"Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand"

GUIDELINES FOR CONDUCTING ECONOMIC VALUATION OF COASTAL ECOSYSTEM GOODS AND SERVICES

UNEP/GEF
Regional Task Force on Economic Valuation

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INTRODUCTION

Mangroves, coral reefs, seagrass and other coastal wetland habitats provide critical ecological, economic, and social services that support the existence of ecosystems and human communities. Coastal habitats support high floral and faunal biological diversity and, coastal people depend on these habitats for their livelihood, through extraction of resources directly or indirectly. They collect fish, fruits, vegetables, medicinal extracts, construction materials, timber, firewood, and many other natural products from these habitats. In the past when coastal populations were small in number the impacts of this use were limited, although as human populations have grown so has the magnitude of the effects of direct use. Frequently inland populations are displaced to coastal areas and take up fishing and gleaning marine resources for their subsistence since coastal resources are treated as open access resources in many parts of Southeast Asia.

Despite the fact that these coastal habitats provide such critical services for human beings, they have undergone serious degradation and loss in the recent past due to industrialisation, urban development, tourism, and other destructive human activities. One of the underlying reasons (root causes) for this widespread degradation and loss of coastal habitats is the failure of markets to recognise the economic value of non-market benefits generated by the coastal habitats. This not only results in a lack of understanding of the economic values of coastal habitats, but also results in the under-valuation of environmental goods and services. Consequently, the role of the ecological functions of coastal habitats in sustaining coastal economies is not well understood, and the conservation benefits of the habitats have not received due attention. Frequently coastal habitats are considered as lands with low or no use value.

Valuing coastal habitats in economic terms provides a direct tool for environmentalists to persuade government officials to take serious account of the benefits of the ecosystems, in their decision-making regarding the choice of development alternatives. This manual provides guidelines for individuals with limited experience in economics to undertake basic economic valuation of habitats. It covers cost benefit analysis, a general valuation framework, details of valuation techniques, and the procedures to value the ecological functions of specific habitats and to value the impacts of land-based pollution on coastal habitats.

Not only is the determination of economic value a critical input to sound decision-making regarding the development and use of coastal habitats but it is also of great importance to the identification of under-utilised goods and services that might provide the basis for development of alternative livelihoods for coastal communities. An activity that is integral to the demonstration site activities undertaken within the South China Sea Project. Determination of economic values, together with an analysis of the costs and benefits of their use by different stakeholders might enable more equitable resource sharing and generate revenues to off-set the costs of sound management.

A further consideration in the framework of the South China Sea Project is the need to justify the costs of any regional programme of interventions addressing the degradation and loss of coastal habitats. Such a regional programme is currently being considered for approval in the form of the revised Strategic Action Programme, which contains a section justifying the proposed programme of interventions on the basis of an analysis of the costs and benefits of action compared with non-action in addressing habitat loss and degradation trends. This analysis was based on the assumption that if action were not taken, habitats would continue to be lost at current rates, and the economic values lost over time were then compared with the costs of the programme and the economic values saved by the proposed investment.

GOODS AND SERVICES DERIVED FROM COASTAL WETLANDS

The Regional Working Groups on Mangroves, Coral Reefs, Seagrass, and Wetlands considered and prepared lists of the goods and services provided by these four coastal habitats to the coastal communities living on the margins of the South China Sea. Table 1 provides a simplified listing of the direct uses of these habitats in the South China Sea as discussed and agreed by the respective members of the working groups.

The direct uses of these habitats have been classified, for the purposes of identifying the appropriate valuation techniques into extractive or consumptive uses and non-extractive or non-consumptive uses. Extractive uses, if they are to be sustainable, must always be limited by the ability of the ecosystem or habitat to sustain the same levels of production, subject to naturally varying, inter-annual limits of production. In fisheries terms such a limit is often referred to as the maximum sustainable yield. Unsustainable use or over-exploitation will ultimately result in the decline of natural productivity and potential collapse of the natural system resulting in loss of other goods and services.

Uses of mangroves

Table 1 indicates that extractive uses of mangrove ecosystems include direct use of the mangrove plants themselves, together with direct use of the secondary consumers and decomposers that are dependent upon the primary production of the mangrove trees. The use of mangrove trees for timber, poles, fuelwood, charcoal production, thatch and fodder are widespread activities throughout the region, whilst the use of mangrove propagules (fruits) for human consumption, bark for tanning, Nipa sap for alcohol, and use of mangrove associates for medicines are more restricted uses, characteristic of certain locations.

Table 1 Summary of Extractive and Non-extractive Direct Uses of Coastal Habitat Types.

Extractive Uses	Mangroves	Coral Reefs	Seagrass	Wetlands
Vegetable Products	Timber	Building materials, curios	*N/A*	Timber
	Firewood	*N/A*	*N/A*	Firewood
	Poles	*N/A*	*N/A*	Poles
	Charcoal	Quick lime	*N/A*	Charcoal
	Leaves/palm fronds (*thatch/fodder*)[1]	*N/A*	Handicraft (woven)	Leaves/Thatch
	Fruits/propagules	Algae	Seeds Food	Fruits
	Bark (*Tannin and dyes)*	*N/A*	*N/A*	Tanning Bark
	Medicine	Bioactive substance	Medicine	Medicine
	Sap *(sugar, Alcohol, Acetic acid)*	*N/A*	*N/A*	*N/A?*
	Wood tar	*N/A*	*N/A*	*N/A?*
			Fertilizer	Peat/energy
Animal Products				
	Fish capture	Fish (food and aquarium)	Fish	Fish
	Crab capture		Swimming crabs	Crab
	Prawn capture	Crustacean	Prawn capture	Prawn
	Shellfish collection	Molluscs	Molluscs	Molluscs
	Insect and larvae capture			
	Worms	Echinoderm	Echinoderm	Worms
	Wildlife hunting			Wildlife
	Zooplankton (koey)			
	Jellyfish			
	Bees, honey, and wax			
	Seaweed			
Non-extractive Uses	**Mangroves**	**Coral Reefs**	**Seagrass**	**Wetlands**
	Tourism/recreation	Tourism/ recreation	Tourism/Recreation	Tourism/Recreation
	Transport			Transportation
	Education	Education	Education	Education
	Research	Research	Research	Research
	Fish culture	Mariculture		Agriculture
	Crab culture			Aquaculture
	Prawn culture			
	Other aquaculture (pearls)			

[1] *Items listed in italics under uses are products derived from a primary resource extracted from the mangrove ecosystem.*

Similarly, the direct uses of many secondary producers dependent upon the mangrove primary production are widespread throughout the region. The mud-crab *(Scylla* spp*.)* penaeid shrimp, and a wide variety of fish and shell-fish, such as *Crassostrea* species, are exploited wherever they are found. The mangrove clam *Geloina coaxans* and the cockle *Anadara granosa* are eaten throughout the region and are found in muddy substrates, often in close proximity to mangrove areas. In some locations specific organisms are exploited depending upon their distribution and abundance. Hence mangroves backed by freshwater swamp forest often provide abundant wildlife, while honey, sipunculid worms, insect larvae, jellyfish, and in some rare instances zooplankton are directly exploited in mangrove areas. In Trat Province, Thailand, Sesarmid crabs are exploited in the back mangroves for production of “pickled” crabs, an essential ingredient of “*Som Tham*”, green papaya salad.

Widespread non-extractive uses of mangroves include their use as venues for tourism and recreation, educational and research purposes, and for various types of mariculture of fish, crabs and prawns in the creeks that meander through mangroves, or in the ocean in front of mangrove areas that do not involve destruction or clearance of the mangrove forest itself. In China, pearl farming takes place along the South China Sea coastline, and the quality and quantity of pearls produced can be directly related to the presence or absence of mangroves along the adjacent coast. Tourism activities include kayaking along the mangrove-lined creeks and nocturnal visits to observe fireflies. Local authorities and community groups in many areas have now constructed boardwalks through the mangroves allowing easy access for both tourists and school parties.

In addition to the direct use of mangrove habitats and their associated resources, mangroves provide a number of environmental and biological services, whilst some areas have particular social, cultural or historical significance, all of these attributes must be valued if a total economic value for a particular mangrove area is to be determined. The importance of mangroves to shoreline protection, prevention of erosion, and flood protection, has been well demonstrated by the impacts of the 2005 tsunami, which were more pronounced in coastal areas where vegetation had been cleared than in areas where intact mangrove stands remained. Where the inputs of allocthonous (land-derived) sediments are high, mangroves may in some instances trap sufficient sediment to cause shoreline accretion and an increase in land area. In addition, mangrove forests provide protection against strong winds, including typhoons, and sequester carbon in the accumulating anaerobic soils and as a temporary sink in the biomass of the trees themselves.

The role of mangroves as a natural filter for land-based materials results from the trapping of fine suspended sediments, and their removal from the water column, as a consequence of the physical slowing of water flow through the mangrove root systems. This leads ultimately to both upward and seaward accretion of the land surface and to, less turbid water immediately in front of mangrove stands. Not only is the suspended sediment trapped within the mangrove system but adsorbed and associated contaminants are trapped leading to an overall improvement in coastal water quality. In addition, mangroves remove nutrients from the water column.

Mangroves serve as nursery and spawning grounds for a number of marine fish and penaeid shrimps and the volume of the off-shore trawl catch of shrimp can be directly related to the area of mangroves on the adjacent shoreline. Juveniles of the giant freshwater prawn (*Macrobrachium* spp*.)* may be found in the landward margins of mangrove swamps. Estuarine fish of subsistence and commercial significance in the region include the milk-fish, *Chanos chanos* and the Barramundi or sea bass, *Lates calcarifer.* In terms of their services to biological diversity mangroves provide habitat to both endangered and migratory species of birds, and in some areas land vertebrates including reptiles such as the estuarine or salt-water crocodile. The diversity of true and associated mangroves species is higher around the margins of the South China Sea than anywhere else world-wide. In some specific locations mangroves have particular social or cultural significance as for example in the vicinity of Fangchenggang, China where mature, *Avicennia marina* are conserved by, the local communities, due to their Feng Shui properties.

Table 2 Summary of Environmental and Biological Services, Social and Cultural Significance of Coastal Habitat Types Bordering the South China Sea.

	Mangroves	Coral Reefs	Seagrass	Wetlands
Environmental services	Shoreline/erosion prevention	Beach protection	Shoreline protection Erosion prevention	Shoreline protection
	Flood protection	*N/A*	*N/A*	Flood Control
	Windbreak	*N/A*	*N/A*	Windbreak
	Carbon sequestration	Carbon sequestration	Carbon sequestration	Carbon sequestration
	Water purification (Prevention of saline water intrusion)	*N/A*	Water purification Waste catchment	Water purification prevention of salt water intrusion & ground water recharge
	Sediment, Contaminant, Nutrient removal/storage	*N/A*	Sediment and nutrient retention	Sediment and Nutrient Retention and Export
	Oxygen release (?)	Climate change record	Oxygen release	Oxygen release
	Nursery feeding area	Nursery ground	Nursery area	Nursery area
	Shoreline accretion/Land increase	*N/A*	*N/A*	*N/A*
	N/A	*N/A*	*N/A*	Climate Change Mitigation
	N/A	*N/A*	*N/A*	Water supply (subsistence value)
Biological diversity services	Existence values of species, genes, and communities	Biodiversity Storage	Biological diversity	Biological diversity (existence value of species, genes and communities)
	Migratory species	Secondary producers	*N/A*	Migratory species
	Endangered Species	Food sources for other biota	*N/A*	Endangered Species
	Ecosystem Existence values	Coral reef Ecosystem Existence values	*N/A*	Wetlands Ecosystem Existence Value
Social/cultural significance	Religious/spiritual significance	*N/A*	*N/A*	Religious/spiritual significance
	Historical importance	*N/A*	*N/A*	Historical importance
	Presence of distinctive human activities	*N/A*	*N/A*	
	Aesthetic	Aesthetic	Aesthetic/culture	Aesthetic

Use of Coral Reefs

Coral reefs are one of the most biologically diverse shallow water marine habitats in the world, and are host to an extraordinary variety of marine plants and animals. Coral reefs provide essential fish habitats, support endangered and threatened species, and serve as nursery and spawning areas for a variety of species. They are a significant source of food, provide income and employment through tourism and marine recreation, and offer countless other benefits to humans, including supplying compounds for pharmaceuticals (Spalding *et al* 2001). The uses of coral reefs can be categorised into four kinds of uses: direct uses (extractive and non-extractive uses) (Table 1), environmental services, biological diversity services, and social/cultural significance (Table 2).

Coastal communities have directly extracted materials and resources from coral reefs for generations. The hermatypic corals themselves are used as building materials and for making quicklime, a practice which is now less prevalent than in the past. An important aspect of coral reefs from the perspective of coastal communities is their contribution to capture fisheries. Reef systems provide shelter to smaller fish and invertebrates and habitat essential as nursery and breeding grounds. Some pelagic fish species such as the “jacks” are found as juveniles in the vicinity of coral reefs. It has been suggested that in Malaysia approximately 40 percent of the commercial fish caught within 30 nautical miles from shore originate from or, make use of, coral reefs.

