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CREST LEVEL ASSESSMENT OF COASTAL STRUCTURES BY FULL-SCALE MONITORING, NEURAL NETWORK PREDICTION AND HAZARD ANALYSIS ON PERMISSIBLE WAVE OVERTOPPING

CLASH

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D39 Report on socio-economic impacts

REPORT

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A_c	= height of armour in front of crest element in relation to S.W.L.	[m]
B	= berm width, measured horizontally	[m]
c_i	= inshore wave celerity	[m/s]
C_r	= average reflection coefficient ($=\sqrt{m_{0,r}}/\sqrt{m_{0,i}}$)	[%]
CF	= complexity-factor of structure section = 1, 2, 3 or 4	[-]
h	= water depth just before the structure (before the structure toe)	[m]
h_{deep}	= water depth in deep water	[m]
h_t	= water depth on the toe of the structure	[m]
h_b	= berm depth in relation to S.W.L. (negative means berm is above S.W.L.)	[m]
D_{n50}	= nominal diameter of rock	[m]
D_n	= nominal diameter of concrete armour unit	[m]
$D(f,\theta)$	= directional spreading function, defined as:	[°]
	$S(f, \theta) = S(f).\ D(f,\theta)$ met $\int_0^{2\pi} D(f,\theta)d\theta = 0$	
f	= frequency	[Hz]
f_p	= spectral peak frequency	
	= frequency at which $S_\eta(f)$ is a maximum	[Hz]
f_b	= width of a roughness element (perpendicular to dike axis)	[m]
f_h	= height of a roughness element	[m]
f_L	= centre-to-centre distance between roughness elements	[m]
g	= acceleration due to gravity (= 9,81)	[m/s²]
G_c	= width of armour in front of crest element	[m]
H	= wave height	[m]
$H_{1/x}$	= average of the highest 1/x th of the wave heights derived from time series	[m]
$H_{x\%}$	= wave height exceeded by x% of all wave heights	[m]
H_s	= $H_{1/3}$ = significant wave height	[m]
H_{m0}	= estimate of significant wave height based on spectrum = $4\sqrt{m_0}$	[m]
$H_{m0,deep}$	= estimate of significant wave height at deep water	[m]
$H_{m0,toe}$	= estimate of significant wave height at the toe of the structure	[m]
k	= angular wave number (= 2π/L)	[rad/m]
L_{berm}	= horizontal length between two points on slope, 1.0 H_{m0} above and 1.0 H_{m0} below middle of the berm	[m]
L_{slope}	= horizontal length between two points on the slope, $Ru_{2\%}$ above and 1.5 H_{m0} below S.W.L.	[m]
L	= wave length measured in the direction of wave propagation	[m]
L_{0p}	= peak wave length in deep water = $gT^2_p/2\pi$	[m]
L_{0m}	= mean wave length in deep water = $gT^2_m/2\pi$	[m]
L_0	= deep water wave length based on $T_{m-1,0}$= $gT^2_{m-1,0}/2\pi$	[m]
m_n	$= \int_{f_1}^{f_2} f^n S(f)df$ = n^{th} moment of spectral density	[m²/s^n]
	lower integration limit = f_1 = min(1/3.f_p, 0.05 full scale)	
	upper integration limit = f_2 = 3.f_p	
$m_{n,x}$	= n^{th} moment of x spectral density	[m²/s^n]
	x may be: i for incident spectrum	

r for reflected spectrum

N_{ow}	= number of overtopping waves	[-]
N_w	= number of incident waves	[-]
P(x)	= probability distribution function	
p(x)	= probability density function	
P_V	= $P(\underline{V} \geq V)$ = probability of the overtopping volume $\underline{V}$ being larger or equal to V	[-]
P_{ow}	= probability of overtopping per wave = N_{ow}/ N_w	[-]
q	= mean overtopping discharge per meter structure width	[m^3/m/s]
R_c	= crest freeboard in relation to S.W.L.	[m]
RF	= reliability-factor of test = 1, 2, 3 or 4	[-]
Ru	= run-up level, vertical measured with respect to the S.W.L.	[m]
$Ru_{2\%}$	= run-up level exceeded by 2% of the incident waves	[m]
s	= wave steepness = H/L	[-]
s_{0p}	= wave steepness with L_0, based on $T_p = H_{m0}/L_{0p} = 2\pi H_{mo}/(gT^2_p)$	[-]
s_{0m}	= wave steepness with L_0, based on $T_m = H_{m0}/L_{0m} = 2\pi H_{mo}/(gT^2_m)$	[-]
s_0	= wave steepness with L_0, based on $T_{m-1,0} = H_{m0}/L_0 = 2\pi H_{mo}/(gT^2_{m-1,0})$	[-]
$S_{\eta,i}(f)$	= incident spectral density	[m²/Hz]
$S_{\eta,r}(f)$	= reflected spectral density	[m²/Hz]
S(f, θ)	= directional spectral density	[(m²/Hz)/°]
t	= variable of time	[s]
T	= wave period = 1/f	[s]
T_m	= average wave period (time-domain)	[s]
T_p	= spectral peak wave period = $1/f_p$	[s]
$T_{H1/x}$	= average of the periods of the highest 1/x th of wave heights	[s]
T_s	= $T_{H1/3}$ = significant wave period	[s]
$T_{mi,j}$	= average period calculated from spectral moments, e.g.:	[s]
$T_{m0,1}$	= average period defined by m_0/m_1	[s]
$T_{m0,2}$	= average period defined by $\sqrt{m_0/m_2}$	[s]
$T_{m-1,0}$	= average period defined by m_{-1}/m_0	[s]
T_R	= record length	[s]
v_z, v_x	= particle velocities in direction z, and x	[m/s]
V	= volume of overtopping wave per unit crest width	[m^3/m]
α	= slope angle	[°]
α_{wall}	= angle that steep wall makes with horizontal	[°]
α_{berm}	= angle that sloping berm makes with horizontal	[°]
β	= angle of wave attack with respect to the structure alignment (0° is perpendicular to the structure axis)	[°]
η(t)	= surface elevation with respect to S.W.L.	[m]
γ_b	= correction factor for a berm	[-]
γ_f	= correction factor for the roughness of or on the slope	[-]
γ_β	= correction factor for oblique wave attack	[-]
γ_v	= correction factor for a vertical wall on the slope	[-]
ξ_o	= breaker parameter (= $\tan\alpha/s_o^{1/2}$)	[-]
$\mu_{(x)}$	= mean of measured parameter x with normal distribution	[..]
$\sigma_{(x)}$	= standard deviation of measured parameter x with normal distribution	[..]
θ	= direction of wave propagation	[°]
ω	= angular frequency = 2πf	[rad/s]

1 Introduction

1.1 Introductions to the assessment of controlling overtopping

The overall aim of WP 6 is the derivation / refinement of guidance on various levels of hazard imposed on people by overtopping at seawalls and related sea defence structures. The specific objectives are to:

- Compare measured events and hindcast events with records of observed hazard in order to derive / refine limits for safety of pedestrians, car users, travellers in other vehicles;
- Derive / refine limits of overtopping for hazard to buildings and related items;
- Evaluate the risks of economic loss.

Task 4 focuses on the assessment of socio-economic impacts. By completing this task methods are presented to evaluate risks of economic losses, where risk is taken as the sum of (occurrence probability times damage per event) for relevant overtopping events. The occurrence probability of overtopping is linked to the occurrence of storms, and performance of the defence. This analysis includes examples of how the loss of life on the coastline can be assessed. WP6 Task 4 has been led by Ghent University (Economics Department) with assistance from partners involved in the hazard analysis (UGent, FCCD, LWI, MOD, UEDIN, HRW) and involves:

- identification and evaluation of generally accepted assessment methods;
- selection of sites and the assessment for potential (and real) impacts, with attention for the costs of increases to protection standard

This report provides a methodological background that will be used in the assessment of hazards of overtopping. Those assessment methods that attach a monetary value to the effects on resources are focussed upon. The relationships between the characteristics of overtopping and the use of specific valuation techniques is further explored. Attention is paid to issues, which ask for methodological decisions. A literature overview of the methods for assessing flood damages will be given. These insights and structuring the process of valuation result into a guidance to the valuation of controlling overtopping. This approach is applied in two case studies.

1.2 Readers guide

Chapter 2 starts with some general definitions on overtopping and an introduction to socio-economic impacts and how to value them. Chapter 3 focuses on the economic valuation of human lives at risk. Based on the insights presented in the former chapters, an approach is presented in chapter 4 that structures and assists the actual assessment of controlling overtopping. This approach is then applied in chapter 5 which deals with the assessment of activities that limit overtopping at two different sites (village De Haan and the port of Rapallo). Finally, chapter 6 presents some conclusions.

2 Defining the damage of overtopping and the valuation of socio-economic impacts

2.1 Introduction

In analysing the safety of a coastal region, any problems arising from wave overtopping will most commonly be treated as part of coastal flooding. In coastal regions, flooding from the sea can be driven by direct wave overtopping, or can be caused by the breaching of sea defence structures. The CLASH project is not intended to deal with breaching failures, but is concerned with direct effects of wave overtopping, including direct hazards to people and infrastructure close to the defences.

At the outset several concepts need to be defined accurately. ***Overtopping*** occurs when waves run up the beach, revetment, seawall or breakwater and pass over the crest of the defence. The resulting flow is often termed ‘green water’ overtopping. The frequencies, volumes and velocities of these overtopping events substantially influence the safety of the defence and of people living, working or travelling close behind the defence structure. A second form of overtopping occurs when waves break on or seaward of the face of the structure and produce significant volumes of fine droplets. The major hazard related to this ‘spray overtopping’ is reducing visibility on coastal highways where the sudden loss of visibility may cause significant driving hazard (Allsop et al, 2003).

Unless otherwise specified, we will use the term ***coastal defence*** to identify structures that protect against wave overtopping effects. Pettit (1999) uses the term as a generic name that includes ***coastal protection*** (protection of the land from erosion and subsequent inundation), ***sea defence*** (protection of land from flooding) and ***tidal defence*** (sea defence upstream of a specified boundary). It includes all forms of structural (engineering for flood defence/erosion protection) and non-structural (development planning in coastal areas) methods of protection from tidal erosion and inundation.

In 1738, Daniel Bernouilli formulated the concept of ***risk*** as the multiplication of effects (expressed in this case in the monetary value of damage) and the probability of an event occurring (a number between 0 and 1). Since then it has been applied without major change. Risk should not be confused with uncertainty, which is a lack of knowledge of a more fundamental kind. Risk thus can be seen as probability of an event (e.g. once every 4.000 years or better 1/4000 per year) occurring multiplied by the damage caused by the event. In many cases a straightforward monetary expression for damage is available. Special valuation techniques exist for those cases where the affected value can not be readily expressed in monetary terms, because, for instance, market prices for specific goods or services are not available. Risk, the result of the multiplication of probability and damage, is therefore the expected value for the damage for a given time horizon. For example, if the chance of a particular event is once in a 100 years and the damage is 1M euros, the expected value of the probable damage is 10.000 euros per year in the period of 100 years.

There is also a broader view of the risk concept, which is used in risk management particularly when for example good actuarial data are not available. It focuses on the effects of extreme events, not on the probability of them occurring. The consequences of risk are divided into *exposure* and *effect*. Exposure is also called vulnerability. Exposure studies look at the ways in which people or objects subject to risk can be subject to change. Effect studies examine what may happen once that exposure has manifested itself. In the literature this is also called hazard. In the FP6 Floodsite project, for example, the concept of hazard or effect is further refined, dividing it into source of hazard (such a meteorological events) and pathways of hazard (concerning, for instance, the morphodynamics of the shore line or the design of coastal defences). In this broader perspective, risk is seen alternatively as the multiplication of *vulnerability (exposure)* and *hazard (effect)*. In this study we will use the more specific risk concept as the multiplication of probability and damage, since in the case of wave overtopping, the occurrence of past events should in principle be sufficiently well documented to calculate a probability.

2.2 Assessing impacts of wave overtopping

2.2.1 Introduction

This section presents an overview of valuation literature that is relevant when investigating damages caused by wave overtopping. Since apparently there is almost no literature dealing specifically with overtopping damage itself, as a starting point of our literature study we chose those studies dealing with flooding events. We first present different ways in which flood damage can be categorised. Possible effects are listed. In the following part, attention is paid to different valuation methods that can be used in valuing flood damages and results from studies that have been described in literature are presented.

In wave overtopping events other values are affected than losses due to direct physical damage or production losses, albeit only because of the occasional loss of human life. One of the reasons for this, is that coastal defence infrastructure has to a certain extent a public good character and externalities are present. Externalities are uncompensated third party effects and in this case can consist of the risk to health and life, production and efficiency losses, damage to reputation of a port, etc.

In economics, ***public goods*** or services have a technical definition. They should not be confused with public utilities, and indeed there is no a priori reason why public goods must be managed by public entities. Public goods are defined as being 'non-rival in consumption'. This means that the amount of e.g. safety enjoyed by one person, does not take away the amount of safety consumed by others. They can also be 'non-excludable', which means that one can not impede others from consuming the good or services. This opens the way to free-riding, or enjoying the benefits while not paying the cost of maintaining the public good or service. For coastal defence works both dimension are present. Public goods are often under-produced, because people can reap the benefits without paying for all the costs.

With public goods, ***positive externalities***, like the value of being free from damage caused by wave overtopping events, often play an important role. Their value can be determined either by looking at insurance payments in undistorted markets, or else by non-market valuation techniques using contingent valuation.

2.2.2 Type of damage caused by wave overtopping

The methods most frequently used to justify the value of fluvial or coastal flood defences are usually applied to (relatively) large areas defended against inundation. The hazards of wave overtopping alone are more local, but may be more damaging. It is noted, for instance, that significantly more deaths arise from overtopping drowning in the UK than from flooding. A number of key features are common to the effects of flooding, so much of this note is based on those methods.

Flood hazards can be categorised in variety of ways. In studying the indirect effects of floods and benefits of flood alleviation, Penning-Rowsell and Parker (1987) define these indirect effects as the secondary impact of direct flood damage and the losses caused by disruption of linkages in the economy. They identify three main types of indirect flood losses: disruption of productive and service activities, disruption of networks and costs of emergency services.

In Belgium, 'The Royal Institute for the Sustainable Management of Natural Resources and the Promotion of Clean Technology' (KINT, Koninklijk Instituut voor het Duurzame Beheer van de Natuurlijke Rijkdommen en de Bevordering van Schone Technologie) conducted a study to evaluate the tangible costs of the floods that occurred in January 1995. A second study followed, in which the intangible effects of the floods of 1998 were evaluated. Damage was classified into direct and indirect damage, which entails direct and indirect costs. Direct costs are linked to the expenditures that are a direct consequence of the disaster. In practice these are the costs of physical damage to buildings, machines, furniture, etc. Indirect costs are the revenues foregone because of the disaster. A second distinction, namely the difference between tangible and intangible costs, is based on the presence of a market price or commercial value.

In the development of a risk approach, Vanneuville et al. (2002) refer to three classifications that can be made when evaluating flood damages. The first distinction is between damage that can or cannot be expressed as a monetary value. One can also distinguish internal and external damage, internal damage being damage within the flooded area. External damage occurs outside the flooded area, and can occur due to dependency of products and/or services of companies that are confronted with the flooding itself or because their market lies within the flooded area. A third distinction is between direct and indirect damage. Direct damage is damage to buildings, installations, goods, crops, etc. Indirect damage are the costs that follow from the inability to produce during a certain period, but also the cleaning costs are included in the indirect damage.

Within the CLASH project, we choose to classify the damage of overtopping as follows:

I. **Direct hazard** of injury or death to people living, working or travelling in the area defended;
II. **Damage to property, operation and/or infrastructure** in the area defended, including loss of economic (or other) resource, or disruption / delay to an economic activity / process;
III. **Damage to defence** structure(s), either short-term or longer-term.

In a stylized way, expected damage from wave overtopping can be classified as small, large, medium, depending on the amount of water involved, but also on the vulnerability of the site. Depending on the interaction of the probability and the possible damage the expected value of the damage caused by the event is more likely to be medium sized than large sized. From a social welfare perspective the interesting question in the case of moderate wave overtopping is, whether preventive actions or spending will be less costly than the expected value of the damage. We will assume that the expected value of the damage of wave overtopping is probably somewhere in the medium range, located on the diagonal in the figure. Within the Clash project is reported on the hazards and the perception of these hazards (WP6, D38).

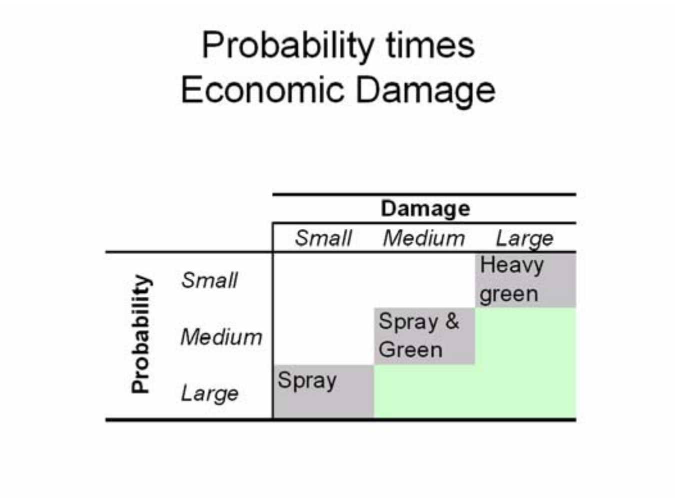


Figure 1: Assumed risk for spray and green overtopping

2.3 Valuation

The former sections make clear that valuation is helpful when decisions are to be made to what extent overtopping needs to be reduced. Only when the damage of overtopping can be valued in economic terms the question can be answered to what extent costs related to reducing these impacts are acceptable. Section 2.3.1 discusses how the process of valuation starts with clarifying the perspective of the valuator. This is followed with a presentation of a number of common valuation techniques.

2.3.1 Damage valuation

If a management perspective is followed, the decision-maker guides the selection of concept(s) used to express an economic value and the extent that risks associated with these concepts should be communicated to him and consequently dealt with. When the valuation concepts are used, results of the process of valuation should be fully recognised by the decision-makers themselves. In this respect a number of conditions should be met when measures in the field of flood management (including overtopping) are to be evaluated. Some of these conditions are:

1. While applying the valuation concept it should be clear what effects of the flood management should be considered. Also, the data about these effects should be available (monitoring condition);
2. The use of modelling techniques to predict the impact of coastal zone management should be possible (modelling condition);
3. The economic values should be acknowledged and understandable by the decision makers (conditions of applicability and acceptance).

For example, when the economic dimension of the quality of ecosystems is to be identified the scope of this dimension needs to be clear. Decision-makers often have the choice from different pathways to value their impacts on ecosystems (see Box 1).

Box 1: the valuation of environmental assets

> "Given that in real world, individual consumers and policy-makers have to make trade-offs, it is fundamentally important to know what is being traded-off against what. It is not possible to know this unless we have some idea of the economic value of environmental assets. To make comparisons involving an unpriced good or service, it is necessary to impute a value. The discipline of economics have developed techniques whereby such techniques can be imputed".
>
> In: Turner, R., Pearce, D., and Bateman, I. (1994) *Environmental Economics*, Harlow, UK: Prentice Hall: p. 108.

A fundamental difference exists between trade-offs within the private sector (economic consequences are presented as private financial costs and benefits) and where the focus is from a society perspectives (social costs and benefits). The latter is addressed within the discipline of economics as economic value in contrast with the financial value. Although the private financial costs and benefits may be distinct from the concepts of social costs and benefits, it can be argued that private firms tend to use the concepts of social costs and benefits when they claim social responsibility. On the other hand governmental agencies may tend to use the more financial oriented concepts of economic value in the case of their budget control. The specific institutional context needs to be assessed to understand the request of the management which value concepts are applicable. Two examples of different institutional contexts within water management will illustrate the variety of scopes in defining the economic value.

An example of a private-business context.
A private owned energy company that generates hydropower by the use of a large dam in a river defines the economic dimension of the intervention in ecosystems in a very limited way. The intervention in ecological quality is restricted to its relationship with efficiency of the production of energy. Lowering the efficiency of the production of hydropower means increasing the ecological quality of the involved river. Clearly the scope of the economic value is limited to a certain category of private costs.

An example of water management at a local level.
Governmental decision-makers in the US, responsible for the management of water quality aimed at maximising welfare, followed a concept of economic value which reflects the impact on welfare. Here households from a local area should indicate what they were willing to pay in extra taxes in order to maintain or increase the water quality (Desvouges et al. (1987)).

