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FP7-ENV-2010 | Project 265280

The Total Cost of Hydrological Disasters:

Reviewing the Economic Valuation Methodologies and Conceptualizing a Framework for Comprehensive Cost Assessments

Work package	1			
Dissemination level	□ Public X Restricted to specific group		□ Restricted to programme □ Confidential	
Publishing date	Contractual: 30.06.2011		Actual: 30.06.2011	
Deliverable	1.4		X Internal	□ Final
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Short abstract	The rising costs of disasters caused by floods and landslides make it a high priority to improve the quality and the reliability of the assessment exercises, so as to inform risk prevention policies. The concept of total cost is much more ambitious than what has been traditionally provided, because it aims at describing the total burden imposed by a disaster to a socio-ecosystem. The true costs of disasters include costs (and benefits) which are difficult to identify and quantify. It comprises all direct, indirect, tangible and intangible costs. Apart from direct and tangible costs, the remaining cost elements have been largely neglected in the field of economics of natural disasters. This report builds on these categories of costs presenting specific examples for the hydrological disasters. A brief review of economic valuation methodologies and project appraisal methods is also provided. Given that the full estimation of the total costs might turn challenging and controversial, we propose alternative options to traditional cost-benefit analysis for processing the retrievable information, including non-monetary impacts.			
Keywords	Hydrologic disasters, economic valuation, risk reduction, climate change, adaptation, indirect costs, intangible costs, project appraisal.			
Document	2011-Kulturisk_D-1-3_internal			

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ACKNOWLEDGEMENT
The work described in this publication was supported by the European Community's Seventh Framework Programme through the grant to the budget of the Collaborative Project KULTURisk ENV.2010.1.3.2-1.

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FUNDAMENTAL NOMENCLATURE

The different meanings of the terminology in use that were found in the literature made it imperative to specify how those terms have been treated **in this report**. Therefore, the fundamental terminology is described below, drawing on the related references.

Damage. A damage caused by a disaster is the physical destruction measured by physical indicators such as number of deaths or number of buildings destroyed. When valued in money terms damages becomes direct costs (NRC 1999).

Disaster. A disaster is the outcome of a hazard negatively impacting on a socio-ecosystem (Okuyama and Sahin 2009, EEA 2010). The magnitude of the disaster is positively related with the intensity of the hazard and with the exposure and the vulnerability of the socio-ecosystem.

Direct Cost. Direct costs are the costs due to the damages provoked by the hazard and which occur during the physical event (Merz et al. 2010).

Exposure. Exposure is defined in this report as the presence of people, livelihoods, environmental services and resources, infrastructure, and economic, social, and cultural assets in areas or places that are subject to the occurrence of physical events and that thereby are subject to potential future negative impacts (UNISDR 2009b; Gasper 2010).

Hazard. The hazard is the occurrence of the physical event, which can happen with a certain probability and intensity. The difference between the hazard and the disaster is that a hazard may not cause any negative impact (EEA 2010). We made use of the classification of hazards (i.e. geophysical, climatological, hydrological, meteorological) of CRED (2008).

Hydrological Hazards. Hydrological hazards, according to the classification of CRED (2008), include floods and landslides (flash floods is a subcategory of floods and debris flow a subcategory of landslides). Landslides are often connected with flood events.

Impact. An impact can be any positive, but predominantly negative, consequences to the social, economic and environmental dimensions of the system interested by the hazard (NRC 1999). Impacts include tangible and intangible costs.

Indirect Cost. Indirect costs are those induced by the hazard but occurring, in space or time, outside the physical event (Merz et al. 2010).

Intangible Cost. Intangible costs are those values lost due to a disaster which cannot, or are difficult/controversial to, be monetized, because they are non-market values (NRC 1999, Merz et al. 2010).

Loss. A loss is a market-based negative economic impact. It includes the direct and indirect tangible (economic) costs, but not the intangible costs (NRC 1999). A loss can also be referred to intangibles but has to be specified (e.g. “Loss of lives”).

Resilience. Resilience is given by the capacity of a system, community or society potentially exposed to hazards to adapt, by anticipating, resisting or promptly recovering in order to reach and maintain an acceptable level of functioning and structure (UNISDR 2005a, Gaillard 2010).

