DELOS WP 1.3 Final Report July 2, 2001

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I. Work package description reminder

(DoW, page 13, EVK3-2000-22038) **Work package number :** 1.3, Inventory of economic models to value the environment. **Start date:** Month 0. **Participant codes :** UB **UTW**. **Person-months per participant:** 4 (UB) 4 (UTW).

1 Objectives: The goal of this Work package is to collect theories and models in the current literature on monetary valuation of environmental changes.

2 Methodology / work description: A review on recent Contingent Valuation studies on Beach Maintenance and Protection of Natural Habitats in coastal zones will be performed. A methodology will be developed to analyse ecological changes in an economic framework.

3 Deliverables: D6: A literature review will be provided in order to perform statistical analyses in WP 4.1. (cost 0.9 %)

4 Milestones: Month 4: Collection of available theories and models. Review report (cost 0.9 %)

II. Introduction

This report has been organised in five sections: Coastal Valuation Methodologies, Benefit Estimates, Benefit Transfer Methodologies and Examples, Other References with relation to coastal defence / management, and General valuation methodologies. The purpose of such organisation is to ease retrieval of information given that the bibliography should serve two work packages: Benefit transfer (WP 4.1) and Case studies (WP 4.2). The former should use mostly the Benefit Estimates and the Benefit Transfer Methodologies sections, while the latter should use the Benefit Estimates and the Valuation Methodologies sections. Both work packages should use the Other References section.

Because the bibliography will be used for benefit transfer, it is good practice to collect not only published works, but also unpublished ones (see i.a. Santos, 1999). The following databases have been explored: TESEO (Spanish theses), ABES (French literature including theses), several Belgian, Italian and English university libraries, the US and Belgian National Libraries, ECONLIT (Economic Literature), NCC (all the Dutch libraries), publishers data bases (Elsevier ScienceDirect, Kluwer online, Blackwell online, National Academy Press), UNESCO, United Nations Environmental Program, US National Oceanographic and Atmospheric Administration, US Environmental Protection Agency, EU European Environment Agency, European and American Associations of Environmental and Resources Economists conference sites. Professors Colin Green, Pere Riera, Donato Romano, and Maria Antonieta Cunha e Sa have been contacted for references in the UK, Spain, Italy and Portugal respectively.

We will first review the economic models to value the environment, then a summary table of the benefit estimates will be presented. Third, we discuss the current methodology on benefit transfer, and assess its prospects for the DELOS project. Finally, a few other issues relevant for coastal management will be presented. Each reference list is reported in the annex. For referencing purposes a small bibliography of valuation methodologies not specific to coastal defence has been added (see list 5 in the appendix).

III. **Coastal Valuation methodologies: Economic Models to value the environment** (List1)

The **Valuation methodologies** section holds 15 references specifically on coastal valuation. The main references for this section are Hanley and Spash (1993), Ridell and Green (1999), U.S. Environmental Protection Agency (2000), and Lipton (1995). The conclusion we may draw from that review of environmental valuation methodologies in economics is that there is little agreement as to how a coastal defence scheme should be valued. The basic idea is to consider a wide range of options, together with a baseline option against which the changes caused by any of the other options will be appraised. There is a multiplicity of methods designed to deal with specific changes. Some theories appear to stress some changes more than other, maybe because they are better equipped for dealing with them, but they all use the same set of valuations methods (presented below).

III.1. A description of Cost-Benefit Analysis

We start with a description of the framework in which economic valuation models are used: the **Cost-Benefit Analysis (CBA)**. Although there are several techniques for appraising policies and projects which impact the environment, the DELOS project concentrates on valuation and CBA. Even though there are other methods to express such impacts that an environmental manager may consider, such as cost-effectiveness analysis, environmental impact assessment, scenario analysis and risk-effectiveness analysis, only CBA can in itself decide whether it is worth implementing a policy or not in the sense that the sum of all the positive impacts of that policy outweighs or not the sum of its negative impacts. In any CBA, several steps must be conducted, they are briefly described in turn.

Step 1: **Definition of the project**. This step includes i. the reallocation of resources being proposed (e.g. building a sea wall); and ii. the population of gainers and losers to be considered. The reason for i. is to state clearly what is going to be appraised, and possibly limit the analysis. The motive for ii. is to determine the population under which benefits and costs are to be aggregated. Often the origin of the funding for the project may be the key, for coastal defence works it seems that funding comes mainly from the national level, hence the aggregation level is the nation. For example, non marketed benefits of foreign tourism should not be accounted for in a national CBA. Frequently some discretion is possible.

Step 2: **Identification of project impacts**. This step consists in drawing a qualitative and (in as much as possible) exhaustive list of the impacts resulting from the project implementation, including a list of all the resources used in the implementation process. Two important concepts are additionality and displacement. Additionality refers to the net impact of the project, for example, the impact on beach erosion of a coastal defence must be computed net of other changes in beach erosion that would have occurred without this policy change (e.g. due to sea-level rise). Displacement refers to shifting a problem somewhere else, for example if a defence structure at one point of the coast causes erosion downdrift. If perfect displacement occurs within the population defined in the previous step, then the project has no value. If displacement occurs outside that population, then it will not be taken into account. A weighting system may be used to discriminate in favour of a region or a specific group.