Indirect uses of coral reefs include tourism and recreation, education and research, and mariculture which is often practiced in sheltered lagoonal areas of reef systems. Reef-based tourism is essentially a non-extractive industry that attracts millions of divers and snorkelers to Southeast Asia each year, and contributes significantly to the economies of countries such as Thailand, the Philippines, Malaysia and Indonesia. Coral reefs provide scientists and researchers with a coastal habitat that has high biological diversity, and coral formations can be used to reconstruct past climates and storm patterns. The also serve as a source of natural products which are in high demand from the international pharmaceutical companies for testing as bioactive compounds.

Coral reefs provide significant “sinks” of biological diversity and support numerous species restricted to such habitats. The reef structure itself is important as a buffer against wave action thus providing protection to beaches on the coast, and as sources of the “white sand” that is so attractive to tourists.

Use of Seagrass

As in the case of the two habitats previously considered seagrass beds provide the basis for sustainable livelihoods in many coastal communities bordering the South China Sea. The range of uses to which the seagrass itself can be put by coastal communities is fewer than in the case of mangroves but includes its use for fertiliser in coastal agriculture, and as raw material for the production of woven handicrafts, including chair seats, mats and baskets. Direct use of seagrass for human consumption is limited in the region being restricted to the experimental production of cookies from seeds of *Halophila* in the Philippines. Seagrass is used directly as a covering for wounds in many coastal communities and some species are used in the preparation of traditional medicines.

Of far greater significance however, is the use of secondary consumers that rely on the high primary productivity and production that characterise tropical seagrass communities. These include a variety of resident fishes including many species in the family Siganidae, echinoderms such as the sea urchin, *Tripneustes gratilla* whose eggs are exploited both for subsistence and commercial production, and molluscs such as the strombid gastropods in particular *Strombus carnarium,* which is widespread along the southern margins of the South China Sea. The sea horses, permanent residents of seagrass beds are commercially threatened along the northern margins of the South China Sea as primary ingredients in various Chinese and Vietnamese traditional medicines and alcoholic drinks.

Non-extractive uses of seagrass beds include tourism and recreation, research and education although these are generally not as well developed as in the case of coral reefs, the generally sheltered lagoon environments in which seagrass beds occur are used as areas for water sports and snorkelling. In some areas seaweed culture is practiced in coral reef and seagrass habitats, whilst in the Philippines healthy seagrass beds are used as grow-out areas in giant clam culture.

Seagrass beds provide a variety of environmental services including reduced erosion of sub-tidal substrates. Seagrass species trap and stabilise suspended sediment providing benefit to adjacent coral reefs by reducing suspended sediment loads in the water. The dense root systems and extensive rhizomes of some seagrass species form an interlocked mat that prevents erosion of the sub-tidal substratum, which may be especially important during storms and hurricanes. As in the case of mangroves the trapping of sediment derived from land-based sources results in significant removal of adsorbed contaminants, which are stored in the sediments.

Seagrass feature high rates of primary production and hence exhibit high rates of oxygen production, which is released to the surrounding waters. Consequently seagrass species can remove elevated levels of nutrients through enhanced primary production. However excessive inputs of nutrients result in fouling of the seagrass leaves by algae and interferes with photosynthesis thus having an adverse impact on primary production and the health of the system. Although seagrass primary production is only 1% of ocean total primary production it may be responsible for as much as 12% of the total amount of carbon stored in ocean sediments. This suggests that seagrass beds may play a role in the regulation of the global carbon cycle.

Seagrass beds serve as nursery and spawning grounds for fish that constitute important constituents of the offshore demersal fish catch. Some species move into and out of seagrass beds over their life history, while others live their entire lives in association with seagrass beds. In addition, seagrass forms the bulk of the diet of the endangered dugong and some marine turtle species whilst some seagrass areas are important feeding grounds for migratory birds. Tiger prawns settle in seagrass beds at the post-larval stage (3-4 weeks) and remain until they become adults while many endeavour prawns also spend their juvenile life stages in the seagrass habitat. Seagrass meadows provide an ideal environment for juvenile fish and invertebrates to conceal themselves from predators, whilst seagrass leaves serve as areas for attachment of larvae and eggs and for filter-feeding animals like bryozoans, sponges, and forams.

While seagrass beds serve as ideal *refugia* for juvenile and small adult fish to escape from larger predators, many in-faunal organisms (animals living in soft sea bottom sediments) also live within seagrass meadows. Species such as clams, worms, crabs, and echinoderms, like starfishes, sea cucumbers, and sea urchins, use the buffering capabilities of seagrass to provide a refuge from strong currents. The dense network of roots established by seagrass also helps deter predators from digging through the substratum in search of in-faunal prey organisms.

As in the case of mangroves the seagrass beds of the South China Sea are the most biologically diverse worldwide, as such they represent a significant store of biological diversity having value of transboundary significance. Whilst many coastal communities use the resources derived from seagrass habitats both directly and indirectly and hence are, to varying degrees dependent upon the health of the system, seagrass is not generally of particular social or cultural significance although the organisms associated with the habitat such as dugong and marine turtles may be in some locations.

Use of Coastal Wetlands

A consideration of the direct and indirect uses of coastal wetlands, their environmental and biological services, and their social and cultural significance is somewhat more difficult than a consideration of the three habitats (mangroves, coral reefs and wetlands) considered above. In part this stems from the broad interpretation of what constitutes a “wetland”, which in the sense of the RAMSAR Convention covers both freshwater and marine habitats to a depth of 6 metres below high tide level. In preparing the tables of direct uses, and the environmental and biological services provided by “coastal wetlands” the Regional Working Group on Wetlands attempted to itemise all possible goods and services provided by a variety of wetland types. In consequence the entries in Tables 1 and 2 are too generic to provide guidance for individuals attempting to value for example, non-vegetated inter-tidal mudflats, where in general the resources available for exploitation are generally limited to burrowing molluscs and worms. In addition, as a consequence of the approach taken by this working group, the entries include the uses and services provided by the other three habitats, which have been specifically itemised in the appropriate columns of these tables.

Specific wetland habitats such as, for example, peat forest provide unique goods and services, for example peat for fuel, that are not provided by habitats such as mangrove or seagrass. Any attempt at economic valuation must take into consideration such unique features that may contribute significantly to the Total Economic Value of a particular habitat type. Similarly it should be recognised that not all wetland types provide all of the goods and services listed in Tables 1 and 2 and the accuracy of the final estimate of Total Economic Value will depend on the correct identification of the specific goods and services provided by each individual habitat type.

Changes in coastal ecosystems and habitats

Changes in coastal environments may result from development activities that result in changes in land use such as reclamation and conversion of mangrove land for housing, for aquaculture or for port and harbour construction. Such changes automatically result in changes to the value of the system, but frequently the value of natural production is not adequately taken into consideration during the decision making regarding the change in use.

A widespread problem for many types of coastal habitats and their associated resources is the problem of changes in value as a consequence of land and ship based pollution. The types of contaminants and pollutants, to some extent, determine the types of impacts on the coastal habitats; hence it was important to identify both the type of pollutant and the specific impact(s) on coastal habitats. Table 3 provides a checklist of potential impacts of various types of contaminant on coastal habitats relevant to the UNEP/GEF South China Sea Project, namely mangroves, coral reefs, seagrass and coastal wetlands. The impacts of land-based pollution on coastal habitats are complex and intertwined, but essentially they fall into three classes from the perspective of changes in economic value, namely: productivity/production, amenity and human welfare. Table 4 provides a checklist of the occurrence or non-occurrence of impacts in each habitat in terms of changes to productivity, amenity and human welfare. Tables 5, 6 and 7 provide a simple guide to the appropriate valuation technique required to determine the economic values of the impacts in each class of value.

Table 3 Checklist of the Impacts of Land-based Pollution in Coastal Ecosystems.

Contaminant	IMPACTS	Mangroves	Coral Reefs	Seagrass	Wetlands
Heavy metals	Water quality	√	√	√	√
	Reduced reproductive capacity in molluscs	√	√	√	√
	Contamination of human food sources	√	√	√	√
	Bio-accumulation	√	√	√	√
Organic matter	Water quality - Increased turbidity	-	√	√	√
Nutrients	Eutrophication	-	√	√	√
	Algal blooms and/or overgrowth	-	√	√	√
	Red tides	-	√	√	√
	Anoxia – fish kills	-	√	√	√
	Fish shellfish poisoning	-	√	√	√
Oil/hydrocarbons	Contamination/tainting of aquaculture and wild fish	√	√	√	√
	Extreme spills smothering of organisms	√	√	√	√
	Water quality	√	√	√	√
Sediments	Smothering of coral reefs, seagrass, and mangrove pneumatophores	√	√	√	-
	Reduced light penetration from increased turbidity leading to reduced primary production	-	√	√	√
	Water quality	√	√	√	√
	Change of water depth	√	√	√	√
	Change of species composition in the benthic community	√	√	√	√
POPs	Water quality	√	√	√	√
	Contamination of seafood	√	√	√	√
	Reduced fish reproductive capacity	-	√	√	√
Solid waste (plastics)	Smothering of organisms	√	√	√	√
	Loss of amenity value	√	√	√	√
	Biosorption of plasticizing agents	√	√	√	√
Thermal pollution	Reduced productivity	√	√	√	√
	Loss of species	√	√	√	√
Bacterial contamination	Loss of amenity value	√	√	√	√
	Contamination of human food sources	√	√	√	√
Acid Pollution	Change in pH	√	-	√	√
	Loss of species (fish)	√	-	√	√

Table 4 Framework for Valuing Impacts of Land-based Pollution on Coastal Habitats. Impacts are Grouped into Three Classes: Changes in Production/productivity; Changes in Amenity Value; and Impacts on Human Welfare.

Types of Contaminant	Impacts	Mangroves			Coral Reefs			Seagrass			Coastal Wetlands		
		PROD.	Amenity	Human welfare	PROD.	Amenity	Human welfare	PROD.	Amenity	Human welfare	PROD.	Amenity	Human welfare
Heavy metals	• Water quality	v	v	v	v	v	-	v	v	-	v	v	v
	• Reduced reproductive capacity in molluscs	v	-	-	v	-	-	v	-	-	v	-	-
	• Contamination of human food sources	-	-	v	-	-	v	-	-	v	-	-	v
	• Bio-accumulation	v	-	v	v	-	-	v	-	-	v	-	-
Organic matter	• Water quality	-	-	-	v	v	-	v	v	-	v	v	v
Nutrients	• Eutrophication	-	-	-	v	-	-	v	-	-	v	v	-
	• Algal blooms and/or overgrowth	-	-	-	v	-	-	v	-	-	v	v	-
	• Anoxia – fish kills	-	-	-	v	-	-	v	-	-	v	-	-
	• Fish shellfish poisoning	-	-	-	-	-	v	-	-	v	-	-	v
Oil and hydrocarbons	• Contamination/tainting of aquaculture and wild fish	v	v	v	-	-	v	-	-	v	-	-	v
	• Extreme spills smothering of organisms	v	v	-	v	v	-	v	v	-			
	• Water quality	v	v	v	v	-	-	v	v	v	v	v	-
Sediments	• Smothering of benthic communities	v	v	-	v	v	-	v	v	-	v	v	-
	• Reduced light penetration from increased turbidity leading to	-	-	-	v	v	-	v	v	v	v	-	-
	reduced primary production							v	v	-	v	-	-
	• Water quality	v	v	-	v	v	-						
	• Change of water depth	v	v	-	v	v	-	v	v	-	v	v	-
	• Change of species composition of benthic communities	v	v	-	v	v	-	v	v	-	v	v	-
POPs	• Water quality	-	-	v	v	-	-	v	v	-	v	v	v
	• Contamination of seafood	-	-	v	-	-	v	-	-	v	-	-	v
	• Reduced fish reproductive capacity	v	-	-	v	-	-	v	-	-	v	-	-
Solid waste (plastics)	• Smothering of organisms	v	v	-	v	v	-	v	v	-	v	v	-
	• Loss of amenity value	v	-	v	v	-	v	v	-	v	v	-	v
	• Biosorption of plasticizing agent												
Thermal pollution	• Reduced productivity	v	-	-	v	-	-	v	-	-	v	-	-
	• Loss of species	v	v	-	v	-	-	v	v	-	v	v	-
Bacterial contamination	• Loss of amenity value (reduced bathing)	-	-	-	-	v	-	-	v	-	-	v	-
	• Contamination of human food sources	v	-	v	-	-	v	-	-	v	-	-	v
Acid Pollution	• Change in pH of water column and sediment pore water	v	-	-	v	-	-	v	v	-	v	-	-
	• Loss of species (fish)	v	v	-	v	v	-	v	v	-	v	v	-

Table 5 Procedures to Undertake Valuation of Impacts of Land-based Pollution on the Productivity of Coastal Habitats and Resources.