Risk. The concept of risk refers to the combination of the probability of a certain hazard to occur and of its potential negative impacts (EC 2007; FLOODsite 2009; UNISDR 2009b). Risk is, therefore, the damage that occurs or will be exceeded with a certain probability in a certain time period (Merz et al. 2010).

Social Cost. The social costs of a disaster represent the total burden imposed by a disaster, that is the value lost to society including the opportunity costs of resources deployed for reconstruction and relief (Dore and Etkin 2000; EPA 2008). The estimation of the full social cost implies the monetization of the social, economic and environmental impacts. This is what we defined as the true cost of a disaster.

Tangible Cost. Tangible costs are the costs which can be easily specified in monetary terms because they refer to assets which are traded in a market (NRC 1999, Merz et al. 2010).

Vulnerability. Vulnerability is defined in this report as the susceptibility or predisposition for loss and damage to human beings and their livelihoods, as well as their physical, social, and economic support systems when affected by hazardous physical events. Vulnerability includes the characteristics of a person or group and its situation that influences its capacity to anticipate, cope with, resist, respond to, and recover from the impact of a physical event (Wisner et al 2004; Schneider et al 2007; Cardona 2010; Gaillard 2010:). The term sensitivity is often used to connote susceptibility in the above context.

1 EXECUTIVE SUMMARY

The rising impacts of natural hazards

Losses due to natural disasters have been increasing in recent years (Downton and Pielke 2005; WB-IEG 2006; Bower et al. 2007; CRED 2007, 2008, 2010; Okuyama and Sahin 2009; UNISDR 2009a). According to the data collected by Munich Re, **global direct losses** due to climatological, hydrological and meteorological disasters have increased from an annual average U.S.$ 8.9 billion, for the period 1977-1986, to U.S.$ 45.1 billion, for the period 1997-2006 (Bower et al.2007). When expressed as a portion of gross domestic product (GDP) estimated losses in developing regions, and particularly in the small island states, are generally higher than those in developed regions (IPCC 2011). Though the losses have been increasing worldwide over the past few decades, the figures show that the **fatalities** have increased in developing countries, but decreased in developed countries (Dore and Etkin 2000). Further, there is high confidence that **climate change** will affect natural disaster risk not only through changes in the probability, intensity, and duration of extreme events, but also increasing exposure and vulnerability, which are currently the main drivers (Pielke and Landsea 1998; Bower et al.2007; UNISDR 2009a). The rising costs of natural disasters make it a high priority to improve the quality and the reliability of the assessment exercises, so as to inform mitigation and risk management policies (Mysiak et al 2009).

Hydrological hazards and disasters

This report focuses on **hydrological hazards**, which according to the classification of CRED (2008) include **floods and landslides** (flash floods is a subcategory of floods and debris flow a subcategory of landslides)[1]. Landslides are often connected with flood events. In fact, hydrological hazards are all associated with heavy and/or prolonged rainfalls, but their consequences are potentially aggravated by land-use management including uncontrolled urbanization (EEA 2010). Okuyama and Sahin (2009) show that in a global sample of 184 disasters over the last 47 years 25% of the total losses came from hydrological disaster (40% of total losses are due to geophysical disasters such as earthquakes).

Flooding is the most dangerous natural hazard in Europe in terms of losses (EEA 2010). Indeed, integrated flood risk management has become a priority for the European Union (e.g. EC 2007; EFAS 2010). Between 2003 and 2009 twenty-six major events produced direct losses of about EUR 17 billion and 320 human fatalities. In public perception human life loss is the most considerable disaster impact (Jonkman and Vrijling 2008). Here, the worst cases are usually related to **coastal flooding, flood defence failure, flash floods and landslides**, but in Europe this risk is quite low (Jonkman and Vrijling 2008; FLOODsite 2009; EEA 2010; Green et al 2011). **Losses** as a consequence of floods and landslides have increased over the past decades in Europe due to an increase of population and assets in the exposed areas. However, some bias might have been introduced by the improvements in data collection in the recent years (EEA 2010).

[1] Although floods from the sea in costal areas are due to meteorological hazards, the insights of this report may still be applicable.