2.3.2 An overview of valuation methods

Valuation can be a controversial issue, especially when environmental externalities are involved. However, even in situations where no direct valuation is carried out, a decision to proceed with a particular option implies a valuation of benefits, at least equivalent to the extra costs incurred. This should be explicitly considered in the decision-making process.(MAFF, 2001a).

The effects of flooding are diverse, yet are important to most countries. Floods have enormous impacts on social, economic and environmental developments. Coastal defence structures have been constructed over many centuries, so it is not surprising that impacts of flooding on society are considered at length in literature. This has been boosted in recent years by the requirement of governments to justify the costs (financial and environmental) of coastal defence structures against all other claims on the public purse. This has led to the development of increasingly sophisticated and complex methods to evaluate the benefits of removing or reducing particular hazards.

Economic appraisal enables the comparison of widely differing options in order to identify those which provide overall best value for money. Cost-Benefit Analysis will normally be a significant factor on which schemes and scheme options will be selected. (MAFF 2001a). One of the prerequisites for sound Cost-Benefit Analysis is the existence of adequate valuation techniques, so that significant but unpriced goods and services can be included. Within the extensive valuation literature, the valuation of effects of flooding events is well documented.

This section highlights some features concerning the practical use of valuation techniques when imputing a monetary value to flooding effects. For a general overview of valuation techniques we refer to, amongst others, Turner et al. (1994). More specific literature concerning the valuation of environmental functions in the context of coastal and water resources can be found in Turner et al. (2001). Each method has its advantages and disadvantages, depending on what has to be measured. Usually, a combination of methods will be needed, as illustrated by the case studies presented below. According to Shabman and Stephenson (1996), one criterion to judge valuation techniques for public-decision making is by choosing the technique that best facilitates collective choices. Only when reasonable consensus and confidence develops among decision-makers, will the technique play a significant role in collective choice.

One of the differences among decision-makers may be related to the types of values (use values/non-use values) they want to consider, which is embedded in formal and informal rules (institutions). From the perspective of welfare economics, a useful common terminology regarding economic valuation is provided. This perspective regards values as the assessment of human preferences for a range of natural or non-natural 'objects', services and attributes (Turner et al., 2001). The Total Economic Value of a resource can be broken down into different categories (Turner et al., 2001):

> *Use values* involve some interaction (actual use) with the resource, either directly or indirectly. Indirect use value derives from services provided by the resource (e.g. the prevention of downstream flooding). Direct use value involves interaction with the resource itself rather than via the services it provides and can be consumptive or non-consumptive (recreational and educational activities,…).
>
> *Non-use or passive use values* are associated with benefits derived simply from the knowledge that a resource, such as an individual species or an entire ecosystem, is maintained (Turner et al., 2001). They suggest non-instrumental values which are in the real nature of the thing but unassociated with actual use, or even the option to use thing (Turner et al., 1994). *Existence values* (derived from the satisfaction of knowing that some feature of the environment continues to exist), *bequest values* (associated with the knowledge that a resource will be passed on to descendants to maintain the opportunity for them to enjoy it in the future) and *philanthropic values* (associated

with the satisfaction from ensuring resources are available to contemporaries of the current generation) are examples of non-use values.

Two other categories of values can be mentioned, not related to the initial distinction between use and non-use values:

Option values refers to the fact that an individual derives benefit from ensuring that a resource will be available for use in the future, it reflects the value people place on a future ability to use the resource.

Quasi-option values are associated with the potential benefits of awaiting improved information, before giving up the option to preserve a resource for future use. These values are thus dependent on scientific information.

Some of these values can relatively easy be expressed in monetary terms, others however are less tangible. Based on micro-economic theory of utility and preferences, different valuation methods have been developed to estimate the value of resources. They are described in the following section. Other methods, which are not based on economic theory will not be discussed here. Within the extensive valuation literature, the valuation of effects of flooding events is well documented. Research into the valuation of the effects of wave overtopping, however, seems to be very limited. We therefore also highlight some features concerning the practical use of the methods in the context of flooding that are also relevant when dealing with wave overtopping.

Market Analysis

When undistorted market prices are available and externalities play a minor role, rather straightforward techniques can be used in valuation. Market prices can be used in many ways when valuing the effects of flooding. Obviously, a prerequisite is that these prices exist. In the *production loss* approach, the losses caused by foregone sales of products or services are added up. Examples are the calculation of the loss of output due to flooding for companies and the agricultural sector. Costs of foregone production during the event can be considered, but also the loss of revenue for hotels or marina's when the occupancy rate drops. *Direct health costs* can be included, such as direct and time costs of doctor visits. The use of this method is restricted to the estimation of use-values. Non-use values have to be measured differently. Productivity losses can also come into the picture in a different way. If one uses the costs of creating retention and flooding areas (Averting Expenditures, see further) to approximate the value of flooding effects, not only investment and maintenance costs have to be taken into account, but also the potential loss of agricultural output due to land conversion.

In certain cases, one could also use public investment, for instance, via land purchase or monetary incentives, as a surrogate for market transactions. This method is called *Public Pricing*.

Hedonic Price Method

With the Hedonic Price Method, an implicit price for an environmental good is derived from analysis of goods for which markets exist and which incorporate particular environmental characteristics (Turner et al., 2001). In other words, the Hedonic Price Method attempts to evaluate environmental services, the presence of which directly affects certain market prices

(Turner et al., 1994). A widespread application of this method is to the property market (using house prices), but the hedonic wage approach can also be mentioned. Referring to the hedonic property value, if one can control for the non-environmental factors (number of rooms, accessibility, etc.), then any remaining difference in house prices can be shown to be the result of environmental differences.

Using the Hedonic Price Method, one can estimate the implicit price land market traders are willing to pay for a marginal reduction in the level of flood risk. Traders seem to be willing to pay lower prices for property that is likely to be flooded. A prerequisite however is that the flood hazard is acknowledged (Shabman and Stephenson, 1996). The hedonic price technique is often said to generate upwardly biased estimates for non-marginal changes in flood risk (Shabman & Stephenson, 1996).

Bartosova et al. found a clear relationship between reduced flooding risk and increased property values. However, the coefficient is extremely low. This finding is not surprising, given that the vast majority of properties investigated are well beyond even the 1.000 year floodplain. Hence a reduction from say 10^{-23} to 10^{-24} is of negligible value to those residents. Their results show that increases in flood risk decrease values for residential properties within the 100 year floodplain. The detrimental effect of the flood risk is eliminated after the expected flood risk falls to once every 33,3 years. In line with the findings of Shabman and Stephenson, they provide evidence suggesting that flooding events heighten sensitivity to such risks and raise the property price premium associated with a given level of flood risk.

Problems with this method are the fact that it is user unfriendly (high degree of statistical skill needed) and the fact that the method relies on the assumption that people have the opportunity to select the combination of house features which they most prefer given the constraints of their income. In reality, the property market does not always operate freely (Turner et al., 1994). Another drawback is that housing prices are not only related to actual environmental quality, but can also depend on expected quality levels. Not taking account of expectations will bias the outcome.

Travel Cost Method

The Travel Cost Method can be used to deduce the positive externalities associated with recreational sites. Costs incurred in reaching a recreation site are used as a proxy for the value of the site. Expenses differ between sites (or for the same site over time) with different environmental attributes (Turner et al., 2001). Income, the number of alternative sites available to each visitor, their personal interest in the type of site, etc. are usually taken into account as explanatory factors. When using the Travel Cost Method, one should be aware of the fact that the time during the year in which people are interviewed might have an effect on the results (e.g. tourist season).

Some problems can arise using this method. One has to take into account that time also has a value for travellers (next to e.g. petrol expenses). If one wants to avoid underestimation of the recreational value of a specific site, this cost should also be taken into account. However, time value is not easy to measure. For people who like travelling, the journey to a recreational site might even be a benefit instead of a cost. Another drawback of the method is that it is difficult to allocate travel costs if people make visits to different sites during a single day’s journey. The availability of substitute sites can also influence the outcome of the study. In addition to this, people may value the recreational function of a particular site so highly, that they buy a house near that site. For those people, travel costs to visit that site are very low, and the use of the Travel Cost Method leads to an underestimation of the value they attach to that particular site. This problem also arises with non-paying visitors, people who didn't incur travel costs to reach the site (Turner et al., 1994).

If one wants to measure the (ex-post) effect of a particular flood event on a particular recreational site, this would imply that the value of the recreational site after flooding has occurred can be compared with the value before flooding (in other words: the Travel Cost Method should also have been implemented before flooding). As this is not likely to be the case, the method is applied in another way in the context of flood damage, namely when evaluating flood control projects. Suppose a recreational site is likely to be flooded in the future, and one wants to investigate if the benefits of a flood control project outweigh its costs. The recreational value of a site that would be lost due to a flood event, appears as one of the benefits of the flood control project. This value can be calculated by means of the Travel Cost Method. If the recreational value of a site is irreversibly lost due to flooding, one could also rely on results from previous Travel Cost Method studies to estimate the recreational value that is lost, provided the recreational sites are comparable.

Contingent Valuation Method

Both the Travel Cost and Hedonic Pricing Method rely upon individual valuations of environmental goods as revealed in purchases of market priced goods which are associated with the consumption of those environmental goods. The Travel Cost method has the additional restriction that it is restricted to users of the site. They are called 'Revealed Preference Methods'. Contingent Valuation on the other hand, is an 'Expressed Preference Method'. Contingent Valuation bypasses the need to refer to market prices by asking individuals explicitly to place values upon environmental assets (Turner et al., 1994). Contingent Valuation is a collective term for various survey-based environmental valuation methods (Turner et al., 2001). By using surveys, one tries to elicit the respondents' willingness to pay (WTP) for a resource. Aggregation of individual preferences is used to encompass the relevant population. This method is used when no markets are available that reveal the willingness to pay directly through the price mechanism.

Questions can also be formulated in the 'willingness to accept (WTA)'-format. This can be done by asking people how large the amount of compensation for a change should be. People tend to state higher amounts when asked for their WTA, than when they are confronted with WTP questions. This can be explained by the fact that individuals feel the cost of a loss more intensely than the benefit of a gain. Respondents are also far less familiar with the notion of receiving compensation for losing something than they will be with the notion of paying for something (Turner et al., 1994).

The willingness-to-pay estimates resulting from Contingent Valuation can be unreasonably small or large, and is difficult to assure that the respondents have understood and absorbed the issues in the survey. However, suitably designed surveys can eliminate or reduce these biases to acceptable levels (Tietenberg, 2000). The major concern with the use of this method has been the potential for survey respondents to give biased answers. Different types of potential bias can be mentioned: strategic bias, information bias, starting point bias, hypothetical bias, part-whole bias, interviewer bias and payment vehicle bias. *Strategic bias* arises when the respondent provides a biased answer in order to influence a particular outcome. This bias occurs when respondents believe that the results of the study can influence policy decisions.

They could understate their preferences, in attempt to reduce any subsequent actual payments (Turner et al., 1994). *Information bias* may arise whenever respondents are forced to value attributes with which they have little or no experience. *Starting point bias (anchoring bias)* is possible with those survey instruments in which a respondent is asked to check off his or her answers from a predefined range of possibilities. How that range is defined by the designer of the survey may affect the resulting answers. *Hypothetical bias* may arise because the respondent is being confronted by a contrived, rather than an actual, set of choices. Since he or she will not have actually to pay the estimated value, the respondent may treat the survey casually, providing ill-considered answers (Tietenberg, 2000). Evidence for the hypothetical bias when using the Contingent Valuation Method (CVM) can be found in Shabman & Stephenson (1996). In some cases, the expression of WTP in the hypothetical CVM bids did not translate into actual choice behaviour (referendum voting behaviour). When people are asked for their WTP for part of a good (e.g. one lake in an entire system of lakes), and subsequently for the total good, (the whole lake system), stated amounts can be approximately the same. This is called the *part-whole bias*, or *embedding effects*. The *interviewer bias* follows from the interviewing technique. The *payment vehicle bias* occurs when the answers depend on the way in which one has to pay for the good. Contingent Valuation studies are rather expensive to conduct due to the need for face-to-face interviews and the sophisticated level of the techniques used.

Despite the possible biases, the contingent valuation method has interesting advantages. It can be used to evaluate resources, the continued existence of which people value, but which they never personally visit (Turner et al., 1994). More generally, contrary to other valuation methods, it can be used to monetarise non-use values. Another advantage is that the method is relatively straightforward.

In the context of flooding, one could ask people for their willingness to pay (WTP) for a project that mitigates the flood risk at a certain location. Aggregation results in an amount that represents the loss of human wellbeing at that location. It reflects the loss in use and non-use values caused by flooding. Asking individuals how much compensation they need to accept a higher flood risk can analogously be considered as an estimate of the total damage due to flooding. Another possibility is to ask the following question: ‘What amount of money do you need to compensate for all damage suffered (both tangible and intangible)?’. One could argue that the use of this willingness to accept (WTA)-question could lead to too large amounts. Another drawback of this question is that people may find it very difficult to measure their emotions or distress in monetary terms. When carrying out a Contingent Valuation study, one has also to be aware of the fact that the results can be influenced by the moment at which the survey is conducted. The traumatic experience of a recent flooding can have an influence on the respondents’ answers.

According to Daun and Clark (2000), flood abatement plans have characteristics of both private and public goods. As there is no immediately observable or readily accessible market for flood risk reduction, this brings them to state that the Contingent Valuation Method is the most appropriate methodology to utilise in this context. With respect to the WTP/WTA issue, they argue that the perceived current property right in most environmental Contingent Valuation cases is the status quo. Consequently, if the environmental amenity in question is an improvement upon the status quo, then the Contingent Valuation question should be elicited in the WTP format. In this manner the respondent is being asked to value the improvement to the status quo. Conversely, if the respondent is being asked to compare the current status quo to a new status quo where the environmental quality has degraded, then the

Contingent Valuation question should be elicited in the WTA format. However, when an expenditure is needed to maintain the level of a public good currently available, and when the level of that public good will deteriorate without the expenditure, the appropriate elicitation is WTP (Daun and Clark, 2000).

The KINT opted to search for the WTP of respondents for a project that would mitigate the risk of flooding in their neighbourhood. This is the approach used by Shabman (1998). One of the results of the study of Shabman is that 30% protest votes were noted: a great deal of people gave a zero answer when asked for their WTP, because they found it unfair that they would have to pay an extra amount of money, on top of the damage they experienced during the last flooding. The KINT developed a questionnaire so as to minimise this effect. However, some respondents still refused to state amounts because in their opinion the government is fully responsible for the mitigation of floods, others mistrusted the government and stated that they already paid enough taxes. A few respondents find flooding very normal, they prepared themselves for the fact that their house is regularly flooded and they have no problem with it.

The results of the Belgian KINT studies (KINT, 1999, 2001) show that stated WTA amounts did not exceed the compensation claims made for material damage. One of the reasons could be the starting-point bias: it seemed that people were fixed on the compensation they expected to receive. They were disappointed that the sum they finally obtained was less than they asked for, but they did not want more than they initially demanded.

Another possibility within Contingent Valuation is to ask people how much more they would be willing to pay for their insurance premium such that their fire insurance would cover flood risks as well. The KINT indicates that such an approach does not permit to make a distinction between tangible and intangible costs, and that the results can be influenced by the level of the current premium (starting point bias/anchoring bias). Furthermore, if the respondent is aware of the fact that risks would be spread about all inhabitants, the WTP could be based on an amount that is equitable from a social point of view, and not on the individual damage. Besides, it seems that faith in insurance companies is lacking.

In the UK, the ‘Yellow Manual’ of benefit assessment techniques (produced by the Middlesex University Flood Hazard Research Centre) aims to guide UK local authorities in developing strategies for dealing with coastal erosion and flooding. More specifically, it helps them to appraise coastal protection and sea defence schemes with greater precision. The Contingent Valuation Method is viewed as superior to the Travel Cost Method for environmental valuation in the UK, as the latter is regarded as inappropriate for assessing the recreational benefits of coastal protection. Its main weakness in this context is that in many UK resorts a high proportion of visitors are local residents who would typically incur no real resource costs in travelling to the nearby seafront area (Whitmarsh et at., 1999). In the context of coastal protection, instead of asking for WTP or WTA the Yellow Manual favours the use of a direct open question about the value which each adult places on the enjoyment from a visit to the beach (the value of enjoyment (VOE) elicitation method). This approach avoids having to deal with the payment vehicle bias. Moreover, it would give a better approximation of the pure recreational value (WTP questions may overstate it because people would take other aspects into consideration, e.g. protection of the local area from the risk of flooding). It may also provide a way of overcoming the embedding problem. On the other hand, it does not reflect the reality of the income constraint faced by individuals when making choices (Whitmarsh et al., 1999).

An alternative to the survey based Contingent Valuation approach is the use of group discussions. The survey based approach gives a snapshot of people's attitudes, preferences and values. Group discussions are a more process-oriented approach (Turner et al., 2001). Reference should also be made to the method of Contingent Ranking. With this method, respondents are given a set of hypothetical situations that differ in terms of the environmental amenity available and other characteristics the respondents are presumed to care about, and are asked to rank these situations in terms of their desirability. These rankings can then be compared to see the implicit tradeoffs between more of the environmental amenity and less of the other characteristics. When one or more of these characteristics can be expressed in terms of a monetary value, it is possible to use this information and the rankings to impute a value to the environmental amenity (Tietenberg, 2000). An application of the Contingent Ranking method in the context of flooding would be to include a flood control project in a list of different features. Individuals are then asked to rank the items according to their own priorities. If the list includes features that can easily be monetarised (e.g. the building of additional sporting facilities in a municipality, financed by taxes of a certain amount), the willingness to pay for the flood control project can be approximated.

Damage Costs Avoided

The value of damage that would occur if a good were not protected can also be used as an estimation of the amount that needs to be invested in the protection of that good. One of the applications of this method is to calculate the Property Damages Avoided. Damage can be defined as the amount of property value, which is lost because of a flood event (Oliveri and Santoro, 2000). Procedurally, the analyst using Property Damages Avoided computes the repair costs to a specific property with and without a flood risk reduction project for a given flood event. The difference between repair costs is the annual flood risk reduction benefit estimate for that flood. The analyst then weighs each benefit estimate by the likelihood of the flood event in a year and sums over all possible floods to calculate the annual expected benefits for the property. The present value of the expected annual benefits, computed at the project discount rate, is the total benefit to the property. This technique is hypothetical since no post-flood repair choices are observed. Instead it is assumed that the property owner would make such repairs (Shabman and Stephenson, 1996).

Although Contingent Valuation and Hedonic Pricing are conceptually able to quantify a wider range of flood control benefits, Property Damages Avoided continues, according to Shabman and Stephenson (1996) to be the primary technique to measure flood control benefits. The reason they give is that because it is clear to decision-participants what Property Damages Avoided is and is not measuring when project investment priorities are set, the calculation of Property Damages Avoided benefits are part of a broader consideration of the 'nonproperty' effects that may be mitigated by a project.

Defensive/Averting Expenditures

Averting Expenditures are those designed to reduce the damage caused by pollution or e.g. flooding by taking some kind of averting or defensive action. Since people would not normally spend more to prevent a problem than would be caused by the problem itself, averting expenditures can provide a lower-bound estimate of the damage caused by pollution (Tietenberg, 2000). In the context of flooding, a vast amount of measures can be categorised as Averting Expenditures. Averting Expenditures on bringing back the natural retention capacity of a river can be mentioned (creation, development and management of retention and flood control areas) (Schuijt, 2001). Other examples are the construction of storage reservoirs, waterproofing of the lower floors of existing buildings, flood warning systems, levees or walls to prevent inundation from floods below some specific design flood flow, drainage and pumping facilities, diversion structures, channel modifications, construction of elevated boulevards (dikes), efforts to raise homes and the creation of individual dikes around properties. By contrast, the Public Pricing approach, is not limited to direct expenditures and can include revenues and transfer payments (subsidies).

Relocation Costs

A particular form of defensive expenditure is Relocations Costs, which consist of the expenditures involved in relocation of affected agents or facilities (Turner et al., 2001). The construction of new, higher situated premises for installations is an example of the use of Relocation Costs. The cost for the government of giving households a premium to move to less flood-prone areas can also be mentioned as one of the applications. Relocation of households might prove to be a very expensive measure and therefore a relocation scenario is not always realistic.

