the object was the whole site.

Questionnaire design: the questionnaire is aimed at collecting information on the consumers behaviour towards the particular environmental good/service to be valued. Information can be subdivided into compulsory and non compulsory information. Compulsory are the origin of visitors, vehicle used for reaching the site, individual socio-economic features, other attributes (e.g., activities carried out in the site, member of environmental association, etc.); non compulsory are travel cost and opportunity cost of time (i.e., those variables that can be estimated outside of the questionnaire).

In this study, the questionnaire was constructed in order to be used both for the TCM method and the CVM. In particular it was subdivided in the following sections:

The first section was only for use of interviewers and was aimed at providing some general information on the interview and interviewers (name of interviewer, location of interview, length of interview, etc.).
The second section was devoted to the collection of socio-economic data. It was assumed here that age, education, income, profession, number of family members, etc. are important determinants in visitors' behaviour towards recreational use or visits to forests.

The third section attempted to identify the costs of travel costs faced by individuals to visit the site, by asking them their origin, the vehicle used to reach the site, the time employed to reach the area from their origin, the trip plan.
The fourth section consisted of few questions aimed at investigating the environmental concern and awareness of visitors. It was assumed that the higher the awareness of environmental problems, the higher the perception of the value of forests' recreational value.
Two further sections have been included for assessing the WTP with the CVM approach. In particular, the payment vehicle, the elicitation form and the market scenario for recreation have been defined. In this example only the ITCM is analysed.

The information provided by the questionnaire will allow the analysts to derive the demand curve for the recreational site (see next section).

Survey strategy: this step is mainly concerned with the organisation and conduction of the survey. Before proceeding with the survey, the type of interview and the sample of interviewees must be defined. In the Liguria case it was decided that interviews should be carried out on site. Therefore, for each single area, sites were identified for carrying out on-site face-to-face interviews. Interviewed visitors were selected randomly among the visitors throughout July, August and September 1993 on both week-days and weekend days. The total number of interviews completed was 800.

The behaviour of people visiting the site during the summertime is most probably different than the behaviour of people visiting the same site in winter and spring (e.g., distance and time spent on site might be shorter). Thus, the total annual value of recreation services provided by the site might be overvalued if the observed behaviour in summer was assumed to be representative of the whole year. This possible bias was taken into account in the final interpretation of the results.

Elaboration of calculated variables and statistical description of the sample: when the survey has been completed, a database is created like the one presented in Table 1, using a simple spreadsheet. In order to check consistency of responses and reliability of data, some statistical analyses are carried out such as correlation analysis, contingency tables, Chi square analysis, mean, median, variance, percentiles, etc.). All these analyses have been tested in the study carried out in Liguria.

Choice of functional form: a functional form relating the dependent variable (visits per year) and independent variables (travel cost, socio-economic variables) must be identified which better fits the particular database. The choice is among four functional forms: linear, log-dependent, log-independent, double log (also named log-log). In the particular case of Liguria, two functional forms were used: the double log form and the linear form.

Estimation of the demand function: once a functional form for the demand curve of the environmental service has been tentatively selected, its parameters are estimated using econometric models. Basic approaches require models to be estimated by Ordinary Least Squares (OLS). More complex ones instead (e.g. truncated demand functions, simultaneous demand systems) require the use of Maximum Likelihood Estimation (MLE) methods, to be run by suitable econometric software packages.

Calculation of the individual Consumer Surplus (CS). Once the most suitable functional form has been estimated, the individual CS can be calculated. Appendix 11.1 provides an analytical specification of the Consumer Surplus calculation for a linear demand function. The exercise below supplies the formula of the CS for a double log demand function.

Calculation of the annual individual average consumer surplus (averaging within the sample). When applying ITCM, the CS is calculated individual by individual, i.e. for each observation of the sample. A summary measure of the sample CS can be obtained taking the sample mean of the CS. Several mean CS can however be calculated considering relevant specific socio-economic features of sample individuals, such as age, education, gender or visit purposes.

Aggregation and further elaboration: if the objective of the study is the estimation of the total value of the site, the individual WTP resulting from the analysis has to be multiplied by the total visitors of the site during one time period (usually the year). Once the total value of the area has been computed, the value per hectare can be obtained by dividing the total value by the extension of the area of the site. Although this calculation has been carried out in the real study, it is not presented in this exercise.

Interpretation and presentation of results: The obtained results need to be explained, interpreted, compared with those of other similar studies.

c) Problem Set

Following the methodology outlined previously, a survey was run and the database organised (Table 1). The variables listed below have been considered and relevant data have been collected:

Observed variables[26]

1.	AGEXXX	:	Age
2	OTSITE	:	Planned visits to other sites
3	DUAPAR	:	Stay in private house
4	TICKET	:	Entrance fee
5	ACCEPT	:	Answer to the offer (Take it or leave it)
6	INCOME	:	Visitor's income

From the observed data, the following variables have been calculated:

Calculated variables

TRAVCO: Travel Cost of the visit (excluding opportunity cost of time).

VISITS : Number of visits per year. Visits of less than one day have been considered as daily visits. Visits lasting more than one day have been considered as many daily visits as the days spent in the forest. All other visits in the year have been considered daily visits.

[26] The real questionnaire had 41 observed variables and 10 calculated variables

Solution Set

Step 3 . Choice of the demand function (full log)

28.31 After a careful analysis of the data collected, the full log (log-log) model has been found to be the most appropriate in this exercise (step 2).

Step 4. Estimation of the demand function (full log)

28.32 To estimate the demand function, a regression of VISITS (dependent) on the other variables (independent) has been run. Table 2 summarises the results.

Table 1. Individual TCM. Database.

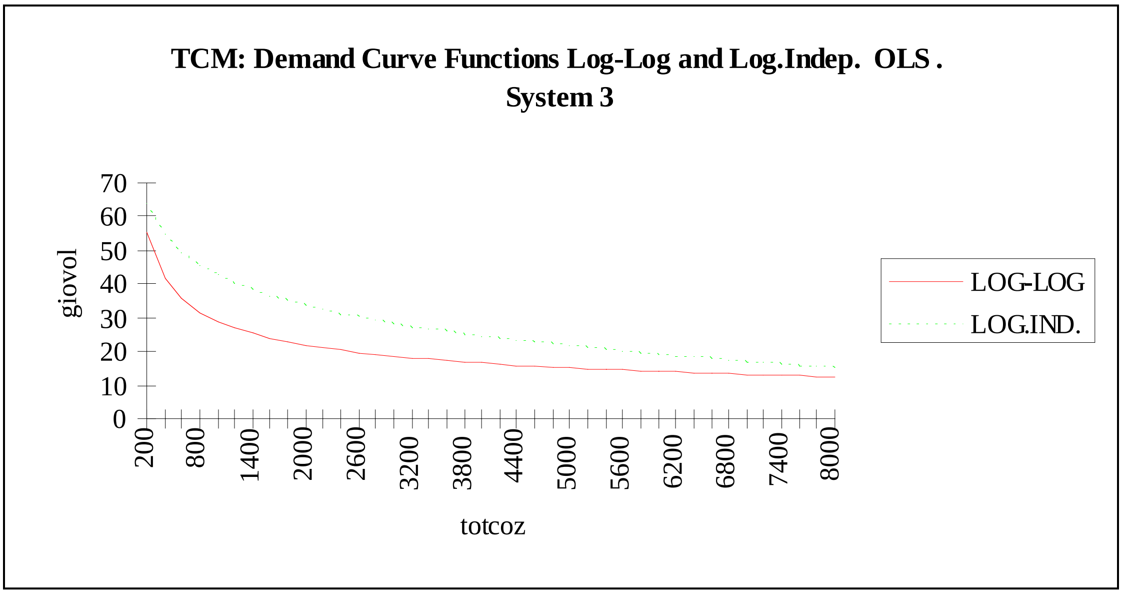
NUMREG	AGEXXX	DUAPAR	OTSITE	INCOME	TRAVCO	VISITS
1	70	1	1	75	47500	32
2	50	1	1	25	1985	31
3	50	1	0	75	910	26
4	50	1	0	55	4750	35
5	40	1	1	8	1049	28
6	50	0	0	15	1000	11
7	50	0	1	75	9501	2
8	50	1	0	25	792	70
9	50	1	0	35	9500	3
10	50	1	1	35	1351	21
11	60	0	0	15	1900	16
12	21	0	1	15	1583	2
13	30	1	0	25	720	2
14	40	0	1	35	2348	16
15	50	0	1	25	10512	4
16	30	0	1	15	2375	2
17	50	0	1	25	3250	7
18	50	0	1	35	3250	2
19	40	0	1	35	3250	2
20	21	0	1	15	2160	5
21	40	1	1	25	3250	2
22	60	0	0	25	400	21
23	40	1	1	35	8540	19
24	50	1	1	35	27075	2
25	30	0	1	25	6900	3
26	21	0	0	15	200	21
27	40	0	1	15	637	31
28	50	1	1	45	936	40
29	30	1	0	8	2167	35
30	21	1	1	15	2982	41
Sample mean	42.800	0.500	0.667	30.200	5,426	18