A **disaster** is the outcome of a hazard negatively impacting on a socio-ecosystem (Okuyama and Sahin 2009, EEA 2010). The **magnitude** of the disaster is directly related with the **intensity** of the hazard and with the **exposure** and the **vulnerability** of the socio-ecosystem. A disaster can be described in many ways: number of deaths, number of building collapsed, kilometres of roads washed away, etc. **Valuation** clearly is a useful way to summarize the available information and economic valuation is usually the preferred approach given that there is a tendency that political arguments have a higher impact when backed up by monetary figures (Economist 2006). In general, when the numbers depict concrete economic gains or losses, political processes and decisions face an increased public awareness, an example being the remarkable impact of the Stern Review (Stern 2006) on the debate about climate change policy and governance.

In the case of disaster risk reduction, economic valuation is of great relevance for public policy in that it may help to determine the relative advantages of different possible measures.

Risk management and economic valuation

The magnitude of the **costs of disasters** is co-determined by the ability of affected individuals and communities to absorb or cushion against hazards (Rose 2004b). One main way to effectively mitigate the risk is to increase the resilience and to reduce the exposure and the vulnerability of the socio-ecosystems to the hazards. However, until the 1990s, disaster management was primarily focused on the response of governments, communities, and international organizations to deal with the **consequences of disasters** after they occurred. Nowadays the focus has been significantly shifted to the role of **knowledge and preparedness** (UNISDR 2004b). The reason is twofold: (a) disasters are permeated with intrinsic uncertainty and this will be exacerbated by climate change; and (b) the magnitude of a disaster will increasingly depend on the behaviour of the affected people behaviour and on the ways it will adapt. This is why the scientific communities related to “disaster risk reduction” (DRR) and “climate change adaptation” (CCA) are progressively converging to the issues of vulnerability, adaptation, resilience and ultimately integrated risk management. A disaster shall be considered as a result of a community’s vulnerability (UNISDR 2004a); therefore vulnerability assessment is at the heart of DRR.

At a global level the United Nations International Strategy for Disaster Reduction is promoting the development of a process that shifts the focus from the protection against hazards to the **management of hazardous risk**, through the Hyogo Framework for Actions (UNISDR 2005b). The same process has been reinforced at the European level, where, in the case of floods, more emphasis is put on non-structural mitigation measures (Green et al 2011).

The **KULTURisk Project** is a further step in this direction because one of its main objectives is to consolidate and disseminate the culture of **risk prevention** with regard to hydrological hazards. This becomes particularly relevant in view of the expected changes in future climate. Including climate change in the disaster risk reduction framework enhances the analysis because climate change is likely to bring hazards for which experience does not exist yet (UNISDR 2004b), and in general it could significantly affect the main features of hazardous events, in terms of magnitude, return period, geographical distribution and scale, etc. For instance, heavy precipitation is likely to increase at the northern and mid latitudes in winter and an increase in the magnitude and/or frequency of rain-generated floods is anticipated in some catchments (Trenberth et al. 2007; Bates et al 2008).

The total cost of disasters

The concept of **total cost** is much more ambitious than what has been traditionally provided in the assessment exercises, because it aims at describing the **total burden** imposed by a disaster to a socio-ecosystem. In public economics it is approximated by the concept of **social cost** (Coase 1960), which is specular to that of **total economic value** (Freeman 1979) used in environmental economics to estimate the benefits of a natural resource.

The true costs of disasters include costs (and benefits) which are difficult to identify and quantify (Downton and Pielke 2005). It comprises all **direct, indirect, tangible and intangible costs**. Indirect costs need to take into account secondary and higher order effects. The latter also includes the opportunity cost (Pearce and Markandya 1989; Turner et al. 2004) of the resources employed for remediation. A further distinction in monetizing the impacts needs to be done in terms of stock and flow, in order to avoid double counting, which is endemic (Cochrane 2004). A comprehensive total cost assessment should also take into account the distributional effects of the disaster costs and of the policies to mitigate them (Mysiak et al 2009). A pre-requisite is the definition of spatial and temporal scales for the assessment (Merz et al. 2010).

Most of the available cost estimates only take into account the **direct and tangible costs** of disasters. Direct costing methodologies are quite consolidated in the literature, but there still seems to be a mismatch between the relevance of the damage assessment and the quality of the available models (e.g. the depth-damage functions) and datasets (Merz et al. 2010).