Step 3: **Which impacts are economically relevant?** This question is grounded in the welfare economics theory underlying CBA. At this stage, assume that society is interested in maximising the weighted sum of utilities across its members. These utilities depend upon, among other things, consumption levels of marketed goods (e.g. fish) and non-marketed ones (e.g. fine views, clean beaches, risk of inundation). The aim of CBA is to select projects that increase that weighted sum of utilities. We term positive impacts on that sum benefits (increase in quantity or quality of goods or reduction of their prices), and negative impacts costs (including the resources used up in the implementation of the project, termed opportunity costs). For example, a sea defence project could i. affect the landscape, and/or ii. have adverse effects on fish spawning grounds. The former is relevant to CBA if at least one person is not indifferent to the landscape change, the latter is relevant if at least one fisherman or one angler captures fewer fishes. The fact that there is no market for landscape is irrelevant, all that matters is that an impact on production or on utility can be recorded. Unpriced impacts are methodologically the most important feature of environmental CBA; they are often referred to as externalities, positive if they confer benefits, negative otherwise.

One class of impacts that should be excluded from CBA are transfer payments because they are mere redistribution of money across the population. For example, if consumers move from one local beach outlet to another because the beach erodes, this is a loss if the level of the CBA is local, but this is a transfer payment if the level of the CBA is national (except possible for increased travel cost).

Step 4: **Physical quantification of relevant impacts**. Here the physical amounts of benefits and costs flows for a project are determined, and the time at which they will occur is identified. In case of a low-crested structure, this could include: changes of the erosion/accretion rate, changes of the seascape, disruption of the fish population, probability of breaching, probability of flooding, life span of the structure, and level of maintenance. All calculations at this step are performed under varying levels of uncertainty.

Step 5: **Monetary valuation of relevant effects**. The essential idea behind monetary valuation is to express all the relevant impacts in a common unit. Money is chosen for convenience only, but the assumption of perfect substitution with money is open to criticism. Competitive markets generate the relative values of all traded goods and services as relative prices: this is useful for comparing e.g. tonnes of concrete with fish catches since they are made co-measurable and an indication of their relative scarcity is given. At this step, the analyst in a CBA has to

i. predict prices for value flows extending into the future,

ii. correct market prices when necessary, and

iii. calculate prices where none exists.

CBA should be carried in real terms, that is the analyst must predict the relative (real) prices of the commodities whose supply is affected by the project, nominal prices must be deflated. Discounting (see later) must be done at the real interest rate.

In a perfectly competitive market, under certain assumptions (mainly, that there are no externalities associated with production and consumption of goods, plus the hypotheses indicated below), the equilibrium price indicates both the marginal social cost and marginal social benefit of the production of one more unit of that good. This is because opportunity costs of production are given by the supply curve (if the input market is perfectly competitive), and the demand curve is a schedule of marginal willingness to pay (if all agents are price takers, that is perfect competition in demand), and the equilibrium price-quantity pair is the intersection of those two curves. In practice these assumptions are most often not satisfied, the less they are satisfied, the less the market price can be considered an indicator of marginal social cost or benefit becomes. There are three main cases: Imperfect competition, Government intervention in the market (due e.g. to externalities), and Absence of a market. In some cases the market is competitive enough for using market prices as a good approximation to values (see the tables below).

Imperfect competition. The price will in general be higher than if the market was competitive (provided there is no scale restriction), thus the true cost to society of one more unit of the product is the marginal cost of production, not the price.

Government interventions may affect the price of a good, shifting it away from the competitive one, this may be due to a variety of reason such as agricultural support or (the correction of) externalities.

Absence of a market. In many circumstances in environmental CBA, the analyst will have to place a value on a good not traded in a market. This is typically the case for environmental resources such as landscape/seascape or biodiversity issues. Two broad classes of techniques have been developed for such cases: stated preferences methods (essentially contingent valuation and choice experiment), and revealed preferences methods (essentially travel cost , hedonic pricing, avoided costs, and factor income). They will be briefly described later.

Step 6: **Discounting**. CBA models are dynamic; once all the costs and benefits have been expressed in monetary terms, we convert them all into present value terms because of time preference (an individual prefers an amount X now than the same amount in the future), even if inflation is zero and there is no risk. Discounting is done using the real interest rate. The difficult question is what interest rate to use, and whether society as a whole should use discounting (intergenerational equity). The larger the interest rate the less important benefits and costs in the future relative to the present. A value of 6% is often advised in practice, but 3% has been used in coastal defence.

Step 7: **Applying the Net Present Value (NPV) test**. The main purpose for applying CBA is to select projects which are efficient in terms of their use of resources. This is achieved if the project sum of discounted benefits exceeds the sum of discounted costs, that is the Net Present Value test. There are a number of alternative tests, but they all refer to the same idea.

Step 8: **Sensitivity Analysis**. The NPV test of step 7 indicates the project efficiency given the data used for calculation. If this data changes, the result of the NPV may also change. The data may change because of uncertainty: in all (ex ante) CBA, the analyst must make predictions concerning future flows and future relative values, these predictions are not necessarily very precise, and it is thus instructive to recalculate the NPV when the value of key parameters are changed (interest rate, physical quantities or qualities, prices, project life span).

III.2. Fundamentals of valuation

The concept of valuation is well defined in Economics since Hicks (1942), it refers always to a change of individual welfare. We distinguish two situations depending on whether the reference point is the initial or the final situation. One first measure of welfare change is the compensating variation: the amount of money such that the individual is exactly as well off in the final situation with that (possibly negative) amount of money as he is in the initial situation. The compensating variation is the willingness to pay for an improvement, or the minimal compensation for a deterioration.

A second measure is the equivalent variation: the amount of money such that the individual is exactly as well off in the initial situation with that (possibly negative) amount of money as he is in the final situation. The compensating variation is the minimum compensation to forego an improvement, or the willingness to pay to avoid a deterioration. There is no reason why the two measures should coincide, it depends on the curvature of the utility function: this is the assumption of substitutability of environmental goods with money. In the extreme (essential goods), any good that a person cannot do without has an infinite value (i.e. is not substitutable with money).