Table 2. ITCM. Estimation of Double log Demand function parameters

VARIABLE	bTRAVCO	bINCOME	bOTSITE	bDUAPAR	bAGEXXX	CONSTA
COEFFICIENT	-0.460	-0.311	0.040	1.086	1.183	1.925
ST.ERROR	0.207	0.430	0.479	0.405	0.724	2.328
T-RATIOS	-2.224	-0.724	0.084	2.678	1.635	0.827
R2	0.39542		ST.ERROR OF Y^			1.05629
TEST.F	3.13936		DEGREES OF FREEDOM			24
SSReg	17.5136		SSErr			26.7779

Figure 1 below shows the double log demand function estimated keeping other variables at their sample mean. Also the graph of the Log. Indep. functional form (estimated outside this exercise) is reported for comparison.

Figure 1 TCM: demand curve functions log-log and log, independent OLS - system 3



Step 5: Calculation of the CS with the model Full Log

For every observation, the annual consumer surplus with double log demand function is calculated, using the formula below:

CONSUR=(EXP(CONSTA+OTSITE*bOTSITE+DUAPAR*bDUAPAR)/(bTRAVCO+1))*INCOME^bINCOME*AGEXXX^bAGEXXX*(UPLIM^(bTRAVCO+1)-TRAVCO^(bTRAVCO+1)

The selection of the upper limit of integration within the sample range of TRAVCO (say, 99th percentile) leads to have some observations with upper limit of integration lower than the lower limit of integration, which in turn generates negative consumer surpluses. If the test for the exclusion of the observations with upper limit of integration lower than the lower limit of integration is included, the formula in the spreadsheet becomes:

```
=IF(TRAVCO<=UPLIM;(EXP(CONSTA+OTSITE*bOTSITE+DUAPAR*bDUAPAR)/(bTRA
VCO+1))*INCOME^bINCOME*AGEXXX^bAGEXXX*(UPLIM^(bTRAVCO+1)-
TRAVCO^(bTRAVCO+1));" ")
```

The results are shown in Table 3 below:

Table 3 ITCM consumer surplus

NUMREG	CONSUR	Notes
1		Upper limit < lower limit
2	275,891	
3	209,095	
4	167,083	
5	330,505	Max CS
6	115,379	
7	37,793	
8	298,463	
9	136,360	
10	263,471	
11	131,156	Close to the mean CS
12	40,571	
13	164,485	
14	62,439	
15	49,286	
16	57,707	
17	83,982	
18	75,626	
19	58,074	
20	38,531	
21	191,019	
22	131,754	Close to the mean CS
23	117,014	
24	0	Upper limit = lower limit
25	35,137	Min. CS different from 0
26	46,188	
27	96,266	
28	254,452	
29	203,255	
30	106,686	
Mean	**130,264**	

Step 6. Calculation of the annual average individual consumer surplus per visit and total WTP

The annual average individual consumer surplus per visit is calculated considering the annual average number of visits.

The total average WTP is calculated summing up the individual consumer surplus per visit and the average travel cost per visit. The results are reported in Table 4 below. Estimations from other systems of the real study are reported for comparison.

Table 4 ITCM: average individual consumer surplus per visit (OLS)

SYSTEM	**CONSTA**	**OTSITE**	**DUAPAR**	**INCOME**	**TRAVCO**	**AGEXXX**
1	4.3188	-0.7032	0.6646	-0.0566	-0.2292	-0.0220
2	4.2962	-0.0897	0.5607	-0.5596	-0.1791	0.2222
[redacted]						
4	6.6042	-0.2874	0.5299	-0.0578	-0.4026	-0.1910
5	2.0307	-0.5200	0.3329	-0.0886	-0.2327	0.4965
6	3.2575	-0.5564	0.5351	0.1053	-0.1869	-0.0531
7	1.4353	-0.0575	-0.1269	-0.2287	-0.0870	0.3643
TOTAL	4.4325	-0.4814	0.8361	-0.0776	-0.2705	-0.0293

Shaded areas refer to results of the present exercise. Other data refer to results of other systems analysed in the same work.

Step 7. Aggregation of results. (outside the exercise)

The population of visitors is calculated outside the exercise and the annual total benefits from the recreational services of the systems is estimated. Annual values can be discounted to get the asset value contribution of the recreational function of forests.

ANNEXURE 5 – Price Functions for Hedonic Pricing Method for Urban Housing

A functional form must be selected for estimating the price function of houses. If a multiplicative model for price is assumed, the price function looks like that presented in Box 1. The first derivative of the price function with respect to. the environmental feature(s) shows how the price of the houses changes for changes of the environmental quality associated. This derivative is expected to be positive, signalling that, other things equal, increasing environmental quality is associated with increasing prices of houses[27].

The first derivative of the house price function can be interpreted as the **Implicit Marginal Price Function** for the environmental good. "Implicit" means implicit in the price of the house which the environmental good is associated with, i.e. reflected by (embodied in) the value of the house, that, ceteris paribus, would have a different value if the associated environmental quality was at a different level. "Marginal" refers to the last unit of environmental quality purchased, being the value of first derivative at a specific point an approximation of the change of the house price for unit changes in the environmental quality.