Replacement/Substitute Costs

The potential expenditures incurred in replacing the function that is lost are looked at; for instance by the use of substitute facilities or 'shadow projects'. In estimating urban structural flood damages, Oliveri and Santoro (2000) considered the replacement value of a structure as the appropriate economic aspect, because it only takes into account those components of total structure value that actually influence the damage. They defined the replacement value as the total cost for replacing the structure with another or like utility, having the same size and use as the existing one. They argue that while for most properties this method represents the correct economic aspect to perform flood damage estimation, it may lead to misleading results when applied to structures of historical, artistic and/or architectural interest, such as monuments and ancient churches. For those estates, a different approach can be followed: the price-demand curve approach. This method relies on the idea that community willingness to pay for preservation, maintenance or exploitation of a given resource attributes to the resource itself a value, equivalent to the settled money. This methodology should be carefully applied because it could be based on random or wrong decisions (Oliveri and Santoro, 2000). Oliveri and Santoro (2000) combined this method with the substitution approach (consider the value of technically equivalent estates, producing a similar utility, for which a market exists). They computed the value of estates having historical, artistic and/or cultural significance out of two different shares. The first share consisted of the value of the structure deprived of its architectural and artistic characteristics and was calculated considering these structures as residential ones, but built with the highest quality materials and the best finishing touch. The other share, only taking into account those characteristics, was assessed after consultation with experts in restoration and maintenance interventions. The property value of artistic structures has been estimated as increasing the value obtained for the maximum quality building type by 50%.

Restoration Costs

This technique looks at the cost of restoring a damaged asset and uses this cost as a measure of the benefit of restoration (Turner et al., 1994). Restoration costs can be increased to include the expenses for dismantling the damaged components before the restoration of the new ones

(Oliveri and Santoro, 2000). In the Belgian KINT studies, material damages were estimated on the basis of the amounts that were granted by the disaster fund ("Rampenfonds"), both in the private as well as in the public domain. Repair costs to public infrastructure as well as costs related to damage suffered by public institutions were added. Several criteria have to be met before the Rampenfonds intervenes (concerning the minimum amount of damage, the average claim per file, etc.). Consequently, the use of data based on amounts granted by the Rampenfonds is restrained to the cases in which those criteria are met. The KINT report indicates that the use of such amounts results in an underestimation of the real damage (not all damage is refunded, only the functional character of a good is refunded, luxury goods for instance are excluded) (KINT, 1999).

Benefit transfer

Environmental value transfer is commonly defined as the transposition of monetary environmental values estimated at one site (study site) through market-based or non-market-based economic valuation techniques to another site (policy site) (Ledoux and Turner, 2002). The conditions for using this technique are in general that, firstly, population groups should have similar preference structures, which is often not the case in different European countries, and secondly, that similar events and scenario's must be used.

Meta Analysis

When applying Meta Analysis, a pool of data from other studies is used to derive conclusions.

It is important to stress that some of the valuation methods described above are preferably used in ex-ante valuation, since after the damage has occurred strategic answers will distort the results. Other methods are not linked to the scale of the event, so can not be used ex-post. The results for both Market Analysis and Restoration Costs approaches e.g. are related to the scale of the damage, so they can be used both ex-ante and ex-post. Approaches such as Defensive Expenditures, Relocation Costs, are not directly related to the scale of the damage, so they can not be used in an ex-post damage valuation. Table 1: presented by Turner et al. (2001), gives a general overview of which valuation methods can be used to monetarise different values.

Valuation Method	Direct Use Value	Indirect Use Value	Non-Use Value
Market Analysis	X	X	
(Public Pricing)	X	X	X
Hedonic Price Method	X	X	
Travel Cost Method	X	X	
Contingent Valuation	X	X	X
Contingent Ranking	X	X	X
Damage Costs Avoided		X	
Defensive Expenditures		X	
Replacement/Substitute Costs	X	X	X
Restoration Costs	X	X	X

Table 1: The measurement of direct use, indirect use and non-use values: an overview of valuation methods (Turner et al., 2001)

A summary of the possible use of valuation techniques in the context of wave overtopping is shown in Table 2: , where hazards (rows) are sub-divided into three general categories (cfr. supra): direct hazard, damage to property and damage to defence structures. This classification is identical to the one used in WP6-Deliverable 38. Hence compatibility of the hazard analysis with the valuation is assured. The table gives an overview of the most suitable valuation techniques for each category of effects. Drawing a line between effects of overtopping and flooding is not simple, and some effects in Table 2: are more significant for flooding than overtopping. As not all methods can be applied to each category of effects, the inclusion of some effect into an assessment puts its limits on the choice of freedom regarding the selection of techniques to monetarise effects. It is also important to keep in mind that the underlying assumptions on which the methods are based can show significant differences. Most of the damage categories mentioned in Table 2: are relatively straightforward, but some merit additional explanation and illustrations:

Damage to public infrastructure does not include damage to coastal structures, as this constitutes a separate category.

Exploitation costs in the shipping industry covers the impossibility to operate, demurrage, the fact that perishable goods may not be delivered on time, etc. A distinction has to be made between costs due to overtopping itself and those related to bad weather conditions in general.

Effects on tourism reflect damage to camping sites and other recreative and sporting facilities, and the fact that more restrictive norms concerning recreation in flood-prone areas can be established. The fact that some people seek to visit sites while overtopping takes place also has to be taken into account.

Damage to individual (personal) property is included in the *damage to property* category, the stress and feeling of uncertainty that this induces is reflected in the *direct hazard* category (well-being of individuals). Well-being can also be affected by the impossibility to exercise their profession, disruption of daily routine, loss of emotional valuable belongings, loss of pets, the fact that time needed for personal property disturbs other activities (work, holiday, recreation etc.).

								Indirect Methods (behavioural trail)		Direct Methods (questionnaires)	
	Market Analysis	Public Pricing	Restoration Costs	Replacement Costs	Defensive Expenditures	Relocation Costs	Damage Costs Avoided	Hedonic Pricing	Travel Cost	Contingent Valuation	Contingent Ranking
<u>Direct hazard</u>											
Use of material and personnel (public institutions, municipalities, emergency services	+	+			+		+			+	+
Costs of evacuation		+			+		+			+	+
Well-being of individuals										+	+
Personal damage (injuries, death)					+		+			+	+
Increased travel time	+				+		+			+	+
<u>Damage to property</u>											
Damage to public infrastructure	+	+	+	+	+	+	+	+		+	+
Interruption of railway transport	+	+			+		+			+	+
Disturbance of gas, water and electricity distribution; telephone connections, mail	+	+			+		+			+	+
Exploitation costs shipping industry	+				+		+			+	+
Production losses in agriculture	+				+		+			+	+
Damage to agriculture infrastructure	+		+	+	+	+	+	+		+	+
Production losses in industry	+				+		+			+	+
Unemployment	+				+		+			+	+
Damage to infrastructure in industry	+		+	+	+	+	+	+		+	+
Distribution of goods		+					+			+	+
Effects on tourism	+				+		+		+	+	+
Damage to vehicles	+		+	+	+	+	+			+	+
Damage to terrains	+		+	+	+		+	+		+	+
Damage to historical buildings and cultural sites		+						+	+	+	+
Damage to cemeteries and crematoria										+	+
Damage to individual property	+		+	+	+	+	+	+		+	+
Environmental deterioration not reflected in other effects									+	+	+
<u>Damage to defence structures</u>											
Damage to coastal defence structures	+	+	+	+	+		+	+		+	+

Table 2: The valuation of flood damages

2.4 The context of damage valuation

A number of valuation concepts and methods have been discussed in the previous section. Clearly, the valuator has to make a number of choices. To some extent the valuator will be steered by his context how the effects of flooding should be monetarised. The choice between a social or private cost-benefit concept will largely be determined by the social responsibility the valuators take. Governments tend to apply the social cost criterion for which a number of valuation methods can be used. Each method has its advantages and disadvantages and the valuator has to weigh this. Decision-makers have a significant input into the valuation process, for example with respect to the choice of effects that need to be valued or the scope of these effects.

The description of methods for monetarising shows that for similar effects a number of different methods can be used. The valuator often decides on the basis of approval by the decision-maker which method (or methods) will be applied. Again a contextual factor has been identified which defines the calculated damages of flooding. Namely, that the attitude towards how to handle uncertainties regarding the outcome of each step in the process of valuation (starting with the identification and selection of effects up to the application of valuation methods) may strongly steer if and how the valuation takes place. When the effects are highly uncertain and difficult to quantify a tendency may be to leave them out of the valuation process.

Despite the crucial awareness that valuation is embedded in a specific context some general accepted guidance to the process of valuation can be given. Before a general approach towards the assessment of overtopping in chapter 4 is presented, a number of technical (methodological issues), process and psychological issues will first be dealt with. With respect to these process and psychological issues, the concept of risk and its operationalization in the valuation process will be focussed upon (section 2.4.2).

2.4.1 Some other technical issues related to valuation

Valuation of damage which has no conventional market price is tricky. Although economists have formulated the theoretical basis of welfare economics in the 1920s, and externality theory in the 1950s, the techniques developed may yield results which differ by a factor 10. Some methods measure partial values, which ideally should be associated with partial damage probabilities. The danger of double counting is present when adding up the obtained values. Other methods do not distinguish between different values, and measure them in an aggregate manner. Multiplication by a probability number, is therefore not straightforward. Finally, some methods are typical ex-ante models, because they are unrelated to the scale of the damage, and should therefore not be used ex-post.

In the process of valuation of the effects of overtopping, assumptions and approaches must be clearly defined, as the theory on valuation does not provide a general applicable approach. Methodological choices need to be made. It is clear that there is no ideal valuation technique, or combination of techniques. Substantial differences in approach exist. The choice of technique depends on the objective of the valuation. If awareness-raising is the goal, results from other studies can be transferred to obtain order of magnitude estimates. This method is called “benefit transfer”, and consist of using results from valuation studies of similar cases to the case under study. It has been shown that benefit transfer can produce order of magnitude estimates, but that it can not be used for different countries or different populations. If more accurate damage valuations must be obtained for purposes of including them in a scientific model, other techniques must be used, which allow more precise estimates.

There are a series of technical issues which are not unimportant. The issue of incorporating risk in ex-post damage valuation depends on which valuation method is used. It can take different forms. When indirect methods are employed, risk notions are assumed to be included in the markets under study e.g. property or insurance markets, which are supposed to be related to the expected value of the damage. When direct, survey based methods are used, for example, it is assumed that respondents incorporate risk notions when determining their willingness to pay bids. In some studies, they can also be asked directly their willingness to pay for a reduced probability of suffering, in this case wave overtopping damage. When partial methods are used, and different types of damage are added, ideally for each type of damage a different probability should be determined, in order to calculate the total expected value of the damage.

As a consequence of different ways of incorporating risk into valuation methods, in the case of damage caused by wave overtopping, several special issues must be dealt with. First, for both private and public property an insurance can usually be obtained on the private insurance market against this type of damage, which neutralizes the risk and eliminates it economic significance. In other cases, it is assumed that the government should pay all the damage, which is also a form of insurance through a disaster fund. The assumption that the state will pay all damage, implies moral hazard and will affect the answers some respondents will give to valuation surveys. Secondly, externalities - non-monetarized, uncompensated third party effects - can be present, although for overtopping damages they are likely to be smaller than in cases, for example, where natural resources values or cultural heritage are affected on a larger scale. Depending on whether such values are included in the survey, risk notions will be incorporated in the results in different manners. Thirdly, the welfare economic basis of valuation assumes marginal changes, not catastrophic changes. Pretending to valuate damage from catastrophic scenarios or when extreme events have just taken place, can be tricky. This point is not realized, even by some famous practitioners, like for instance by the authors of the much quoted article, which pretends to value of all the world's eco-system goods and services (Constanza e.a., 1997). Wave overtopping is a phenomenon which fits non-catastrophic category, unless, of course it leads to loss of life or major damage to property.

Finally, there are a series of psychological issues related to working with respondents to questionnaires. The human tendency to loss aversion undermines rational choice framework (Kahnemann, 1991). This is not the place to go further into these issues, but it is important to realize that human respondents are likely to react neither purely rational, or purely emotive when determining their decisions towards risk.

2.4.2 Psychological issues and the concept of risk

The incorporation of risk in valuation processes was already highlighted. It should be noted that very small probabilities of occurrence reduce the appropriateness of several valuation techniques. Land market traders appear unable to incorporate flood potential without some major flood to anchor their perceptions. Hedonic estimates are sensitive to the market traders' recent experience with a natural hazard. Hedonic estimates are either very large or zero depending on the timing of the study vis-à-vis the latest flood (Shabman and Stephenson, 1996). Bartosova et al. (1999) show that when using the Hedonic Price Method, the detrimental effect of flood risk is eliminated after the expected flood risk falls to once every 33,33 years. In line with the findings of Shabman and Stephenson (1996), they provide evidence suggesting that flooding events heighten sensitivity to such risks.

In the project 'Risk Based Urban Watershed Management – Integration of Water Quality and Flood Control Objectives' (Institute for Urban Environmental Risk Management, Marquette University, Milwaukee), a hypothesis was advanced that the willingness to pay parameter (used in Contingent Valuation Studies) could be correlated with the risk of flooding. The study confirmed the hypothesis that a household's WTP for the maintenance of current levels of flood risk is positively related to flood risks as proxied by the household's distance from the river (Daun and Clark, 2000). With respect to the Contingent Valuation Method, it is also worthwhile noting that the surveyed sample can have an influence on the results. Some people might have decided to relocate to avoid flood risks. Including those people in the survey would result in a higher WTP for a project that would mitigate the risk of flooding.

It can be concluded that the choice of valuation techniques determines to some extent the weight given to uncertain flooding effects. The results from some techniques used to value flooding effects (such as Replacement/Substitute Costs) are unaffected by the probabilities. Other techniques (like the Hedonic Price Method) are highly affected by the probabilities.

Not only does the probability of occurrence have an impact on the result of valuation studies, the fact that governments and individuals are aware of the probability of occurrence of an event is a prerequisite for the use of some valuation techniques. Using Averting Expenditures to measure the possible effects of flooding implies that individuals and/or the government have taken measures to reduce the effects of such an event. This will only be the case if one is aware of the risk of flooding, and if the probability of flooding is assumed to be large enough to make Averting Expenditures worthwhile. With respect to the Contingent Valuation Method, a consideration made by Daun and Clark (2000) is that in watersheds were residents did not believe that the creek was flooding and was a problem in their community, they had a hard time to provide WTP amounts.

Natural hazards do not only affect infrastructures and interrupt economic life. If they occur in populated areas they affect also the people living there. So one cannot make an economic analysis of overtopping without giving some attention to the human hazards. In the next chapter, the different approaches to valuing risk to human life and health will be analyzed more fully.

Risk to human life from overtopping

Humanity has built dikes to protect land and people from the sea. Due to different factors the population at sites with a significant risk from sea related hazards has increased. At some places the population grew so fast the last decades that they needed more space and cities expanded towards the sea. Other places became tourist attractions and are very populated in the holiday season and abandoned in low season. Harbour facilities also caused the growing of near-sea cities. All this increased the risk of human life to natural disasters such as overtopping. We will briefly discuss the hazards and possible methods to quantify those hazards.

We have already stated that this study only handles about the immediate effects of overtopping. If overtopping occurs and people are at the dike then the least that can happen to them is getting wet. But for people at the dike overtopping involves also the risk of being swept away by the water and possibly getting drowned. So the immediate effects range from light injuries till death. Psychological distress, loss of social relations, dislocation, and other secondary effects are consequences which are not the subject of this study.

Thus one possible hazard to mankind is death, which is an unambiguous consequence, someone is dead or not. However, the other consequence, injury, is less unambiguous. No doubt there is a whole range of medical literature on the different sorts of injury due to being swept away by water, but all this is not very helpful to us. To quantify effects we need clearly defined concepts. If someone is swept away due to overtopping we will assume that death will be the consequence. We take the worst case scenario from the moment that there is a possibility of injury. This is a strong assumption, but it is made from the point of view that nothing can be worse than being death[1].

Total mitigation of natural hazards seems very unrealistic, but it would be nice to reduce the consequences at a reasonable price. To do so we need first of all some kind a measurement of what we want to reduce. Once we have that measure we can study the reduction in hazard due to human actions like a heightening of the dike for example. If we could measure the consequences in money we even could balance the benefits against the cost as we will show in a next chapter.

A very common way to measure hazards to mankind is with the aid of the concept of risk. If we can measure the risk to people we have a basis to take decisions to mitigate or reduce the risk. Afterwards we can measure the reduction in risk due to such decisions and evaluate the results. Authorities can also set standards such as the maximum allowed risk and undertake risk reducing projects if the risk is higher than the standard. The identification and measurement of the hazards is usually called risk assessment. Trying to control or reduce the risk is then called risk management.

Risk literature defines *risk* as the probability of a consequence multiplied by the consequence itself. The difference between risk and uncertainty is that in the case of risk we thus have an idea of the probabilities whereas with uncertainty we know nothing about the probabilities. In the case of natural disasters such as overtopping, there are somewhat more specialised risk concepts we will discuss now.

If the only consequence we will consider is death, a common used measure is *individual risk (IR)*. Bottelberghs (2000) defines it as the probability that an average unprotected person, permanently present at a certain location, is killed due to an accident resulting from a hazardous activity. He also states that the individual risk is dependent on the geographic situation and thus not characteristic for any person but for the location for which it is calculated. Individual risk is often displayed in the form of contour lines on a geographic map.
So whether people are present or not, the individual risk stays the same. One can write:

$IR = P_f \times P_{d|f}$,

[1] This can be discussed. Certainly there are injuries which are worse than being dead, but for the analysis that follows it seems no problem to put injury equal to death.

where P_f is the probability of failure and $P_{d|f}$ is the probability of dying of an individual in case of failure, assuming the permanent unprotected presence of the individual. In our case the probability of failure is then the probability that overtopping occurs. The probability of dying when overtopping occurs will then depend on some other factors like the magnitude of overtopping. These factors that influence the probabilities and thus also the risk in the case of overtopping will be discussed further. Problem with this measure is that in the case of overtopping, a permanent unprotected presence seems very unrealistic at a place like a dike[2].

Another risk measure, the societal risk, is defined as the probability that a group of more than N persons would get killed due to an accident at a hazardous activity (Bottelberghs, 2000). It is given as a function of the group size in the form of a plot of frequency versus groups size, with frequency equal to probability per year (F). Societal risk is thus not dependent on the location but characteristic for the hazardous activity in combination with its populated surroundings. If no people are present at the time of overtopping, there is no societal risk whereas individual risk need not to be nil.

A somewhat similar measure is population at risk (PAR). This is the population who are directly threatened by a hazard. This measure gives an impression of the magnitude of a disaster. One can plot the frequency as a function of the people at risk, where with societal risk we plot the frequency as a function of the fatalities. In the case of overtopping PAR could be a better measure than the societal risks because of the limitation of the latter to fatalities alone. With PAR we can incorporate the possible injured people we made abstraction from earlier.

The problem with PAR is then the absence of a probability. The PAR says nothing about the probability that the hazard will have negative consequences. Take a sunny afternoon in high season at an attractive dike in a tourist place. The PAR will probably be very high where the societal risk could be nil because of the fact that there is maybe no chance that overtopping will occur.

Laheij et al (2000) use the measure Potential Loss of Life (PLL), defined as the expectation value of the number of deaths per year. This PLL can be calculated from the individual risk as follows:

$$PLL = \int\int IR(x,y)m(x,y)dxdy\,,$$

where IR(x,y) is the individual risk at location (x,y) and m(x,y) is the population density at that same location. The PLL can also be calculated from the societal risk as

$$PLL = \sum_{N=1}^{\infty} F(N)\,,$$

with F(N) the frequency of accidents with N or more victims. The two approaches need not necessarily give the same outcome because the individual risk and the societal risk are not always calculated with the same data[3]. If we have a risk measure, either individual or societal risk, we can thus calculate the potential loss of life by using the method above. If we already know how many people will be affected, this is a big step towards the valuation of human losses due to overtopping.

[2] Except maybe the ice cream vendor in summer season

[3] Laheij gives the example of the Netherlands where individual risk is calculated for an unprotected individual and societal risk is calculated taking protection in account.

Risk Influencing factors

Understanding the measures above is not that difficult, calculating the measures is somewhat more difficult because there are a lot of factors influencing the risks. In what follows we will give some influencing factors that can be of importance when considering the effects of overtopping without pretending to give an exhaustive list.