Indirect costs are very often not captured because they are much more difficult to measure, even though they can be as relevant as direct costs (Okuyama and Sahin 2009). In the case of floods there can be long-term indirect impacts such as altered migration flows, relocation of industries, depressed housing values, and altered government expenditures that result from the new patterns of migration and regional development (Merz et al. 2010). Indirect economic loss assessment methodologies exist but with large uncertainty and method-dependent results. **Intangible costs** are usually neglected (Cochrane 2004) and the focus is limited to impacts measured by market values. Assessing intangible impacts in the social, cultural and environmental fields is much more difficult and there is little agreement on methodologies. However, psychological effects hit people in a stronger way and last longer in comparison to the physical damages (FLOODsite, 2009). Loss of leisure, a sense of place, historic monuments/cultural assets ("iconic" assets), and government services are simply neglected (Cochrane 2004). Moreover, the quantification of life value in monetary terms is an open ethical issue, even if this concept is widely applied for the evaluation of many health and safety initiatives (Jonkman and Vrijling 2008).

The assessment of risk reduction measures

The general valuation case in the DRR context can be described as follows:

1. an **hazardous event** is identified and described (e.g. an intense rainfall event with a return period of 100 years);

2. the specific **vulnerability** of the area of interest to that event is assessed (e.g. vulnerability to flood risk);
3. the **total cost** deriving from the estimation of the damages expected in association to that event is calculated;
4. a set of possible **risk reduction measures** is defined; they could be alternative or incremental, but in general they have an expected effectiveness in terms of reducing the expected damage;
5. in monetary terms the effectiveness of the measures can be defined as **avoided damage** and calculated;
6. the difference between total cost and avoided damage is calculated and identified as **residual cost**;
7. the **costs** associated to the **measure** implementation are calculated;
8. the cost of each measure is compared with the correspondent avoided damage; all the measures costing more that the avoided damage are excluded from further consideration;
9. the final decision is taken about the preferred solution which is quite often determined as a **combination of measures**, which would produce the reduction of the residual damage below a given **acceptable threshold**, at the **minimum cost**.

Cost-Benefits Analysis (CBA) is the “natural” methodological solution for supporting the assessment approach described above, when a full monetization of the variables to be considered is feasible. But the use of Cost-Benefits Analysis is largely questioned with regard to the monetizing and valuation of intangibles. The approach is often too narrow, e.g. considering only one flood scenario, and not systemic, e.g. focusing on the flood plain only (Green et al 2011).

The issue of providing a monetary value to all the losses associated to the hazardous event (including losses of lives, damages to ecosystems, of cultural heritages, etc.) is quite likely the main weakness of CBA and for this reason **Cost-Effectiveness Analysis** (CEA) if often seen as a preferable alternative. In this case the costs of implementing possible alternative measures is compared with a given objective and the effectiveness is assessed, i.e. typically the cheapest measure allowing to meet the predefined objectives is identified as the most cost-effective.

The use of **Multi-Criteria Analysis** (MCA) tends to be preferred for assessing social, environmental and cultural heritage, although lacks of knowledge and methods exists in how and which indicators, scoring and weighting system should be used (Green et al 2011). In this case the effects of disasters in terms of intangible costs are more manageable and quantified by means of quantitative indicators expressed in units different from monetary values. Similarly, the benefits of plausible risk reduction measures can be measured in monetary terms but also in other units (e.g. surface area of high value land preserved, or number of avoided causalities).

Remarkably, while CBA finds a way to convert all the components of the problems in a single unity – money – thus allowing also for characterising every alternative option with a single value (the Net Present Value), CEA and even much more MCA methods approach the decision issue as a multi-dimensional problem, and this is quite often considered as a positive asset by decision makers.