With few exceptions, in practice those welfare measures can only be estimated by stated preferences methods, whose reliability is still questioned (see below). However, when we are concerned with evaluating the sum of individual welfare changes, it has been shown that the consumer surplus was a good approximation. The consumer surplus is the area below the demand curve from the current market price to the market choke price (where no one would buy).

A clear focus in economic valuation is the idea of social choices: whether a public intervention is deemed worthwhile. To take a public decision, we construct a decision function called social welfare function, that has to satisfy a certain number of criteria. Often, the main criterion is that of efficiency: we decide in favour of the public intervention if its benefits outweigh its costs. For such purpose, all the individuals' benefits and costs (values) in society are summed up (with equal weights). Since economists usually want to check the efficiency criterion before any other, we use representative sample (either through observable demand and supply curves or through surveys). Other criteria may be used or added, often on equity grounds; the weights of the social welfare function are then adjusted to reflect them. The equity issue is usually not explicitly dealt with in CBA, but instead information can be presented on the distribution of costs and benefits in different regions or different social groups, and the final decision as to which equity criterion to apply is left to the decision maker.

III.3. An overview of the valuation techniques

The valuation techniques are divided into stated and revealed preferences. **Revealed preferences** (or indirect) methods rely on market information, in general collected through surveys, we can distinguish several steps. First, we estimate the demand curve of a market good (sometimes the supply curve may also be necessary). Second, based on that estimate, we forecast the change in demand (and possibly supply) caused by the change that we want to value and compute the new market equilibrium. The changes in consumer and producer surplus are then the changes of the areas below the demand curve and above the supply curve at the new equilibrium. As mentioned above, the price of a market good is sometimes equivalent to the marginal social cost and marginal social benefit of a unit of that good; as an approximation, and if the market satisfies the above mentioned conditions, the social benefit of a project that increases marginally the output of such a good can be taken as the product of price times quantity.

For some goods, there is normally no observable demand but there is a complementary or substitute market good that can be used instead. We will review them briefly here. The **travel cost method** is concerned with changes in the quality of a recreational site. The basic idea is that the consumer surplus of the demand for travel to that site is equivalent to the consumer surplus for that site in the sense that if the site disappeared, travel there would also disappear. Hence, changes in consumer surplus for travel caused by changes in quality of the site can be considered as a measure of individual value for such quality changes. This method is technically involved and requires to take into account substitute sites, which complicates the statistical analysis. It is also difficult to measure adequately the price of travel (proxied by the cost of travel), and to characterise the environmental quality of the site. Often only one level of quality will be observable during the survey, it will then be necessary to ask respondent how their travel habits would change given some hypothetical and carefully described quality changes.

The **hedonic pricing technique** captures the willingness-to-pay measures associated with variations in property values that result from the presence or absence of specific environmental attributes. By comparing the market value of two properties which differ only with respect to a specific environmental attribute, we may assess the implicit price of that amenity (or its cost when undesirable). Of course, it is impossible to find two properties differing on a single attribute, so we resort to statistical techniques. The price of a house may be affected by factors such as the number of bedrooms, the square footage, the existence of a pool, the proximity to local schools, shopping, highways, polluted area, and proximity to, or quality of, environmental (dis)amenities (typically air quality, noise level, and amenities such a beach, a lake or a forest). We want to estimate a price equation for housing so as to estimate a change in implicit price for a change in, say, air quality. However, a change in price is not directly a measure of welfare change: If air quality changes, housing prices should change, and thus supply and demand. Usually, we assume that supply will not change and that the individual consumer surplus change can be approximated by the price change.

This technique is quite uncontroversial and has been used to value inundation risks, and beach proximity.

The **production function approaches** link environmental changes to changes in production relationships. This may relate to firms producing goods and services, or to households producing services that generate utility. For example, a rural household may combine the quality of water in its well with water treatment equipment to produce drinking water. A fisherman combines water quality with purchased inputs to produce fishes. The main idea of the approaches in this group is that changes in expenditures are due to the need to substitute other inputs for changes in environmental quality. One such approach is called **avoided cost** (or **defensive expenditure**): the value of an environmental improvement can be inferred directly from the reduction in expenditures on defensive activities. The **dose-response function** is another such approach (also known as **factor income** method), it links environmental quality and the output level of a marketed commodity, such as water pollution impacts on fisheries.

The revealed preferences methods only elicit a fraction of the economic value. For example, the travel cost method can only elicit values related to the recreational use of a site, while the full economic value may be larger: I may be willing to pay something to preserve a site quality even though I never go or intend to go there. To refer to these differences, we usually resort to the concepts of use and non-use values. There is often a confusion between revealed preferences methods and some economic techniques not aimed at estimating a value. For example, accounting methods measure the volume of money associated with the trade of a good; it is important to realise that prices are related to values only through the notion of consumer surplus. Second, methods often used in courts to settle damages, such as **replacement costs**, do not indicate economic values but are sometimes used as proxies for values in some analysis.

Stated preferences methods are used for changes in non marketed good with no complementary or substitute market good demand (landscape, natural or cultural heritage, altruism for other people's employment, ...). In that case, one can only resort to directly asking individuals (in a survey) how much they are willing to pay to obtain that change. The precise way to ask that question is the subject of much debate and has given rise in practice to several methods. The ones that have been most used are contingent valuation and choice experiment; there are others, but they still have to be thoroughly tested. How to ask the valuation question has also been the topic of much theoretical and experimental literature, but without much focus on implementability.

The **contingent valuation** is the most ancient and most developed stated preferences method and is now very well documented even if there remains important contentious areas. It consists in directly asking individuals to state their willingness to pay for some previously described change in a non-marketed good. There are several ways of asking such a valuation question: in the open-ended format we simply describe the proposed change and ask the survey respondent to state how much he would be willing to pay for that change (if it is an improvement), in the close-ended format (or discrete choice contingent valuation), we propose a amount of money and the respondent simply state whether he would pay it or not (a more advanced statistical analysis is then required to estimate the average willingness to pay). There exist other formats, but they are essentially variations based on the previous two.