To start explaining all influencing factors it is useful to define some concepts of risk which will ease the explanation later. A *hazard* is a potential danger, in this case for human life the hazards are death and injury. The *consequence* is the hazard after it actually happened, the uncertainty is gone. So the hazard can be injury and the consequence after all influencing factors accounted for could be a small injury. Every hazard has an *initiating event*, in this case the initiating effect would be a natural phenomenon that causes waves to surge, like a storm for example. The fact that this initiating event will lead to some consequences will primarily depend on the *system response* to that event. A small storm will not likely cause overtopping of a well constructed dike. And even if we have overtopping there is no certainty that this will have its consequences for mankind. If there is no one there at the time of overtopping, nobody can get hurt. So we need another concept to indicate the vulnerability of human life which is generally called *exposure*. Examples of exposure are the time of day, the season, warning signs to alert people and the sightseeing value of the potential dangerous place.

To summarize: an initiating event will lead to a consequence for human life depending on the system response and the exposure of mankind for some sort of hazard. See Table 3: for an illustration of the same initiating event leading to different consequences. The example is purely illustrative.

Initiating Effect	*Hazard*	*System Response*	*Exposure*	*Consequence*
Severe storm	People at the dike could get hurt by the storm (ranging from being wet to death by drowning)	No overtopping	Doesn't matter	Nothing
		Small overtopping	No exposure (e.g. at night, no people allowed at the dike,…)	Nothing
			Small exposure (e.g. low season, at nightfall, …)	Some people getting a bit wet
			Great exposure (daytime, high season, …)	Everybody at the dike wet
		Huge overtopping	No exposure (e.g. at night, no people allowed at the dike,…)	Nothing
			Small exposure (e.g. low season, at nightfall, …)	Some people injured
			Great exposure (daytime, high season, …)	Some people die

Table 3: Illustrative example of different risk concepts

Both the system response and the exposure influence the risk and thus also the potential loss of life. The system response is in our case what happens at the dike. The dike should protect the inland from wave surges and the normal system response is that the water doesn't reach further than the dike, which is evidently the original purpose of the dike. If the waves go over the dike, we speak of overtopping. The exposure is in our case the amount of people who are exposed to the hazard of overtopping. Some places do not allow people at the dike, so there the exposure is nil, other places are such tourist places that the exposure is dependent on the season and at other places there is a constant exposure such as a railroad in vicinity of the dike. If we can manage these two factors the risk of overtopping can be minimized or even eliminated. The initiating effect is actually also an influencing factor in the sense that without a storm there is no risk of overtopping. So we need to multiply the probability of overtopping when there is a severe storm with the probability of a severe storm. We will ignore the initiating effect because we study the effects of overtopping and thus assume there is an initiating effect that could lead to overtopping such as a storm for example.

Overtopping can have different gradations so we need some continuous measure for the system response or overtopping. In the literature mean discharge is used as a measure for overtopping. *Mean discharge* is expressed as flow rate per metre run of seawall. The main limits to identify the danger to pedestrians are defined relative to mean discharges. At which level of mean discharge overtopping becomes dangerous for people is not so easy to define. The General Methodology Report suggests an 0,05 m^3/m upper safe limit for pedestrians and vehicles driven at any speed. So we could state that from 0,05 m^3/m on, the probability of dying in case of overtopping is positive. While difficult to place real numbers on the question at which level the overtopping becomes dangerous, we now have a measure for the system response or overtopping. We will use the mean discharge as an indication for the severity of overtopping. Allsop et al. (2003) advice to limit overtopping to 0,03 litre/m (which is 0,00003 m^3/m) for unaware people and 0,1 litre/m or 0,0001 m^3/m for trained staff.

By limiting the mean discharge the consequences of overtopping can be diminished or even eliminated. This requires well built dikes with enough height to stop the water even during very severe storms. This is easy written but one can see immediately this requires heavy decisions. The higher dike will give more protection, but will diminish the sightseeing capacity if you are at a lower point than the dike. So people living at the site will often not agree with a heightening of the dike. That sort of infrastructures requires also a descent design and planning which costs time and money. The touristic value of the dike can be of such a high level that the economic costs of losing that value could be higher than the benefits. All this requires thus objective information about the economic benefits and cost of overtopping.

Now back to exposure. We defined exposure in our case as the amount of people who are at the potential hazardous place. The hazardous place is the dike, there and only there the overtopping occurs. So the exposure handles about the people at the dike at the moment of overtopping. At some dikes people are not allowed and the exposure should be zero there[4] and at other places the dike is such a tourist attraction that the exposure is quite big, especially on a very sunny day in the high season. Influencing factors here are the time of day, the tourist value of the place, the time of the year, the possibility to alert people of the dangers and the awareness of the people of those possible dangers and the possibility to close the dike at dangerous times. All this influencing factors can be incorporated in the PAR measure introduced earlier.

As with the system response it is also possible to diminish or eliminate the exposure. A very easy way for eliminating the exposure and immediately eliminating the risk for human life is to deny people the access to a potential hazardous site. As said earlier, at tourist places the cost of such a measure could be economically unwise. Less effective measures but still exposure-diminishing is to alert people of the possible dangers when stormy weather is announced or to deny the access only at specific dangerous periods. This will surely reduce the people at the dike and thus the people at risk. It will however not completely eliminate the risk because there will always be thrill seekers.

Speaking of thrill seekers there are some words to say about awareness. The awareness of people of the dangers of overtopping can greatly influence the exposure. If people are fully aware of the dangers there will be no one at a dike on a moment when overtopping risk is real. The problem is that people are not fully aware of the dangers of overtopping. The dike gives people the illusory feeling of safety. Yet worse are thrill seekers who are out to experience overtopping from real close, thinking there is only the risk of getting wet. If there is a possibility to influence this awareness, the authorities should be able to reduce the exposure

[4] More exactly the exposure then is the probability that somebody will ignore the prohibition and enter the dike times the people who see the prohibition sign while having the intention to go to the dike.

and thus also the consequences of overtopping if it occurs. Information campaigns, warning signs and guards at times of danger are helpful instruments to enhance awareness and reduce exposure.

Once we defined the geographical area where there is risk of overtopping and we analysed the different influencing factors it should technically be possible to put a number on the population at risk. It should also be possible to calculate the individual risk or the societal risk depending on the mean discharges spoken of earlier. Bringing these two together makes it possible to compute the potential loss of life of overtopping at a specific site[5]. This way it is possible to put a number on the risk to human life of overtopping and this can then be used when discussing policy measures to ameliorate the safety at potential hazardous sites.

[5] For tourist sites it will be better to compute the potential loss of life for different seasons because of the big variation in people at the site over the year.

3 Economic Valuation of Human Lives at Risk

The economic valuation of human life is already for quite some years a very hot debated topic in the economic literature. Since the growing popularity of cost-benefit studies for all sorts of projects, the need to value the influences on human life also became necessary. A lot of projects have a human factor and economists, trying to develop the most complete cost-benefit study of a project, continuously search for more accurate methods to value these gains or costs to human life.

Economists trying to put a value on someone's life are reviled by moralists saying that it is immoral to express the value of a human being in monetary terms. Undoubtedly this is a hot topic. Why do we want to value life? A lot of decisions involve risks to human life. When people could get hurt or die, this has to be considered in advance of doing something. So when the government values some kind of project we would like it to value every consequence involved, benefits and costs, thus also human benefits and costs.

But is it moral to place a finite value on someone's life? Life does not have a market value[6]. Who can determine the correct value? If life would be of infinite value then no costs would be too much for making traffic that safe that nobody dies: if it costs billions of euros to save one life, it is still less than the infinite value of saving that life. So why do all those people die in traffic every year? Not all the money that the government spends goes to life saving actions. If the value of life is infinite, no matter what the cost, government would invest in enhancing safety until the last possible cause of death is extinct. This does not happen, why? The answer is opportunity cost. If the cost to save one more life in traffic is becoming very high because already a lot of money is spend on traffic safety and it gets harder and harder to safe an extra life, then it might be more efficient to invest money in other things like safe public transport, so people do not have to be in potentially dangerous car traffic. When policy makers make this trade-off they implicitly agree that life has a finite value.

Secondly, people often say it is impossible to value someone's life in money. However economists do not try to value someone's particular life. It is mere a statistical concept. We try to evaluate the benefits of reducing some risk to human life without talking about somebody in particular. So why do we try to value something precious as life in money, the same unit of measurement we use to buy vegetables and clothes? The unit of measurement is free, but it is common to value life in terms of money because the rest of the gains and costs of some project or decision will also be valued in money as it is the standard unit of value in our society. Once it was the size of your cattle, then it was gold en now it is a currency, e.g. euros, we use to express value.

We only have the intention to give as much details about the benefits and the costs as efficiently possible to give policy makers the opportunity to engage or not to engage in projects. Policy makers can decide to do some project with a net cost or to abandon a project with net benefits, that is their choice. As an economist we merely want to express as much details as possible. And because people are important, some valuation of life and the risk to

[6] It is the same with environmental problems. What is the market value of the environment? Some similar techniques as those explained further are also used to value the environment and we can already reveal that the values obtained often induce discussion about their validity or even the method's validity.

life will be useful whenever lives are at risk. The possibility to save 1000 lives for certain cannot be ignored because of a small risk of killing 1 person, whose life is of unlimited value.

The European Union (EU) values transport fatalities around € 1,5 million. For victims of environmental pollution the EU uses a value of €1 million. The difference arises from the fact that victims from environmental pollution are mostly older people and thus the future potential of these victims is less than with traffic victims[7]. Further we will explain the concept of a statistical life, after which we will explain the most widely used methods to value life. To conclude we try to give some implications for the socio-economic valuation within the CLASH project.

3.1 Value of a statistical life

The rationale behind Cost-Benefit Analysis is the Pareto criterion. Something is good for society if nobody is made worse off and at least one person is made better off. This situation is then called a Pareto improvement. Because this rationale is pretty rigorous there exists a less stringent criterion, the *potential* Pareto improvement. In this case it is possible that some people are made worse off but the gains from the people who are made better off should be sufficient to compensate the losers. If the net gains[8] can be distributed in such a way that at least one person is made better of and ex post nobody is made worse off, then we have potential Pareto improvement.

To state this more formally we use the compensating variation (CV) measure. Let V_j be the value of this CV. If someone will gain because of some project or action his CV will be positive because he or she is willing to pay some amount to be sure that the project is carried out. If that someone will lose, V_j will be negative. A potential Pareto improvement is then only possible if the net gains are positive, because then it is possible to make everyone at least as good off as before, and at least one person better off. Formally this means that $\sum_j^n V_j > 0$.

According to Mishan (1975) and Jones-Lee (1974), the loss of someone's life has to be valued by that person's CV, which is the minimum sum he or she is prepared to accept for the fact that he or she will die. The problem is that the potential Pareto improvement is not possible anymore after death has occurred, because it is no longer possible to compensate that person. Valuing somebody's life would thus be inconsistent with the Pareto criterion. Valuing a specific person's life in conditions of certainty about death seems inconsistent with the rationale behind Cost-Benefit Analysis.

Above propositions only apply to cases where there is certainty about the death. But it is seldom the case that we can predict who is going to die if we conduct some risky project. In most cases we can only predict that some people will die, like for instance the statement that a project will increase risk to death with 1/1000. This means that out of 1.000 people, one will be killed. Which individual will be killed we cannot say. "It is this fact of complete ignorance of the identity of each of the potential victims that transforms the calculation", as stated by Mishan (1975). The negative CV's from specific people facing a certain death are now replaced with the CV's from everybody involved for the additional risk they bear. In stead of some people with a certain death we now have everybody with an increased risk to die as a consequence of some action. This transforms the case in such a way that there is no conflict

[7] We do not wish to give a value judgement about this adjustment. The figures merely have the purpose to give an idea of the values used within EU cost benefit analysis.
[8] Net gains is the sum of the gains of the people who win less the sum of the losses of the people who lose.

anymore with basic cost-benefit assumptions. People are accepting an increased risk to die (costs) if there is a net gain. People find it easier to attach a value to increased or decreased risk than to their life itself.

Whenever we will talk about the value of life from now on, we implicitly mean the value of a statistical life. There is no person of flesh and blood connected to the value. It is a statistical concept and with aid of statistical methods we derive some value of life, a 'statistical' life thus. The next example illustrates the concept of 'statistical life'.

Assume people living at the coast without any real protection against huge waves. They do have a small dike which protects them from modest wave overtopping. There are 100.000 people living near that coast and every year there are several people dying from serious wave overtopping, against which the dike offers no protection. The government intends to heighten the dike and it is estimated that after the project the risk of dying will be reduced with 1/100.000, which means that for a population of 100.000 people there will be one fatal accident less every year. Suppose the inhabitants are asked for their willingness to pay for this risk reduction and they are willing to pay 10 € each. Then the value of that statistical life is 10 € multiplied by 100.000 people which gives 1.000.000 €.

We will now summarize the most common ways to value life - a statistical life that is - along with the criticism on the particular method. Where possible we will illustrate the theory with figures from different studies. The reader will immediately see great differences between methods, but also great differences between studies using the same methods.

3.2 Human Capital approach

The human capital (HC) method assumes that the value of someone's life can be measured by the possible future production of that person. The value of someone's life, and thus the loss to the economy due to the decease of that person, is then calculated as the discounted future earnings. According to Mishan (1975) a possible expression for the loss to the economy, according to the human capital approach, would be:

$$HC_1 = \sum_{t=\tau}^{\infty} Y_t P_\tau^t (1+r)^{-(t-\tau)}$$

Y_t is the expected gross earnings during the tth year. It are solely the earnings that are lost when the person deceases. Earnings from assets or rents are not included because they continue after death and are not lost for society as a whole. $P^t{}_\tau$ is the probability in year τ that the person will be alive during year t[9]. r is the social rate of discount expected in the year t. This method is also called the gross human capital approach because it uses gross income.

According to Mishan (1975) this method can be rationalized only if maximizing gross national product (GNP) is the goal of economic policy. If this were true, the simplest way of maximizing GNP would be to allow unlimited immigration. Unlimited immigration does not happen but this does not mean that the method is completely irrational. The main reason why this method is broadly used is because the calculation is very straightforward.

[9] $P^{25}{}_1$ is the probability that someone will be alive during year 25, measured at year 1 while $P^{25}{}_{24}$ is the probability that someone will be alive during year 25, measured at year 24. These probabilities differ because there can happen a lot during those 24 years which influence the probability to be alive at year 25.

The fact that this method is very straightforward to calculate does not mean that it is easy done. First of all we need the future expected earnings. Because they are expected we can never tell how much these figures differ from the real ones. Some companies have a straightforward plan for job advancement and can compute the earnings for someone depending on age and education. But there is the possibility of dismissal or resignation. Above that our economy has evolved to one where people have different employers through their life and earnings are more difficult to calculate.

Secondly the probabilities of being alive in some year in the future are very hard to compute. We have data from the past which are used by insurance companies to calculate a life insurance premium. But again, our society evolves very fast so we cannot be sure how precise our estimation will be. The probability today that someone will be alive 30 years from now, intuitively feels very vague. So human capital measures for relatively young people will have very wide confidence intervals which makes them statistically very vague.

A third factor that complicates the calculation is the social rate of discount. Future values have to be transformed in present values which is done by discounting. For investments the discount rate is often the average rate on government bonds. But for more intangible concepts like the value of life this is more difficult. Which rate to use? Because we are discounting earnings here, any market rate of return can be used, as long as the same rate is used for the rest of the study. There is however some discussion about the validity of discounting in cost-benefit studies. Discounting attaches lower weight to future values. So if the costs for life saving projects have to be made now and the benefits only pay off in twenty years it is possible the study concludes the project is not justified. The value of that discount rate can greatly influence the outcome of the study. Because we are talking about earnings, and earnings in the future do not have the same value as the same earnings now[10], discounting seems rational here. Typically a discount rate of 3% is used in this type of calculations.

We calculated some values of life using the HC_1 measure and used multiple discount rates to see how they influence the results. The income and life expectancy data are mean values for Belgium. We assumed that nobody earns money until 18 years old and from 65 years on[11]. The life expectancy data are not completely in line with theory because it are the probabilities somebody will be alive in the future from now on. In our example the probability that somebody of 20 will be alive one year later is the same as the probability that a fresh born child will be alive at his 21st year.

[10] Because we can save the earnings now and earn an additional return on them in the future.

[11] From 65, people in Belgium have a retirement pay but the measure assumes this is not the case. Above that, this are gross earnings which include a part for the retirement pay.

For a discount rate of 3% a fresh born would we worth something more than 400.000 €. This value will then rise to reach its maximum at the age of 25 with a value of 690.000 €. After the age of 25 the value gradually falls and reaches zero after 65 years, because from then on all future earnings are assumed to be zero. Lower discount factors lead to higher values and vice versa. Graphically this calculation gives a clear picture of the influence of the discount factor used.

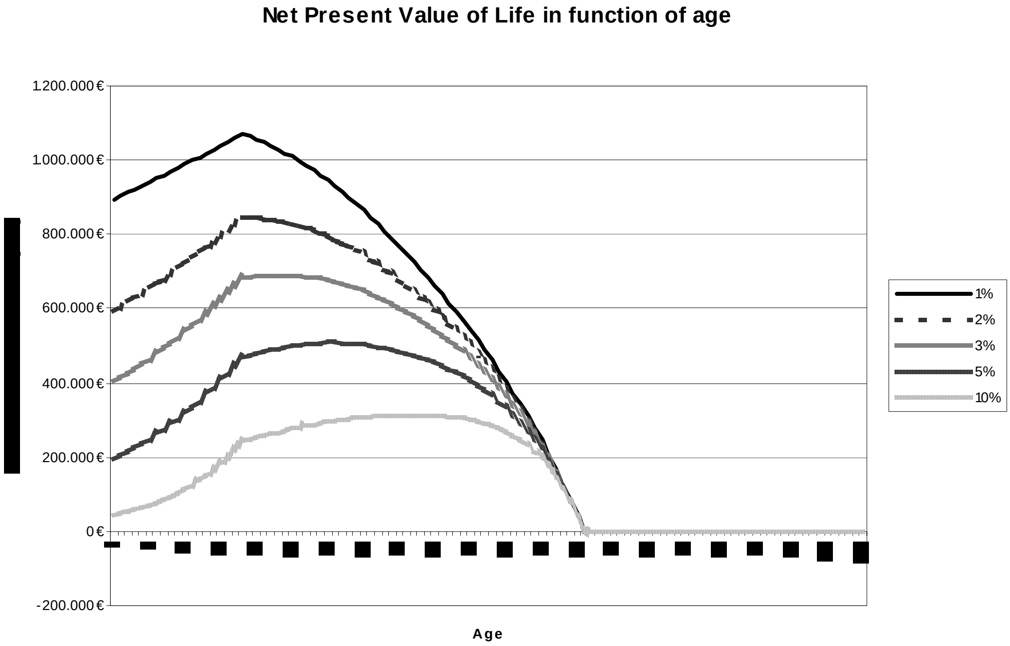


Figure 2: Value of Life as calculated with the HC1 measure

There is a related method called the net human capital approach. It is the present discounted value of the losses over time accruing to others only (Mishan, 1975). The expression is:

$$HC_2 = \sum_{t=\tau}^{\infty} P_\tau^t (Y_t - C_t)(1+r)^{-(t-\tau)}$$

C_t is the personal expenditure of the individual during the year t, expected at time τ. This measure will thus be lower because the person's claim on future consumption is also lost, leaving more for the rest of society. HC_2 will become negative for persons where consumption is greater than their income with the certainty that income will not rise in the future, which is the fact with retired people. The death of these non-working consumers will lead to a benefit for society. At least according to this method that is, and this method only looks at the financial part of somebody's involvement in society. While this method pretends to look at the benefits or losses to society, it only looks at the interests of the surviving members of society, which is an ex post approach. The difficulties of measure HC_1 remain and above that we have the additional difficulty of measuring future consumption. We can transform this 'personal' measure to a statistical measure in the same way as for the HC_1 approach.

As said before this method is very straightforward, but can we use this kind of measures to indicate someone's value of life? This measure is clearly very rough and does not incorporate more than income and consumption. It is safe to state that human life consists of more than earning some money and consuming a part of those earnings. So a measure that only considers earnings cannot be the most appropriate. Most authors who use this method clearly indicate its shortcomings. The method is used to give some idea of the value in a particular case. The human capital value is only a part of the total value of human life, the intangibles which cannot be calculated are not included.

The methods described above do not measure the value of statistical lives, but of particular ones. A said in the previous section this does not comply with the idea behind Cost-Benefit Analysis. However, we can aggregate a population's HC values to find a mean HC value for the whole population and this way it would be the value of a statistical life and not the value of one particular person. The statistical value is then $\frac{1}{n}\sum_{i=1}^{n} HC_i$ with n the dimension of the population measured and HC_i the value of the life of individual i, measured with the HC approach described above. The statistical significance of the value will depend on the data used, the calculation of the individual measures and the sample population's composition.