Box 1. Price function of houses: the multiplicative model

If the relationship between the price of houses and their features is supposed multiplicative, the price function is:

$$P_i = aE_i^{\beta_e} \subseteq_{d=1}^{p} (e^{\delta_d D_{di}}) \subseteq_{j=1}^{k} (X_{ji}^{\beta_j}) e^{u_i}$$

Where: **Pi** is the price of the house i; **Ei** is the environmental quality of the house (namely, the broad-leave trees concentration); **Xij** a set of j attributes (location, structure) referring to house i; **u_i** is the stochastic term referring to observation i; **D_d** is a set dummy variables, each of them that assumes value 1 when a specific feature is present for observation i and value 0 when the specific feature is absent for observation i; **a**, **_e** and **_j** are parameters to be estimated. This model, taken in logarithmic form becomes:

$$\ln P_i = \ln\left[a \subseteq_{d=1}^{m} (e^{\delta_d D_{di}}) E_i^{\beta_e} \subseteq_{j=1}^{k} (X_{ji}^{\beta_j}) e^{u_i} \right]$$

$$\ln P_i = \alpha + \sum_{d=1}^{m} \delta_d D_{di} + \beta_e \ln E_i + \sum_{j=1}^{k} \beta_j \ln X_{ji} + u_i$$

Where: _ **=ln(a),** i.e.: a=e–

After estimating the parameters _ , _s and _s, the price relationship is obtained.[28]

The second derivative of the house price function i.e. the first derivative of the implicit marginal price function is expected to be negative, signalling decreasing implicit marginal prices for increasing environmental quality units. This means that the implicit price of a unit of environmental good when the environmental good is largely available is less than the price of one unit when the availability of the environmental good is limited. When a multiplicative model for prices of houses is chosen, the Implicit Price Function takes the form shown in Box 2.

Box 2. The Implicit Price Function (multiplicative model)

This is the first derivative of the house price function shown in the box 1.

$$\frac{dP_i}{dE_i} = a\beta_e E_i^{(\beta_e - 1)} \subseteq_{c=1}^{p} (e^{\delta_d D_{di}}) \subseteq_{j=1}^{k} (X_{ji}^{\beta_j})$$

$$\frac{dP_i}{dE_i} = \frac{\beta_e}{E_i} P_i \text{ . Calling } \frac{dP_i}{dE_i} = Pe_i \quad ? \quad Pe_i = \frac{\beta_e}{E_i} P_i$$

It results that the first derivative, when the house price model is multiplicative, is not constant but varies with the price (and the environmental quality) level. Because the first derivative is expected to be positive, in the multiplicative model _e is expected to be positive. (assuming E is a positive measure of an environmental good).

To some extent the marginal price function could be considered the inverse demand function for the environmental good (inverse because the price of the good is expressed as function of the quantity). This is however correct only if some restrictive conditions on the shape of individual utility functions hold (identical utility functions). Estimated implicit prices for different houses refer to different individuals. Every estimated implicit price is only one observation of the true individual demand curve and corresponds to the individual willingness to pay (WTP) for a marginal unit of environmental good only for that specific level of environmental good purchased.

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[27] Obviously, this is true when the environmental attribute is a good (not a bad).

[28] To be consistent with the probabilistic structure of the model, we must recall that the u_i are assumed to be random variables normally distributed with 0 mean and common variance:
u_i_ N(0,_2) and that OLS estimates allow to obtain estimates of the expected value of the random variables Pi, E(Pi).

Instead of using the implicit marginal price function for directly estimating the change in the individual consumer surplus, it can be better utilised for calculating the implicit marginal price paid by every household. A second stage estimation of the inverse demand curve can be obtained regressing the implicit marginal price on the quantity of environmental good purchased and other socio-economic features of individuals. When, for example, a multiplicative inverse demand function is chosen, the functional form is that shown in Box 3.

The variation of the Consumer Surplus due to a change of an environmental service is calculated as the definite integral of the inverse demand function with respect to the quantity of the environmental good between the initial level of the environmental good and the final level.

Box 3. Inverse demand function: the multiplicative model

The equation below expresses a multiplicative model for the inverse demand function:

$$P_{ei} = gE_i^{\lambda_e} \subseteq_{f=1}^{q} (e^{\chi_f H_{fi}}) \subseteq_{r=1}^{s} (Z_{ri}^{\lambda_r}) e^{h_i}$$

i=1...n (Index of the observations), f=1...q (index of multiplicative dummies), r=1...s (index of socio-economic variables); Where: **Pe** is the (estimated) implicit marginal price of the environmental good for observation i; **Ei** is the quantity of the environmental good for the observation i. **Hfi** is a set of s dummies reflecting the socio-economic and other individual features of observation i. **Zri** is a set of socio-economic variables referring to observation i; **g**, _ **s** and _**s** are parameters to be estimated; e^{u} is the random error.

λ_e is expected to be negative. Taking the log form the model becomes:

$$\ln P_{ei} = \ln \left[gE_i^{\lambda_e} \subseteq_{f=1}^{q} (e^{\chi_f H_{fi}}) \subseteq_{r=1}^{s} (Z_{ri}^{\lambda_r}) e^{h_i} \right]$$

$$\ln P_i = \gamma + \lambda_e \ln E_i + {}_{f=1}^{q} \chi_f H_{fi} + {}_{r=1}^{s} \lambda_r \ln X_{ri} + h_i$$

And can be estimated by OLS.

Graphically, CS is represented in fig.1., where Q0 is the initial level of the environmental service Q and Q1 is the final level. Notice that the variation of the surplus can be allocated entirely to the consumer, i.e. the house owners only if the price they pay for obtaining the improvement is zero. Despite these distributional issues, the improvement of the environmental service generates a WTP roughly represented by the area CS. However, CS cannot be considered a net gain as in the case of the CS for a marketable good, where CS is net of the price paid for the good and the price reflects the production costs of the good. In this case, if a measure of the net benefit of the environmental improvement is required, the costs of producing the environmental improvement must be considered. When, for example, the multiplicative inverse demand function is chosen, the consumer surplus is calculated as shown in Box 4.

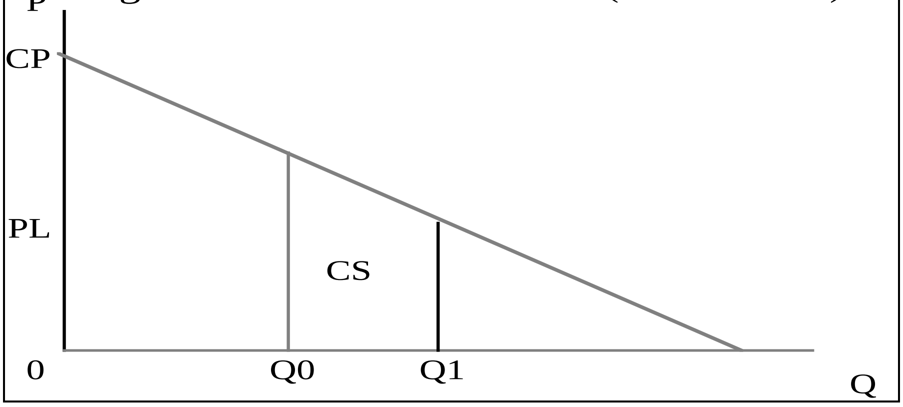


Fig. 1. CS in HPM valuation (linear demand)

Box 4. Consumer surplus: the multiplicative model

The consumer surplus for the multiplicative inverse demand function is:

$$\left[P_e dE\right]_{E_1}^{E_2} = g\frac{1}{\lambda_e + 1} \subseteq_{f=1}^{q} (e^{\chi_f H_{fi}}) \subseteq_{r=1}^{s} (Z_{ri}^{\lambda_r}) \left[E_2^{(\lambda_e+1)} - E_1^{(\lambda_e+1)}\right]_{\text{If } \_e < -1,}$$

$E_2^{(\_e\text{-}1)}$ goes to 0 as E_2 goes to infinity. the CS assumes therefore finite values even if no upper bound is imposed to the definite integration.

if -1<$\_e$ < 1, and the upper bound of integration is _ , the CS is infinity unless a finite upper bound is imposed to the integration.