The **choice experiment** method recognises that a respondent may not find easy to state a value on a good which he is not accustomed to buy (a non-marketed good). That method strives to place the respondent in a more natural choice situation: two to four options are carefully described using attribute levels and pictures (for example, different kinds of defence structure may be pictured, along with levels of biodiversity such as number of birds, and some measure of recreation, e.g. expected fish catch), the cost to the respondent of each option is simply another attribute. The respondent is then asked to indicate which option he prefers. Statistical techniques are used to estimate trade-offs between attributes, which result in monetary values when the costs is used in the trade-off. This method is about as statistically involved as the close-ended contingent valuation method, and still evolving much.

III.4. Synoptic tables on the valuation of costs and benefits of coastal defence in practice

Below, we present tables on different approaches to value the costs and benefits of coastal defence in practice. To understand those tables, one should remind that CBA consists first in establishing “options” – a description of the consequences of a given course of action. One of those options is the baseline, from which all the others are going to be compared. It is usually advised to use “do-nothing” as the baseline option, this can mean abandonment of maintenance of an existing defence structure, or not taking any action if there is no such structure. The physical, environmental, social and economic consequences at some time horizon of these options are then described. Then the difference between the baseline option and any other are valued. We want to examine as many options as possible, but this is an iterative process, at first many options are roughly described, then some may be eliminated, then the description improves, allowing to eliminate more options.

Conventional CBA Approach. Adapted from Ridell and Green (1999).

Nature/Description	Valuation Method
Properties	
Permanent domestic and other urban properties at risk of total loss	Market value (minus goodwill for commercial)
Temporary and semi-permanent structures (mobile home, caravan, chalet)	Cost of moving, or resale value (market value minus depreciation)
Infrastructure: Road, rail, pipelines, cables, pumping stations, sewers, ...	If local, included in market value of property, else construction cost minus depreciation and obsolence
Infrastructure: Bridges, marinas and sport facilities	Construction cost minus depreciation and obsolence
Infrastructure: Sea defence itself including drainage pumps	- Value is zero else double counting - Capital, maintenance and running costs to be included in option costs
Agriculture	Changes in agricultural net product (possible changes in practices) adjusted for changes in agricultural support
Development benefits (intensification of land use)	Value is zero: Coastal defence funding should not be used for private gains
Indirect losses: Commercial and industrial sales losses (assume competitive markets)	- Firms: Transfer payment (value is zero) - Consumers: Price rise (if any)
Indirect losses: Traffic disruption	Extra time needed (consumers)
Non-monetary impacts on households (stress, health effects, loss of memorabilia)	No agreed valuation method, contingent valuation could be used
Recreation (angling, ...) if no equivalent in the area	- Value of enjoyment x nº visits (UK) - Stated preferences (contingent valuation, ...) - Travel cost
Environmental & heritage issues excluding use values	Ideally stated preferences, else as lower bound: · Cost of creating a similar site elsewhere · Cost of relocating · Cost of local protection (lowest of the 3)

Conventional CBA focuses on real estate and strives to make the CBA exercise cheap. It is not well suited for ecological changes that are not directly observable (especially changes in biodiversity) because they have little or no observable effects on market and it is difficult to explain them in a stated preferences survey. It lacks a structure for environmental issues, it is more of a case by case approach.

Ecological function approach (adapted for coastal defence from de Groot, Wilson and Boumans, 2001). Legend: A = Market pricing, B = Avoided costs, C = Replacement cost, D = Factor income, E = Travel cost, F = Hedonic Pricing, G = Contingent valuation. The more + the more it has been used (in other contexts), an o indicates it has not been used, but could be.

Functions	Example goods and services	A	B	C	D	E	F	G
Regulation Functions: Maintenance of essential ecological processes and life support systems								
Disturbance prevention	Storm protection by coral reefs Flood prevention by wetlands and forests		+++	++	o		o	+
Water regulation: Regulating runoff & river discharge	Drainage and natural irrigation Medium for transport	+	++	o	+++		o	o
Soil retention	Maintenance of arable land Prevention of damage from erosion & siltation		+++	++	o		o	o
Habitat Functions: Providing habitat (suitable living space) for wild plant and animal species								
Refugium: food & shelter habitat	Maintenance of biological & genetic diversity	+++		o	o		o	++
Nursery: reproduction habitat	Locally harvested species	+++	o	o	o		o	o
Production Functions: Provision of natural resources								
Raw materials: Conversion of solar energy into biomass	Fodder & fertilizer (krill, leaves, litter)	+++		o	++			+
Ornamental resources	Fashion, handicraft, jewellery, pets, worship, decoration & souvenirs	+++		o	++		o	o
Information Functions: Providing opportunities for cognitive development								
Aesthetic	Enjoyment of landscape features (scenic roads, housing , etc.)			o		o	+++	o
Recreation	Travel to natural ecosystems / landscapes for tourism, outdoor sports, etc.	+++		o	++	++	+	+++
Cultural & artistic	Use of nature as motive in art, folklore, national symbols, advertising, etc.	o			o	o	o	+++
Spiritual and historic	Use of nature for religious or historic purposes (i.e. heritage value)					o	o	+++
Science & Education	School excursions Scientific field laboratories	+++			o	o		o

The ecological function approach is not much concerned with socio-economic changes, but can serve as a guideline for incorporating the environment in conventional CBA. It has not been applied to coastal defence yet.

Integrated Coastal Management Approach. Source: Bower and Turner (1998).