3.3 Revealed and expressed values

The concepts used in the measures above all involve market prices which gives them the advantage of relative easy data gathering. Actually we don't really value life in those measures, we value the discounted future earnings and take that value as a proxy for the value of life. Whereas this method has the advantage of a straightforward calculation, the problem exists in the linkage between the proxy and what we want to value. A better method would try to value the 'intangible' instead of using a proxy. However, this has the possible disadvantage that data become more difficult to retrieve.

One way to do this is to just ask some carefully selected sample population what they think their life is worth. Problem with this method is that most of the answers will be 'infinite' or even 'zero'. This is because people tend to have difficulties with putting an objective value on non-market goods. The 'zero' is some protest answer because that person feels uneasy with valuing life and concludes it is impossible to do so, the 'infinite' is an expression of the feeling that valuing something superior as life in something earthly like money is impossible. We already indicated before that the value is unlikely to be infinite because our society does not devote infinite resources to the preservation of our lives.

Two types of methods for deriving the value of a statistical life are the stated preference method and the revealed preference method. The contingent valuation method (CVM) uses a carefully designed questionnaire to discover people's willingness to pay for a reduction of the risk of death. This method is thus a stated preferences method. The other method we will describe is the wage differential approach. This is a revealed preferences method, we analyse the difference in wage for jobs with a difference in risk to die. We assume that more risk to die is compensated by a higher wage. The difference in the wage to have a less risky job is then assumed to be the willingness to pay for less risk. We will describe both methods with their advantages and disadvantages.

3.4 An application of the Contingent Valuation Method

As stated before the willingness to pay (WTP) reflects a persons preferences and attitude to risk. This attitude can vary among people and can vary among different hazardous situations. The same person who is prepared to pay 10 € for the heightening of a dike is maybe prepared to pay 100 € for the same heightening if he lives closer to the dike, or is not prepared to pay anything to save the same statistical life in traffic, maybe because he finds traffic already safe enough or does not participate in it.

We will describe briefly how such a survey is conducted and will then pass on to the difficulties with this sort of analyses. First of all a hypothetical scenario is needed. In the case of overtopping this could be some hypothetical project to reduce the risk of overtopping by heightening the dike. A good scenario will provide more realistic answers because the respondents will be able to empathize more with the situation. Secondly the choice of a ‘payment vehicle’ is important. A payment vehicle is the way people will have to pay for the project. This can be income taxes, one time donations, buying of shares,… The payment vehicle can influence the answers, so testing with small focus groups in advance of the real survey can clarify the differences in survey methods. Third important step is the choice of payment question. There are open ended questions like “How much will you pay for this?” and there are closed ended questions like “Are you willing to pay X€ for this?”, where the answer is given by a yes or a no. In general the latter gives better results because of the fact that people tend to have difficulties to elicit how much something is worth to them in monetary terms. No method will be the best for all situations so testing is again very useful. After these questions are resolved the survey can be conducted. After all data are processed, the sample WTP values can be calculated as the sum of all individual WTP values. From this total WTP a mean WTP value can be calculated by dividing the total WTP by the sample size. A value of a statistical life (VOSL) can be calculated by dividing the mean WTP value by the risk reduction.

The Contingent Valuation methodology suffers from some biases, which can luckily be minimized by the design of the survey, but are nevertheless important issues. We will summarize the most frequent biases and the solutions to minimize them. One possible problem is the strategic behaviour of the respondents. It is possible that respondents do not reveal their true WTP because they want to influence the outcome. If somebody would like the provision of a public good like a swimming pool he can state a high WTP to make sure the project will be accepted. He can do this if he is convinced the government will never ask him to really pay his stated WTP. On the other side it is possible somebody states a zero WTP value for that swimming pool, not because he does not like to swim, but because he is afraid that the government will ask him to pay for it. Careful design of the questions can minimize this strategic behaviour.

In closed ended questions there is often some bias called starting point bias. If the survey asks the question if people are willing to pay 10 euros, more than ten euros or less than ten euros for some risk reduction a lot of people tend to think that 10€ will be the ‘correct’ answer. Another bias is vehicle bias. Suppose you ask one group for their WTP for some project, to be paid in the form of a one time donation and you ask some other –demographic similar- group the same question but to be paid with an increased tax. Very often the average WTP values will differ. The former could be higher because people have some aversion when it comes down to higher taxes and state their value lower if the vehicle is a tax, the latter could be higher because with an increased tax the amount does not have to be paid at once. Another bias can occur because of lack or abundance of information. This is then called information bias. If you ask for the WTP for a higher dike because without that higher dike a certain storm will kill ten people every time it occurs, the WTP will be much higher than if you also tell those people that such a storm only occurs once every hundred years. A last important bias is the sample selection bias. If there are differences in the characteristics between people in the sample and people out of the sample, then the WTP values are not representative for the population and thus biased. If you ask environmentalists for their WTP of the preservation of the Lesser Sooty Owl[12], their WTP will be much higher than if you sample the population correctly and ask the same question.

All these biases can be reduced to an ‘acceptable’ level by means of careful survey design and testing through focus groups. A complete list of guidelines are given by Arrow et al. (1993)[13]. We will only give a short description of the most important elements. For the survey type the personal interview seems the best method, but is of course the most expensive one. Mail surveys can suffer of high non-response rates or even worse, people can fill out mail surveys without eliciting their true preferences which would result in values far from the real preferences. A personal interviewer can make sure people take the questions seriously. There is however need for testing interviewer effects in advance. The presence of the interviewer could result in a ‘social desirability’ bias, where the respondent tries to please the interviewer. This can be tested for in focus groups, in advance of the full scale survey. In general mail surveys will be the more cost efficient option and with a careful design of the survey the negative elements can be minimized.

Another important element in the design is the way in which the respondents are asked for their WTP. An open ended question gives the problem that somebody might have absolutely no idea of his WTP, the closed-ended format gives the problem of starting point bias. Commonly used elicitation methods are the bidding game, the payment card method, the discrete choice, the discrete choice with follow up and the modified dichotomous approach. The bidding game is identical to an auction and thus very familiar for most respondents. The interviewer iteratively states a different amount of money until the respondents willingness to pay is identified. This method cannot be used in mail surveys for obvious reasons. This method is also subject to starting point bias. The payment card method is similar to the bidding game but uses an additional visual aid, a card with a number on it, indicating the WTP. The discrete choice or dichotomous choice are all synonyms to the previous mentioned closed-end format. Respondents only choose yes or no. Respondents find it often easier this way, but for the researcher this method means many more observations because it gives only a discrete indicator of maximum WTP in stead of a total WTP value. In the discrete choice with follow up, if a respondent is willing to pay a certain amount, there is a next question with a higher WTP, until the respondents answers ‘no’. This seems to give better estimates than one time answers like the discrete choice, but the problems inherent to discrete choice still remain.

A last point of interest is the question whether to use willingness to pay or willingness to accept (WTA). In stead of asking people their WTP for a risk reduction, one could ask their WTA for an increased risk to death. In the literature there has been much debate on which measure to use. Arrow et al. (1993) recommend the use of WTP, albeit their reasons are scientifically poor founded[14]. The problem with WTA is that for the same hypothetical project WTA answers tend to be systematically greater than WTP values where these should be the

[12] Some sort of owl
[13] See also Harrison, G.W. (2002) for a critique on the NOAA Panel Report of Arrow et al.
[14] They recommend WTP because it is the most conservative –read lower- value of the two.

same in theory. Respondents are clearly biased if the question is changed to getting money in stead of paying money. Maybe the correct value lies somewhere between WTA and WTP, no one can tell for sure. In literature, WTP is used more frequently.

As already indicated, CVM is more used for valuing the environment than human life, but there have been some studies which give us some indication of the magnitude of the VOSL.

Table 4: somewhat indicates the different ranges of values across different studies. In all tables the orginal values are given. The same values in 2003 dollars are reported between brackets. In cases where results were not reported in US dollars, they were first converted to current dollars, using the OECD-Eurostat 2004 edition of Purchasing Power Parity (PPP) exchange rates., using http://www.oecd.org/dataoecd/61/56/1876133.xls. These exchange rates correct for distortions in financial markets which can cause currencies to be over- or under-valued. Values before 1980 where converted using the Economic History Net: http://eh.net/hmit/exchangerates/. Finally, we took the dollar values for the current year and converted them to 2003 dollars, using the US Consumer Price Index (CPI). A handy tool for doing this is **http://www.westegg.com/inflation/**. When doing international comparisons over longer time periods this method is required.

The great difference between WTP and WTA is also illustrated. WTA is more than twice the WTP in the particular study. According to Viscusi (1993) the estimates of the value of life by means of contingent valuation are between \$3 million and \$7 million.

Author	Year	Nature of Risk	Survey Method	Implicit Value of Life (in millions of \$)
Jan Acton	1973	Improved ambulance service, post heart attack lives	WTP door-to-door sample of 36 (US)	\$0,1M *(\$142.000)*
Jones-Lee	1976	Airline safety and locational life expectancy risks	WTA mail survey sample of 30 (UK)	\$15,6M *(\$22M)*
Gerking, deHaan & Schulze	1988	Job fatality risk	WTP, WTA Mail survey	WTP \$3,4M *(\$4,8M)* WTA \$8,8M *(\$12M)*
Jones-Lee	1989	Motor vehicle accidents	WTP	\$3,8M *(\$5,4M)*
Ted Miller & Jagadish Guria	1991	Traffic safety	WTP	\$1,2M *(\$1,7M)*

Table 4: Value of life estimates from past studies (1990 US \$)

Source: Viscusi (1993)[15]

3.5 Wage differential approach

One controversy with the Contingent Valuation Methodology is the hypothetical market. As economists we would feel better if we can use a real market to analyse. The problem is that there is no real market for death. The human capital approach uses market data with a very hypothetical model, viz. that value of life is equal to present value of discounted future income. CVM uses a hypothetical market and derives conclusions about the real market. This third method uses the risk approach of the Contingent Valuation Method, but with market data. In short we will derive the WTP for risk reduction by the difference in wage between a

[15] See also Viscusi (1993) for the references to the studies used. We only give this table to indicate the great difference in values, without commenting on the scientific correctness of the studies used in the table

high risk job and a lower risk job. The employee is willing to pay for a less risky job or is willing to accept more wage for a more risky job. For the worker, more risk requires more wage. For the firm, less risk requires more investment in safety and thus higher costs, which ends up in lower wage for the workers. For a more detailed explanation of how the dynamics in this model work, see Viscusi (1993). In short, there will be a difference in wage, δw for a job with a different risk, δp. The marginal rate of substitution between wages and risk would then be equal to δw/δp and is taken as a proxy for the value of a statistical life. There are also similar studies who derive the WTP for a risk reduction from the WTP for extra safety like in cars etc., but the main studies use the labour market so we will confine our analysis to the labour market studies only.

To empirically deduct a VOSL we need to specify a wage equation like the following:

$$w_i = \alpha + \sum_{m=1}^{M} \beta_{1m} x_{im} + \beta_2 p_i + \beta_3 q_i + \beta_4 q_i WC_i + u_i$$

For every worker i, w_i is the wage rate, x_{im} are the personal and job characteristics with M characteristics included, p_i is the risk of death, q_i is the nonfatal risk attached to the job and u_i is the error term reflecting wage influencing factors that are not included in the wage equation. WC_i reflects the compensation benefits paid to worker i in a case of nonfatal injury, which needs to be multiplied by the risk of being nonfatally injured in the equation.

To estimate this sort of equations detailed data sets are needed. As well for the worker's characteristics as for the job (risk) characteristics. A common problem with a lot of studies is the aggregation of risk data per industry, in stead of per firm. According to Viscusi (1993) the aggregated industry data makes it difficult to isolate the wage premium specifically linked to increased risk form other sources of wage premiums. The most important variable in this equation are the risk variables. Usually researchers use a data set with industry risks based on job classification. In general, how better detailed the risk information of the worker, how better the estimates will be. Where a stated preference method like the contingent valuation method suffers from the possibility of subjective answers, this revealed preference method suffers from a lack of good and detailed data.

According to Ford et al. (1995), "the wage differential approach does not seem to be grounded firmly in the accepted theory which runs in terms of expected utility theory and the individual's willingness to sacrifice a part of his or her wealth to secure a reduction in the probability of death". Ford et al. developed a model to show that the results obtained with the wage differential approach differ from theoretical results derived from the model. They argument that the wage differential theory is thus not in line with theoretical cost-benefit foundations, whereas the Contingent Valuation Method is more in line with the basic rationale behind cost-benefit studies. Dorman and Hagstrom (1998) also conclude that values obtained through wage/risk studies theoretically are very weak and sometimes have insignificant outcomes[16]. The estimates would be highly sensitive to the choice of risk variable and model specification. They conclude that one or more assumptions underlying the conventional theoretical model on wage differences induced by risk differences are inapplicable.

Landefeld and Seskin (1982) indicate some additional problems, which lead to the great differences in values obtained by this type of studies, next to the ones we already mentioned. First of all, workers do not have complete information about the risk involved with the work. If there is no complete information, wage premiums may not accurately reflect workers risk

[16] which are of course seldom published and by this seldom known

preferences. Secondly, labour markets are not perfect. If there is more supply than demand on the labour markets, there are people willing to work for a smaller risk premium than their preference because the need an income and find that anything is better than nothing. Related to this there is the problem of sample self-selection. Workers in risky jobs are often less risk averse than the modal person, so their willingness to pay for a more safe working situation will underestimate the population's WTP.

Again we will end this part by giving some figures from earlier studies. These figures give some indication of the range in which we can expect the VOSL, measured by the wage differential approach. According to a meta-analysis[17] of Viscusi (2003) the VOSL measured by the wage differential approach has a median value of $7 million in the US. The study also concludes that the VOSL decreases with age and that unionised workers seem to enjoy greater risk premiums.

In outcomes of the studies presented in Table 5: there are again great differences between the types of studies and countries. One source of difference is the effect of income. If safety is a normal good then we will 'buy' more safety once we get richer and that could explain the difference between poorer countries and richer countries. The income elasticity lies between 0.5 and 0.6 according to Viscusi (2003). This means that if income doubles the VOSL, calculated with the wage differential method, will only increase with approximately 50%.

Smith	1974	US	$9,2M *($9,7M)*
Thaler & Rosen	1975	US	$1,0M *($1,05M)*
Viscusi	1981	US	$8,3M *($8,8M)*
Garen	1988	US	$17,3M *($18,2M)*
Marin and Psacharopoulos	1982	UK	$4,2M *($4,4M)*
Kim and Fishback	1993	South Korea	$0,8M *($0,84M)*
Lanoie, Pedro and Latour	1995	Canada	$19,6 - $21,7 *($20,7M-$22,9M)*
Shanmugam	1996	India	$1,2-$1,5M *($1,3M-$1,6M)*
Liu, Hammitt and Liu	1997	Taiwan	$0,2-$0,9M *($0,21M-$0,95M)*

Table 5: Value of Life Estimated through Wage Differential Studies (2000 US $)

Source: Viscusi (2003)

3.6 Implications for valuation of overtopping control measures

The properties of the site under study often determine which method is most capable of giving objective results. If the site under study is a residential place, where people live but do not work, then the wage differential approach will be least fit to do the job. We think the Contingent Valuation Method is the most proper method because it is the most versatile. A well conducted study that takes all known difficulties in account from the beginning will probably give the best results. The wage differential approach seems unusable outside a working environment and the human capital approach fails to incorporate important intangibles that cannot be ignored in our current society.

One other possibility is to use economic valuations of risks from other studies and possibly adapt them if necessary to the wave overtopping context. According to Pearce (2000) this not

[17] A study that uses a pool of data from other studies to derive conclusions

really a good idea. Most studies suffer from context dependent influences and it is extremely difficult to filter out those influences, so using the same values in an other context would be misleading. There are also insufficient studies to perform meta-studies that could give an context-free estimate of the value of life. He argues that more primary studies are needed to make future meta-studies possible. Besides the arguments of Pearce there is also the simple fact that there are little or no valuation studies about natural disasters like wave overtopping.

A CVM study about some hypothetical project to reduce wave overtopping would probably give the best estimates. One of the problems with a CVM study is the population affected. If you only ask people who have been eye to eye with huge waves the WTP will be a lot higher than if you ask the whole population of a region nearby the coast. Maybe there are even people who want to pay to see overtopping. They would have some negative WTP for risk reducing projects. Because the CLASH case is about reducing wave overtopping, we think a relevant population are those who suffer from wave overtopping, primarily the people most nearby the coastline. A well conducted CVM study with that population being investigated will give an estimate of the WTP, and eventually the value of a statistical life, of coastline inhabitants for risk reduction in the wave overtopping context.

4 A guide to the valuation of damages

4.1 Introduction

This chapter aims at providing some guidance to the valuation of overtopping damages. First an overview of valuation studies is presented which outcomes can be used as estimations of the values of damages in specific contexts. These outcomes are related to specific categories of damages. A decision tree for selecting a valuation method is presented in section 4.3 which is at hand if the valuation is conducted by the assessor himself. The chapter concludes with remarks on the trade-off between the costs and benefits of controlling overtopping (section 4.4).

4.2 Overview of values

Based on a literature review, this section gives an overview of flood damages that have been valued in past studies. Values of life from other studies are included as well. The values are classified according to the categories that we defined previously. One of the problems that we encountered in doing so, is the fact that several valuation studies give an overall picture of the damages caused by flooding, but do not provide a further breakdown of these figures. This hampers their use in a general framework to value the effects of overtopping, as they are closely linked to the magnitude of the particular flooding event. Another important remark to keep in mind is the fact that damage is influenced by the water level. An example of depth-damage functions can be found in Vanneuville W. et al. (2002).