Impacts	Valuation Technique	Indicator of Measurement	Data Needed	Notes and Assumptions
Changes in water quality	On site sale value for marketed goods using net price For directly used goods, use market values for equivalent goods. If not available use indirect opportunity cost approach (using wages forgone for harvesting goods)	Total annual value of production for each product (US$)	**For direct valuation:** • On site market price of each product (before and after) • Quantities of products harvested, sold, given away and used (before and after) • Total areas under consideration (before and after) • Concentration level of heavy metals • Exchange rates and the years of data collected **For indirect valuation:** • Price per unit for equivalent goods • Cost of material inputs • Time spent harvesting/gathering/ culturing product • Equivalent local wage for labour • On site market price of each product (before and after degradation of water quality)	• Values prior to the impact to be determined. • Market price can be adapted to account for seasonal and other price changes. • Market price represents true market value within a competitive market at equilibrium (i.e. prices are not distorted). • All externalities are identified and included in the price.
Reduced reproductive capacity	On site sale value for human food sources using net price	Loss of income due to decreased production of food sources	• Prices before and after pollution • Change in production before and after heavy metal pollution	Change of productivity is caused only by heavy metals
Contamination of human food sources	On site sale value for human food sources using net price	Drop in price due to the decrease in demand Loss of income due to decreased demand	• Prices before and after pollution • Quantities of products harvested, sold, given away and used (before and after)	• People are aware of the polluted food sources • Market price changes reflect the changes in demand • All externalities are identified and included in the price.
Bio-accumulation	On site sale value for marine food products	Drop in price due to the decrease of demand	• Prices of marine food before and after pollution	• People are aware of the bio-accumulation of marine food products • Market price changes reflect the changes in demand
Eutrophication **Algal blooms** **Anoxia, fish kills**	On site sale value for marketed goods using net price For directly used goods, use market values for equivalent goods. If not available use indirect opportunity cost approach (using wages forgone for harvesting goods)	Total annual value of production for each product (US$)	**For direct valuation:** • On site market price of each product (before and after) • Quantities of products harvested, sold, given away and used (before and after) • Total areas under consideration (before and after) • Concentration level of heavy metals • Exchange rates and the years of data collected **For indirect valuation:** • Price per unit for equivalent goods • Cost of material inputs • Time spent harvesting/gathering/ culturing product • Equivalent local wage for labour • On site market price of each product (before and after degradation of water quality)	• Values prior to the impact to be determined. • Market price can be adapted to account for seasonal and other price changes. • Market price represents true market value within a competitive market at equilibrium (i.e. prices are not distorted). • All externalities are identified and included in the price.

Table 5 *cont.* Procedures to Undertake Valuation of Impacts of Land-based Pollution on the Productivity of Coastal Habitats and Resources.

Impacts	Valuation Technique	Indicator of Measurement	Data Needed	Notes and Assumptions
Extreme spills smothering of organisms	On site sale value of reduced production	Loss of income due to decreased production of food sources	• Prices of aquaculture and wild fish • Production before and after oil/hydrocarbon	• Change of production is caused only by oil/hydrocarbon
Smothering of mangroves	On site sale value of reduced production	Loss of income due to decreased production of human food sources	• Prices of aquaculture and wild fish • Production before and after smothering	• Change of production is caused only by sediments
Change in water depth & species composition of benthic communities	On site sale value of changed production	Changes in income due to changes in production	• Prices of aquaculture and wild fish • Production before and after increased sediment loading	
Smothering of organisms	On site sale value of reduced production	Loss of income due to decreased production	• Prices of aquaculture and wild fish • Production before and after smothering	• Change of production is caused only by solid wastes
Biosorption of plasticizing agents reduced production	On site sale value of reduced production	Loss of income due to decreased production of food sources	• Prices of aquaculture and wild fish • Production before and after smothering	• Change of production is caused only by biosorption of plasticising agents
Reduced production	On site sale value for marketed goods using net price For directly used goods, use market values for equivalent goods. If not available use indirect opportunity cost approach (using wages forgone for harvesting goods)	Total annual value of production for each product (US$)	**For direct valuation:** • On site market price of each product (before and after thermal pollution) • Quantities of products harvested, sold, given away (before and after) • Total areas under consideration (before and after) **For indirect valuation:** • Price per unit for equivalent goods • Cost of material inputs • Time spent harvesting/gathering/ culturing product • Equivalent local wage for labour	• Values prior to the impact to be determined. • Market price can be adapted to account for seasonal and other price changes. • Market price represents true market value within a competitive market at equilibrium (i.e. prices are not distorted). • All externalities are identified and included in the price. • Exchange rates and the years of data collected
Loss of species	On site price for marketed products Substitute price of non-marketed products*	Total annual value of production for each product (US$)	**For all approaches:** • Species identified before and after • Quantities of equivalent products harvested, sold, given away (before and after) **For direct valuation:** • On site market price of each product (before and after thermal pollution) • Total areas under consideration (before and after) **For indirect valuation (incl. substitute price approach):** • Price per unit for equivalent goods • Cost of material inputs • Time spent harvesting/gathering/ culturing product • Equivalent local wage for labour	• Values prior to the impact to be determined. • Market price can be adapted to account for seasonal and other price changes. • Market price represents true market value within a competitive market at equilibrium (i.e. prices are not distorted). • All externalities are identified and included in the price. • Exchange rates and the years of data collected • Substitute material acceptable • Market values not distorted

Table 6 Procedures to Undertake Valuation of Impacts of Land-based Pollution on the Amenity Value of Coastal Habitats and Resources.

Impacts	Valuation Technique	Indicator of Measurement	Data Needed	Notes and Assumptions
Water quality including contamination of recreational areas	Travel cost: Amount of money and time spent on the site	Annual recreational value of the site (US$)	Data from visitors survey (before and after water contamination) • Socio-economic variables • Geographic origin • Time spent travelling • Expenditures incurred in visiting the site • Frequency and duration of visits • Number of visitor-days for the site	**Assumptions** • Access to the site is available to all • Visits have a single purpose • Demand function relationship can be specified • No factors aside from travel cost influence site use • Market prices used in valuation are not distorted
	Contingent valuation: willingness to pay for good water quality	Recreational value of the site as valued by willingness to pay by users (US$) Total cost value	Answers to valuation questions from survey/bidding game technique/ dichotomous choice	• Subjects understand choices offered and give meaningful and honest answers • Subject have sufficient information to give informed choices • Sample is representative and captures the full spectrum of users who value the site • No free riders • No strategic bias/influences
	Replacement cost: cost to clean up heavy metals	Total cost value	• Type of pollutants • Sources of pollutants	• Technologies to clean up the pollutants are available and the cost of technologies is affordable
	Prevention cost	Total cost to prevent bacterial contamination	• Cost of constructing facilities for individual economic activities • Cost of volumes of projected waste • Size of impacted areas • Sources of contaminants	
	Opportunity cost	Total value of best alternative uses	Potential alternative uses of the resources Investments in the best alternative uses	Stakeholders agree on the best uses of the resources
Contamination /tainting of aquaculture and wild fish	Travel cost: Amount of money and time spent on the site	Annual recreational value of the site (US$)	Data from visitors survey (before and after water contamination) • Socio-economic variables • Geographic origin • Time spent travelling • Expenditures incurred in visiting the site • Frequency and duration of visits • Number of visitor-days for the site	• Assumptions • Access to the site is available to all • Visits have a single purpose • Demand function relationship can be specified • No factors aside from travel cost influence site use • Market prices used in valuation are not distorted
Extreme spills smothering of organisms	Travel Cost Travel cost/opportunity cost: Amount of money and time spent on the site	Annual recreational value of the site	• Data from visitors survey (before and after water contamination) • Socio-economic variables • Geographic origin • Time spent travelling • Expenditures incurred in visiting the site • Frequency and duration of visits • Number of visitor-days for the site	• Assumptions • Access to the site is available to all • Visits have a single purpose • Demand function relationship can be specified • No factors aside from travel cost influence site use • Market prices used in valuation are not distorted

Table 6 *cont.* Procedures to Undertake Valuation of Impacts of Land-based Pollution on the Amenity Value of Coastal Habitats and Resources.

Loss of amenity value including loss or change of species, smothering of organisms, changes in sediment quantity and quality	Hedonic Pricing	Differences in the value of the assets/real estates of the same quality	Prices of assets and real estates in different locations	Different prices of the assets/real estates of the same quality are influenced only by the surrounding habitats
	Replacement cost: cost to clean up solid waste	Total cost value (US$)	• Sources of solid waste • Volume of solid waste	Technologies to clean up the pollutants are available and the cost of technologies is affordable
	Travel cost: Amount of money and time spent on the site	Annual recreational value of the site (US$)	Data from visitors survey (before and after water contamination) • Socio-economic variables • Geographic origin • Time spent travelling • Expenditures incurred in visiting the site • Frequency and duration of visits • Number of visitor-days for the site	• Access to the site is available to all • Visits have a single purpose • Demand function relationship can be specified • No factors aside from travel cost influence site use • Market prices used in valuation are not distorted
	Hedonic Pricing		Answers to valuation questions from survey/bidding game technique/ dichotomous choice	
Loss of biological communities	Contingent valuation: willingness to pay for good water quality	Recreational value of the site as valued by willingness to pay by users (US$)	• Answers to valuation questions from survey/bidding game technique/ dichotomous choice	• Subjects understand choices offered and give meaningful and honest answers • Subject have sufficient information to give informed choices • Sample is representative and captures the full spectrum of users who value the site • No free riders • No strategic bias/influences

Table 7 Procedures to Undertake Valuation of Impacts on Human Welfare of Land-based Pollution of Coastal Habitats and Resources.

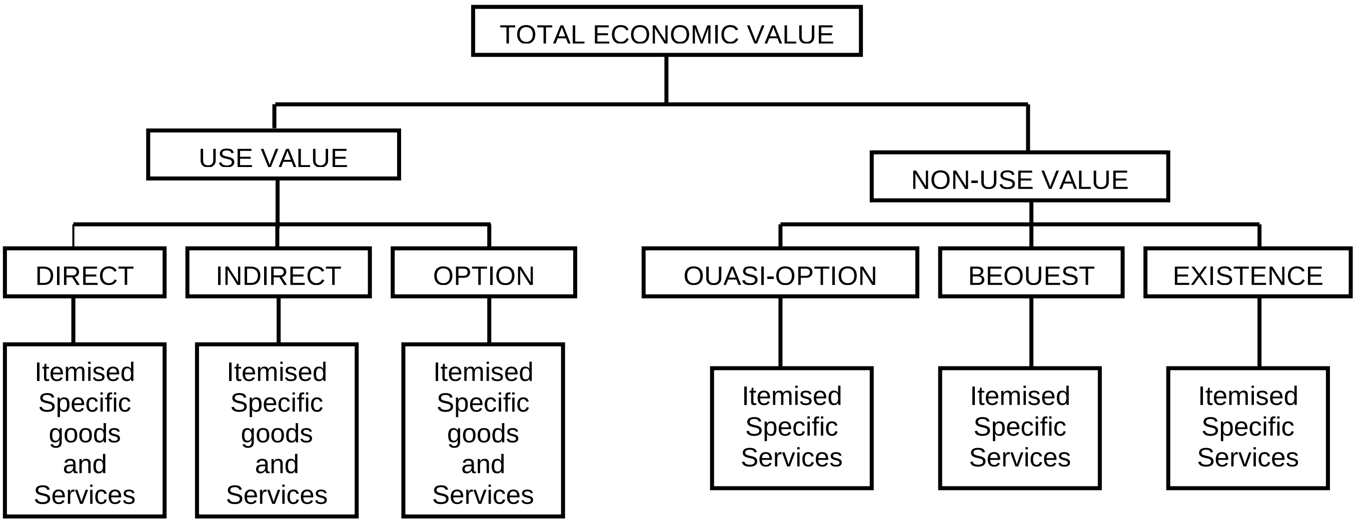
Impacts	Valuation Technique	Indicator of Measurement	Data Needed	Notes and Assumptions
Recreational Water quality	Cost of illness	Total value of lost human labour (US$), total cost of treatment	• Salaries/wages for labour • Duration of illness and recovery (number of days lost) • Hospitalisation and treatment cost	• Health and productivity can be restored to previous levels
Contamination / tainting of human food sources including bio-accumulation toxins derived from harmful algal blooms shellfish poisoning	Cost of illness	Total value of lost human labour (US$), total cost of treatment	• Salaries/wages for labour • Duration of illness and recovery (number of days lost) • Hospitalisation and treatment cost • Salaries/wages for labour • Duration of illness and recovery (number of days lost) • Hospitalisation and treatment cost	• Health and productivity can be restored to previous levels

THE GENERAL/OVERALL VALUATION FRAMEWORK

Total Economic Value

The *total economic value* (TEV) is the sum of all the benefits that are attributable to the specific resource or ecosystem being valued. The total economic value is composed of (i) *use value* (UV) and (ii) *non-use value* (NUV). *Use value* can be further broken down into direct use value (DUV), indirect use (IUV), and option value (OV). *Non-Use Value,* on the other hand can be further broken down into quasi-option, bequest, and existence value. Figure 1 outlines an economic valuation approach to valuing coastal habitats (UNEP, 2004).