ANNEXURE 6 – Hedonic Pricing Valuation

a) Background

The annex presents a case of Hedonic Price Method applied for the valuation of benefits induced by the improvement of broadleaves coverage rate in an urban area. The local government decided to improve the quality of urban parks and green spaces near residential areas. Prior to the implementation of the project it undertook a study aimed at the assessment of net benefits of the action. The project consisted of various activities. This study focuses on the valuation of only one of them, namely the increase of broadleaves coverage. For eliciting the value assigned to a change in broadleaves coverage, the price of houses in areas with different coverage rate is observed. The price component due to the environmental asset is isolated by mean of econometric techniques.

b) Problem Set

Step 1, Establishing Data Base

The analyst must first identify a sample of households to investigate and collect relevant data. The database displayed in Table 1. Definitions are provided on the next page.

Table 1: Database: absolute and ln values. 30 Observations.

OBSERV	PRICEX	NUMROO	INDEPE	DISTAN	MURDER	BROADL	REDHOU	COMPON
1	50,847	1	0	6.0	1.8	2.0	21.0	2.0
2	53,593	2	0	44.0	3.1	4.0	25.0	3.0
3	54,019	2	0	45.0	4.5	6.0	23.0	4.0
4	59,940	3	0	41.0	2.5	5.0	28.0	5.0
5	60,849	2	0	7.0	3.5	8.0	32.0	4.0
6	61,947	3	0	39.0	2.2	1.0	34.0	4.0
7	75,908	2	0	10.0	1.0	6.0	30.0	3.0
8	81,304	4	0	50.0	4.5	5.0	36.0	2.0
9	85,028	3	0	48.0	2.1	30.0	43.0	2.0
10	88,484	4	0	35.0	3.0	10.0	38.0	2.0
11	98,648	2	1	13.0	1.5	15.0	49.0	3.0
12	98,920	3	0	9.0	0.9	13.0	55.0	3.0
13	111,049	3	0	24.0	1.2	18.0	72.0	2.0
14	121,345	4	0	50.0	0.5	22.0	68.0	3.0
15	132,049	4	1	6.0	0.1	11.0	62.0	4.0
16	136,018	4	0	15.0	0.5	7.0	78.0	5.0
17	142,546	6	0	43.0	0.1	28.0	74.0	4.0
18	145,584	4	0	3.0	1.5	5.0	80.0	3.0
19	173,394	4	1	5.0	1.4	42.0	92.0	4.0
20	173,904	3	0	3.0	0.9	23.0	87.0	5.0
21	180,394	4	1	4.0	0.3	11.0	85.0	3.0
22	198,765	3	0	5.0	0.7	40.0	93.0	4.0
23	212,038	5	1	0.5	0.1	45.0	96.0	6.0
24	234,194	5	1	0.5	0.6	90.0	80.0	4.0
25	241,879	5	1	7.0	0.4	70.0	93.0	5.0
26	267,944	4	0	0.1	0.1	85.0	78.0	4.0
27	267,975	7	1	24.0	0.6	80.0	83.0	6.0
28	271,039	6	1	10.0	0.1	75.0	98.0	3.0
29	294,048	5	1	12.0	0.4	39.0	105.0	4.0
30	295,536	4	1	1.0	0.1	80.0	110.0	4.0
mpl.mean	148,973	3.70	0.37	18.67	1.34	29.20	64.93	3.67

Where:

Variable	Description
OBSERV	Number of the observation
PRICEX	Price of house (Usd, 1995)
NUMROO	Number of rooms in the house
INDEPE	Dummy variable: INDEPE=1 Detached house. 0 otherwise.
DISTAN	Distance from downtown (Km)
MURDER	Murder rate of the area (murders/year per 1000 residents)
BROADL	Broadleaves tree coverage rate (covered area/total area)
REDHOU	Annual income of the household (Usd, 1995)
COMPON	Number of components in the household

Step 2 Estimation of the House Price Function

The general functional form for the price of houses, given the variables in the database, is:

PRICEX = f (BROADL, NUMROO, DISTAN, MURDER, INDEPE).

Assumed the multiplicative model, it is specified as:

Independent (detached) houses (i.e. dummy..... = 1):

$PRICEX1 = a\, e^{b1}\, BROADL^{b2}\, NUMROO^{b3}\, DISTAN^{b4}\, MURDER^{b5}$

Not independent (attached) houses (i.e. dummy... = 0):

$PRICEX0 = a BROADL^{b2}\, NUMROO^{b3}\, DISTAN^{b4}\, MURDER^{b5}$

Run the regression of LnPRICEX on lnBROADL, lnMURDER, lnDISTAN, INDEPE, plus CONSTANT, using the suitable EXCEL procedure.

Step 3 Estimation of the implicit price function

Calculate the derivative of the price function with respect to the variable BROADL, as suggested in step 2 of the methodology. The implicit price relationship becomes:

IMPLIP = (coeff. lnBROADL / BROADL) x PRICEX

Insert the formula in the database as variable IMPLIP[30].

Step 4 Estimation of the Implicit Inverse Demand Function.

The implicit inverse demand function assumes the form:

$PIMPLI = e^{d1}\, REDDHOU^{d2}\, COMPON^{d3}\, BROADL^{b4}$

The estimation of this curve can be done with OLS method transforming it in logarithmic form: after calculating the natural logarithm of PIMPLI, (lnPIMPLI) regress lnPIMPLI on CONSTANT and the logarithm of the other variables in the equation above.

Step 5 Calculation of the consumer surplus.

Apply the formula in Annexe 11.5, to every observation, supposing an increase in the coverage rate of 10% for every household. Name this new variable CONSUR.

---

[30] In row 4 of the data base substitute "?" with the formula B39/G4*B4.

c) Solution Set

After the data base has been created (step 1), the following steps are necessary to solve the exercise.

Step 2 Estimation of the house price function

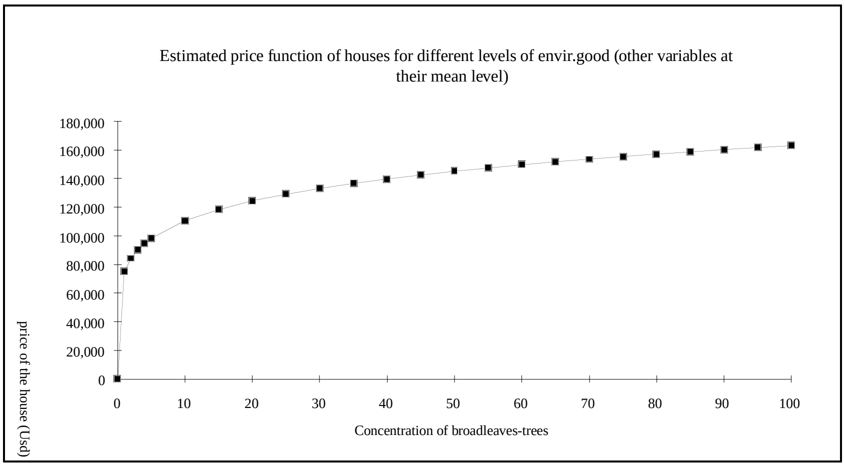
Table 2 summarises the result of the regression of the variable lnPRICEX on the logarithm of the other variables. Most of the variables included in the model are highly significant by the statistical point of view for explaining the variability of the price of houses. Notably, the coverage rate of broadleaves exhibits a positive relevant relationship with the price, other things equal, i.e. after controlling for the other features of the house.