Direct hazard

Category	Values	References
death	WTP (improved ambulance service, post heart attack lives, US): 0,1 million $ (1990$) *($1,4M)*	Acton J., 1973 (from Viscusi, 1993)
	WTA (airline safety and locational life expectancy risks, UK): 15,6 million $ (1990$) *($22M)*	Jones-Lee, 1976 (from Viscusi, 1993)
	WTP (job fatality risk): 3,4 million $ (1990$) *($4,8M)* WTA (job fatality risk): 8,8 million $ (1990$) *($12,4M)*	Gerking, deHaan & Schulze, 1988 (from Viscusi, 1993)
	WTP (motor vehicle accidents): 3,8 million $ (1990$) *($5,3M)*	Jones-Lee, 1989 (from Viscusi, 1993)
	WTP (traffic safety): 1,2 million $ (1990$) *($1,7M)*	Miller, T. & Guria J., 1991 (from Viscusi, 1993)
	wage differential (US): 9,2 million $ (2000$) *($13M)* [nonfatal risk included, significant]	Smith, 1974 (from Viscusi, 2003)
	wage differential (US): 1 million $ (2000$) *($1,1M)*	Thaler & Rosen, 1975 (from Viscusi, 2003)
	wage differential (US): 8.3 million $ (2000$) *($8,7M)* [nonfatal risk included, significant]	Viscusi, 1981 (from Viscusi, 2003)
	wage differential (US): 17,3 million $ (2000$) *($18,2M)* [nonfatal risk included, significant]	Garen, 1988 (from Viscusi, 2003)
	wage differential (UK): 4,2 million $ (2000$) *($4,4M)*	Marin & Psacharopoulos, 1982 (from Viscusi, 2003)
	wage differential (South Korea): 0,8 million $ (2000$) *($0,85M)* [nonfatal risk included]	Kim & Fishback, 1993 (from Viscusi, 2003)
	wage differential (Canada): 19,6-21,7 million $ (2000$) *($20,7M-$22,7M)*	Lanoie, P. & Latour, 1995 (from Viscusi, 2003)

	[nonfatal risk included]	
	wage differential (India): 1,2-1,5 million $ (2000$) *($1,3M-$1,6M)*	Shanmugam, 1996 (from Viscusi, 2003)
	wage differential (Taiwan): 0,2-0,9 million $ (2000$) *($0,2M-$1M)*	Liu, Hammitt and Liu, 1997 (from Viscusi, 2003)
	Meta-analysis based on wage differential studies: median value of $7 million in the US ($7M)	Viscusi, 2003

Damage to property

Category	Values	References
individual property (houses and furnishings)	compensations asked for (2000): 495.678 BEF / 295.663 BEF (average values) *($11.379-$6.787)* 263.900 BEF / 163.000 BEF (median) *($573-$2540)*	KINT, 2001 Grinwis et al., 2001
	compensations received: 209.072 BEF / 93.946 BEF (average values) *($6.057-$2.156)* 143.429 BEF / 53.196 BEF (median) *($3.293-$1.221)*	KINT, 2001 Grinwis et al., 2001
	WTP flood insurance (2000): 2.800 / 3.358 BEF yearly (average) *($65-$77)* 2.000 / 2.000 BEF yearly (median) *($43-$43)* [tangible effects]	KINT, 2001 Grinwis et al., 2001
	WTP flood mitigation project (2000): 4.032-5.544 / 3.396-6.396 BEF yearly *($93-$127 / ($78-$147)* [including intangible effects]	KINT, 2001
	maximum damage to houses based on average selling price (2001): €95.569 (Flanders) *($87.780)*	Vanneuville W. et al., 2002
	average damage to furnishings = 50% of average damage to building	Vanneuville W. et al., 2002
	indirect damage = 1%-15% of direct damage (depending on water depth)	Vanneuville W. et al., 2002
	oceanfront property: - increase in beach width from 79 to 80 feet: increases value of developed lot by $558 ($754 for undeveloped lot) (selling prices, 1983) *($1.015 and $1.371)* [storm protection and recreational values] - increase in beach width from 119 to 120 feet: increases value of developed lot by $371 ($501 for undeveloped lot) (selling prices, 1983) *($675 and $911)* [storm protection and recreational values] ***property 0,5 mile from the beach:*** - increase in beach width from 79 to 80 feet: increases value of developed lot by $254 ($165 for undeveloped lot) (selling prices, 1983) *($462 and $300)* [storm protection and recreational values] - increase in beach width from 119 to 120 feet: increases value of developed lot by $169 ($110 for undeveloped lot) (selling prices, 1983) *($307 and $200)* [storm protection and recreational values]	Pompe and Rinehart, 1995
cars	average purchase price (2002, Belgium): €13.957 *($13.329)* average value (2002, Belgium): €4.627 *($4.447)* price (€) = $11405e^{(-0,2215x)}$ (x = age in years)	Vanneuville W. et al., 2002
public infrastructure	maximum damage to infrastructures: €96,2267/m² *($92)*	Vanneuville W. et al., 2002
recreational facilities	€0,0270/m² (mainly cleaning costs; for infrastructures on recreational sites: see category 'public infrastructure') *($0,03)*	Vanneuville W. et al., 2002

contamination (leakage from oil tanks,…) carrying away of soil contaminated by hydrocarbons removal of waste	5.000-9.000 BEF/m³ (1999) *($119-$214)*, depending on degree of contamination .	KINT, 1999
disruption of road traffic	marginal costs of road traffic disruption-cost/vehicle/day (1976-1977) major urban highway: £0,83 *($2,19)* major rural road: £0,56 *($1,48)* intermediate rural road: £0,61 *($1,61)*	Penning-Rowsell E.C., Parker D.J., 1987
disruption of shipping	*immobilisation of ships:* 10 BEF/ ton demurrage (1999) *($0,24)* personnel cost/day: two persons * 12 hours/day * 900 BEF/hour (1999) *($21,35)*	KINT, 1999
disruption of productive and service activities	average gross margin per m² floor space clothing and footwear shops: £4.3 per week (1977) manufacturing (interruption of commuter flows) 25-33 £ value added per person/day (1979) service sector (interruption of commuter flows) 12-40 £ wages cost per person/day (1980)	Penning-Rowsell E.C., Parker D.J., 1987 (from Penning-Rowsell and Chatterton)
	based on surface of industrial zone (2002): € 96,2267/m² *($91,90)*	Vanneuville W. et al., 2002
	based on number of employees (2002): energy: €199.715/employee *($190.736)* manufacturing industry: €199.715/employee *($190.736)* construction: €48.661/employee *($46.473)* traffic and transport: €228.101/employee *($217.846)*	Vanneuville W. et al., 2002
	indirect damage = 35%-45% of direct damage (depending on water depth)	Vanneuville W. et al., 2002
agriculture	€0,327/m² *($0,31)* agricultural land (2002); €0,073/m² *($0,7)* grassland (2002) (mean values for Flanders) indirect damage (cleaning costs, loss of soil fertility,…) = 10% of direct damage	Vanneuville W. et al., 2002

Damage to defence

Category	Values	References
fluvial flood defence	replacement costs: £8.400/km/yr *($9.971)*	DEFRA, 2001
tidal flood defence	replacement costs: £10.300/km/yr *($12.225)*	DEFRA, 2001
coastal flood defence	replacement costs: £32.300/km/yr *($38.338)*	DEFRA, 2001
coast protection	replacement costs: £53.700/km/yr *($100.786)*	DEFRA, 2001

Table 6: The value of flood damages: results from the literature

When assessing coastal defence investments on the basis of Cost-Benefit Analysis, the flood damage that can be avoided appears as a benefit. Defence costs constitute an important part of the cost-side. Average values, based on replacement costs, for different generic location types were found in DEFRA (2001).

It was assumed that the defences are constructed for a nominal 50 year design life but with the expectation that they may continue to provide residual protection to a similar standard for a further 10 years. Therefore, they will need to be replaced once every 60 years. A value of 38% of the annual capital costs has been determined to provide a reasonable estimate of actual maintenance costs required (i.e. average annual expenditure for each defence equivalent to 38% of 1/50th of the capital cost of providing a defence with a 50 year life).

4.3 Decision tree for selecting a valuation method

The state-of-the-art in valuation techniques produces a palette of options, from which inevitable trade-offs follow. We tried to indicate a possible procedure for choosing among different alternatives. The diagram is rather self explicatory, and shows that many ways lead to Contingent Valuation.

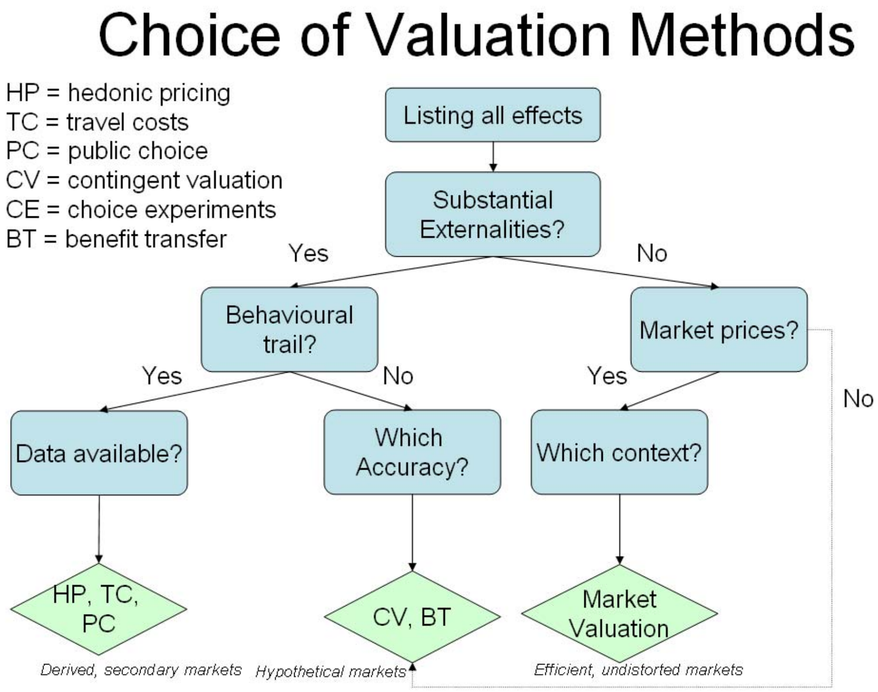


Figure 3: Decision tree for choosing valuation techniques

Environmental economists tend to prefer pure survey based CV methods, but when market prices for direct and indirect damages can be obtained, mixed approaches can be more informative for decision making. Care should be taken to exclude use values from CV studies, in order to avoid double counting. It must be noted that for wave-overtopping the Value of a Statistical Life can be determined using WTP estimates for a reduction in risk exposure.

4.4 Cost-Benefit Analyses of controlling overtopping

When evaluating flood alleviation schemes by means of Cost-Benefit Analysis, identifying and imputing a value on costs and benefits is an essential task. However, other crucial factors are the determination of the appropriate discount rate and the project life of the proposed scheme.

The outcome of the use of a valuation technique is often used to calculate present values in the context of Cost-Benefit Analyses. This implies that weights are attached to future effects. We refer to Annex 1 for more details on the use of discounting tables and annuities in Cost-Benefit Analysis. Defining the appropriate discount rate is not straightforward and no firm conclusions can be drawn on which rate should be used. In the study of Penning-Rowsell and Parker, for example, the standard Treasury Test Discount rate of 5 per cent is used and a scheme life of 50 years is assumed.

The social discount rate, measured as either the social rate of time preference (SRTP) or the social opportunity cost of capital (SOC), can be expected to be lower than the equivalent individual rate of discount. The rates currently recommended for project evaluation by the UK Treasury, for example, are 8% for commercial investments, 6% for public sector projects and 3% for the forestry sector. In a recent study by Pearce of the factors determining the social rate of discount in the UK, measured as the consumption rate of interest, it is argued that a rate of nearer 2% would be more appropriate (Ledoux and Turner, 2002).

As we saw earlier, some valuation techniques, particularly Contingent Valuation by working with questionnaires can include risk notions of the respondents. There are other ways, however, of integrating the results of Cost-Benefit Analysis in risk assessment, such as the scoring system developed in the UK at the Ministry of Agriculture, Fisheries and Food (MAFF) for administering the Grand Aid scheme for coastal erosion and flood defence schemes. As with any scoring system no theoretical or objective justification can easily be given.

In this scoring system equal weights are given to the priority, urgency and economic dimensions of a proposed project. Priority is graded on a scale from 1 to 5 ranging from rural areas where flood defence is of local significance (1), rural areas with environmental assets of national significance (2), urban areas with environmental assets of international importance (3), urban areas bordering the sea (4) and areas where flood warnings have been given (5). In the context of wave overtopping this could be applied in a similar manner. It means essentially that a third of the final score depends on the number of people potentially affected combined with the presence of environmental assets.

Urgency is ranked on the basis of expected failure, not expected within 5 years (1), expected within 5 years (2), expected within 2 years (3), already occurred (5). For wave overtopping risk the frequency of the past occurrence of events could be taken. Finally, the economic dimension is based on cost/benefit ratios ranging between 1-1,5 (1), between 1,5 and 2 (2), between 2 and 3 (3), between 3 and 5 (4) over 5 (5). In sum, the size of the population and environmental assets at risk, the frequency of occurrence of risk, and cost/benefit ratio determine the likelihood of a project receiving funding. This seems a quite reasonable proposal, also in the context of wave overtopping.

5 Cases

5.1 Introduction

This section presents the results of two case studies, in which we applied the valuation approach that was presented earlier. The first case study focuses on the village of De Haan (Belgium), where a beach nourishment project has been carried out after the coast was hit by a severe storm in 1990. The port of Rapallo (Italy), where the storm of November 6th 2000 caused extensive damage, is the setting for the second case study. Several criteria were important when selecting the case studies. One of the objectives was not to use the same valuation technique in both case studies, but to apply a selection of the methods described previously. Furthermore, in order to show that the institutional setting matters when dealing with overtopping, it was important to select cases within different institutional contexts. Data availability and time constraints also played a role. For both cases, the decision tree for selecting a valuation method was used.

5.2 The village of De Haan (Belgium)

5.2.1 Introduction

The focus of this case study is on the coastal defence works that have been carried out in De Haan, Belgium. The Flemish regional government opted for the approach of beach nourishment, a "soft" coastal defence measure. The first part of the case study concentrates on coastal defence in Belgium. Attention is also paid to policy in the neighbouring countries, in particular the Netherlands. Paragraph 5.2.3 will highlight some aspects of beach nourishments. Before discussing the economic implications related to the beach nourishment project in De Haan, we will go more deeply into the economic valuation method of Public Pricing and provide some examples of other valuation methods that have been applied in the context of beach nourishment schemes.

From an economic point of view, the risk of overtopping cannot really be separated from the risk of flooding for many coastal areas. This is also the case for the coastal barrier at De Haan, as it protects the polder lowlands. The measures that were taken after the storm that hit the Belgian West coast in 1990, reduced both the flood risk and the risk of overtopping. The beach nourishment scheme that was carried out did not only protect against the direct effects of overtopping, but also against flooding. When looking at Figure 3: , this means that substantial externalities are involved. As data are available on the behavioural trail, namely the costs related to the coastal defence works, this leads us to use the method of Public Pricing. Our valuation approach will thus consist of using public investment amounts, namely the costs of execution of the nourishment scheme, as well as the maintenance costs.

The current policy in Flanders (Belgium) is to protect against damage instead of protecting against a certain water level. 'Risk' replaces 'probability' as a central concept, whereby risk is defined as the 'probability of an event x the damage caused by the event'. If the damage caused by flooding is large, the probability of occurrence needs to be lowered (Vlaamse Regering, 2001). Safety requirements can be slightly less stringent in areas where flood damages are less severe. Socio-economic considerations in which both the consequences of potential flooding, as well as the costs related to flood protection are important, are the basis of the water control strategy.

Coastal defence schemes can take several forms: hard structures, nourishment schemes, managed retreat, etc. The combination of measures is another possibility. For beach nourishment, the design criteria in Flanders are the following:

a) The existing dune-foot must remain stable after two consecutive storms with a return period of 100 years;

b) If the same sequence of storms hits a section of the coast where a seawall exists, the beach nourishment must prevent the seawall from being exposed to direct wave attack by the first following storm.

The sea wall along the Dutch coast for example has to provide protection against water levels with a 1:10.000 probability of occurrence (the so-called Delta norm). No legal safety norms are in place for areas outside the dikes.

5.2.2 Safe Minimum Standards and the precautionary approach

An important concept in the context of possible irreversible damages to the environment is the Safe Minimum Standards decision rule, which recommends that when an impact on the environment threatens to breach an irreversible threshold, the conservation option should be adopted unless the costs of forgoing the development are regarded as 'unacceptable'. It is based on a principle of minimising the maximum possible loss, rather than cost-benefit and risk analysis which is based on maximising expected gains. (Ledoux and Turner, 2002). Design criteria such as the Delta norm in the Netherlands (protection against water levels with a 1:10.000 probability of occurrence) are an application of the Safe Minimum Standards rule. Damages caused by water levels with a probability of occurrence larger than e.g. 1:10.000 are regarded as inadmissible. According to the definition above, the use of a Safe Minimum Standards decision rule can be translated as follows: if the absence of a coastal defence structure would lead to damages larger than with the 1:10.000 threshold, the coastal defence works have to be carried out, unless the costs associated to the works are found to be unacceptable. Safe Minimum Standards decision rules do not necessarily exclude Cost-Benefit Analysis; both approaches can be used in combination.

5.2.3 Beach nourishment schemes

In Belgium, as well as in other countries such as the Netherlands, there is a tendency towards soft engineering approaches in dealing with coastal hazards. Solutions such as sand suppletions are preferred to the more traditional approaches of constructing "hard" coastal defence structures such as seawalls, groynes or breakwaters. Sand addition is also sometimes combined with hard defence structures.

In order to stop any further structural recession of the coast line, the Dutch Government adopted the national policy of "Dynamic Preservation" in 1990. It implies making optimal use of natural processes, and the principal method is sand nourishment. Sand suppletions emerged some 25 years ago in the Netherlands for the repair of beaches and dunes after erosion. 65 million m^3 of sand has been suppleted between 1991 and 2001 in the Netherlands, 11 million (15%) of which beneath the water surface. Since 2001, the Netherlands nourishes it's coastal system with a yearly amount of 12 million m^3/year. The nourishment budget has been raised and amounts to 41 million Euro per year.

A similar evolution can be discerned in the United Kingdom. During the 1930s, and especially after the January 1953 storm surge flooding, sea wall and groyne emplacements were built to deal with both erosion and flooding. Starting in the 1960s, the interaction of coastal engineering techniques with the environment gained importance, and alternative techniques including soft engineering solutions such as beach recharging, artificial headlands and offshore breakwaters were adopted occasionally. The need to understand natural processes and to work with nature rather than against it has been growing ever since. Less emphasis is now placed on hard defences and greater account has been taken of coastal processes through the adoption of soft and semi-soft defences (Pettit, 1999). The United States is another example of a country where beach nourishments are frequently carried out.

A certain ambiguity can be detected in the debate on "soft" or "hard" coastal defence solutions. On the one hand, "hard" measures can impact recreation negatively, e.g. when leading to a reduced contact with the sea. At certain locations however, the opposite is true. In the case of Ostend (Belgium) e.g., the direct contact between the sea and the dike is put forward as an argument against a beach nourishment scheme. Other examples of positive experience values that people attach to dikes can be given (e.g. Den Helder in The Netherlands).

Beach nourishments have been carried out in Belgium for over 20 years. The beach renourishment project at Knokke-Heist was completed in 1979. About 8.4 million m^3 of sand was executed. Earlier (but smaller) examples can, amongst others, be found in France (1961-1962), California, Brazil, The Netherlands,… The earliest beach nourishment project may well have been the dredging, in 1920, of Santa Barbara Harbor, California, and deposition of the material on the eroded beach down coast from the breakwater.

Natural processes become increasingly important within coastal defence. Some of the disadvantages of hard constructions are the relatively high maintenance and repair costs related to storm damage and their relative rigidity, which implies that possibilities to take uncertainties in e.g. climate conditions into account are limited. Nourishments can easily be adapted to changes in coastal patterns. So-called permanent structures are not flexible and may become harmful in a new situation, necessitating removal. In the long run, artificial accretion is less costly.

Sand suppletion schemes have several advantages. They are an effective and flexible way of dealing with coastal degradation. They are relatively cheaper than other defence measures and have the advantage that costs can be spread over time. The yearly maintenance costs in the Netherlands amount to 39 million Euro. More than 50 million Euro would have been needed if one had opted for "hard" measures. Furthermore, they fit well into the natural system. However, their disadvantages cannot be ignored. Two categories can be distinguished, namely the ecological and social (including recreative) disadvantages. Both beach nourishment as well as sand suppletion beneath the water surface eliminates the benthic population. In some cases this could lead to food shortage for certain bird or fish species. The works themselves can disturb the seabird population. Executing sand suppletions during the winter months, if possible, can mitigate those effects, as the chances of recovery are greater. This is also beneficial from a recreational point of view. The structure of the sand that is used can affect drifting patterns. Physical and chemical analyses can be useful to monitor the sand quality and detect possible contamination. Despite the detrimental ecological effects, suppletion schemes are considered to be the "least worst" alternative from an ecological point of view, compared to other coastal defence strategies, including the "do-nothing" option. Social effects include the nuisance caused during the works. Visual effects need to be mentioned as well. Furthermore, the fact that maintenance works have to be carried out quite frequently can have an impact on the feeling of safety.

Sand suppletion schemes are not only related to safety purposes. The importance of recreation and tourism in coastal zones has risen over the years and this trend is expected to continue in the future. A balance has to be found between safety, recreation, nature, economic functions and housing. Maintaining or improving coastal safety is of primary importance. However, this does not preclude pursuing other interests in the coastal zone. Sand suppletion schemes allow taking other considerations into account besides safety issues. The simultaneous stimulation of recreational facilities and consequently economic development can entail win-win situations.

In the Netherlands, suppletion beneath the water surface is becoming more popular than beach nourishments. Cost considerations play an important role. However, from a recreational point of view, beach nourishments are the preferred option, as they increase the beach width. The increased experience value can attract more tourists and thus lead to more tourist expenditure and job creation. This can also bring along an increase in the value of real estate. If recreational arguments lead to larger beach nourishment schemes than would be considered for pure safety-reasons, not only the benefits but also the increased costs (maintenance, ecological effects,…) have to be taken into account when evaluating the scheme. From an ecological point of view, beach nourishment is less harmful than suppletion beneath the water surface. It should also be mentioned that the effects of sand suppletion beneath the water surface only become apparent after nearly five years.

Morphology, ecological aspects, technical issues, administrative matters, political acceptability, as well as financial/economic criteria have to be considered when sand suppletion schemes are being evaluated. High costs are involved and maintenance works have to be carried out every five years.

If the concept of risk, defined as probability x effect, is central in a country's coastal defence strategy, a paradoxical situation can emerge. Beach nourishment schemes with a recreational impact lead to higher damage (effect) figures if the coastal defence fails. This in turn leads to a higher risk.