Assessment of DRR measures in the context of global change

The approach for the assessment of risk reduction measures can be easily translated to the context of CCA, in particular in those cases in which the valuation exercise is properly conducted with focus on climate variability and extreme events rather than on average trends. But there are also peculiar features of the DRR case:

1. In this case the risk considered is usually characterised by a probability of occurrence (i.e. the return period), which by tradition is calculated upon **historical record**. In the case of CCA, the probability of occurrence is substituted by a scenario approach. The latter resulting from the recognition that associating probabilities to **future projections** in the long run is not possible and thus alternative plausible scenarios – each of which is determined by an internally consistent set of assumptions –should be considered;
2. Once the multiple scenarios are identified, in CCA quite often the projections are considered in the valuation exercise as **point values**, without confidence intervals or statistical distribution. In the DRR case valuations are instead **probabilistic in nature**, and associated to the results of **risk assessment**;
3. Given the probabilistic feature defined in terms of return period, in the case of DRR the hazardous event is not allocated in a particular future time frame (i.e. for example it may happen tomorrow or within 100 years), therefore the issue of identifying the adequate interest rate for calculating the present value of future damages **(discount rate)** issue can be circumvented. In the case of CC policy instead the discount rate is a major issue, since valuation exercises are based upon trends and projections and calculated expected damages in “average” conditions of a specific future time frame, therefore discounting future damages and current or postponed investments is of greatest relevance for policy/decision making.

In very recent time it can be noticed a remarkable effort to make the DRR and CCA research streams to converge within the policy context. From the DRR stand point this means introducing a perspective of evolving phenomena, thus considering historical records not suitable anymore for defining probabilities of occurrence and preferring to include possible future trends in the analysis, while still maintaining the solid tradition of quantitative and statistical analysis developed within the risk management discipline. Overall this means introducing another source of uncertainty in an already challenging context because of the many other sources already considered, such as the uncertainty associated with damage estimation, monetization methods, input data (e.g. land use maps), etc.

The social dimension

Innovative approaches to DRR and CCA have in common a new perspective on the process of **decision making** with an increased **involvement of stakeholders** (those who may count and those who may be affected) and of **participatory approaches**. Of specific relevance for DRR is the subjective perceptions of risk, the strategic preferences of stakeholders and their tactical reactions in case of extreme events.

The KULTURisk project will contribute to bringing forward the principles of participation and cost-efficiency, contained in the Water Framework Directive (EC 2000), Indeed, stakeholders' engagement is a crucial element in order to achieve a widespread culture of hydrological disaster risk prevention. Supporting the **local community's involvement** throughout the decision-making process is crucial for implementing strategies that will lead to a culture of safety (UNISDR 2004a). This is by definition a social process but economics plays a major role in helping the stakeholders in the process of making better informed choices. Flood risk management should consequently reflect the concerns and the priorities of the relevant stakeholders. Different decisions must be made by different stakeholders before, during and after the flood, and their relevance is a matter of subjective judgements. In case of flood risk management, a particular concern is the overall functioning of the catchment and the impact of stakeholders that may intervene in it (Green et al 2011).

The integration of disciplines and methods

Sustainable development (WCED, 1987) has usually been defined as the result of balancing of three main pillars – environment, economy and society – and in some cases a fourth one is considered focused on the institutional dimension and governance. Bringing this concept into the context of DRR means defining the basis for an integration framework in which **economic valuation** is integrated with [environmental] **risk assessment**, through a process supported by methodologically sound methods for public participation and within a solid policy framework. All the above mentioned components are dealt with by specific deliverables to be circulated within the first months of the KULTURisk-project.

D1.6 at month 18 will provide the "Framework for comprehensive assessment of the risk prevention measures", but since now the requirements that economic valuation should have, in order to facilitate the integration of disciplinary works, are rather clear.

Economic valuation methods should in particular:

- Concerning the policy and institutional dimension, be compatible with the principles of the main policy references. In this case the Flood Directive and the Water Framework directive, as developed in D1.1;
- concerning the environmental dimension, facilitate a deep integration with the risk assessment and management methods proposed in D1.2;
- concerning the social dimension, facilitate the integration of subjective risk perceptions and stakeholders preferences concerning water-related natural hazards, analysed in D1.3;
- be compatible with applications in the case studies selected by the KULTURisk project.