Table 2: Regression of the house price on structural and environmental features

VARIABLE	lnBROADL	lnMURDER	lnDISTAN	lnINDEPE	lnNUMROO	lnCONST
COEFFICIENT	0.16871	-0.05785	-0.08952	0.13697	0.50855	10.78918
ST.ERROR	0.04898	0.04570	0.03133	0.09606	0.13320	0.15815
T-RATIOS	3.4445569	-1.2659477	-2.857664	1.4259517	3.8178773	68.222569
R2	0.90026		ST.ERR.Y^		0.19924	
TEST.F / D.F.	43.32314		Degrees of Freedom		24.00000	
SSReg.	8.59852		Sum of squared residuals		0.95268	

The estimated price variable (price function) calculated with the estimated parameters reported in table 2, is reported in Figure. This graph is drawn other things equal, i.e. with the other variables fixed at their sample average level. From the Figure 1 it can be seen that the change in house price, due to the change in the environmental good (rate of coverage) is not constant. It is indeed increasing but approximating to 0 as the coverage rate approximates to 100. this means that a unit increase in the rate of coverage when the coverage rate is relatively high is not so influent on the price of the houses as the same unit increase when the coverage rate is relatively low.

Figure 1 Estimated price function



Step 3 Calculation of the implicit price function of the broadleaves coverage

The considerations above, about the relationship between the broadleaves coverage and the price of houses are also apparent when looking at the implicit price function derived from the house price function. This function, as described in the methodology, is the first derivative of the house price function with respect to the broadleaves tree rate. The implicit price function is:

IMPLIP = (0.16871 / BROADL) x PRICEX

This function is used for estimating, observation by observation, the implicit price of an additional unit of broadleaf coverage. These estimates are summarised in Table 3. Notice that, overall, low levels of coverage lead to an high implicit valuation of an additional unit of coverage. Conversely, high levels of coverage lead to a low marginal valuation of an incremental unit of coverage. Of course, this relationship is not systematic because Table 3 shows data resulting from an econometric model instead of from an analytical relationship. Broadly speaking, this estimate reflects to some extent the willingness to pay of owners for the last unit increase of the coverage rate.

Step 4 Estimation of the inverse demand function.

The estimation of the inverse demand function is a second stage estimation based on the result of the first estimation (house price function and related first derivative). The estimated implicit price of the broadleaf coverage unit (in this case, the percent point) is regressed on the observed coverage rate and the socio-economic features of the owners. Table 4 summarises the results of this second stage estimation.

The inverse demand function is therefore estimated as:

$$PIMPLI = EXP(6.34)\ REDDHOU^{0.76}\ COMPON^{0.11}\ BROADL^{-0.85}$$

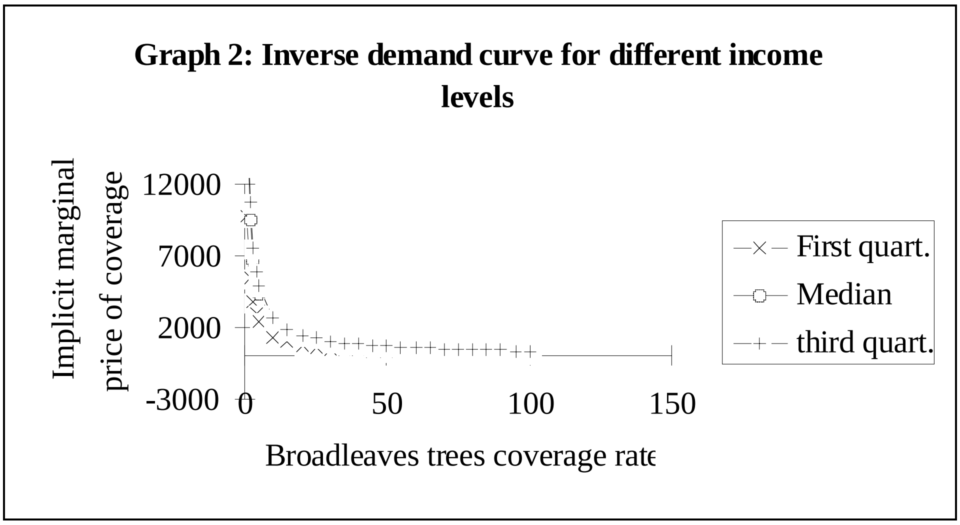
Figure 2 shows the inverse demand function for three different levels of income: the sample first quartile, the sample median and the sample upper quartile. The variable COMPON is fixed at the sample mean level. Notice that lower levels of income imply a lower demand of broadleaves coverage for every level of the price than higher income levels (the demand curve for the first quartile income lies below those of the median and upper quartile income levels. Whilst the difference between the lower quartile income demand curve is noticeable, the difference between the median and upper quartile demand curve is more contained.

Table 3a: Estimated implicit price of an additional unit of broadleaves coverage.			Table 3b. Change in the CS for a 10% of BROADL	
OBSERV	BROADL	IMPLIP	UPPLIM	CONSUR
1	2.0	4,289	12	14,113
2	4.0	2,260	14	12,508
3	6.0	1,519	16	9,856
4	5.0	2,022	15	12,902
5	8.0	1,283	18	10,794
6	1.0	10,451	11	27,797
7	6.0	2,134	16	11,700
8	5.0	2,743	15	14,161
9	30.0	478	40	5,200
10	10.0	1,493	20	10,000
11	15.0	1,109	25	9,782
12	13.0	1,284	23	11,735
13	18.0	1,041	28	11,098
14	22.0	931	32	9,645
15	11.0	2,025	21	14,746
16	7.0	3,278	17	23,520
17	28.0	859	38	8,913
18	5.0	4,912	15	27,178
19	42.0	696	52	7,757
20	23.0	1,276	33	11,910
21	11.0	2,767	21	18,183
22	40.0	838	50	8,119
23	45.0	795	55	7,936
24	90.0	439	100	3,817
25	70.0	583	80	5,367
26	85.0	532	95	3,922
27	80.0	565	90	4,510
28	75.0	610	85	5,004
29	39.0	1,272	49	9,079

Table 4: Regression of the inverse demand function

VARIABLE	LNCOMPON	LNREDHOU	LNBROADL	LNCONST
COEFFICIENT	0.1073	0.7619	-0.8530	6.3412
ST.ERROR	0.0991	0.0930	0.0388	0.2950
T-RATIOS	1.0827	8.1942	-21.9976	21.4966
R2	0.9620	ST.ERR.Y^		0.1581
TEST.F	219.4173	Degrees of Freedom		26.0000
SSReg.	16.4636	Sum of squared residuals		0.6503

Figure 2 Inverse demand curve



Step 5 Calculation of the consumer surplus

The consumer surplus is calculated integrating the inverse demand curve with respect to the implicit price and calculating the Riemann integral observation by observation (variable CONSUR) between the present coverage rate (E1=BROADL) and the new coverage rate (UPLIM) planned by the policy maker.

$$CONSUR = EXP(6.34) * 1/(1-0.85) * COMPON^{0.11} * REDHOU^{0.76} * [UPLIM^{(1-.85)} - BROADL^{(1-0.85)}]$$

The value, observation by observation, and the sample mean of the change in the consumer surplus (variable CONSUR) and the related planned coverage rate (variable UPLIM) are reported in the Table above.