5.2.4 The valuation of beach nourishment projects

As has been stated before, we will use the method of Public Pricing to evaluate the effects of the coastal defence project that has been carried out in De Haan, Belgium. Before doing so, we will first provide a brief overview of valuation studies related to beach nourishment projects, in which other valuation methods have been applied. These studies have already been referred to in Table 6: .

Several costs and benefits can be associated with beach nourishment schemes. On the benefit side, in addition to storm protection, beaches can be associated with recreational and aesthetic values, both for tourists as well as residents. The protection level is higher as beaches are wider, and recreational values have also been found to increase with beach width. Erosion affects both the ability of the beach to provide protection against storms, as well as its recreational use. According to the Hedonic Pricing technique, the storm protection and recreational values are reflected in property values. Beach width, used as a partial measure of beach quality, thus contributes to the value of coastal property. Pompe and Rinehart (1995) studied property values in two South Carolina coastal towns. They have calculated that for oceanfront property, increasing the beach width of the high tide beach from 79 to 80 feet, increases the value of developed and undeveloped lots by $558 and $754 (actual selling prices, adjusted to 1983 prices by the national price index for housing), respectively. For lots located 0,5 mile from the beach, these values amount to $254 and $165. They have also discerned diminishing returns, as an increase of beach width from 199 to 120 feet leads to a rise of only $371 for oceanfront developed lots ($169 if the lots are located 0,5 mile from the beach) and $501 for oceanfront undeveloped lots ($110 if the lots are located 0,5 mile from the beach).

The importance of ocean frontage and distance to the beach has also been demonstrated by Parsons and Powell (2001). A $300.000 house for example, can attribute nearly $132.000 of its value to having that frontage (2000$). For houses inside a half-mile from the beach, each 25 feet from the coast is worth about $1200 for the same type of house.

Ledoux and Turner (2002) give an extensive overview of valuation studies on coastal and ocean resources. They find that the recreational value of beaches varies from 1,75 to 56 $2000 per person and per visit. The values seem to be lower in the UK than in the US.

5.2.5 Public Pricing

One of the methods that has been briefly mentioned when discussing valuation techniques is Public Pricing. With this method, public investment is used as a surrogate for market transactions. According to Turner et al. (2001), who describe this method in the context of wetlands, both use and nonuse values can be captured when using this technique. Investment by public bodies in conserving wetlands can be interpreted as the total values attributed to the wetland by society. However, they warn that this valuation technique is an extremely rough approximation of the theoretically-correct economic measure of social value, which is the sum of individual willingnesses to pay.

An example of an economic assessment of a beach renourishment scheme can be found in Knokke-Heist (Belgium), where a new beach with a width of about 100m at high tide was created. During the winter storms of 1976, a beach section of 9 km in length was eroded in front of the Knokke-Heist municipality. The beach profile was restored by beach nourishment, involving approximately 8,5 million m³. The works were carried out in the period 1977-1979. Only the economic rent derived from beach-based tourism was considered in the economic assessment. Income from visitors was estimated in 1984 at US$ 142 million/year (1984: 1 US$ = 66 BEF; 1988: 1 US$ = 35 BEF). Beach maintenance costs amounted to US $ 1 128 000 or about 20 c/tourist/day. It should be mentioned that the amortisation of the investment in the original project was not accounted for in the calculation, and the dredging could be written off as a no-cost item in this particular case, since it was required to provide a navigation channel. An additional beach replenishment of approximately 1 million m³ of sand was executed in 1986.

In the Netherlands, 259 million Euro has been spent on sand suppletion schemes in the period 1990-1999. The decreasing interest in hard constructions can be illustrated by comparing this figure with the 11 million Euro that was invested in “hard” solutions. The costs for beach nourishments in the Netherlands amount to 8 Euro/m³, whereas suppletions beneath the water surface cost 2-3 Euro/m³, although it has to be mentioned that those figures are of the lowest in the North-Sea area. However, the latter require sand volumes that are three times larger in order to obtain the same effectiveness. Total costs are influenced by the type of suppletion, the magnitude of the works, and the way in which they are executed.

5.2.6 Application of the valuation approach

De Haan, a tourist location, is centrally situated at the Belgian coast. Its beach is used for recreational purposes and different water sports such as sailing and windsurfing can be practised. The coastal barrier at De Haan protects the polder lowlands. The coast at De Haan suffered from severe erosion over the last 20 years. The Belgian West coast was hit by a severe storm in 1990. In the vicinity of De Haan, the beach almost disappeared and threats of floods became very real. The sloped seawall foundation was eroded.

In 1990, the Flemish regional government started to build coastal defence works in a coastline section at De Haan, using sandfill following the profile nourishment feeder berm concept (profile nourishment in combination with a feeder berm, using sand suppletion beneath the water surface). It was the first time that the feeder berm concept was executed in Europe. After a multi-criteria analysis of different solutions, this appeared to be the most appropriate and cost-effective system. The first phase, located at the centre of De Haan, involved the installation of ca. 1 300 000 m³ of sand (feeder berm + profile nourishment) over a length of 1990m. The works were carried out in the period 1991-1992. The nourishment at the centre of De Haan is designed to withstand two consecutive storms with a wave height with a 50-year return period.

A second phase, which concentrated on the zone westwards of phase 1, was started in 1993 after the severe storm of November 14, 1993. It ended in 1995. This second phase also included a suppletion of the dunes, on top of the feeder berm and profile nourishment (length: 3480m). The same safety level holds as for the first phase. By 1995, a total amount of 3 506 600 m³ has been suppleted in and westward of De Haan since 1991. The works in De Haan were carried out in several phases mainly for budgetary reasons.

As was mentioned before, the current policy in Flanders (Belgium) with respect to flooding is to protect against damage instead of protecting against a certain water level. In the past however, the value of the protected area was not explicitly considered in decision making processes. Consequently, monetary values of the benefits of the coastal defence works that have been carried out in De Haan are lacking. The valuation approach that is used in this case study is therefore based on the costs of the coastal defence works. When looking at these costs, both the costs of execution as well as maintenance costs need to be taken into account. On average, maintenance works related to beach nourishment projects are carried out after 5 to 10 years, depending on the erosion rate.

It is important to note that when using public investment amounts as a valuation approach, the problem of overtopping can not be separated from flooding. As the two problems are interrelated, the investments in coastal defence were not made to tackle them separately. By carrying out the project, both probabilities of flooding and overtopping were reduced.

We will focus on the works at the centre of De Haan, as this is the area where the problem of overtopping is relevant. The following table gives an overview of the volumes of sand that where involved in this area since the beginning of the works in 1991.

Year	m³	
1991-1992	661 787	feeder berm
1992	794 364	profile nourishment
1999	18 467	feeder berm
2000	260 493	profile nourishment
	101 989	feeder berm

Table 7: Sand volumes involved in the coastal defence works at De Haan

For the centre of De Haan, the costs of execution amounted to 7,928 million Euro or 3983,7 Euro/metre protected coastline. 6,661 million Euro was related to the profile nourishment. Maintenance costs need to be estimated and added to this figure in order to obtain a global picture of the costs that have been made for coastal defence at the centre of De Haan since 1991. This is done using the sand volumes for the maintenance works in 1999 and 2000 given in 0, and the average cost for beach nourishment and feeder berm projects in Belgium, which is between 5-10 euro/m³. Using 1992 as the reference year, 0 gives an overview of the maintenance costs. We present the results of calculations based on interest rates of 0%, 2%, 4% and 6% and costs of 5 euro/m³, 7,5 euro/m³ and 10 euro/m³. The table shows that the choice of which interest rate to use in a Cost-Benefit Analysis clearly impacts the results.

interest rate (%)	*0%*	*2%*	*4%*	*6%*
costs/m³				
5 euro/m³	1,905	1,627	1,394	1,199
7,5 euro/m³	2,857	2,441	2,092	1,798
10 euro/m³	3,809	3,255	2,789	2,397

Table 8: Maintenance costs (1992 million euro) of coastal defence works at De Haan

Total costs (execution costs and maintenance costs) are summarised in Table 9: . The table also gives the relative importance of maintenance costs for the different scenarios.

interest rate (%)	*0%*	*2%*	*4%*	*6%*
costs/m³				
5 euro/m³	9,833 maintenance: 19,4%	9,555 maintenance: 17%	9,322 maintenance: 15%	9,127 maintenance: 13,1%
7,5 euro/m³	10,785 maintenance: 26,5%	10,369 maintenance: 23,5%	10,02 maintenance: 20,9%	9,726 maintenance: 18,5%
10 euro/m³	11,737 maintenance: 32,5%	11,183 maintenance: 29,1%	10,717 maintenance: 26%	10,325 maintenance: 23,2%

Table 9: Total costs (1992 million euro) of coastal defence works at De Haan.

When using these figures in a Cost-Benefit Analysis, one has to take into account the fact that if no coastal defence works are undertaken, the beach needs to be levelled up yearly (mostly carried out in the months May and June). Moreover, in the 'no-project' scenario, provisions need to be made for repairs such as the repair of storm damage to hard coastal infrastructures. Obtaining average yearly estimates for the repair costs is difficult, as such works are carried out on an irregular basis. Provided that the necessary maintenance suppletions are executed, the coastal defence project will make such repair costs redundant. Maintaining and repairing the brushwood however needs to be done both with and without the project, although its efficiency increases because of the works. Adminstratie Waterwegen en Zeewezen (1995) estimated the maintenance costs in both situations ('project'/'no-project'). Using an average yearly cost of levelling up the beach (which was encountered before the coastal defence works) of 0,402 million Euro (1992 prices), they concluded that maintenance costs of the beach located at the centre of De Haan are lower than if the works would not have been undertaken.

5.3 The port of Rapallo (Italy)

The port of Rapallo (North-Western Italy) was hit by a storm on November 6th 2000, which caused extensive damage. This port is mainly used for recreational purposes, and some small-scale fishing also takes place. There was extensive damage to the coastal defence structure, some damage to ships and no lives were lost. Losses to production were assumed to be zero. Apart from the damage to the coastal defence, other types of damage were not sufficiently documented, so we had to rely on telephone interviews and assumptions had to be made, in order to complete the exercise. The main purpose was to establish a method, and when more exact data become available, the results can be used in a straightforward manner.

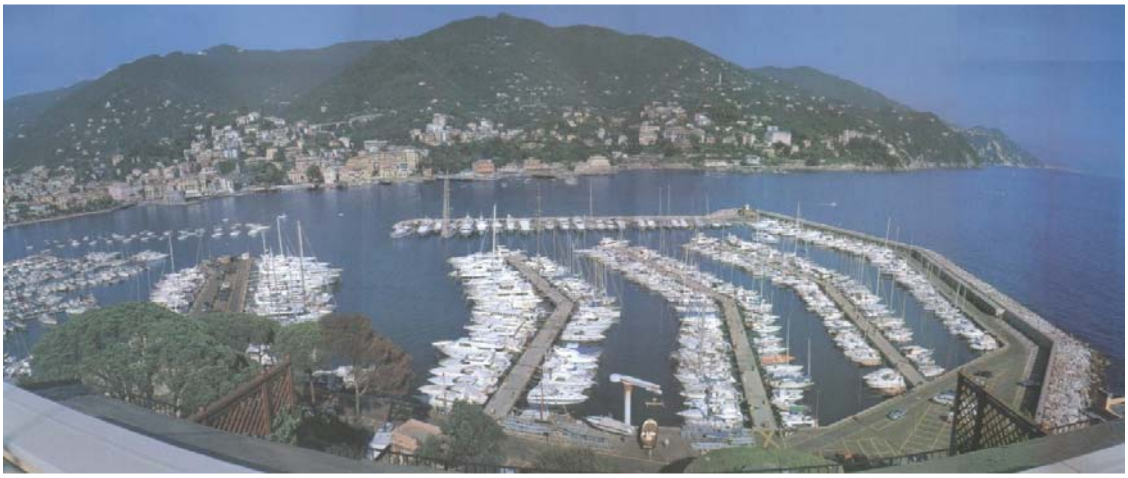
There seems to be no general policy on safety levels for Italy. In studies for Venice, the desired level is not so clear since the city inundates various times a year, and several protection options are still being considered. For other areas, however, there is no general norm used in public planning.

The possible damage of a wave overtopping event depends on a large number of factors: the presence of human settlements in the affected area, the income characteristics of the population, the timing and intensity of the event, the presence and value of private property, the value presence of companies, the amount of traffic, the level of investment in other infrastructure, the type of activities taking place, etc. Applying a cost/benefit criterion, the cost of preventing this damage should be less than the damage. Structural modifications to prevent damage produce a series of benefits, among which increased protection from wave overtopping but also from flooding in more severe cases of extreme weather. These modifications also produce some welfare losses in the sense that a marina becomes less attractive visually for users as well as neighbouring inhabitants. Indirect damage can consist of income loss for the marina's due to for example: lower occupancy rate of the marina; income loss by yacht owners due to higher insurance premiums; some efficiency losses due to restricted operations during the wave overtopping events themselves but also during periods in which damage is being repaired; damaged reputation for safety of the marina; possible landscape values affected by the damaged dams, the periods of reconstruction and the new coastal defences, etc.

5.3.1 Description of the port

In the practically tideless Italian seas, most harbours are built on open coasts and are protected by breakwaters. Typically, these harbours provide berths along a quay wall at the rear side of the main breakwater behind a concrete crown wall. In many cases the design of the parapet wall crest is constrained by stringent visual impact criteria, which are strictly enforced. The storm of November 6th 2000 caused extensive damage to moored yachts and to harbour structures and utilities at Marina Porto Sole in San Remo, Marina degli Aregai in Imperia and the Marina Carlo Riva in Rapallo in the Liguria region. The events caused by the storms were rather exceptional estimated to occur once every 70 years because of the wind direction and the long wave lengths. After this extreme weather event, the Italian government declared the state of emergency (Franco, 2003) (Modimar, 2003).

For reasons of data availability for damage to coastal defence structures, we chose the port of Rapallo. In many ways, the marina at Rapallo is representative of any of the aforementioned smaller ports. The port consists of two small basins, separated by a pier, one being the international port “Carlo Riva”, the other one being the municipal port. The Carlo Riva port, being the one on the sea-side, is the most vulnerable to damage from wave overtopping events. The number of berths is around 900 for Rapallo, 1.100 for San Remo and 600 for Imperia. The marina Carlo Riva is protected by a dam. About 500 m. deeper into the bay there is an area where shops and restaurants are located. During wave overtopping events, these areas can be affected by damage from partial inundation of the quays.



5.3.2 Application of the valuation approach

In the case of the damage valuation for this event at the port of Rapallo we chose to combine a market prices approach for the documented damage to coastal defence. Similarly, for damage to property, we focussed on the yachts. Based on telephone interviews, we assumed the extent of the damage. For production losses, we assumed a loss in the occupancy rate. All these valuations were done with market prices. Finally, for damage to human health or life, we assumed that once every 70 years a life was lost by similar events. The Value of a Statistical Life was taken to be 1.000.000 euro, but other values may be used. It was also assumed that no significant environmental externalities were affected by the wave overtopping event. It must be remembered that this calculation was done in order to illustrate the methodology. When more precise data become available, they should be used.

5.3.2.1 Material damage from overtopping

For the port of Rapallo not much data is available in order to assess the damage caused by this wave overtopping event. Damage assessment for the port of Rapallo will use mostly market prices associated with direct damage on public and private property. We have no idea in what measure the results obtained can be generalized, but the calculation is undertaken in order to illustrate the decision tree method proposed. For this marina we have the exact amount of restoration costs (4.254.891.803 lira = 2.197.468 euro), provided by a calculation done by the company "La Barbera Srl."

For estimating the production losses for the Marina we will use some rather cavalier assumption in order to illustrate the method. We will try to calculate a maximum upper bound estimate by rounding upward. This allows for externalities, which can not be valued by these partial methods, and just might have a relevant economic impact on welfare. We will also assume that damages are caused by wave overtopping and not by other associated phenomena like wind, flying debris, etc.

Suppose for one year the occupancy of the marina diminishes by 10%. This would include reduced efficiency during restoration works. For a total of about 900 berths (399 at the Marina Carlos Riva and 500 at the Porto Communale) this would correspond to 90 yachts giving up their place at the Rapallo port for a year. In another scenario, a 2 or 3 year period could be taken with lower associated loss in occupancy rate, but the results would be similar in order of magnitude. The yearly average rent for a yacht in the Marina is about 2.000 euros, so the total would be a one-time loss of 180.000 euro. In order not to create a false impression of accuracy we will round this upward to 200.000 euro, allowing for other cost increases associated with the event for the Marinas (overhead, administration costs, safety procedures, etc.).

For estimating the restoration costs to private property, we can suppose that 5 yachts (0,6% of total yachts) suffered damage for a total of 200.000 euros, or 40.000 euros per yacht. We can assume that a major part of this damage is covered by private insurance. In Table 11, we can appreciate that the amounts of production losses and restoration costs to private property does not exceed 11% of total damage and 61% of the damage to port infrastructure.

When n.a. (not available) is stated, no data were available at the moment of the investigation in the spring of 2004.

				Private property	Port infrastructure	Human Life and Health	Total
Minimal externalities	Undistorted Market prices available	(1) Production losses		200.000 €	- €	- €	
		(2) Restoration Costs Direct Damage		200.000 €	2.197.468 €	- €	
		(3) Relocation costs	n.a.				
		(4) Replacement costs	n.a.				
		(5) Mitigation costs	n.a.				
Significant externalities	Indirect methods (behavioural trail)	(6) Hedonic Pricing	n.a.				
		(7) Defensive expenditures	n.a.				
	Direct methods (questionaires)	(8) Contingent Valuation (Value of a Statistical Life)	n.a.			1.000.000 €	
		(9) Benefit tranfer	n.a.				
	Total			400.000 €	2.197.468 €	1.000.000 €	3.597.468 €
	Percentage			11%	61%	28%	100%

Table 10: Example of damage calculation for the Port of Rapallo

5.3.2.2 Non material damage

When we apply the decision tree mentioned above to choose the appropriate combination of valuation methods, we should first conclude that significant environmental externalities are probably not present. This is because no natural resources were severely damaged. Cultural resources might be present, but no valuation study exists. If natural and cultural resource would need to be included, a Contingent Valuation study should be carried out, but this falls beyond the scope of the current study.

With regard to other non-material damages, the image of the port of Rapallo might have been dented, but the low frequency of the event and the quick restoration of the damage must have minimized the loss of value associated with it. The restoration or improvement itself, however, could create some negative externalities by changing landscape values for the inhabitant of the port area. This is because some neighbours might object to a higher wall, for instance, which impairs their view to the sea. Similarly, with regard to decisions or behaviour associated with this event in derived secondary markets, the effects of a similar one-time event with relatively moderate impact must assumed to be minimal. We checked whether insurance premiums had gone up due to this event, but this does not seem to be the case. With regard to studies estimating the loss of these values due to wave-overtopping using hypothetical markets, no study which uses a similar scenario is known to us at this point, so we can not transfer any values "benefit transfer" because they were never mentioned in a comparable context. A specific Contingent Valuation study could be carried out for this particular case, but would be rather costly and outside the scope of the CLASH project.

Concerning the effects on human health or increased mortality risk, calculations can be made using values for the value of a statistical life (VOSL, or a statistical death avoided, SDA) from indirect labour costs or transportation studies, or direct methods that determine the willingness to pay for mortality risk reductions. More than 100 of these studies exist for many countries all over the world. By way of illustration, the indirect methods give results for the value of a statistical death avoided of between 1 and 17M dollars (2000), with an elasticity of income between 0,5 and 0,6 [Kip Viscusi & Aldy, 2003: 19-21]. The direct methods give somewhat lower values between $400.000 and $2M.

We will assume that that the effects of wave overtopping on human health are negligible. By way of illustration for the Value of a Statistical Life (VOSL) in one case 1M euros and in the other 10M euros is taken. During the specific event 4 ports suffered overtopping damage and 4 people died in or around these ports. Consequently, for one port we can assume one life lost. If we assume a probability of this event of once every 70 years, and the VOSL of 1M euros for this period, the net present value (NPV) or expected value of the damage for each year during this period is 231.027 euros, or rounded to 230.000 euros. We can also calculate the annuity for this sum. An annuity is the annual fixed sum at the given interest rate of e.g. 4% that would have to be saved for paying the calculated damage in the future. In this case the annuity is 9.495 euros, rounded to 10.000 euros. In the case we take the VOSL of 10M euros, the NPV of the damage would be 809.002 euros, and the annuity 33.251 euros, rounded to 35.000 euros.