Value name	Example	Valuation Method
Total Use		
Direct Use	Fish, Fuel wood, Recreation, Transport/navigation	Market pricing Non-market methods
Indirect or Functional Use	Flood control, Storm protection, Nutrient cycling, Waste assimilation, Sedimentation, Habitat loss reduction	Avoided costs Factor income Replacement costs
Option	Insurance value of preserving options for use	Contingent valuation
Quasi-option	Value of increased information in the future	Contingent valuation
Total Nonuse		
Existence Bequest	Knowing that a species or system is conserved Passing on natural assets intact to future generations Moral resource	Contingent valuation

Integrated Coastal Management lacks a detailed treatment of valuation in practice, at this stage it has not been applied and is to be considered more of a guideline.

As can be seen, there is not a single approach as to what and how benefits and costs should be taken into account and evaluated. First of all, we have different methods according to the thing valued, for example, property value is often analysed with hedonic pricing while recreation has often been valued with contingent valuation. Second, different approaches stress more some types of benefits than others, for example, the ecological function approach does not consider changes in commercial activity. All the approaches recommend contingent valuation for non-marketed benefits and costs, and even for recreation. Apart from that, there is little agreement as to the choice of the valuation technique, and even valuation itself is sometimes questioned.

IV. **Benefit Estimates** (List 2)

The **Benefit Estimates** list has 34 references on any figure(s) of benefit of coastal defence and/or costs of coastal erosion. It is striking for its variety, as shown in the following table. Two pairs of references share the same sets of data, they are not accounted for in the table.

<table>
<tr><td colspan="3">Variety in Benefits and costs</td></tr>
<tr><td rowspan="2">“One cause” benefits</td><td>Maintenance of recreational activities</td><td>10, mostly UK</td></tr>
<tr><td>Damage mitigation, mostly to coastal properties</td><td>9, mostly US</td></tr>
<tr><td rowspan="2">Costs of defence</td><td>Eutrophication</td><td>1</td></tr>
<tr><td>Natural aspect of the coast</td><td>1</td></tr>
<tr><td>Cost-effectiveness</td><td></td><td>1</td></tr>
<tr><td>Others</td><td></td><td>2</td></tr>
<tr><td colspan="3">Variety of Valuation Methods</td></tr>
<tr><td>Hedonic</td><td>House prices, Insurance</td><td>3</td></tr>
<tr><td>Contingent valuation</td><td></td><td>13</td></tr>
<tr><td>Market pricing</td><td></td><td>4</td></tr>
<tr><td>Travel cost</td><td></td><td>1</td></tr>
<tr><td>Benefit transfer</td><td></td><td>2</td></tr>
<tr><td>Others</td><td>Rules of thumb, non conventional methods</td><td>6</td></tr>
</table>

The implication of such a variety for the DELOS project will be addressed in the next section, but for now, it is important to note that some references have more than one estimate, and that more estimates may still be found after personal interviews with local decision makers have been carried out. Some of these references may possibly not be used for benefit transfer because they lack critical descriptive data: there is a trade-off between the number of explanatory variables in the benefit transfer function (see below) and the number of references that can be used.

V. Benefit Transfer Methodologies (List 3)

The **Benefit Transfer Methodologies** list has 45 references on applied and theoretical works on benefit transfer in environmental economics. Benefit transfer is a series of techniques with the aim of inferring the benefits of a given policy at some new site (called policy site) from the benefits of similar policies already estimated for sites (called study sites) similar to the policy site. It is faster and cheaper than actually estimating the benefits for the policy site, but its reliability is dubious. There are three main types of benefit transfer:

- **Benefit value**, in which the value of one study site is directly transferred to the policy site. The non marketable goods need to be the same, the population characteristics should be similar, and one has to take into account that value estimates may vary over time. This technique has been found to be very unreliable.
- **Benefit function based on single studies**, in which the value of one site is expressed as a function of socio-economic characteristics only, and the transfer exercise is done to a similar site, applying the same function, with different levels of the socio-economic characteristics. This technique has proven quite unreliable, but sometimes useful for decision making.
- **Benefit function based on multiple studies**, in which the benefit function now depends upon socio-economic, site, and valuation method characteristics. If the parameters associated with the valuation method are significantly different from zero, benefit transfer is deemed unreliable in that particular situation; if they are zero, then benefit are transferred adjusting the socio-economic and site characteristics for the new site. This technique has proven sometimes reliable, but requires numerous studies, and is more data demanding.

The statistical specification of the benefit transfer exercise based on multiple studies is still evolving. However, for illustrative purpose the general form of such function is presented here (from Brouwer, 2000). Writing *WTP* as the willingness to pay for a given policy, we have:

$$WTP_i = \alpha + \beta X_i + \gamma Y_i + \delta Z_i + \varepsilon_i \,,$$

where $\alpha\,\beta\,\gamma\,\delta$ are parameters, X is a vector of site characteristics, Y is a vector of socio-economic characteristics (often, the sample means), Z is a vector of study characteristics (among others, the valuation techniques that have been used, if more than one; or the year of the study), and i indexes the studies.

The formula is expressed as a linear combination and can in principle be estimated by ordinary least squares. Several complications may arise however, for example, one may want to take into account that a willingness to pay is by definition at least zero, which requires using truncated regression techniques. Also, it is desirable that the δ coefficient associated to the valuation method that has been used be not significant, otherwise benefit transfer for that kind of site and policy is deemed unreliable. The essential output is that given values of X, Y, and Z for the policy site, and estimated parameters, the above formula produces an estimated WTP.

There have been some benefit transfer exercises that relate to some of the aspects of Coastal Defence: Loomis and Crespi (1999) for recreational benefits, and Fankhauser (1995) and Yohe, Neumann and Marshall (1999) for property values. We now turn to summarise these references here.