ANNEXURE 7 – Contingent Valuation Using Dichotomous Choice

a) Background

The following study estimated the total use-value of forests in Liguria Region (Italy). Its purpose is to illustrate the methodology used for assessing the recreational value of the forested areas and to provide some insight on the policy implications of the results obtained. A rough and ready method for obtaining WTP estimates from dichotomous choice data is presented. Besides, the explanation of a method that implies the use of Logit models is outlined. Considering the training purpose of this example, the number of observations has been reduced in order to facilitate the handling of the database. Only one of the seven areas surveyed is analysed here.

Liguria Region used to be an important producer of timber and chestnuts in the past. Over the years, the relative importance of these activities has dramatically declined, thus leading to forests abandonment and emigration of its population in the urban areas situated in the coastal zones. Consequently coastal areas are now suffering of high and unsustainable population densities, especially during the summertime, whereas the internal forested areas are progressively deteriorating due to lack of management and maintenance of both forests and historical sites within the forested areas. This study seeks to estimate the benefits of the recreational use of these forests. In Liguria Region, recreation is a non-priced public good, therefore its value could not be assessed with conventional market techniques. The procedure for applying the CVM method in this context kept into account the following specific points:

Identification of the site: In the particular case of this study, the sites to be were identified on the basis of the following criteria: suitability of the area for tourism; actual flow of tourists; and the Plans of Liguria Region for creating regional parks. Maps and photographs of the site greatly contributed during the interviews to clearly communicate to the interviewees the object of the survey.

Definition of the environmental good/service to be valued: the good or service to be valued was defined so that no misunderstandings occurred. In general, environmental goods or services of a forested area could be either the whole area of the site or one of the particular services provided by the forest (i.e., aesthetics, cycling, fishing, etc.). In the Liguria case, the object of the valuation study was the whole set of recreational services.

Questionnaire design: In this study, the questionnaire was constructed in order to be used both for the TCM method and the CVM. In particular it was subdivided in the following sections. (i) The first section was only for use of interviewers and was aimed at providing some general information on the interview and interviewers (name of interviewer, location of interview, length of interview. The second section was devoted to the collection of socio-economic data. It was assumed here that age, education, income, profession, number of family members, etc. are important determinants in visitors' behaviour towards recreational use or visits to forests. The third section attempted to identify the costs of travel costs faced by individuals to visit the site, by asking them their origin, the vehicle used to reach the site, the time employed to reach the area from their origin, the trip plan. This section was therefore relevant to TCM. The fourth section consisted of few questions aimed at investigating the environmental concern and awareness of visitors. It was assumed that the higher the awareness of environmental problems, the higher the perception of the value of forests' recreational value. The fifth section concerned the scenario presentation and the WTP elicitation question.

Scenario design: the hypothetical market was stated as follows: "*The site you are visiting is deteriorating due to lack of management and maintenance. Let us assume that the local government is planning to rehabilitate the area and that due to budget constraints it is also considering to asks visitor to contribute to the investment costs by paying an entrance fee for one day visit. Would you accept to pay the following fee?*"

Elicitation form: the elicitation form chosen in this study is the Dichotomous Choice format. In this case respondents are asked whether they accept or not to pay a pre-determined price for entering the park.

Payment vehicle: the payment vehicle used in this study is the payment of an entrance fee.

Survey strategy: it was decided that interviews should be carried out on site. Therefore, for each single area, sites were identified for carrying out on-site face-to-face interviews. Interviewed visitors were selected randomly among the visitors throughout July, August and September, on both week days and weekend days. The total number of interviews completed was 800. Since the behaviour of people visiting the site during the summertime is most probably different than the behaviour of people visiting the same site in winter and spring (e.g., distance and time spent on site might be shorter), the total annual value of recreation services provided by the site might be overvalued if the observed behaviour in summer was assumed to be representative of the whole year. This possible bias was taken into account in the final interpretation of the results.

Statistical Description: when the survey was completed, a database was created like the one presented in Tab. 7.1 below, using a spreadsheet. In order to check consistency of responses and reliability of data, some statistical analyses were carried out such as correlation analysis, contingency tables, Chi square analysis, mean, median, variance, percentiles, etc.).

WTP estimation: when using dichotomous choice approaches, the usual way of estimating WTP measures is to apply Logit models. A simplified approach is however possible, at least when rough and ready results are required or for illustration purposes. Hereafter, two step by step exercises concerning the estimation of the WTP in the dichotomous choice framework are developed: (i) Estimation of WTP based on descriptive statistics; (ii) WTP estimation using a LOGIT based method with Weighted Least Squares (WLS). The estimated results using Maximum Likelihood Estimates (MLE) are reported in appendix for check and discussion.

Aggregation: if the objective of the study is the estimation of the total value of the site, the individual WTP resulting from the analysis has to be multiplied by the total visitors of the site during one time period (usually the year). Once the total value of the area has been computed, the value per hectare can be obtained by dividing the total value by the extension of the area of the site.

b) Methodology

The objective of the dichotomous response approach is to derive a measure of the maximum individual Willingness To Pay (WTP) to be used as an estimate of the value individuals attach to a given environmental asset or service. To this end, dichotomous choice data can be analysed with a descriptive approach based on sample frequencies. Rough and ready WTP measures are therefore obtained in a fairly simple way introducing few assumptions. As simple example, suppose we have collected data about the proposed entrance fee and the related acceptance/refusal answers in the dichotomous format (0,1) as reported in the Table 1 below (the names of the variables used in the exercises are reported in brackets).

Table 1 Example of a (shortened) dichotomous CVM database

Number of questionnaire (NUMOB)S	Proposed entrance fee (TICKET)	Accept(1)/reject(0) answer (ACCEPT)
1	13,000	0
2	3,000	1
3	8,000	1
4	8,000	0
5	13,000	0
6	3,000	1
7	13,000	0
8	3,000	0
9	8,000	0

The following step by step procedure allows to obtain individual max. WTP estimates.

Sort the database in increasing order by proposed entrance fee (TICKET)[31] (Table 2).

[31] Names in brackets refer to variables used in the spreadsheet .

Calculate the acceptance frequencies for each level of proposed entrance fee, i.e. the conditional acceptance frequencies (CONFRE) (for each level of entrance fee, this frequency can be easily obtained as the ratio of the positive answers on the number of questions referring to that level or, in a handier way, taking the mean of the dichotomous variable (ACCEPT) for each group of answers) (Table 3)

Table 3 Sorted database for dichotomous CVM

Number of questionnaire (NUMOB)S	Proposed entrance fee (TICKET)	Accept(1)/reject(0) answer (ACCEPT)
2	3,000	1
6	3,000	1
8	3,000	0
3	8,000	1
4	8,000	0
9	8,000	0
1	13,000	0
5	13,000	0
7	13,000	0

Table 3 Relative frequencies of acceptance and refusal

Number of questionnaire (NUMOB)S	Proposed entrance fee (TICKET)	Accept(1)/reject(0) answer (ACCEPT)	Acceptance rel. frequencies (CONFRE)	Relative frequencies of Refusal
2	3,000	1		
6	3,000	1	66.6%	33.3%
8	3,000	0		
3	8,000	1		
4	8,000	0	33.3%	66.6%
9	8,000	0		
1	13,000	0		
5	13,000	0	0.0%	100.0%
7	13,000	0		

Consider the above frequencies as the cumulated frequencies of acceptance for each level of proposed entrance fee. It is required to assume that the conditional frequencies above reflect the behaviour of the whole population (i.e.: each sub-set of the sample by level of entrance fee is representative of the population).

Calculate the cumulated frequencies of refusal (The complement to 1 of the accept frequencies) (see last column of Table 3).