Conventionally for the analysis of investment projects with a time-span of more than 50 years, we take a discount rate that is lower than the commercial rate. For very long-term projects even a 1% or 2% discount rate is used. There is however no theoretical or experimental basis for using one or the other discount rate. If we take again 1M euros for the VOSL, for example, but a commercial interest rate of 6% instead of 4%, the NPV of the damage becomes 60.896 euros and the annuity 3.506 euros.

From this simple sensitivity analysis, it can be concluded that in the case of damage from wave-overtopping events the results of the social Cost-Benefit Analysis will hinge critically on the value of a statistical death avoided (or life saved) and the discount rate used. Unfortunately, the wide range of values for the VOSL that have been reported in various studies, and the lack of theoretical justification for using one or the other discount rate, will not allow reporting very accurate results.

If externalities of all kinds are not substantial - in terms of uninsured third party damage, environmental resources, cultural heritage, human life and health or landscape externalities - partial valuation methods based on undistorted market prices should be used.

Subsequently, if research budgets permit these can be supplemented with valuations of passive use or option values. Estimates for these values can be obtained by a variety of methods, of which Contingent Valuation (CV) is the most flexible and complete. CV studies use questionnaires and describe hypothetical markets. With the help of a precisely described scenario, willingness to pay for, in this case, a decrease in the risk of becoming victim of a wave overtopping scenario is obtained through some kind of bidding game. With or without significant externalities, Contingent Valuation studies can still be used as supplemental information, but in all cases scenarios would have to be constructed very carefully in order to avoid protest bids or and invalid responses. Benefit transfer studies are impossible since no similar studies have been identified up to now.

Taking an interest rate of 4% and a Value of a Statistical Life of 1M euros, an illustrative calculation for the consequences of the storm of November 6th for the two Marina's at Rapallo – with a probability of occurring once every 70 years - show that around 11% of damage is directly linked to private property or to production losses while 61% is related to the port infrastructure, and 28% to loss of human life. Given the margins of error in these calculations, it is better to report these numbers respectively as around 10%, 60% and 30%. This implies that justification for costly works to prevent all wave-overtopping damage will be based mostly on damage avoided in future events to the infrastructure, not on other associated value losses. An additional issue is that some of the works to prevent damage, notably the construction of a wall that impairs an unobstructed view to the sea from the port, might cause significant value losses.

6 Conclusions and recommendations to policy makers

Within the scope of this study (Clash-Task 4, WP6) a theoretical background and practical guidelines to the assessment of the socio-economic impacts of overtopping at seawalls and related coastal defence structures are presented. Despite a lack of consensus on the economic values for a number of damage categories, an approach is presented and applied in two cases. One case is situated in a Belgian context (the village De Haan) and the other case is located in Italy (the port of Rapallo).

Both cases show how a trade-off between the costs and benefits of controlling overtopping can be framed. This study indicates that a valuation is a process which asks for a number of assumptions and an awareness of how the final trade off between costs and benefits is strongly influenced by how the concept of risk is dealt with. Nevertheless, the study tried to provide some general guidance on how to identify and deal with the contextual embeddings of identifying and assessing the socio-economic impacts of overtopping.

Depending on the expected levels of overtopping, the risks of economic losses can be identified. Policy makers that decide on the acceptable level of overtopping will be confronted with assessing both the costs and benefits of controlling overtopping. Clearly, these assessments take place within a decision-making process context that is different for each of the EU member states. WP 6 (Deliverable D38) provides guidance to classify hazards and how they are perceived.

The perception of direct hazards indicates that the risk of death is an ultimate level of hazard. Whether this is to be included into the economic assessment, is to be decided by the decision-makers themselves. If, the answer is yes, then WP 6 (Deliverable D39) provides valuation methods and some results currently available in literature.

In many cases the context of decision-making is such that the explicit valuation of the risk of death will not take place. Here decision-makers might deal with it implicitly by introducing safety norms. These norms do not necessarily define the acceptable level of overtopping (**defence standard**) but might also provide standards with respect to:

- **Acceptance of human activities** (thereby modifying the land use category and/or habitat status of the area affected by the overtopping (hazard zone))
- **Acceptance of occasional hazard** at acceptable probability (acceptable risk) by providing for temporary use and/or short-term evacuation with reliable warning and evacuation systems, and/or use of temporary / demountable defence systems;

With respect to the valuation of hazards this report presents a procedure. Effects might be valued by using monetary values provided by the current literature (see section 4.2). Hence, if these values need to be further specified for a specific site some guidance is given on which valuation method can be applied (Figure 4:). Different effects of overtopping ask for different valuation techniques. Damage to houses and furniture for example, can be defined by using market prices (market analysis). Whereas damage to ecosystems (defined as an externality) can be valued by using a Contingent Valuation Method.

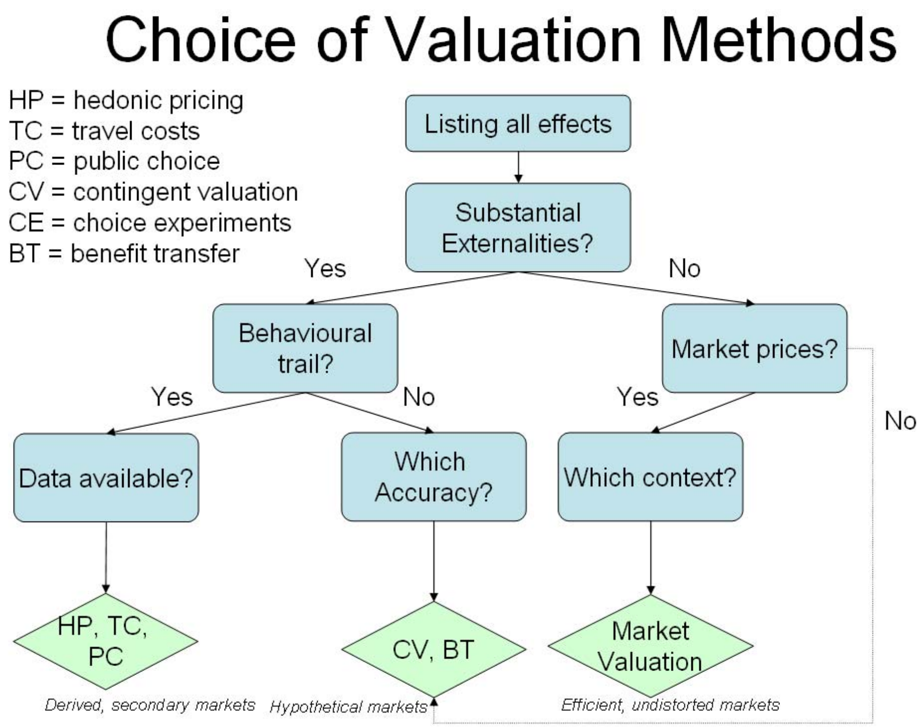


Figure 4: Decision tree for choosing valuation techniques

Environmental economists tend to prefer pure survey based Contingent Valuation Methods, but when market prices for direct and indirect damages can be obtained, mixed approaches can be more informative for decision making.

When evaluating flood alleviation schemes by means of Cost-Benefit Analysis, identifying and imputing a value on costs and benefits is an essential task. However, other crucial factors are the determination of the appropriate discount rate and the project life of the proposed flood alleviation scheme.

The outcome of the use of a valuation technique is often used to calculate present values in the context of Cost-Benefit Analyses. This implies that weights are attached to future effects. WP6 (Deliverable D39) provide details on selecting a discount rate and the use of discounting tables and annuities in Cost-Benefit Analysis. Two case studies illustrate how the effects of overtopping can be valued (WP6, Deliverable D39).

Annex 1: The use of discounting tables and annuities in Cost-Benefit Analysis

A payment for an investment in coastal defence, for instance, made in the future has a lower value today due to discounting. The amount that it is worth today is called present value (PV). Conversely, a similar payment made today has a higher value in the future, which is called Future Value (FV). In the case of calculating the present values of net benefits, the first step is to calculate the PV of the flow of all cost and benefits using Table 11: or Table 12: , and then sum them up. Secondly, the annuity, or annual payment or revenue can be calculated using Table 13: for the same interest rate and project life-time.

Money invested in a project has an opportunity cost, since alternatively it could be put in an interest bearing bank account. If money is put in a bank account, usually an interest rate is paid. If not withdrawn from the account, the interest payment is included in the calculation of the interest in the following period, leading to compound interest calculation. Sometimes it is calculated on a yearly basis, more often on a continuous basis.

In the first discrete case, the amount paid out after one year is FV = PV (1+r). In the second year, FV = PV $(1+r)^2$, and in year t: FV = PV $(1+r)^t$. Conversely, PV = FV / $(1+r)^t$. These formulas were used to calculated the values in Table 11: .

Table 1a: Discrete compound interest rates and rates of discount for year t and rate r

t r	10	15	20	25	30	35	40	45	50	55	60	65	70
0,0%	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0,5%	1,051	1,078	1,105	1,133	1,161	1,191	1,221	1,252	1,283	1,316	1,349	1,383	1,418
	0,951	0,928	0,905	0,883	0,861	0,840	0,819	0,799	0,779	0,760	0,741	0,723	0,705
1,0%	1,105	1,161	1,220	1,282	1,348	1,417	1,489	1,565	1,645	1,729	1,817	1,909	2,007
	0,905	0,861	0,820	0,780	0,742	0,706	0,672	0,639	0,608	0,579	0,550	0,524	0,498
1,5%	1,161	1,250	1,347	1,451	1,563	1,684	1,814	1,954	2,105	2,268	2,443	2,632	2,835
	0,862	0,800	0,742	0,689	0,640	0,594	0,551	0,512	0,475	0,441	0,409	0,380	0,353
2,0%	1,219	1,346	1,486	1,641	1,811	2,000	2,208	2,438	2,692	2,972	3,281	3,623	4,000
	0,820	0,743	0,673	0,610	0,552	0,500	0,453	0,410	0,372	0,337	0,305	0,276	0,250
2,5%	1,280	1,448	1,639	1,854	2,098	2,373	2,685	3,038	3,437	3,889	4,400	4,978	5,632
	0,781	0,690	0,610	0,539	0,477	0,421	0,372	0,329	0,291	0,257	0,227	0,201	0,178
3,0%	1,344	1,558	1,806	2,094	2,427	2,814	3,262	3,782	**4,384**	5,082	5,892	6,830	7,918
	0,744	0,642	0,554	0,478	0,412	0,355	0,307	0,264	0,228	0,197	0,170	0,146	0,126
3,5%	1,411	1,675	1,990	2,363	2,807	3,334	3,959	4,702	5,585	6,633	7,878	9,357	11,113
	0,709	0,597	0,503	0,423	0,356	0,300	0,253	0,213	0,179	0,151	0,127	0,107	0,090
4,0%	1,480	1,801	2,191	2,666	3,243	3,946	4,801	5,841	7,107	8,646	10,520	12,799	15,572
	0,676	0,555	0,456	*0,375*	0,308	0,253	0,208	0,171	0,141	0,116	0,095	0,078	0,064
4,5%	1,553	1,935	2,412	3,005	3,745	4,667	5,816	7,248	9,033	11,256	14,027	17,481	21,784
	0,644	0,517	0,415	0,333	0,267	0,214	0,172	0,138	0,111	0,089	0,071	0,057	0,046
5,0%	1,629	2,079	2,653	3,386	4,322	5,516	7,040	8,985	11,467	14,636	18,679	23,840	30,426
	0,614	0,481	0,377	0,295	0,231	0,181	0,142	0,111	0,087	0,068	0,054	0,042	0,033

Table 11: Discrete compound interest rates and rates of discount for year t and rate r

In the case of continuous compound interest calculation, the natural logarithm e is used to calculate the future value. FV = PV e^{rt}. Using these formulas the values in Table 12: were calculated, for relatively low interest rates and long periods customarily used for investment in infrastructure projects. It is customary to use the continuous compound interest formula for similar projects.

Table 1b: Continuous compound interest rates and rates of discount for year t and rate r

t r	10	15	20	25	30	35	40	45	50	55	60	65	70
0,0%	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0,5%	1,051	1,078	1,105	1,133	1,162	1,191	1,221	1,252	1,284	1,317	1,350	1,384	1,419
	0,951	0,928	0,905	0,882	0,861	0,839	0,819	0,799	0,779	0,760	0,741	0,723	0,705
1,0%	1,105	1,162	1,221	1,284	1,350	1,419	1,492	1,568	1,649	1,733	1,822	1,916	2,014
	0,905	0,861	0,819	0,779	0,741	0,705	0,670	0,638	0,607	0,577	0,549	0,522	0,497
1,5%	1,162	1,252	1,350	1,455	1,568	1,690	1,822	1,964	2,117	2,282	2,460	2,651	2,858
	0,861	0,799	0,741	0,687	0,638	0,592	0,549	0,509	0,472	0,438	0,407	0,377	0,350
2,0%	1,221	1,350	1,492	1,649	1,822	2,014	2,226	2,460	2,718	3,004	3,320	3,669	4,055
	0,819	0,741	0,670	0,607	0,549	0,497	0,449	0,407	0,368	0,333	0,301	0,273	0,247
2,5%	1,284	1,455	1,649	1,868	2,117	2,399	2,718	3,080	3,490	3,955	4,482	5,078	5,755
	0,779	0,687	0,607	0,535	0,472	0,417	0,368	0,325	0,287	0,253	0,223	0,197	0,174
3,0%	1,350	1,568	1,822	2,117	2,460	2,858	3,320	3,857	**4,482**	5,207	6,050	7,029	8,166
	0,741	0,638	0,549	0,472	0,407	0,350	0,301	0,259	0,223	0,192	0,165	0,142	0,122
3,5%	1,419	1,690	2,014	2,399	2,858	3,404	4,055	4,831	5,755	6,855	8,166	9,728	11,588
	0,705	0,592	0,497	0,417	0,350	0,294	0,247	0,207	0,174	0,146	0,122	0,103	0,086
4,0%	1,492	1,822	2,226	2,718	3,320	4,055	4,953	6,050	7,389	9,025	11,023	13,464	16,445
	0,670	0,549	0,449	*0,368*	0,301	0,247	0,202	0,165	0,135	0,111	0,091	0,074	0,061
4,5%	1,568	1,964	2,460	3,080	3,857	4,831	6,050	7,576	9,488	11,882	14,880	18,634	23,336
	0,638	0,509	0,407	0,325	0,259	0,207	0,165	0,132	0,105	0,084	0,067	0,054	0,043
5,0%	1,649	2,117	2,718	3,490	4,482	5,755	7,389	9,488	12,182	15,643	20,086	25,790	33,115
	0,607	0,472	0,368	0,287	0,223	0,174	0,135	0,105	0,082	0,064	0,050	0,039	0,030

Table 12: Continuous compound interest rates and rates of discount for year t and rate r

The discounting table gives the multiplication factors for future or present value calculations. In Table 11: and Table 12: , we can see, for example, that when $100 is left in a bank account paying 3% interest, after 50 years it is worth $438,30 using the discrete formula, or $448,20 using the continuous formula. Conversely, the value today of $100 in 25 years at 4% interest is, respectively $37,50 and $36,80. (see Table 11: and Table 12: , the highlighted factors).

In Cost-Benefit Analysis, first a flow of costs and benefits in different years is tabulated for the duration of the project. These costs and benefits can be different amounts in different years. Then the PV of each of these values is calculated. The PVs are then summed leading to PV of the costs C_{pv} and PV of the benefits B_{pv}. Benefits are then substracted from costs. We would like to know now, with a given interest rate and duration of the project, to what annual benefit or cost (if the result is negative) this corresponds. Since the flow of costs and benefits in time is uneven, we can even this out to an average annual sum. This is called an annuity. In a standard accounting book $C_{pv} - B_{pv}$ corresponds to the original amount borrowed.

The annuity formula for the discrete case is:

$$A = (C_{pv} - B_{pv}) \frac{r(1+r)^t}{(1+r)^t - 1}$$

For the continuous case the factor e^{rt} is used instead of $(1+r)^t$. Note that the values found in Table 13: for the continuous case are slightly higher.

Table 2: Factor for annuity payment A when PV is known (discrete and continuos case)

t	10	15	20	25	30	35	40	45	50	55	60	65	70
r													
0,0%	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
0,5%	0,103	0,069	0,053	0,043	0,036	0,031	0,028	0,025	0,023	0,021	0,019	0,018	0,017
	0,103	0,069	0,053	0,043	0,036	0,031	0,028	0,025	0,023	0,021	0,019	0,018	0,017
1,0%	0,105	0,072	0,055	0,045	0,039	0,034	0,030	0,028	0,025	0,024	0,022	0,021	0,020
	0,106	0,072	0,055	0,045	0,039	0,034	0,030	0,028	0,026	0,024	0,022	0,021	0,020
1,5%	0,108	0,074	0,058	0,048	0,041	0,037	0,033	0,031	0,028	0,027	0,025	0,024	0,023
	0,108	0,075	0,058	0,048	0,042	0,037	0,033	0,031	0,029	0,027	0,025	0,024	0,023
2,0%	0,110	0,077	0,061	**0,051**	0,044	0,040	0,036	0,034	0,032	0,030	0,029	0,027	0,027
	0,111	0,078	0,061	**0,051**	0,045	0,040	0,037	0,034	0,032	0,030	0,029	0,028	0,027
2,5%	0,113	0,080	0,064	0,054	0,047	0,043	0,040	0,037	0,035	0,033	0,032	0,031	0,030
	0,114	0,081	0,064	0,054	0,048	0,043	0,040	0,037	0,035	0,034	0,032	0,031	0,030
3,0%	0,116	0,083	0,066	0,057	0,051	0,046	0,043	0,040	0,039	0,037	0,036	0,035	0,034
	0,117	0,084	0,067	0,057	0,051	0,047	0,043	0,041	0,039	0,037	0,036	0,035	0,034
3,5%	0,119	0,086	0,070	0,060	0,054	0,050	0,046	0,044	0,042	0,041	0,040	0,039	0,038
	0,120	0,087	0,070	0,061	0,054	0,050	0,047	0,044	0,043	0,041	0,040	0,039	0,038
4,0%	0,121	0,089	0,073	0,063	0,057	0,053	0,050	0,048	0,046	0,045	0,044	0,043	0,043
	0,123	0,090	0,074	0,064	0,058	0,054	0,051	0,048	0,047	0,045	0,044	0,043	0,043
4,5%	0,124	0,092	0,076	0,067	0,061	0,057	0,054	0,052	0,050	0,049	0,048	0,048	0,047
	0,126	0,093	0,077	0,067	0,061	0,057	0,054	0,052	0,051	0,049	0,048	0,048	0,047
5,0%	0,127	0,095	**0,079**	0,070	0,064	0,061	0,058	0,056	0,054	0,053	0,053	0,052	0,052
	0,130	0,096	*0,080*	0,071	0,065	0,061	0,058	0,056	0,055	0,054	0,053	0,052	0,052

Table 13: Factor for annuity payment A when PV is known (discrete / continuous case)

When the PV of the net benefits of an investment is $100, for example, the payment over 25 years at 2% interest is $5,10 a year. Similarly, when the PV of an investment is $100, over 20 years with an interest of 5%, the payment with the continuous calculation method would be $79, while with the discrete method $80. We can appreciate that in the calculation of annuities for low interest rates and long periods, the difference between the discrete and continuous case is negligible.

Annex 2: Distributional issues: who pays the bills?

By way of comparison, if no insurance or state disaster fund were to exist, the Marina would need to set up a revolving fund and safe the total sum in a bank account during 70 years in order to compensate for all damage. Suppose the initial sum were donated by the State. We can also assume that the Marina can distribute this payment to the revolving fund over its members. Table 14: below shows the total payment in case the money is invested at a 3% interest rate and in the case it is invested at a 6% interest rate.

Interest rate	Yearly payment	Number of owners	Sum per member
3%	-11.264,24 €	900	-12,52 €
6%	-2.683,52 €	900	-2,98 €

Table 14: Distributional Issues: yearly insurance payments

This calculation shows how much would be paid by 900 yacht owners if they decided to set up a private fund to insure against similar damage. It can be concluded that a similar risk-tax of between 3 and 13 euros compared to an average yearly payment for a berth of about 2.000 euros, consists of only between 0,1% and 0,6% of yearly costs for each yacht owner. This tiny increase in costs for a presumably high income group of the population does not seem to warrant a transfer of public money to compensate for this type of wave overtopping damage. In absence of a disaster fund or insurance policy, setting up a revolving fund to insure against this type of damage would involve a sum of less than 13 euros per year. Truly not a sum to justify a transfer of public money.

Annex 3: Port of Rapallo contact data

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