Structure and contents of the rest of the report

In the following chapter we build on the aforementioned **categories of costs** presenting specific **examples for the hydrological disasters**. In the chapter about the **valuation methodologies** we show how different costs have been monetized in the past and we highlight important research gaps. In the chapter about **project appraisal** we indicate three main methodological options (CBA, CEA, MCA) by which the retrieved information can be processed in order to support the decision making process. We preferred not to propose a single methodological framework for a comprehensive cost assessment, because economic valuation should always be tailored to the case study according to its boundaries and the available data. Quite likely the reader will have a perception that the full estimation of the total cost might become challenging and controversial, and thus prefer to leave some typologies of impacts and losses in non-monetary terms. This is not an unexpected outcome of the report and in fact a similar perspective should have been shared by the European legislator and in particular the staff of experts supporting the implementation of those directives of crucial interest for the topic of this report. Indeed even if there is no preferred method clearly identified in the **Water Framework Directive and its Common Implementation Strategy** (WFD-CIS, 2003), in the latter and in the implementation practice there is an evident orientation towards Cost-Effectiveness Analysis, and, in some cases for Multi-Criteria Analysis.

2 CATEGORIES OF COSTS IN HYDROLOGICAL DISASTERS

In defining the categories of cost of a hydrological disaster we are referring to the negative impacts that the disasters might imply for the population, the environment and the economy. Conversely the benefits refer to the positive impacts and/or avoided negative impacts.

In case of an assessment of one or more hydrological risk mitigation measures, the benefits refer to the avoided negative impacts with respect to the "business as usual" situation. Thus, the assessment relies to some extent on the assumptions about the base-line scenario, meaning how the socio-ecosystem would have been evolving without any hydrological disaster or adaptation measure. A future scenario should therefore include: (a) the hazard, (b) the risk mitigation/adaptation measure and (c) the base-line scenario.

In terms of strategies of adaptation, the KULTURisk project is meant to consider three categories of risk mitigation measures:

1. early warning systems and preparedness;
2. non-structural initiatives: mapping, planning and risk transfer;
3. structural measures, such as the design of flood defence structures.

Which costs (and benefits)?

A summary of the main costs of hydrological disasters are reported in Figure 1. Given our definition of true cost we keep on framing the problem in the four quadrants resulting from the categories of tangibility (i.e. characterized by market values) and directness (i.e. characterized by contiguity in space and time with the occurrence of the hazard).

However, for the purpose of this chapter, which is to identify the cost elements and bring examples related to hydrological disasters, we emphasize the distinction between tangible and intangible costs (i.e. respectively the right and the left quadrants of Figure 1).

Tangible costs are those deriving from the economic impacts and their estimation has been matter of a consolidated body of research in the field of economics of natural disasters (NRC 1999). Intangibles pertain to the people and the environment. Non economic losses such as human lives, cultural heritage, ecosystem services are difficult to identify and, most of all, to measure in monetary terms.

These cost elements have been largely neglected in the field of economics of natural disasters even though there is great body of work on the value of statistical life and on the evaluation of environmental goods (Krutilla and Fisher 1985; Viscusi and Aldy 2003). This might be due to the fact that:

1. including all these costs in a single economic assessment is considered to be too challenging and resource consuming;
2. a one dimensional result is not considered to be acceptable by a decision maker, especially when ethical implications are strong;
3. to estimate the total cost could lead to the justification of every adaptation investment in a cost-benefit analysis context.

It, therefore, may be the case to adopt a cost-effectiveness approach, as suggested by the Water Framework Directive (EC 2000). In this regard a cost-effectiveness approach shifts the focus to the analysis of the alternative measures which are considered to achieve a certain level of risk reduction, to be defined specifically for each case study.

Scope and scales

As the World Bank (2010) points out, economic impacts may not all be adverse, especially in areas outside the flood zone. Indeed, the results of any assessment depend on the spatial and temporal boundaries of the study. For example, a flood might devastate a community. At the same time, nearby communities might experience economic benefits, since the flood might trigger business opportunities that cannot be exploited by the flood-affected companies. For example, the 1993 US Midwest floods impeded barges to navigate the river. Because of this lack of barge traffic, several trucking companies gained about 13 million US$ in additional revenue due to the increased demand for road transportation (Pielke, 2000).

Van der Veen (2004) and Merz et al (2010) distinguish in micro-, meso- and macro-scale. This is, on the one hand, related to the spatial extent of the damage assessment. On the other hand, there is a methodological distinction of these approaches in their need for aggregation. The net effects of disasters will vary across the scales of aggregation: individuals, firms, communities, regions and nations (Scanlon 1988; Cochrane 2004).