5. Calculate the cumulated frequencies of the WTP. Consider that if an individual refuses to pay a given entrance fee, his maximum willingness to pay (WTP) is lower than that entrance fee. Besides, assume that: the max. WTP is equally distributed within each class of values. This allows us to consider the mean of the bounds of each class as the mean max. WTP within each class. E.g. see Table 4 below:

Table 4 Cumulated frequencies of the maximum willingness to pay

Cumulated frequen. of fee reject.	**⇒ WTP upper bound**	**⇒ frequency for WTP classes**	**Assumption on class mean**
33% reject lit.3000	33% have WTP < lit. 3,000	33% have 0_ WTP < 3000	mean WTP of 33%: 1500
66% reject lit.8000	66% have WTP < lit. 8,000	33% have 3000 _ WTP < 8000	mean WTP of 33%: 5500
100%reject lit 13000	100% have WTP <lit.13,000	33% have 8000 _ WTP < 13000	mean WTP of 33% 10500

Hence, the cumulated frequencies of the max. WTP are (Table 5):

Table 5 Cumulative frequencies of the maximum WTP

Cumulat.frequen.(x100)	0%	33.3%	66.6%	100.0%
Mean WTP of each class	lit. 0	lit.1,500	lit. 5,500	lit. 10,500

6a. **Calculate of the mean WTP**. The mean WTP of the whole distribution is easily calculated summing up the mean WTP of each WTP class, weighted with the frequency of the class (Table 6).

Table 6 Mean WTP

Mean WTP of each class	lit. 0	lit.1,500	lit. 5,500	lit. 10,500
Rel.freq.of each class	0%	33.3%	33.3%	33.3%
Mean WTP x Rel. freq.	lit. 0	lit. 500	lit. 1,833.3	lit. 3,500
Mean WTP = lit. 5,833.3.				

6b. Calculate of the median WTP. The median WTP can be calculated in a graphical way, drawing the graph of the cumulated frequencies and finding the value corresponding to the 50% cumulated frequency or in an analytical way, using the formula of the median for data grouped in classes:

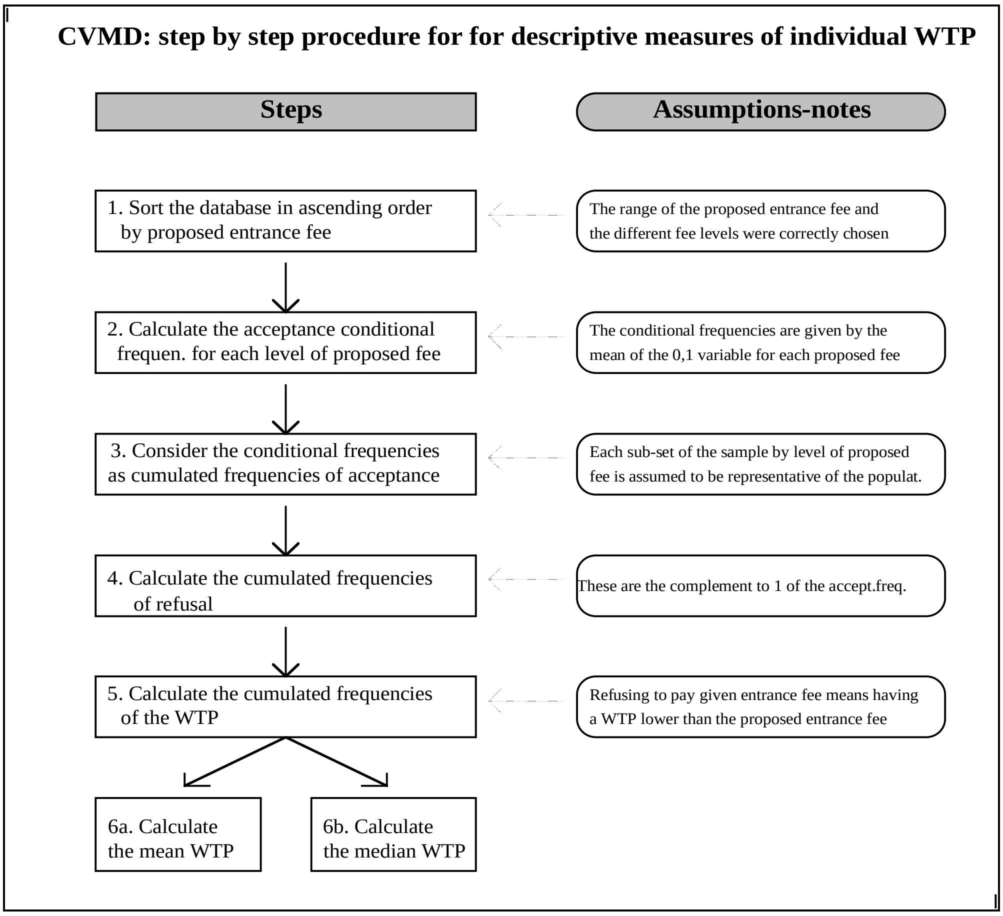
Me = L + [(0.5-FL)/FM] W

Where: Me = Median; L = Lower bound of the median class (say, lit 1,500); U = Upper bound of the median class (say lit.5,500); W = Median Class width (W=U-L, where, say 5,500-1,500 =4000); FL = Cumulated frequency at L (say 33%); FU = Cumulated frequency at U (say 66%) FM = Frequency of median class (FM=FU-FL, say 33.3%). This gives:

Me = 1,500 + [(0.5 - 0.33)/0.33**]** 4,000 = 1,500 + 2,060.61 = 3,560.61

Figure 1 below summarises the procedure for obtaining descriptive measures of the individual maximum. WTP.

Figure 1 Dichotomous choice CVM - Step by step procedure for descriptive measures of individual maximum WTP



c) Problem Set

Table 7 below shows the database obtained running the survey at the forest site. The following questions are addressed:

Calculate the conditional frequencies of acceptance for each level of proposed entrance fee.
Calculate the cumulated frequencies of acceptance and the cumulated frequencies of refusalto pay the proposed entrance fee, for the different levels of the entrance fee.
Plot the cumulated frequencies above on a graph.
Work out the cumulated frequency distribution of the max. WTP.
Plot them on a graph.
Calculate the median max. WTP
Work out the relative frequency of the different WTP levels and plot them in a graph. Calculate then the mean max. WTP using the relative frequencies as weights.

Table 7 Database

NUMOBS	TICKET	ACCEPT
1	3000	1
2	8000	1
3	18000	0
4	13000	1
5	23000	0
6	3000	1
7	3000	1
8	18000	0
9	18000	0
10	13000	0
11	18000	0
12	23000	0
13	18000	1
14	23000	0
15	8000	0
16	3000	1
17	3000	1
18	23000	0
19	23000	0
20	13000	0
21	8000	1
22	13000	0
23	13000	1
24	8000	1
25	13000	0
26	18000	0
27	23000	0
28	3000	1
29	8000	0
30	8000	1

d) Solution Set

Question 1.

The question 1 is answered sorting the database in ascending order by the variable TICKET and calculating the conditional relative frequencies for every group of observations (see Table 8). Notice that the observations are grouped according to the proposed entrance fee.