Figure 1 Economic valuation approach



Use Values

Direct Use: The direct use values of a resource or a system are the tangible or physical aspects of such resources, which can either undergo physical processing or provide direct (personal) utility or satisfaction and which have direct market prices for quantification. According to Bann (1997), these are the "values derived from the direct use or interaction with a (for example) mangrove's resources and services". These direct use values are further categorised as extractive or consumptive, and non-extractive or non-consumptive (Ebarvia, 1999). Examples of extractive or consumptive use values are the use of Nipa fronds and poles from mangroves. Examples of non-extractive or non-consumptive values are the recreational or tourist values of wetlands or coral reef areas.

Indirect Use: Indirect use values consist of the various functions that a natural system may provide, such as shoreline protection functions, carbon sequestration, and nutrient or contaminant retention. These values have no direct market prices but equivalent values can be derived through the use of different valuation methods. The indirect use value of an environmental function is related to the change in the value of production or consumption of the activity or property that it is protecting or supporting (Ebarvia, 1999).

Option Use: Option Use or *option value* is a special category of value, which arises because of an individual's uncertainty about his or her future demand for a specific resource, or the availability of this resource in the future. It is still considered as a "use" value since it still relates to future direct or indirect use of the resource (Barbier *et. al*., 1997). This concept may be termed or understood as the *potential* direct and indirect uses of a natural system and the *"additional amount that an individual would be willing to pay above the actual current price to maintain the natural resource and to avoid irreversible damage that would inhibit possible future use of the resource*" (Ebarvia, 1999).

Non-Use Values

Quasi-Option Value: This non-use value is related to option value such that there is still willingness to pay by the individual for the preservation of the resource, but instead of worrying about its future use, the preservation is for the value that it can presently provide.

Bequest Value: This is an important subset of non-use value that results from an individuals' willingness to pay for the preservation or conservation of a resource so that future generations will still be able to reap its benefits. This may be particularly high among those who are currently enjoying the rights to use the resource because they may want their heirs and future generations to be able to derive the same benefits from the system.

Existence Value: Existence value can be related to aesthetic, cultural, and moral aspects that a resource may have in that it is the value that an individual places on the resource because of the satisfaction that he or she derives from merely knowing that the resource, ecosystem or species exists, regardless of whether it will be used or not. This is a form of non-use value which is difficult to measure since it involves subjective valuations by individuals unrelated to their own or others' use. What for example is the monetary value of a "species", whilst many individuals might place a high existence value on whales or turtles, few would place high existence values on worms or micro-organisms, yet from a genetic perspective the values of worms or micro-organisms could potentially be of far greater than the intrinsic value of whales and turtles.

VALUATION TECHNIQUES

Valuation techniques can be categorised into three groups namely: market-based value; surrogate market-based value; and simulated survey-based value. Figure 2 outlines the main categories and the specific techniques under each category, while Table 8 provides a listing of techniques for valuation applicable to various types of use and non-use.

Figure 2 Valuation Techniques.

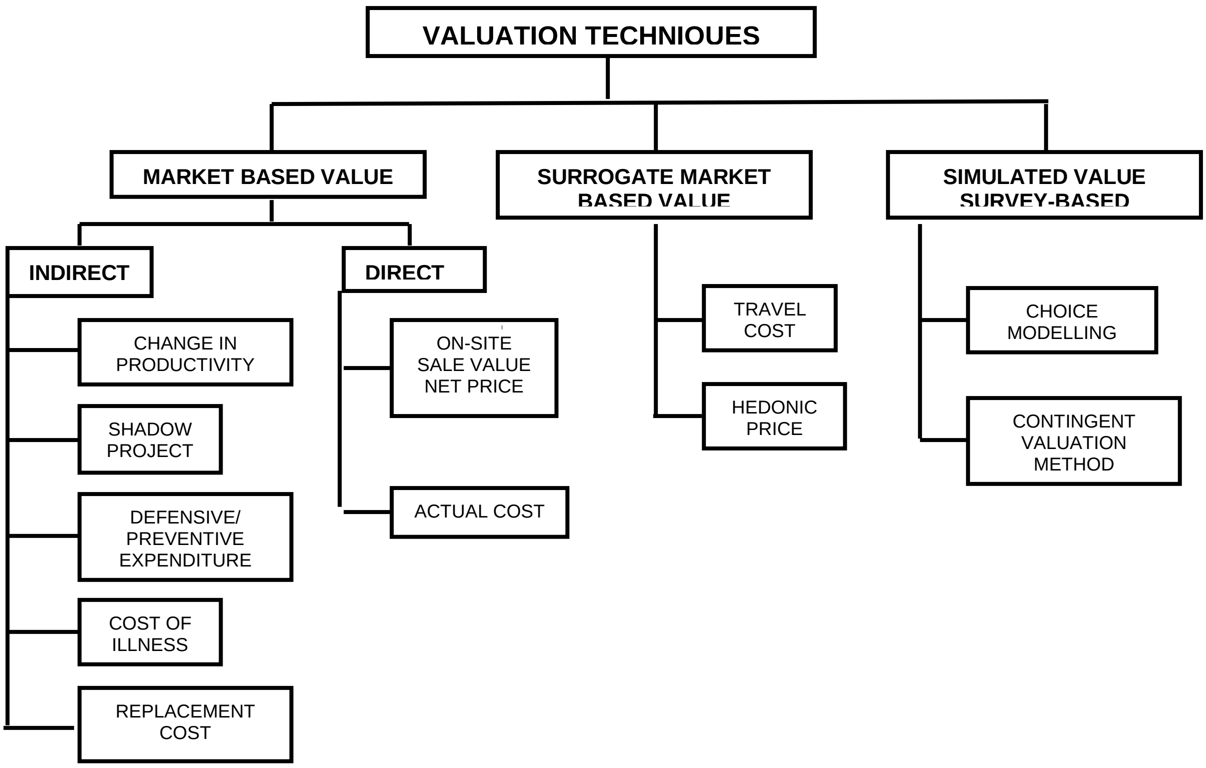


Table 8 Economic Valuation Techniques, Indicators, Data Requirements and Assumptions for Various Types of Use and Non-uses of Coastal Habitats.

Types of Uses	Valuation Technique	Indicator of Measurement	Data Needed	Notes and Assumptions
Extractive Use	On site sale value for marketed goods. using net price[2] For directly used goods, use market values for equivalent goods. If not available, use indirect opportunity cost approach to assess time spent harvesting in terms of wages foregone.	Total annual value of production for each product (US$).	**For direct valuation:** On site market price of each product ($US/kg). Quantities of product harvested, sold, given away and used within the household (kg/ha/year) Total area of the project (Ha) **For indirect valuation:** The price per unit for equivalent goods ($US/unit). Cost of material inputs ($US). Time spent harvesting/culturing product (hours/week). Equivalent local wage for labour ($US/day) Exchange Rate Year (Date of the data collected)	Market price can be adapted to account for seasonal and other price changes. Market price represents true market value within a competitive market at equilibrium (i.e. prices are not distorted). All externalities are identified and included in the price.
Non-extractive Uses Tourism/recreation	Travel costs: Amount of money and time spent by visitors to the site.	Annual recreational value of the site (US$)	Data from visitor surveys: Socio-economic variables. Geographic origin. Time spent travelling. Expenditures incurred in visiting the site. Frequency and duration of visits. Number of visitor-days for the site.	Access to the site is available to all. Visits have a single purpose. Demand function relationship can be specified. No factors apart from travel cost influence site use. Market prices used in valuation are not distorted.
Transport	Market price of transport using alternative means, e.g. motorcycle. [Substitute price approach]	Total annual value for waterborne transport enabled. (US$).	Frequency of journeys Numbers of travellers and volume of products transported. Distances travelled. Origins and destinations. Market costs of transport using substitute means.	Substitute means of transport is an acceptable substitute. Seasonal variations in transport trends can be accounted for. Market prices used in valuation are not distorted.
Education	Substitute price approach: costs of teaching at other locations. [Actual cost of teaching (?)].	Total annual value for educational activities enabled (US$).	Annual number of educational activities. Costs of conducting activities at alternative locations.	Substitute locations are acceptable/comparable and are within reach. Market prices used in valuation are not distorted.
Research	Substitute price approach: Costs of undertaking research at other locations or through other techniques. [Actual cost of research (?)]	Total annual value for research enabled (US$).	Annual number of research visits. Costs of conducting activities at alternative locations or using alternative techniques.	Substitute locations/ methods are acceptable/comparable and are within reach. Market prices used in valuation are not distorted.

[2] *Net Price = market price less harvesting/production cost.*

Table 8 *cont.* Economic Valuation Techniques, Indicators, Data Requirements and Assumptions for Various Types of Use and Non-uses of Coastal Habitats.

Types of Uses	Valuation Technique	Indicator of Measurement	Data Needed	Notes and Assumptions
Fish culture Crab culture Prawn culture Shellfish culture Other aquaculture (pearls)	On site sale value for marketed goods. For directly used goods, use market values for equivalent goods. If not available, use indirect opportunity cost approach to assess time spent harvesting in terms of wages foregone.	Total annual value of production for each product (US$).	For direct valuation: Market price of each product ($US/kg). Quantities of product harvested, sold, and used within the household (kg/month). For indirect valuation: Replacement prices for equivalent goods ($US). Cost of material inputs ($US) Time spent harvesting/culturing product (hours/week). Equivalent local wage for labour ($US/day)	Market price can be adapted to account for seasonal and other price changes. Market price represents true market value within a competitive market at equilibrium (i.e. prices are not distorted). All externalities are identified and included in the price.
Environmental services Shoreline/erosion prevention	Replacement costs (preventive expenditure): costs of providing alternative engineered sea defences.	Total annual value provided by mangroves in preventing coastal erosion (US$).	Length of coastline protected. Cost of constructing replacement defences ($US/km).	Influence of mangroves in preventing off-site coastal erosion can be identified.
Flood protection Windbreak	Rehabilitation costs: costs of rehabilitating/replacing property and assets protected from flooding/storms (damage costs avoided).	Total annual value provided by mangroves in protecting against floods/storms (US$).	Frequency – severity function for flood/storm events (derived from historical records). Flood maps and models. Property locations and asset replacement values.	Assets could and would be rehabilitated. Protective function can be modelled.
Carbon sequestration	Preventive expenditure (abatement cost).	Total annual value provided by mangroves in fixing carbon (US$) (?)	Price per ton of carbon fixed (?). Carbon sequestration rate for mangrove forests.	Meaningful figures for carbon fixation prices and carbon sequestration rates are available (?).
Water purification (Prevention of saline water intrusion)	Change in productivity: value of lost production for agricultural, water supply, fishery and other uses.	Total annual value provided by mangroves in preventing saline water intrusion (US$).	Area and annual production of agricultural land protected. Number and value of wells/ water supply sources protected. Price of products and services.	Protected area can be identified. Protective function can be modelled. Seasonal influences can be accounted for.
Sediment, Contaminant Nutrient removal/storage	Replacement costs: costs of removing sediment/nutrients/toxicants by other means.	Total annual value provided by mangroves in removing pollutants (US$).	Pollutant loads. Quantity of water treated (flows). Costs of treatment.	Equivalent standard of treatment by each method.
Oxygen release (?)	Replacement costs: Costs of generating oxygen elsewhere.	Total annual value provided by mangroves in generating (oxygen (US$).	Price per ton of oxygen generated. Oxygen release rate for mangrove forests.	Meaningful figures for oxygen generation prices and oxygen release rates are available.
Nursery feeding area	On site sale value, based on contribution of mangroves to commercial fisheries and marine animal catches and swallows nest collection.	Total annual value provided by mangroves in contributing to productivity of fisheries, other marine animals, and swallows nests (US$).	Market prices of fish, marine animals, and swallows nests etc. Volume of fish, marine animals and swallow nests etc. Harvesting cost.	Production function relationship can be meaningfully defined. Mangrove area is limiting factor for productivity.

Table 8 *cont.* Economic Valuation Techniques, Indicators, Data Requirements and Assumptions for Various Types of Use and Non-uses of Coastal Habitats.