V.1. Benefit transfer exercises relating to coastal defence

Loomis and Crespi (1999) are primarily interested in estimating the effects of climate change on 41 outdoor recreational activities in the US, 3 of which take place in coastal areas and have sufficient data. Their methodology essentially consists in finding an estimate for a daily average value for a given activity, and an estimate of the change in the number of visitor days for some scenarios of climate change over the whole US. This is deemed to understate gains and overstate losses. Their data sources for the coastal activities are documented in their paper. Their basic scenario is + 2.5 º C and + 7% precipitation, corresponding to a doubling of CO_2 impacts expected for 2060.

Table: Current (baseline) coastal activities in Loomis and Crespi (1999)

Activity	Visitors days (Millions)	Value per day (1992$)	Climate Elasticity (see below)
Coastal waterfowl hunting	16	30.45	0.275 Coastal wetlands
Coastal bird viewing	169	29.91	0.173 Coastal wetlands
Beach visitation	192	16.30	1.6 to 2.1 Temperature –0.008 to –0.41 Rainfall +0.09 to 0.43 Shoreline

Beach visitation. They estimated the following regressions per region: ln (visits) =

.302 + 1.903 ln (temp) - .414 ln (rain) + 1.15 Summer + .425 meter in North-eastern US

2.89 + 1.618 ln (temp) - .307 ln (rain) + .469 Summer + .096 meter in Southern US

1.53 + 2.126 ln (temp) - .0085 ln (rain) + .1145 Summer + .147 meter in Western US where *visits* is total number of activity days per month, *temp* is average daily temperature, *rain* is inches of rainfall during the month, *summer* indicates summer holidays months, and *meter* is the length of the beach in meter (public beaches included in the NOAA survey only). The t-statistics and R-squared can be found in the reference. The regressions are used to predict changes in recreation under 2 scenarios for the meter variable (for +2.5º C + 7% rain). The 1st scenario is that no beach will be lost (because beach nourishment is technically- and cost-effective for +2.5º C + 7% precipitation following Yohe et al., 1999, and Leatherman, 1989, and where it is not protected the beach moves inland). The 2nd scenario is that 16% of the beach will be lost (Fankhauser, 1995).

Coastal waterfowl hunting: The elasticity in the table results from computation from documented secondary results, a 1% change in wetland acres results in a .275% change in hunter days. Changes in wetland acreage due to climate change induced sea level rise are documented in Smith and Tirpak (1989).

Coastal bird viewing: Using documented primary data, a regression is estimated resulting in a prediction of a change in .173% bird viewing trips for a change of 1% in the number of birds seen per trip. To link that result to sea level rise, it is assumed that a reduction of 1% of wetland area results in an equal reduction of bird population, which in turn results in an equal reduction of birds seen per trip.

Using these estimates, Loomis and Crespi (1999) can estimate the change in days for their central +2.5º C + 7% precipitation as in the following table, for maintained 1990 use levels and for predicted 2060 use levels. Sensitivity analysis indicates robustness for beach recreation (not performed for the other activities). This analysis is just gross benefits and does not take adjustment costs (e.g. beach nourishment) into account. Other limitations of the results are indicated.

Activity	Year	Visitors days (Millions)			Change in economic value (1992$)
		No climate change	+ 2.5º C +7% rain	Change in days	
Waterfowl hunting	1990	15.96	15.76	-0.20	-5.80
	2060	19.08	18.85	-0.23	-6.94
Bird viewing	1990	169.34	169.26	-0.08	-2.26
	2060	277.03	276.88	-0.15	-3.77
Beach visitation	1990	191.70	218.65	26.95	+337.90
	2060	256.10	292.15	36.05	+451.48

The next two references are somewhat halfway between a benefit transfer exercise and a case study: they use secondary data (that is, that they do not collect them), but they build a model of their own to make use of the data. Both are global studies, the first over the whole US coasts, the second over OECD countries.

Yohe, Neumann and Marshall (1999) are interested in damage to coastal properties. There are 3 scenarios of Sea Level Rise (SLR): 33 cm, 67 cm, and 1 m. SLR occurs following the equation SLR(t) = b t^2 where the value of b changes in each scenario, t is zero in 1990 and 110 in 2100. For a sample of 30 sites in the 4 US coastal regions, they forecast inundation patterns in 5-year increments until 2100 on 500 m x 500 m cells spatially explicit including natural land subsidence. Decision can be taken at any decade t0 (from 1990 to 2100) to protect such a cell until some decade T (abandonment). The decision is based on an adaptative CBA rule which represents a mixture of efficient public and private decisions. The CBA rule is the maximum discounted intertemporal welfare with benefits and costs described below.

Benefits of protection from t0 to T = true opportunity cost of abandoning the property = economic damage of future SLR if the property is not protected. They first need a satisfactory description of the evolution of real estate price as a function of future development in the absence of threat, this is given by $d\left[\ln(P_t)\right] = \alpha_0 + \beta_L g_L + \beta_Y g_Y + \beta_{-1} d\left[\ln(P_{t-1})\right]$ where P_t is the real price at t, g_L is the population growth rate, and g_Y is the per capita income growth rate. The symbol *d* is left unexplained but probably indicates a growth rate. This equation is estimated for each of the 30 sites in the sample and it is valid both for coastal land and coastal structures (i.e. properties). When the threat becomes real, the evolution of values is different for land and for structures and changes in each cell.