Table 8 Question 1 - conditional relative frequencies

NUMOBS	TICKET	ACCEPT	Cond.Freq.
16	3,000	1	
6	3,000	1	
28	3,000	1	
1	3,000	1	
7	3,000	1	
17	3,000	1	1.00
2	8,000	1	
21	8,000	1	
29	8,000	0	
15	8,000	0	
24	8,000	1	
30	8,000	1	0.67
23	13,000	1	
22	13,000	0	
10	13,000	0	
25	13,000	0	
4	13,000	1	
20	13,000	0	0.33
3	18,000	0	
11	18,000	0	
13	18,000	1	
8	18,000	0	
26	18,000	0	
9	18,000	0	0.17
27	23,000	0	
18	23,000	0	
19	23,000	0	
12	23,000	0	
5	23,000	0	
14	23,000	0	0.00

Question 2.

Table 9 shows the answer to question 2 reporting the cumulated frequencies of acceptance and refusal to pay the proposed entrance fee. Notice that the refusal relative frequencies are the complement to 1 of the acceptance relative frequencies.

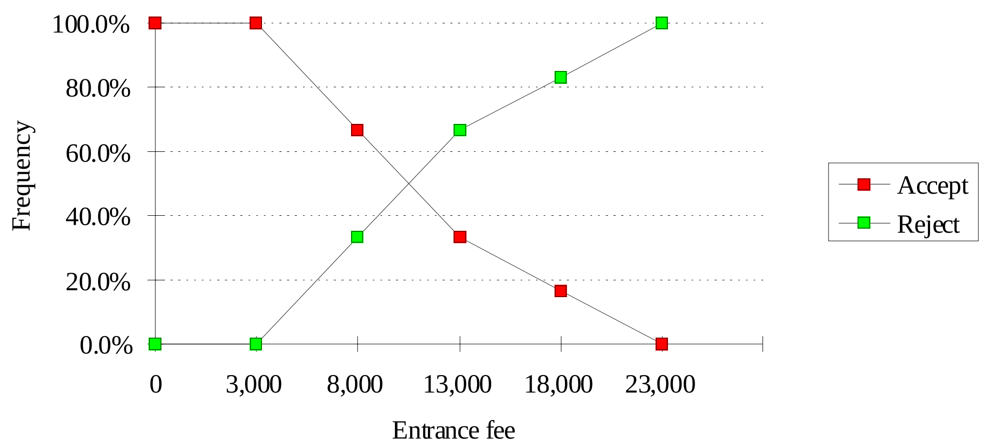
Table 9. Relative frequencies of acceptance and refusal.

Entrance fee	0	3,000	8,000	13,000	18,000	23,000
Accept answers	100.0%	100.0%	66.7%	33.3%	16.7%	0.0%
Reject answers	0.0%	0.0%	33.3%	66.7%	83.3%	100.0%

Question 3.

Figure 2 plots the cumulated frequencies of acceptance and refusal to pay the proposed entrance fee.

Figure 2 Relative frequencies of acceptance



Question 4.

Table 10 reports the frequency distribution of the maximum WTP. Notice that here it is assumed that the maximum willingness to pay is uniformly distributed within each interval of the proposed entrance fee. The narrower are the intervals, the more this assumption is harmless.

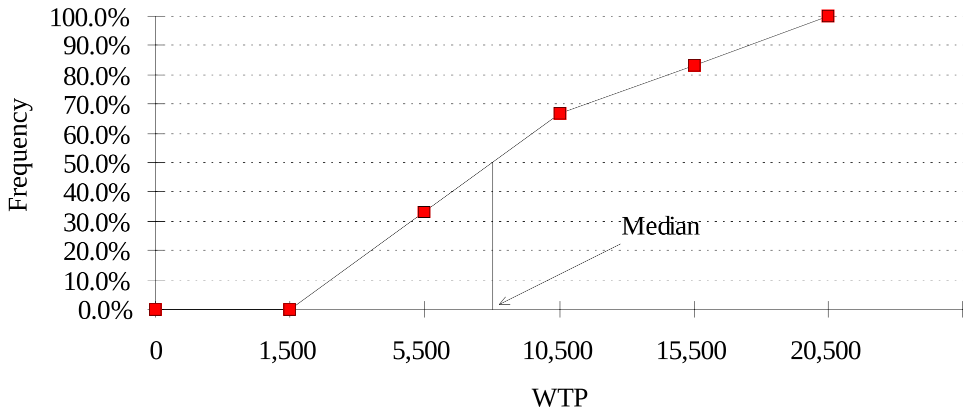
Table 10 Cumulated frequency distribution of maximum willingness to pay.

Max. WTP	0	1,500	5,500	10,500	15,500	20,500
Cum.frequency	0.0%	0.0%	33.3%	66.7%	83.3%	100.0%

Question 5.

Figure 3 graphs the cumulated frequency distribution of the maximum willingness to pay.

Figure 3 Cumulated frequency distribution of the maximum willingness to pay.



Question 6.

Table 11 shows the calculation of the median WTP. The formula for the median calculates the share of the median class frequency below the 0.5 cumulated frequency; it uses this proportion to split the median class width and adds to the lower bound of the median class the same proportion of the class width. The calculation is based on the following assumption: the max. WTP is equally distributed within the median class.

Table 11 Median of the maximum WTP

Lower bound of the median class(L)	5,500
Upper bound of the median class (U)	10,500
Median Class width (W=U-L))	5,000
Cumulated frequency at L (FL)	33.3%
Cumulated frequency at U (FU)	66.7%
Frequency of median class (FM=FU-FL)	33.3%
Median (Me=L + [(0.5-FL)/FM] x W)**	8,000

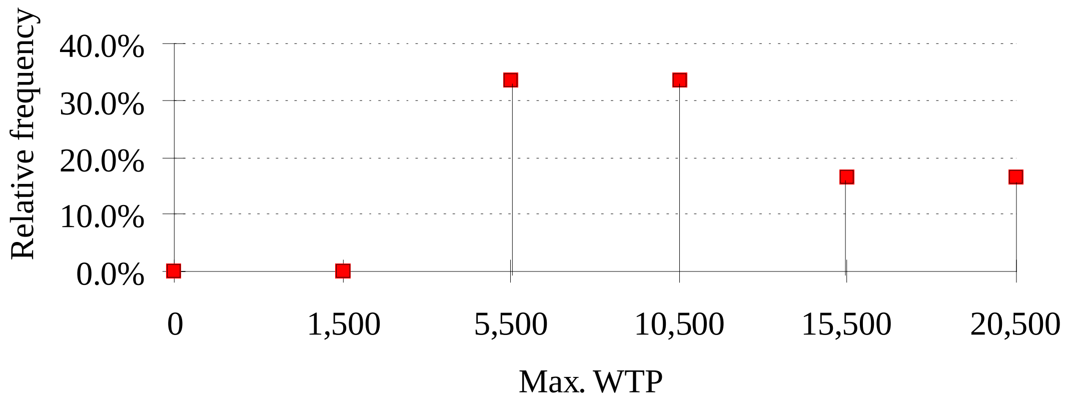
Question 7.

The figure 4 illustrates the relative frequencies of the maximum WTP. Table 12 shows the calculation of the relative frequencies and the calculation of the mean maximum WTP. Notice that the mean is obtained as the weighted sum of the maximum WTP data, where the weights are the relative frequencies.

Table 12 Relative frequencies and mean of maximum WTP

Max. WTP	0	1,500	5,500	10,500	15,500	20,500
Rel. frequencies	0.0%	0.0%	33.3%	33.3%	16.7%	16.7%
Max.WTP x freq.	0	0	1,833	3,500	2,583	3,417
	Mean max.WTP		**11,333**			

Figure 4 Relative frequency of the maximum WTP



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MODULE 9

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