Types of Uses	Valuation Technique	Indicator of Measurement	Data Needed	Notes and Assumptions
Shoreline accretion/Land increase	Market price for land based on local prices.	Total annual value provided by mangroves in contributing to land building along the coast.	Annual accretion rate at which new land develops. Prices of land locally.	Market price represents true market value within a competitive market at equilibrium (i.e. prices are not distorted). All externalities are identified and included in the price.
Biological diversity services Existence values of species (migratory; endangered), genes, ecosystems and communities Wilderness	Contingent valuation: willingness to pay for biodiversity functions.	Biological diversity value of mangroves as valued by willingness to pay of users/local residents (US$).	Answers to valuation questions from survey/bidding game technique/dichotomous choice.	Subjects understand choices offered and give meaningful. Honest answers. Subjects have sufficient information to give informed choices. Sample is representative and captures the full spectrum of users who value the mangrove forest. No free riders. No strategic bias/influences.
Social/cultural significance Religious/spiritual significance	Contingent valuation: willingness to pay for social/cultural significance	Social and cultural value of mangroves as valued by willingness to pay of users/local residents (US$).	Answers to valuation questions from survey/bidding game technique/dichotomous choice.	Subjects understand choices offered and give meaningful and honest answers. Subjects have sufficient information to give informed choices. Sample is representative and captures the full spectrum of users who value the mangrove forest. No free riders. No strategic bias/influences
Historical importance Presence of distinctive human activities Aesthetic	Contingent valuation: willingness to pay for aesthetic value.	Aesthetic value of mangroves as valued by willingness to pay of users/local residents (US$)		

MARKET BASED VALUES

The valuation techniques that use market price can be used to value products from coastal habitats, i.e., resources that are marketed and used both directly and indirectly.

Direct Value (On site value)

Direct values can be attributed to both extractive and non-extractive uses of the ecosystem. The benefits and costs of fishery products, fuelwood, genetic materials and raw materials derived from coastal habitats can be estimated as can non-extractive uses such as recreation and tourism. The values of both extractive and non-extractive uses are based on market price (accounting price), which can be quantified and monetised from the direct use of the coastal ecosystem (Bann, 1997).

On Site Sale Value, Net = $\sum\{P_iQ_i - C_i\}$

Where P_i = Farm-gate price of Product
Q_i = Quantity of product collected
C_i = Costs involved in collection, production and marketing of product consisting of:
G = gathering or collection cost
CT = transport cost to point of sale.

Example:

A one hectare mangrove area yields raw materials for 1,760 Nipa palm shingles per year. Collection and production of 1760 shingles takes 1.5 man-months to complete and the minimum monthly wage in the area is US$75. Costs of transport and portage of the shingles is 20 cents per 100 pieces. The farm gate price of a Nipa palm shingle is 50 cents per shingle, using the above formula the Net value is therefore:

On site Sale Value, Net = (0.5*1760) – {(75*1.5)+(0.2*17.6) US$
= (880) – {112.5 + 3.52} US$
= 880 – 116.02 US$
= + 763.98 US$ per hectare per year

<u>FORMULA</u>: 1

Local direct use value = Net income generated for local use =$\sum\{P_i Q_i - C_i\}$

Where: P_i = prices of product *i*
Q_i = amounts of product *i* being collected
C_i = costs involved in the collection of product *i*

Using the above given assumptions, and following the same procedure used in computing the direct use value of the nipa shingles, the corresponding values for the other mangrove forest products can be computed. Resulting values for each of the identified mangrove forest products can be summed-up to get the resulting total direct use value for mangrove ecosystems.

Indirect Value

When the values of the coastal habitat goods are difficult to determine using the appropriate market price directly, the values can often be estimated indirectly as for example in the case of changes in productivity.

Change in Productivity

Development plans that affect a coastal habitat may increase or decrease productivity, thus banning fishing in a protected area may result in an increase in fish biomass that could be used to support tourism. The loss in fish captured represents a loss in value that can be calculated using the market values of the fish concerned and estimates of the annual sustainable yield. This loss is counterbalanced by the increase in local revenues from tourism that result from the greater numbers and visibility of fish to divers. Such values for change can be calculated in terms of the direct value of the increased production or, the value of the damages prevented or a combination of both.

Change in productivity refers to the minimum value of an environmental change estimated in terms of the resulting loss or decrease in productivity/output, it estimates the negative effects of a degraded environment resource on-site and off-site economic activities. This approach employs production relationships/functions, which include environmental quality as an input (www.deh.gov.au).

Example:

A mangrove area is known for its production of mud-crab however a portion of the area was converted to a beach resort with a resulting decline in mud-crab production. Over the period 1990 – 2003, prior to the change in use of the area, the average mud-crab gathered was 638kg/Ha/year. In 2004 and 2005 the average mud-crab collected in the area was 416.7kg/Ha/year. The price for mud-crab for 2005 was US$1.5/kg.

To calculate the change in value of the mud-crab production the following formula is used:

$$\Delta P = [(Q_i^n/N) - Q_i^t]*P^t$$

Where Q_i^n/N = the quantity of the good produced per unit area prior to the change: (638kg^{-ha-yr})

Q_i^t = the quantity of the good produced per unit area following the change: (416.7kg^{-ha-yr})

P^t = the farm-gate price of the good (US \$1.5^{-Kg})

<u>Computation for Change in Productivity = (ΔP)</u>

ΔP	=	**$[(Qi^n/N) - Qi^t] * P^t$**
	=	(638kgs – 416.7kgs) * $1.5/kg
	=	221.3 * 1.5
	=	$331.95

In this example the loss of mangrove forest cover led to a decrease in annual production of mud crabs, equivalent to about 221.3kgs/hectare or US$331.95/hectare loss of income from mud crab catch. It may be concluded that the decrease in forest cover resulted in an **environmental cost** equivalent to US$331.95 per hectare per year. It is important in remember in this example that this represents the loss in value for only one year, 2005, at 2005 prices. The loss however is an annual recurrent loss in production and hence the loss in value should be computed over the anticipated life-span of the development project when decisions are made regarding whether or not to proceed with the development. It is also important to remember that the market price of mud crabs is likely to increase year by year hence the values for future years need to be computed taking into account such potential increases in value.

The actual cost of the development of the beach resort is therefore not only the actual direct costs incurred in construction but also the costs of lost production from the natural environment.

<u>FORMULA</u>: 2

<u>Change in value of production</u> **$\Delta P = [(Qi^n/N) - Qi^t] * P^t$**

Where: **ΔP**	=	Change in Productivity
Qi^n/N	=	amount of good ***i*** collected within the timeline being considered
Qi^t	=	amount of good/service being collected at baseline year
P^t	=	unit price of good **Q** at baseline year

Replacement Cost

An alternative way of computing the costs of lost production is to calculate the cost of replacement, which might be done by simply taking the costs of importing the equivalent volume of mud-crabs from the nearest site of production, or by taking the cost of a locally available alternative food such as swimming crabs. A further alternative is to determine the cost of producing the same volume of mud crabs hence the actual cost of the project is:

Total Project Cost = Actual Cost of Project + Cost of Providing Alternative Goods or Services

Shadow Project

The shadow project technique is a special version of the replacement-cost technique which relates to the cost of replacing the entire range of environmental goods/services or replacing productive assets damaged by improper management practices by, using the costs of a hypothetical supplementary project. This approach is essentially the same as the replacement cost approach and is increasingly being mentioned as a possible way of operationalising the concept of sustainability at the project level. This approach assumes that there is a social constraint to maintain environmental capital intact and therefore it could be more appropriate when "critical" environmental assets are at risk.

When evaluating projects that have negative environmental impacts, this approach involves the design or costing of one or more "shadow projects" that provide or substitute environmental services to compensate for the loss of environmental assets under the proposed project. Here, the total cost of the alternative is added to the actual costs of the project to estimate a full social cost. It likewise assumes that existing market prices reflect scarcity and the optimal allocation of resources (i.e. economic efficiency) (Hoban & Tsunokawa, 1997).

More simply put, the Shadow Project Method refers to the costs of providing an equal alternative good or service elsewhere. The possible alternatives may range from asset reconstruction such as providing an alternative habitat site for a threatened wildlife habitat; asset transplantation that is moving the existing habitat to a new site; asset restoration that is enhancing the quality of an existing degraded habitat and restoring it to its original state. The cost of the chosen option is added to the basic resource cost of the proposed development project in order to estimate the full cost. Inclusion of shadow project costs gives an indication of how great the benefits of the development project must be in order to outweigh the losses it causes. In other words the shadow project approach provides a minimum estimate of the presumed benefits of programmes for protecting or improving the environment (Panayotou, 1997).

The underlying idea in asset reconstruction (replacement) and asset transplantation (relocation) is that, by measuring the costs of reconstruction, one has an idea of what the benefits would be if the damage did not occur. If a development project leads to the destruction of the habitat, one way to measure the benefits from preventing that loss from occurring would be to estimate the cost for reconstruction (Cistulli, 2002). Even if all of the benefits in terms of the supplies of goods and services of a natural system can in fact be replicated the costs are likely to be extremely high, as for example in the construction of an artificial lagoon and wetland to replace all services of an estuary including fish breeding habitat, fish catches, bird habitat, and recreational activity as part of a flood mitigation project.

The total project cost is therefore the actual cost of the project plus the cost of providing alternative goods and services, i.e.:

$$\text{Total Project Cost} = \text{Actual Cost of the Project} + \text{Cost of Asset Replacement}$$

Consequently the benefits derived from the flood mitigation project over its' lifespan should not be less than the Total Project Cost if it is to be economically cost effective.

Replacement Cost

This approach takes into consideration the cost incurred in the replacement of a previously existing environmental resource or a human made good, service or asset. The resulting value reflects the willingness of individuals to pay to continue receiving a particular benefit provided by that environmental resource. Replacement cost provides an estimate of the value of changes in the quality of the environment/resource and its services measured in terms of the cost of restoring/replacing the damaged environmental asset. This approach can be used in estimating the costs of land degradation, such as costs of replacement of public assets such as roads, rivers, and water storage capacity affected by land degradation. It examines the expenditures people make to correct a problem after the potential impact has occurred.

The value of the ecosystem function is determined through the following steps (Hoban and Tsunokawa, 1997):

1. Cost of construction of defensive, preventive structures such as dikes/breakwaters, which substitute for the natural protective functions of previously existing ecosystems.
2. Cost of acquiring equipment/facilities which would help combat, mitigate pollution levels.
3. Cost of all other measures taken by individual or a group of people to reduce effects of poor environmental quality

EXAMPLE: Mangroves for Coastal Defence
For example, a community in a coastal area that relied on the mangroves along its coastline for protection from strong waves in cases of bad weather finds that it needs additional protection against wave intrusion from the sea because uncontrolled cutting of the mangroves for subsistence purposes which has decreased significantly the effectiveness of the mangroves as a buffer. The local government then decides, to allocate around US$20 million for the construction of artificial breakwaters to compensate for the now-inadequate protection. The cost of conducting this project then represents the preventive expenditure cost for the area and hence the value of the previous protection provided by the un-modified mangrove fringe.

The costs of replacing productive assets damaged by lowered environmental quality or by improper on-site management practices can be taken as a minimum estimate of the presumed benefits of programs for protecting or improving the environment (Hufschmidt *et al*, 1983). If in the above example the degradation of the mangrove ecosystem makes the coastal area more vulnerable to wave and tidal erosion then the coastal community's income from economic activities such as brackish water pond aquaculture, coastal agriculture may be affected. The project to construct a breakwater may also result in avoidance of the cost of replacing soil that would otherwise have been necessary to maintain the agricultural production. If one considered only replacing the soil, it would have been necessary to replace 150 tonnes of soil, per ha, per year. If the cost of soil and transportation per tonne is US$10; then the total replacement cost would US$1,500/ha/year which does not include improvement of environment and economic activities. If the cost of breakwater construction is less than this value, then the economic benefit of the breakwater development project exceeded the resource costs, and the breakwater would be the recommended option.

Defensive/Preventive Expenditure

Defensive/Preventive Expenditure is a technique that estimates an individual's minimal valuation of habitat or environmental quality in terms of their willingness to incur cost in order to avoid adverse effects on habitats or environment. This approach examines the expenditures that people actually make or are willing to make in order to avoid damage that would result from environmental degradation (Bann, 1997). The approach assigns values to perceived negative environmental attributes by looking at how individuals or groups of individuals spend money in order to avoid the negative attributes being experienced. In this case, the "negative" has not happened yet but the individual or group of individuals believe that they would occur if money were not spent to prevent them from occurring.

Defensive/Preventive Expenditure involves the following steps:

1. Identification of perceived negative environmental effects or environmental "disbenefits" – those that individuals/groups recognise as undesirable if present in their habitat.
2. Identification of alternative approaches (whether equipment or structures) that would ensure, to some degree, that these disbenefits will be avoided.
3. Identify extent of application/implementation of each approach.
4. Assign equivalent costs to the implementation of these defensive/preventive measures.