Land values continue to follow the equation and drop to zero when inundation occurs (time T), however the lost value is the value of land located inland because the premium for coastal land shifts inland (exception are coastal barriers and possibly wetlands, but they do not explain whether they take that into account). Structures values start depreciating 30 years before inundation in an efficient market and reach zero at T at which time they are abandoned (True Economic Depreciation, 30 years is the lifespan of a structure from the point of view of the US IRS). This is a scenario of perfect foresight. If the market is not efficient or if abandonment is uncertain then the market has less than 30 years to react and properties do not have a value of zero at time of abandonment, they investigate a scenario of no foresight at all, as if SLR would occur instantly. In this case, the equation applies until T.

Costs of protection from t0 to T is the time trajectory of protection costs. The costs of protecting structures is assumed to be $750 per linear foot for a generic hard defence (called fixed or structure cost) + 4% per year maintenance cost (variable cost) or 10% per year if the site is on the open ocean. These costs are different in their 3 scenarios and increase geometrically with SLR, this is represented by: cost for 1m SLR = 2 x cost for .67 m SLR = 4 x cost for .33 SLR. They do not say for what scenario their baseline costs apply. The cost of protecting beaches is the cost of nourishment (based on amount needed and local price of sand) if SLR is no bigger than .33 m and if protection starts at t0 (for some sites, protection should have been started before 1990, when it did not, then protection did not start at t0). When SLR is larger than .33 m, a hard defence is built at the back of the beach with maintenance 10% per year (open ocean).

The discounted sum of costs and benefits are then computed for each site (after estimating the inundation pattern) until 2100, and decision is taken to protect in some year on a cell-by-cell basis. The 3-pages long table 7.9 presents the results for each site for each SLR scenario with perfect and no foresight and the decision to protect or not (sensitivity analysis is also done for protection costs). This table is summarised in table 7.10 reproduced below (millions of 1990$, 3% discount rate):

Scenario	Present value	Annuitized annual cost	Transient cost in 2065	Percent protected
1 m, perfect foresight	5 465	164	333	40
1 m, no foresight	6 440	193	384	70
.67 m, perfect	2 802	84	170	60
.67 m, no	2 988	90	195	78
.33 m, perfect	895	27	57	88
.33 m, no	930	28	57	96

Transient costs are actual costs incurred in the year indicated. The small cost increase for no foresight is easily explained: 1. a lot of properties are protected under perfect foresight, so improved information is not much valuable; 2. because of the pace of SLR (rising with time squared), a lot of the properties are protected only in the distant future, thus the cost is very much discounted. Their results are the lowest in the literature, by a factor of about 10, because earlier estimates had higher SLR and/or no adaptation (i.e. market depreciation). It is noted that storms or other stochastic events, and distributional issues are not taken into account. They recognise that their model is quite data intensive and maybe difficult to use outside the US.

The trajectory for SLR maybe one key assumption of their model: it causes most of the inundation to occur in the far future, thus their costs are discounted, if the trajectory was more linear (instead of quadratic) more damage would occur sooner and their estimates would be higher. They do not analyse the sensitivity to this assumption. Even though this is not explicit, they consider all kind of lands, including undeveloped lands and wetlands, in their approach since they use market data on a sample of regions. They do not specify how the sample was taken nor how they estimated values for wetlands.

Fankhauser (1995) builds a general model of adaptation to SLR. He recognises that optimal coast protection is a regional problem because of the regional specificity of the coastline, but he does a top down approximation. His model is built on a CBA rule: adaptation should take place as long as benefits from avoided damage (caused by land loss in his model) is larger than the incremental cost of additional action.

Since Fankhauser's work is set primarily in a context of climate change, he first presents a result linking protection to greenhouse effect: A 2-step process in which decisions on adaptation are taken locally while optimal abatement level is taken globally is equivalent to simultaneous optimisation provided that the global warming damage is specified as the cost minimising combination of adaptation plus cost of damage. From here on, we can focus on protection alone.

Optimal SLR protection

Fankhauser makes the following simplifications: 1. the two available SLR responses are retreat or protect (no accomodate as in the IPCC reports), 2. a single protection measure is available per region (actually a one time decision to protect a percentage of the region coast by a sea wall), 3. there is only 2 kinds of coasts, dryland and wetland (wetland is saltwater marshes), 4. there is no saltwater intrusion, 5. there is no storm and flood damage costs, 6. there is no added pressure on the natural environment, 7. the amount of SLR is known with certainty, 8. defence is built as SLR increases, 9. dryland is protected highest value first (thus the average value of lost dryland depends on how much has been protected), 10. wetlands cannot be protected but can migrate inland if there is no seawall, else they are lost to sea (wetland loss is inversely proportional to defence and increases with the speed of SLR).

Thus for each region (an OECD country in Fankhauser's empirical analysis), the costs of SLR = cost of protection + dryland loss + wetland loss, and we seek to minimise the discounted sum of these 3 streams. The control variables are the percentage of dryland protected and the height of the protection. Since defence is built as SLR rise, the optimal height is equal to SLR in each period. The optimal percentage of coast protected can be shown to be

$L^* = 1 - \frac{PC^{pv} + WG^{pv}}{2DL^{pv}}$, or zero in case the formula would return a negative

The new notation is pv for present value, PC for protection cost, WG for wetland gain (sum of the amount taken away by the sea minus inland migration), DL for dryland loss. Derivating L^* with respect to SLR yields the change in optimal percentage of protected coast for a change in SLR, it has an ambiguous sign because on the one hand more protection is needed when SLR increases, but it is also more costly, so this will depend on regional particulars. Finally, the previous derivative allows Fankhauser to express costs as a function of SLR.