Similar considerations hold concerning the temporal scale. Floods can cause long-term consequences, such as health effects, which are not captured if a too short time horizon of the damage assessment is chosen (Merz et al 2010). In case of full monetization of such negative impacts the choice of the appropriate discount rate remains one of the most controversial issues in the literature.

In general, before starting any assessment it is worth considering who is requesting the study and what is the purpose (Green et al 2011). Public and private intentions may diverge as social and financial costs normally do. For the purpose of this report we aim at presenting the cost of hydrological disasters from the broadest point of view. Further, it will be a task of the project's cases studies to tailor the assessment on their needs.

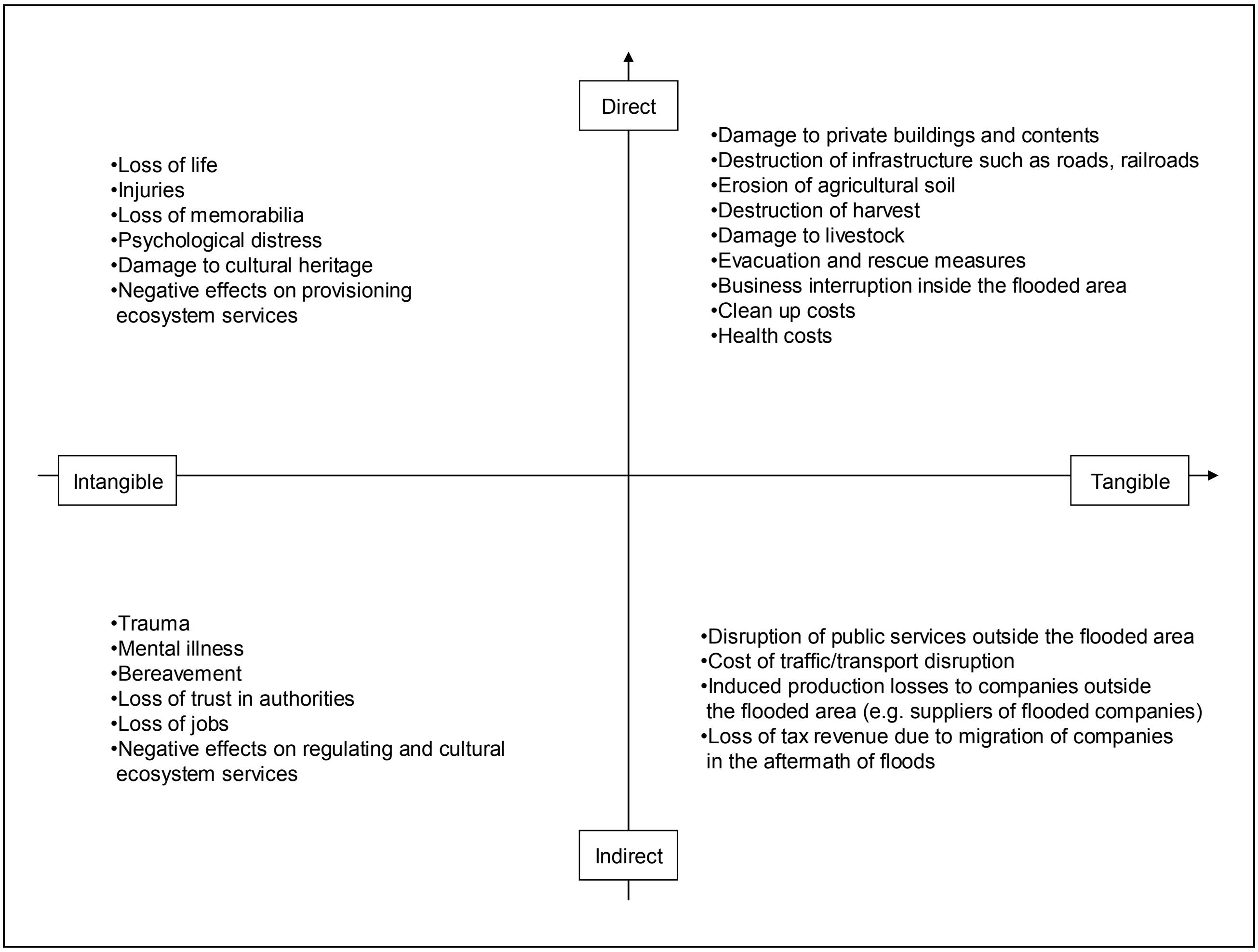

Figure 1. The main costs of a hydrological disaster (adapted from Penning-Rowsell et al 2003 and Merz et al 2010)