EXAMPLE: Mining Operations

The presence of mining operations in a catchment adjacent to a community places its' riverine source of domestic and irrigation water at risk of being contaminated with toxic chemicals and heavy metals discharged from the mine. Suppose that there are two alternatives to prevent this from happening, the first of which costs US$50 million, and the second alternative costs US$30 million. If the first method is selected then the value attributable to the river is US$50 million; if the second method is chosen the value attributable to the river is set at US$30 million. This mode of valuing an environment or its' services is likely to be generally an underestimate and is unlikely to yield comparable values to the direct valuation of individual goods and services provided by the river, and their summation in the form of Total Economic Value. Steps in the process would be:

1. Identify the perceived negative environmental effect in this case the release of contaminated wastewater (Acid Mine Discharge) into the natural waterways of the adjacent community
2. Identify alternative approaches to ensuring that this will not happen:
   a. Active treatment of the acid mine discharge through dissolution by introducing the water to limestone, hydrated lime, or through precipitation of metals.
   b. Passive treatment of the acid mine discharge by passing through aerobic and anaerobic wetland systems.

In this example, the cost equivalent of whichever scheme is implemented by the mining company to minimise the impacts of the acid mine discharge will also be the value attributable to the environment.

Cost of Illness

Changes in environmental quality can have significant effects on human health. The monetary value of the damage to human health can be determined by calculating the forgone earnings, the medical expenses and the physical costs.

The Cost of Illness (COI) is an approach which aims to value the changes in human health or well-being arising from a change in environmental quality. This consists of the following factors:

1. Direct monetary cost of illness such as medical expenditures, costs incurred by medical insurance
2. Value of lost time and productivity of ill person (foregone income, foregone leisure)

FORMULA:

Cost of Medical Expenditure + Value of Lost Time

Where cost of medical expenditures can consist of:

- Medical Fees
- Hospitalisation Fee
- Cost of Medicine
- Cost of Rehabilitation (if any)

And, value of lost time = lost wages/ earnings

In a recent paralytic shellfish-poisoning outbreak, caused by a red tide a husband and wife were taken ill. Both were employed, with the husband having a daily wage of US$20 and the wife having a daily wage of US$25. Both were confined to hospital for 5 days with a hospitalization cost of US$10/day. The total cost of medication for each was US$30 and the doctors' fee was US$50 for each individual. The husband did not require physical therapy but the wife required 3 days of physical rehabilitation with a total cost of US$20 and during this period the wife was unable to work.

To compute the costs of illness for the family due to paralytic shellfish poisoning the formula:

Cost of Illness = ∑ cost of medical expenditures + value of lost time

Cost of Illness (Husband) = medical fee (US$50) + hospitalisation fee (US$50) + cost of medicine (US$30) + value of lost time (5*US$20 = 100US$)
= (50+50+30+100) US$
= US$230

Cost of Illness (Wife) = medical fee (US$50) + hospitalisation fee (US$50) + cost of medicine (US$30) + cost of rehabilitation (US$20) + value of lost time (wife) (8*US$ 25 = 200)
= (50 + 50 + 30 + 20 + 200) US$
= US$350

Therefore Total Cost of Illness to Family = ∑ (cost of Husband's illness) + (cost of Wife's illness)
= (230 + 350) US$
= US$580

SURROGATE MARKET BASED

Hedonic Price

The hedonic price method is used to value an attribute, or a change in an attribute, whenever its value is capitalised into the price of assets, such as houses. Environmental benefits (e.g. improved water/air quality, scenery) can be measured by using the surrogate markets for the commodities sold which possess the attributes of the environmental benefits. The price of the surrogate commodity is used to proxy the value of un-priced environmental goods/services. This technique derives the values from the change in house prices (for example) resulting from a change in this particular attribute while holding all other factors constant. This valuation approach assumes that people, if given a choice between 2 similar houses, would prefer to buy a house that has a relatively better view, or more pleasant atmosphere (tree shades/canopied walks, a clean stream/water body, etc.), even if it will entail an additional cost. This additional cost can then be assumed to be attributable to the change in scenery and, accordingly, to the implied value of environmental goods/services.

Steps for applying Hedonic Price Method (HPM):

1. Estimate the additional cost of houses with marginally better views, holding other variables affecting house prices constant
2. Estimate WTP for better view, holding income and other socio-economic factors constant

=== or ===

1. Identify the specific environmental quality variable
2. Construct an indicator for the environmental quality which people recognize and which is strongly correlated with the price of the surrogate commodity
3. Specify the hedonic price function:

   price of the surrogate commodity = *f* (environmental quality, structural characteristics, neighborhood characteristic, socio-economic characteristics)
4. Run the regression and interpret the results. The coefficient of environmental quality provides an estimate of the marginal implicit price of environmental quality, i.e., the additional amount of money that must be paid by the individual to move to an identical property but with a higher level of environmental quality.

Example:

One application of the HPM is in measuring how the siting of hazardous waste facilities affects prices of nearby properties. A study by Kohlhase (1991), who finds that housing prices in the Houston area are positively affected by distance from a declared Superfund site up to 6.2 miles. According to this research, an additional mile in distance from the site adds US$2,364 to a property's value. In a similar study of single-family homes in Woburn, Massachusetts, Kiel (1995), estimates the analogous marginal benefits to be US$1,377 for the period when the waste facilities were declared Superfund sites.

Travel Cost

The willingness of an individual to pay for use of an environmental resource is inferred from travel expenditures of those who visit it. In such cases, an increase in output due to the change is a measure of an increase in benefit, and a decrease in output is a measure of an increase in cost. This approach is primarily used to measure the perceived benefits that consumers receive from their use of an environmental good. Demand for the good is not only a function of the price or admission fee but also the total cost of going to that place. This entails determining the opportunity cost and then adding this to the admission fee to get the total cost or price of going to that particular site.

Opportunity Cost/Explicit Cost

1. Opportunity cost of time allotted for the trip (i.e. wage rate, if travel was done on a weekday)
2. Depreciation cost of vehicle (in cases where private transportation is used)
3. Accommodation cost at site (including meals)
4. Parking fee (if any)

Example:

Assumptions: **Admission Price is US$10.00**
Opportunity cost of time = US$9.40/hr
Travel Time = 0.5 hours
Distance = 2 kilometers
Marginal vehicle operating opportunity cost (MVOC)= 15 ¢/km

Travel Cost/person = (Opportunity Cost * Travel Time) + (Distance * MVOC)
Round Trip Cost/person = Cost per trip * 2
Total Cost/ person = Round trip cost + admission price

Travel Cost/person	**=** (US$9.40*0.5) + (2*0.15)
	= 4.7 + 0.3
	= US$5.00
Round trip cost	= US$10.00
Total Cost	= US$20.00

SIMULATED VALUE SURVEY-BASED

Contingent Valuation

Contingent Valuation Method (CVM) is a method that enables economic values to be estimated for non–marketed goods, such as environmental assets, amenities, and services. CVM relies on surveys to ascertain respondents' preferences regarding an increase or decrease in the level of environmental quality. The preferences are valued through surveys to ascertain how much respondents would be willing to pay for the preservation or improvement of a certain resource or environment or to accept payment for doing away with said resources or environment (Tietenberg, 1996). This survey-based technique is used for eliciting preferences for non-marketed goods (e.g. environmental assets, amenities, services, etc.). A sample of individuals is directly asked to state their preferences (Willingness to Pay (WTP) or Willingness to Accept (WTA)) regarding a certain environmental quality/good or any non-marketed attribute of the good.

Steps:

1. Identify the environmental impact, its direction and the policy issue
2. Identify the affected or prospective respondent population covered by the environmental impact or policy
3. Construct a sample frame, determine where and how to interview
4. Design the survey instrument/questionnaire

Example:

Communities A, B and C are situated along the coast. Not far from these communities is a four hectare stand of old-growth mangroves. These mangroves are however, slowly thinning because of unsustainable subsistence cutting. Interviews with the residents of the three communities were undertaken. The questionnaire included questions regarding their household size, and a series of questions regarding how much they value their surrounding mangrove forests, ending with a question regarding their willingness to pay an amount for the rehabilitation of the mangrove forest. The gathered data were summarised as presented in the following table.

	COMMUNITY A	COMMUNITY B	COMMUNITY C	TOTAL
Number of Households	115	73	165	353
POPULATION	648	389	1,033	2,070
Average Household Willingness to Pay (USD) per month	1.35	2.15	1.63	1.63
Total Willingness to Pay per month (USD)	155.25	156.95	268.95	575.64
Total willingness to pay per year (USD)	1,863.00	1,883.40	3,227.40	11264.57
Population WTP per year (USD)	10,497.60	10,036.20	20,205.48	40,739.26

where: Average household willingness to pay per month is computed by dividing the total willingness to pay for all households in the same community, by the number of households in that community. The willingness to pay (WTP) per month (USD) is computed by multiplying the average households' WTP with the total number of households in the same community. For example for Community A, the WTP per household per month is [1.35*115] = US$155.25. The WTP per year (USD) is computed by multiplying the resulting WTP per household per month by 12, such that for Community A, the WTP per household per year is [155.25*12] = US$1,863.00. The WTP per year of the entire population is obtained by multiplying the average households' WTP per year by the number of individuals in each community; thus for Community A, the Population WTP is [1.35 *12*648] = US$10,497.

Based on the above information, the value of the mangroves is estimated as follows:

Value of Mangroves/Ha/Yr = Total Population WTP per year for the 3 Communities divided by the area of the mangrove stand
= US$40,739.28 per year/4 hectares
= US$10,184.82/ha/year

Rather than simply conducting an open-ended survey such as the above example it may be better to ascertain WTP in a "structured market". A sample of individuals is asked to state what they are willing to pay for the preservation or improvement of a particular resource or environment; or to accept (WTA) compensation for doing away with that resource or environment, in a carefully structured hypothetical market (Tietenberg 1996, Hanley *et al* 1994)

Steps:

1. Preparation: set up hypothetical market
   - Identify the environmental impacts, its direction and the policy issues
   - Identify the affected or prospective respondent population covered by the environmental impact of policy
   - Construct a sample frame, determine what to ask (WTP or WTA), where and how to interview
   - Design the survey instrument/questionnaire
2. Survey: survey methods include on site (face to face), house to house, or mail/telephone (remote)
3. Calculate measures of welfare changes: mean/median bids after cleaning data by removing outliers, protest bids

Derive a bid function, for example: $WTP_i = f(Y_i, E_i, A_i, Q_i)$
Where:

i: indexes respondents
Y: income
E: education
A: age
Q: variables measuring the environmental quality being bid for

4. Aggregation: calculate total WTP/WTA from mean WTP/WTA. For example by multiplying the sample mean WTP/WTA of visitors to a site by the total number of visitors per annum.
5. Study appraisal: testing the validity and reliability of the estimates produced

Methods for obtaining bids:

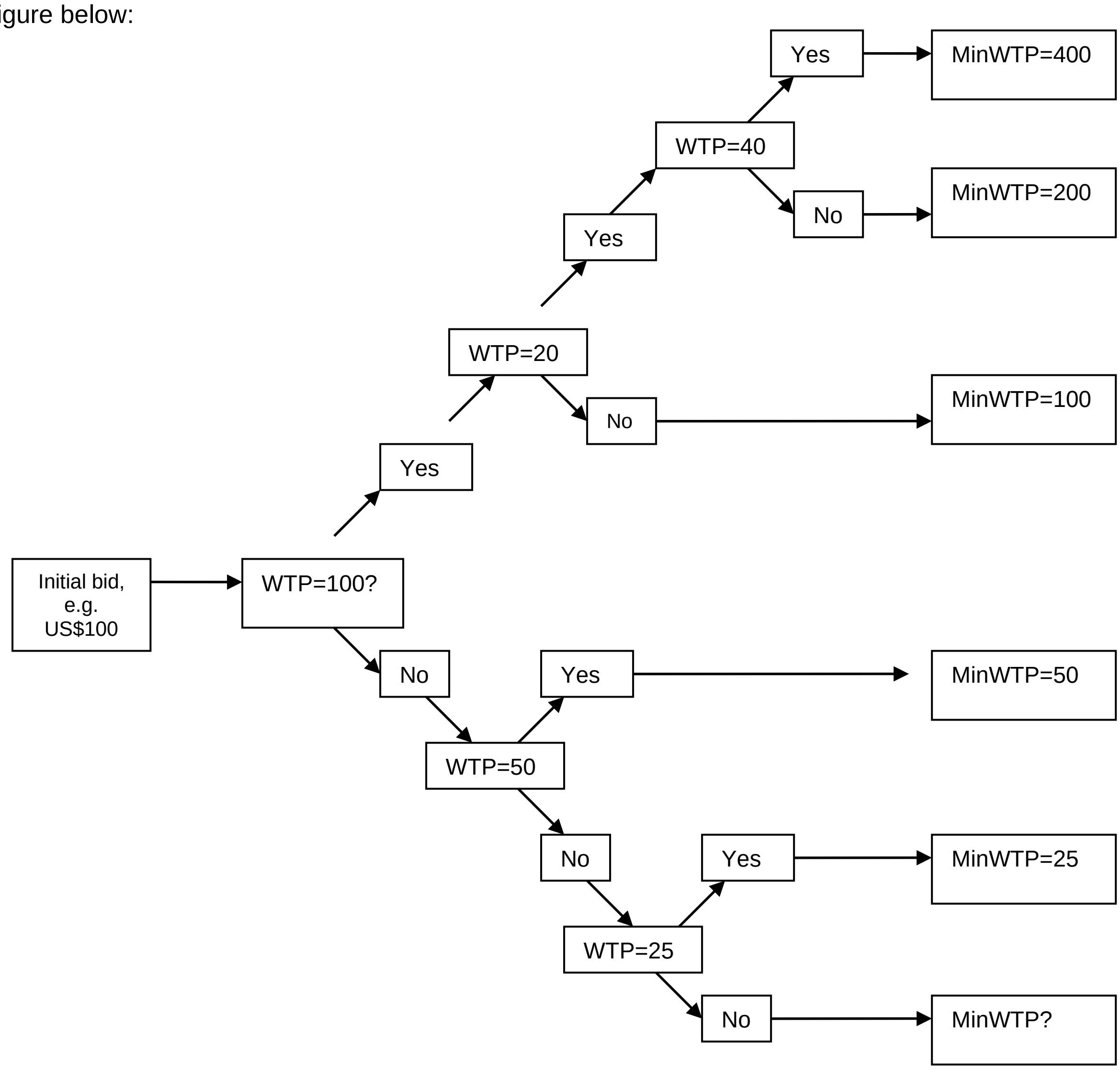
- Open–ended questions: respondents are asked for their maximum WTP/WTA with no values being suggested to them.
- Closed–ended referendum: ask respondents whether they agree or disagree with a suggested single payment.