Simulation for OECD countries

Data sources are mostly IPCC (1990), but also Titus et al. (1991) and Rijsberman (1991), and are sometimes extrapolated. IPCC distinguishes 4 types of coasts: cities, harbours, beaches and open coasts. Wetland are assumed to occur on open coasts only, beaches are protected by beach nourishment, the rest is protected by sea dikes. The length of each type of coast is given in a table. Average land value is set to $2 m/km2 for open coasts and beaches, $5 m/km2 for wetlands, $200 m/km2 for cities and harbours (somewhat lower for the former USSR and China). Fankhauser claims that his figures have low reliability and then provides optimal percentage of protection per type of coast for levels of SLR in year 2100 from .2 m to 2m. On average for the OECD, nearly 100% of cities and harbours are protected, about 80% of open coasts and 50 to 60% of beaches, but there are wide variations across countries. The bulk of damages comes from wetland loss (about 80%), followed by protection costs; dryland loss is negligible. For a 1m SLR by 2100, the cost is $425 bn for the US, $22.4 bn for The Netherlands, and $45.3 for Italy. Damages looks roughly proportional to the length of coast. There is important sensitivity to land values, especially wetland, to SLR pace, and to discount rate.

These three benefit transfer exercises (Loomis and Crespi (1999), Yohe, Neumann and Marshall (1999), Fankhauser (1995)) seem carefully done, and relatively well documented (except in the case of Yohe, Neumann and Marshall (1999)). There is however no confidence intervals on their predictions but only a rather arbitrary sensitivity analysis and some comparisons with the literature. In essence, all three are crude benefit (value) transfer exercises because they base their estimates on intuitive/arbitrary averages of sites values, without specifying where these values come from, and transfer these values to sites with potentially very different characteristics, population, and policy options.

V.2. Benefit Transfer in the DELOS project

Regarding the use of benefit transfer for the DELOS project, the previous section is illustrating what the literature appears to consider the two main benefits of coastal defence: maintaining recreational opportunities and avoiding property and land losses. The benefit transfer exercises that have been summarised help understand some issues of coastal defence in a broad perspective. They are not useful at the local level (i.e. a CBA a specific site), but clearly put forward the need to take substitute sites into account: it is not possible to reach an efficient level of sea defence globally or at the nation level if only local benefits and costs are accounted for.

For local coastal defence, the benefit estimates section results show that we have relatively few applications of valuation methods (given that the number of explanatory variables to include in a benefit transfer function is certainly no less than 10, at least in the first estimation runs, one should have at least 20 to 30 points of data to reach conventional confidence levels). Many sites are in the US, in Europe many are British studies, and no application have yet been found for some European countries such as Italy. On the one hand, this was not an obstacle for Fankhauser (1995) for property values, but on the other hand it precludes the ability to take cultural differences into account, and they may play an important role in recreational or non use values. In particular, the US and British coastal sites for which benefit estimates exist are very different from the coastal Italian sites chosen as case-studies in DELOS (Pellestrina, Trieste and Lido di Dante).

For the Italian Pellestrina island case-study, the coastal defence structure (sea dike plus beach) defends land and property in Pellestrina, and can of course be used for recreational activities by residents and (national and foreign) non residents, but surely the main value of Pellestrina island defence structure is the protection of Venice and its lagoon (that is, a non-use value). Even though there are other barrier islands in the world, the nature of Venice makes this case-study quite unique.

For the Trieste case-study, it does not seem there exists a similar study site from which to transfer estimated benefits. Trieste is a town in the north-west of Italy where about three kilometres of artificially defended beach will be built and will serve the residents for recreational activities. We have found only one other study in an urban setting (beach recreation in Boston), but the method applied is the travel cost method and users are mostly day trippers who have a travel cost to go to the beach. Because residents in Trieste have very limited travel costs to go to the beach, the contingent valuation will be applied to estimate benefits.

The Lido di Dante case study is most interesting from the point of view of benefit transfer, because a lot of Italian beach resorts are similar. Lido di Dante has a well developed tourist industry, with few residents, but many national and foreign tourists. The beach has an important recreational use value, and a part of it is defended by low crested structures. We did not find any similar study sites in the US or in Europe. In addition, although in Italy we can find other similar sites, with almost the same kind of tourism and almost the same defended beach, we have not found applications of valuation methods in Italy at this kind of sites. Therefore, we believe that the results of a CV survey about the recreational activities of the beach at Lido di Dante could be transferred to other similar Italian sites if substitution between sites can properly be taken into account.

The conclusions of that section are that benefit transfer of existing study sites to the DELOS sites is bound to be difficult because of the variety of costs and benefits valued. It would be a useful contribution to the literature and to the DELOS project itself to construct first a framework for valuation of coastal erosion mitigation. We could list potential costs and benefits of coastal defence, possibly ranking their importance (by country and/or type of coast), give an assessment of the usefulness of each valuation method for estimating them, and give the costs & benefits estimates for the cases in the literature. This information could be summarised in a table to help the design of the DELOS case studies.

VI. Other References with relation to coastal defence / management (List 4)

The section on **Other References with relation to coastal defence / management** holds about 80 references that contribute to a better understanding of coastal erosion as a social problem. It introduces several issues that the literature considers are not properly addressed in CBA, such as uncertainties (climate change, sea-level rise, physical response to defence), long-run economic costs and benefits, irreversibility, ecosystem complexity, strong sustainability, and strategic issues about development planning. There is a scale problem in coastal management : erosion is caused by a combination of global and local factors, local CBA may not be the right answer. Some externalities need to be incorporated in CBA such as defence at one point causing erosion at another point, or offshore mining and habitat distortion having effects outside the range of the defence project. Whether these considerations should have some bearing for the DELOS project is unclear at present.

VII. General Valuation Methodologies (List 5)

The only purpose of this list of 11 references is to ease referencing within the RT4 participants to critical contributions in the field of valuation.

VIII. Annex: Lists of references

VIII.1. List 1: Coastal Valuation Methodologies

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