- Dichotomous choice referendum: interviewer selects random values from a range, respondent then accepts or rejects.
- Payment card: offer respondents a range of values (2 4 6 8 10) on a card for them to select highest WTP/WTA.

In fact, people have a tendency to state a lower WTP than the actual WTP, and a much higher WTA than the actual amount they would in fact accept.

***Example**:* Estimate recreational values of a mangrove area

A sample of 2051 respondents was asked whether they were willing to pay for the protection of the mangroves. An initial dichotomous choice question was supplemented with up to two further dichotomous questions after which an open–ended WTP question was asked as illustrated in the figure below:



The best fit model for the above bidding tree was as follows:

$$LnWTP = 2.104 + 0.373LnBID + 0.000005INC + 0.176FISH + 0.172ENV – 0.122FIRST$$

Where:
LnWTP: natural log of respondent's final WTP statement
LnBID: natural log of the amount presented to respondents in the first dichotomous choice questions
INC: household income
FISH =1 if respondent does participate in some fishing activity (=0 otherwise)
ENV = 1 if respondent is a member of an environmental group (=0 otherwise)
FIRST = 1 if respondent is on his/her first visit to the area (=0 otherwise)

The final mean WTP calculated was US$74.91 per household per year. Multiply this by the total number of visitors per annum, say 76,000, we have the total WTP per year is US$5,693,160. This amount is the estimated recreational and amenity value of the site[3].

Choice Modelling

Choice modelling is a technique, which predictively models choices (such as consumption decisions) that cannot be represented by a continuous variable. It estimates the likelihood of a consumption choice based upon preferences of the subject (user) and the attributes of the elements of the set containing the choices.

When using CM, respondents are presented with various\alternative descriptions of a good, differentiated by their attributes and their levels, and then are asked to rank, rate or choose their most preferred among the choices.

Choice modelling follows the following steps:

1. *Selection of attributes*
   Identification of relevant attributes of the good to be valued. Literature reviews and focus groups are used to select attributes that are relevant to people while expert consultations help to identify the attributes that will be impacted by the policy.
2. *Assignment of Levels*
   The attribute levels should be feasible, realistic, non-linearly spaced, and span the range of respondents' preference maps. Focus groups, pilot surveys, literature reviews and consultation with experts are instrumental in selecting appropriate attribute levels. A baseline 'status quo' level is usually included.
3. *Choice of experimental design*
   Statistical design theory is used to combine the levels of the attributes into a number of alternative scenarios or profiles to be presented to respondents.
4. *Construction of Choice Sets*
   The profiles identified by the experimental design are then grouped into choice sets to be presented to respondents. Profiles can be presented individually, in pairs, or in groups.
5. *Measurement of Preferences*
   Choice of a survey procedure to measure individual preferences: ratings, rankings, or choices.
6. *Estimation Procedure*
   Regression or maximum likelihood estimation procedures (logit, probit, ordered logit, conditional logit, nested logit, panel data models, etc.). Variables that do not vary across alternatives have to be interacted with choice-specific attributes.

Furthermore, Choice Modelling can be of 4 various types:

1. Choice experiments
   Choose between 2 or more alternatives, wherein one is the status quo
2. contingent ranking
   Rank a series of alternatives
3. contingent rating
   Score a series of alternatives on a scale of 1-10
4. paired comparison
   Score pairs of scenarios on a similar scale

Example: Water Allocation

Example of a Choice Set from the Macquarie Marshes Questionnaire (table taken from Morrison *et al,* 1998). Respondents were asked for their preferred choice from each of the 4 options: Option 1 – *Status quo*, Option 2 and 3 – improvements in wetland quality, Option 4 – not choosing any of the first three options because the preference is for more water to be allocated for irrigation. The percentage of respondents of the target population that chooses each option can be projected to the whole of the same population.

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[3] *Note: This is a very simplified description of CVM in order to provide readers with general understandings of environmental valuation techniques.*

Table 9 Choice set from the Macquarie Marshes Questionnaire (from Morrison *et al*., 1998).

Outcome	**Option 1: Continue Current Situation**	**Option 2: Increase Water to the Macquarie Marshes**	**Option 3: Increase Water to the Macquarie Marshes**
Your water rates (one-off increase)	No change	US$20 increase	US$50 increase
Irrigation related employment	4400 jobs	4,350 jobs	4,350 jobs
Wetlands area	1000km^2	1,250km^2	1,650km^2
Waterbirds breeding	Every 4 years	Every 3 years	Every year
Endangered and protected species present	12 species	15 species	25 species
__ I would choose option 1 __ I would choose option 2 __ I would choose option 3 __ I would not choose any of these options because I would prefer more water to be allocated for irrigation			

Computation for the equivalent amounts would indicate the acceptable increase in water rates (whether zero for Option 1 and 4, or US$20 and US$50 for Options 2 and 3, respectively). For this study, a total of 986 questionnaires were processed, with 25 percent (247) choosing option 2; 35 percent (345) for option 3, and the remaining 40 percent (394) for options 1 and 4.

Total Willingness to Pay = [(247*US$20) + (345*US$50) + (394*US$0)]
= US$22,190.00 for the sample population of 986
= US$22.51 per respondent.

Assuming that the total population affected by plans to improve the environmental quality of the 3,000 km^2 wetland is approximately 3,341 individuals, the total WTP is equivalent to US$75,205 (3,341*US$22.51) This is equivalent to about US$75.21 per km^2/year of wetland.

COST BENEFIT ANALYSIS

Generally, cost-benefit analysis is a widespread analytical tool used by many economists in making decisions as well as in evaluating development plans. In this respect, cost benefit analysis can then be used in evaluating any development activity, project, programme or policy related to coastal resources and environment conservation. The framework of a "project" is frequently referred to when applying with the cost benefit analysis approach, including projects on coastal resources and environment development. In the typical process of cost-benefit analysis, both the costs and benefits of a project or a programme will be measured and expressed in comparable "monetary", terms. The estimated benefits are then compared with the estimated costs to justify whether society will be better off if such a project or programme is undertaken. In other words, the comparison is needed in order to demonstrate that the total benefit is found greater than the total cost. For example, a cost benefit analysis can be simply used to decide whether or not port construction on coastal mangrove land should be implemented. In this case the benefits from shipping and transportation will be estimated along with the costs of investment in developing, and operating the port, where part of the "costs" are the reduction in mangrove goods and services.

Accordingly the cost benefit analysis, methodology involves at least four essential steps in the estimation process:

1. Specify clearly the project or programme especially in terms of activities from the beginning to the end, inputs needed, output expected and various impacts potentially created.
2. Describe and quantify in monetary value, simply through using market price, the inputs and outputs of the project.
3. Estimate in economic value through market-based value or appropriate non-market valuation techniques all other costs and benefits that result from the project.
4. Compare the total benefit and total cost to justify the project implementation.

Each of these four steps incorporates a number of components.

The very first step is to decide on the background information and perspective from which the analysis is to be done. Step 1 should then include a complete specification of project elements such as objectives, activities, location, timing, technology, groups involved and connection with other projects or programmes etc.

Following the specification of the project, the next step, step 2, is to quantify specific inputs and outputs of the project in terms of direct project costs and direct project benefits. Since these costs and benefits are usually derived through market price and used in practical decision making from the private investment viewpoint, this may step may also be considered as the financial analysis.

Step 3 deals with the estimation of the economic values of real costs and benefits provided by the project to society as considered from the public viewpoint. Other than the estimated direct costs and benefits determined in step 2, selected non-market valuation techniques may be applied to valuate various external (negative) costs (impacts) and external (positive) benefits from the project. Project impacts or externalities created on coastal resources and environments are the main targets in this context. Thus, the total value of market and non-market costs and benefits provide an estimation of the real "economic" costs and benefits to the society.

Finally, step 4 compares the total cost and total benefit as well as involving estimation of the net benefit derived from a project or program. Key indicators of a cost benefit analysis include: benefit-cost ratio (BCR); net present value (NPV); internal rate of return (IRR). More specifically, a cost benefit analysis using the direct market costs and benefits, from step 2, is considered as the ordinary analysis while that using the total real economic costs and benefits, from step 3, would be considered as an extended analysis.

In addition to these 4 steps in conducting a cost benefit analysis, at least 2 more issues also need to be discussed. Firstly, cost benefit analysis will usually involve a consideration of the temporal value of money since many development projects or programmes have a project life span over many years. Cases of coastal resources and environment conservation are good examples of how time factors are involved before costs and benefits can be clearly valued. Secondly, a cost benefit analysis can be conducted at any time of the project life, including: before implementation of the project (as ex-ante evaluation); during implementation of the project (as on-going evaluation); and, following completion of the project (as ex-post evaluation).

The following text provides an elaboration of the ordinary and extended cost benefit analyses in the case of reforestation of a mangrove area.

Ordinary Cost Benefit Analysis

Ordinary cost benefit analysis is an evaluation of the "financial" aspects of a project, namely all of the direct costs and benefits incurred. An ordinary cost benefit analysis is usually employed by the private sector using the direct market values or market-based values of all inputs and outputs. Non-market values of the various external impacts on coastal ecosystems, from either a cost or a benefit perspective, will not be included in such an analysis. Within the framework of a project related to the development of a coastal area such as for example intensification of fish and shellfish production, annual direct benefit and annual direct cost during the project life are computed as follows:

Annual Benefits

Annual benefits are considered in monetary terms as market value per year or market-based value per year of both extractive use and non-extractive use of coastal resources:

-**Extractive use benefit**: value of final products from coastal resources per year both for sale and for annual household consumption (i.e. $B_{1...}$, B_{10}) such as various marketable goods derived from coastal mangrove forest.

-**Non-extractive use benefit**: value of final products or services per year from coastal resources (i.e. B_{11},B_{12}, B_{13}) such as recreation, education, research, transport, tourism etc.

Table 10 Total Benefits for Ordinary Cost Benefit Analysis.

Benefits	Symbol
Extractive use benefits	
Firewood	B_1
Poles	B_2
Charcoal	B_3
Fruit/propagates	B_4
Bark (tanning & dyes)	B_5
Medicine	B_6
Sap (sugar, alcohol, Acetic acid)	B_7
Wood tar	B_8
Insect and larvae collection	B_9
Worms (polychaetes)	B_{10}
Non-extractive use benefits	
Recreation	B_{11}
Research	B_{12}
Education	B_{13}

Total annual benefit in this case is then the summation of all extractive and non-extractive use values of the coastal resources each year or $\sum(B_1 + B_2 + ... + B_n)$, where n is equal to 13 in this case.

Annual Costs

Annual costs considered in monetary terms derived from the investment cost and operating cost per year of the project as follows:

Investment costs such as land, capital and construction costs. Normally, investment costs are considered as fixed costs to the project and will be concentrated during the initiation of project implementation.

Operating and maintenance costs including labour, fuel, transport, and raw material costs. These cost items occur every year, while the project is still under implementation.

Table 11 Total Costs for Ordinary Cost Benefit Analysis.

Costs	Symbol
Investment Costs	
-Land cost	C_1
-Construction cost	C_2
-Capital cost	C_3
Operating and maintenance costs	
Labour cost	C_4
intermediate capital cost	C_5
fuel cost	C_6
raw materials cost	C_7
transport cost	C_8

Total annual cost is then summation of all investment and operating and maintenance costs each year or equal to $\sum(C_1 + C_2 + ... + C_n)$ where n is equal to 8 in this case.

Annual Net Benefit

Annual net benefit will be the difference between total benefit and total cost in each year. Accordingly, annual net benefit in the early years of the project may turn out to have negative values because there will be much higher investment costs as compared to negligible benefits. However, the net benefit will become positive in the later years of the project as the benefits increase and the costs decrease.
Net benefit for ordinary cost benefit analysis = $\sum(B_1 + B_2 + ... + B_n)$ - $\sum(C_1 + C_2 + ... + C_n)$

Since the summation of values from different times must take into account the "time value of money", discounting technique will be applied to adjust all values to the same base year, such as at the current year.

Extended Cost Benefit Analysis

It is necessary for a complete cost benefit analysis of development of a coastal resource system to include all impacts, both positive and negative. Any development project in a coastal area not only involves direct costs and benefits during the project life, but also creates significant external (positive) benefits and external (negative) costs to society. An extended cost benefit analysis takes into account all these external benefits and costs together with the ordinary benefits and costs already outlined above. The comparison between such total real "economic" benefits and the costs incurred by the society will then provide the justification for implementing a project or not. The information needed to undertake an extended cost benefit analysis for a coastal development project is reviewed below.

Annual Extended Benefits

Annual extended benefits are considered to include monetory values of both extractive and non-extractive uses, just as in the conduct of an ordinary cost benefit analysis. Valuation of these benefits per year can be determined from market or market-based values. In addition, external benefits (EB) or positive impacts resulting projects in coastal ecosystems are estimated by applying appropriate non-market valuation techniques. Selection of the economic valuation technique is a crucial factor affecting the magnitude of the values of the estimated impacts. Data availability concerning various impacts is another factor that affects the reliability of estimated values.

Examples of external benefits potentially created from a coastal development project are recreation, tourism, offshore fishery linkages, research, aesthetics, carbon sequestration, oxygen release, etc. Benefits from these positive impacts on coastal ecosystem can be valued by applying valuation techniques including market-based values, surrogate market-based values or simulated survey-based values.

Table 12 Total Benefits for Extended Cost Benefit Analysis.

Benefits	Symbol
Extractive use benefits (see table 1)	B_1.... B_{10}
Non-extractive Use Benefits (see table 1)	B_{11}....B_{13}
External Benefits	
Nursery fishery	EB_1
Carbon sequestration	EB_2
Oxygen release	EB_3
Aesthetic	EB_4

The total extended benefit in this case, therefore, consists of all from extractive use benefits, non-extractive benefits and various external benefits.

$$\text{Total extended benefit} = \sum (B_1 + B_2 + ... + B_n + EB_1 + EB_2 + ... + EB_n)$$

Annual Extended Costs

Annual Extended Costs are considered in the same manner as those in the ordinary cost benefit analysis, including investment, operating and maintenance costs. In addition, external costs (EC) or negative impacts resulting from the project are also included since they are part of the real economic cost of the project borne by society. External costs or negative impacts are damages created by the project in the coastal ecosystem. Examples might include water pollution, solid wastes, shoreline erosion, loss of resources and biodiversity, sedimentation and loss in aesthetic value.

Table 13 Total Costs for Extended Cost Benefit Analysis.

Cost	Symbol
Investment cost (see table 2)	$C_1 \ldots C_3$
Operating and Maintenance cost (see table 2)	$C_4 \ldots C_9$
External costs	
Water Pollution	EC_1
Sedimentation	EC_2
Shoreline erosion	EC_3
Biodiversity loss	EC_4
Solid Waste	EC_5

Accordingly, the total extended cost = $\sum (C_1 + C_2 + ... + C_n + EC_1 + EC_2 + ... + EC_n)$

Extended Net Benefits

Annual extended net benefits will be considered as being the difference between total extended benefits and extended costs of the project, as follows:

$$\text{Net extended benefit} = \sum (\mathrm{B}_1 + \mathrm{B}_2 + .. + \mathrm{B}_n + E\mathrm{B}_1 + E\mathrm{B}_2 + .. + E\mathrm{B}_n) - \sum (C_1 + C_2 + .. + C_n + EC_1 + EC_2 + .. + EC_n)$$

Methodology of Cost Benefit Analysis

A complete data set on the costs and benefits of a project enables calculation of key indicators including Net Present Value (NPV), Benefit–Cost Ratio (BCR), and Internal Rate of Return (IRR). These can be used to evaluate the suitability of a project.

Since calculation of cost and benefit values may reflect different time periods, as for example from the beginning to the end of project, there is a need to adjust the values with respect to the value of money in a given period, often referred to as the base year. Future cost and benefit values expected from a project that is not yet implemented will have to be discounted to the present value, as determined in the *ex-ante* evaluation. Past cost and benefit values that have already been incurred in the project will have to be compounded to the present value, as considered in the *ex-post* evaluation. Evaluations undertaken somewhere during implementation of a project, as considered in an *on-going* evaluation, will need to apply a combination of both discounting and compounding techniques. In the following example, discounting techniques for a cost benefit analysis of a coastal development project will be elaborated.

The general formula of discounting technique will involve the adjusting the future value (FV) into the present value (PV) as the following:

Formula for discounting to determine Present Value

$$PV = FV / (1+r)^{t}$$

Where:

r is discount rate

t is number of years to be discounted.

When the above formula is applied to discount the annual project cost (C) or annual project benefit (B) from the future value to the present value, it then becomes:

$PVC = FVC / (1+r)^{t}$

or

$PVB = FVC / (1+r)^{t}$ respectively.

Summation of these annual discounted values will then reflect the total value of the costs or benefits over the whole life of the project[4].

In calculating the three indicators, including NPV, BCR and IRR, some other economic data and assumptions will be needed regarding the discount rate (reflecting time value of money) namely long term interest rates, project life (number of years for discounting) and constant prices (for valuing inputs and outputs).

Net Present Value

This net present value (NPV) presents the net benefits of the coastal development project such as mangrove plantation, or port construction. Annual cost and annual benefit throughout the project are estimated from the perspectives of an ordinary and extended cost benefit analyses. The flow of annual costs and benefits over different periods of time are discounted into present values before calculating the value of total discounted costs and discounted benefits, which is the net present value of the project.

The formulas for calculating NPV to serve the purposes of a cost benefit analysis (CBA) are illustrated as follows:

$$\text{NPV (ordinary CBA)} = \sum_{t=1}^{T}\sum_{i=1}^{n} Bit / (1+r)^{t} - \sum_{t=1}^{T}\sum_{i=1}^{n} Cit / (1+r)^{t}$$

$$= \sum_{t=1}^{T}\sum_{i=1}^{n} (Bit - Cit) / (1+r)^{t}$$

$$\text{NPV (extended CBA)} = \sum_{t=1}^{T}\sum_{i=1}^{n} [(Bit + EBit) - (Cit + ECit)] / (1+r)^{t}$$

If	B	=	annual benefit of the project
	C	=	annual cost of the project
	EB	=	annual external benefit of the project
	EC	=	annual external cost of the project
	r	=	discount rate (assuming market rate equal to shadow rate)
	i	=	each of benefit or cost, i= 1, 2, 3…..n
	t	=	period of time, t= 1, 2, 3…T

The NPV should be a positive value in order to justify the implementation of the project. This would suggest that the development project will potentially create a net benefit to the private sector (in case of ordinary CBA) or to the public sector (in case of extended CBA). The magnitude of the NPV value simply indicates the magnitude of the profit to the private investor or, the economic contribution of the project to society. Changes in magnitude of the NPV (increasing or decreasing) when the NPVs derived from an ordinary or an extended CBA represent effect of externalities or project impacts suffered by the coastal ecosystem.

Benefit-Cost Ratio (BCR)

Benefit-Cost Ratio (BCR) is an indicator of efficiency of project investment since it compares total benefit with total cost of the project. In other words, BCR will simply reveal the benefit received per unit cost spent in the project. BCR can thus be used to justify the most cost efficient alternative among choices of development projects. For example, a proposed mangrove plantation project or a port construction project will both yield different Benefit Cost Ratios when evaluated in different sections of the coastline. The investor or the public sector authority can therefore justify whether or not a development project should be implemented and where the project should be implemented**.**

[4] *It is noted that the compounding technique is only the other way around since the general formula will become FV = PV. $(1+r)^t$.*

The formulas for calculating the benefit cost ratio are as follows:

$$\text{BCR (ordinary CBA)} = \left[\sum_{t=1}^{T}\sum_{i=1}^{n} Bit / (1+r)^{t}\right] / \left[\sum_{t=1}^{T}\sum_{i=1}^{n} Cit / (1+r)^{t}\right]$$

$$\text{BCR (extended CBA)} = \left[\sum_{t=1}^{T}\sum_{i=1}^{n} (Bit + EBit) / (1+r)^{t}\right] / \left[\sum_{t=1}^{T}\sum_{i=1}^{n} (Cit + ECit) / (1+r)^{t}\right]$$

If	B	=	annual benefit of the project
	C	=	annual cost of the project
	EB	=	annual external benefit of the project
	EC	=	annual external cost of the project
	r	=	discount rate (assuming market rate equal to shadow rate)
	i	=	each of benefit or cost, i= 1, 2, 3…..n
	t	=	period of time, t= 1, 2, 3…T

If the BCR is found greater than 1 then the project is economically justifiable. The higher the value of the BCR the more cost efficient the coastal development project is. Change in value of the BCR when comparing ordinary and extended CBA shows the effect of external benefits and external costs included in the BCR. For example, the value of a BCR can be decreased from the ordinary analysis to the extended analysis if negative impacts or environmental costs are more significant that the positive impacts or environmental benefits. Such development projects may yield satisfactory financial returns to the private investor, but have unacceptable costs to society as a whole.

Internal Rate of Return

The internal rate of return (IRR) provides the project investor or the public with information regarding the minimum rate of return that can potentially be expected from the development project if the NPV is equal to 0 or the BCR equal 1. The rate of return from the project can be compared with opportunity costs of funds invested in the project that is with the interest rate on a comparable loan. Justification for the development project is apparent when the IRR is found to be greater than the loan rate i. Theoretically speaking, the project is worth investment from the private or public viewpoint if the internal rate of return from the ordinary or the extended CBA are higher than the market interest rate or the social discount rate respectively. In the case of an open and competitive economy, the market rate for loans and the social discount rate are assumed to be the same.

The IRR can be calculated from the same formula for NPV, or BCR, since the internal rate of return in this case is simply the "value of r" that will lead the NPV to be equal to 0 or BCR to be equal to 1. All other data in the formula, including annual benefit and cost values as well as time, will thus remain the same as during the calculation of NPV and BCR. Using the NPV formula, the internal rate of return can be found from the relationship when:

$$\sum_{t=1}^{T}\sum_{i=1}^{n} (Bit - Cit) / (1+r)^{t} = 0$$

Or using the formula for an extended CBA, the internal rate of return can be found from the relationship when:

$$\sum_{t=1}^{T}\sum_{i=1}^{n} [(Bit+EBit) - (Cit+ECit)] / (1 + r)^{t} = 0$$

In brief, the cost benefit analysis methodology helps to justify the project or program if it is found that:

-NPV greater than 0
-BCR greater than 1
-IRR greater than i

It should be noted that coastal resources and the physical environment always co-exist as complex ecosystems, and consequently all development projects in coastal areas will inevitably disturb the equilibrium of the system hence creating significant externalities. Moreover, coastal ecosystems are generally considered public property, hence there is a need to sustain them rather than to consider them merely as short term investment opportunities. Economic indicators derived from extended CBA are recommended when justifying coastal developments rather than merely a financial analysis resulting from an ordinary CBA.

Sensitivity Analysis

Despite the convenience of employing the three economic indicators in a cost benefit analysis, a disadvantage is that the indicators are all "static". When elements in the cost benefit analysis are changed under real world conditions, particularly in the pessimistic direction, these economic indicators will not respond. In order to make the static economic indicators of NPV, BCR and IRR into more dynamic ones, they can be re-calculated with respect to assumed negative changes in some important factors. One can thus see in advance how the economic indicators of project feasibility are sensitive, more or less, to any specific factor. This process is referred to as a sensitivity analysis (SA).

The process of conducting a SA is in fact nothing more than the calculation of NPV, BCR or IRR taking into consideration assumptions regarding changes in crucial factors of the project, for example a 10% increase in each significant project cost. The re-calculated economic indicators under the changes in critical factors will indicate how sensitive the project is to any particular factor.

Crucial factors that are generally assumed to have negative impacts on the economic indicators of a project include, *inter alia*:

- Increase in market fuel price
- Increase in land and labour cost
- Increase in inflation and interest rate
- Increase in degree of pollution
- Increase in contaminated areas
- Decrease in project output, quantity or price
- Decrease in number of beneficiaries

For convenience in conducting a sensitivity analysis, one normally assumes a constant percentage change in crucial inputs to evaluate the different degrees of change in the economic indicators. If such potential changes to critical inputs, or outputs, are derived from specific trend analysis or predictions from models then this improves the reliability of the analysis.

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