2.1 TANGIBLE COSTS OR "THE ECONOMIC SIDE"

Tangible costs derive from the impacts on the economic system. Economic costs can generally be broken down into damage costs (or losses), adaptation costs, and residual damage costs (Benson and Clay 2003). The benefits of adaptation can be assessed as the value of avoided damages. In the adaptation literature, residual damage costs can be distinguished from avoidable losses (Parry et al. 2009). The residual damage cost is the loss that would not, or cannot, be avoided when all desirable adaptation actions have been implemented.

Skoufias (2003) distinguishes between *ex-ante* mitigation of and *ex-post* coping with natural disaster. However, *ex-ante* mitigation clearly costs resources, and therefore it is necessary to engage in a careful evaluation of the likely *ex-post* impacts and the probability of disasters occurring (Cavallo and Noy 2010).

Stock and Flow

Economic costs can be measured as direct loss of economic assets or stocks as well as the consequential indirect effects on economic flows, such as GDP or consumption (ECLAC 2003). There has to be a clear distinction among stocks and flows. The economic impacts can be identified as direct when stocks are impacted and indirect when flows are affected (Benson and Clay 2003; Cavallo and Noy 2010).

The stocks are counted as existing stocks (i.e. before the floods) directly impacted at a specific time (i.e. during the flood event). These stocks can also include the stocks for future production. In addition floods may induce a stop of production during the floods and after, during the recovery phase. Because the losses of what could have been produced, without any stop, occur in time they are easily measured as losses to flows (Green et al 2011). In principle, each loss can be estimated as a change in the stock or a change in the flow: the value of a change in a stock being given by the discounted present value of the change in flow (Rose 2004a; Green et al 2011). The practice is to calculate whatever is easier to estimate. However, the choice of the appropriate discount rate is one of the main sources of uncertainty.

If both stock and flow values are used in the assessment an essential rule is to monetize each individual component of a damage of any category either by stock values or by flow values (Messner et al 2007). Including both for one component would mean double counting.

First, Second and Third Order

The issue of double counting is endemic (Cochrane 2004) also because the relationships between direct and indirect costs are not easy to capture (Heinz Center for Science 2000; BTE 2001). Following the “Source - Pathway - Receptor - Consequence” approach (Gouldby et al 2005), which is adopted in flood damage assessments, it is common to distinguish between first, second and third order effects depending on the contiguity of the consequence to the occurrence of the hazard. Direct costs would derive from first order consequences. Indirect costs would derive from higher order consequences.

First order consequences are located in the flood area and they would potentially depend on the contact with water (Green et al 2011). Direct costs of this type would include the value of damages to physical assets in the flooded area, but also the costs for emergency services, including public spending for evacuation and clean-up, and health costs. The costs for emergency services are easily measurable and often outweigh the remaining direct economic costs (Penning-Rowsell and Wilson 2006).

Consequences of the second order may also unfold indirectly, affecting receptors near to flood area and altering their activities (Green et al 2011). These kinds of consequences might depend on the network structure of the system rather than on the receptor’s spatial proximity to the flood. For instance, if a minor road is flooded, it may induce indirect effects within a few kilometres. But if a railway is flooded, it may have consequence hundreds of kilometres around. If an international airport is flooded it will affect other parts of the world. Indirect costs of this type would include the costs due to the disruption of production and to traffic diversion.

The third order consequences are related to what is happening after the flood and to the recovery phase (Green et al 2011). Indirect costs of this type would include: decline in investments, drop in national/regional income, opportunity costs of flood-related budget expenditure, increase in food imports, etc.

However, reconstruction can also lead to positive economic consequences: new investments may lead to a disaster recovery booming. Much depends on the availability of capital within the impacted area or from outside. This is definitely a characteristic which substantially contributes to the resilience of the economic system. In particular, it has been proved that some disasters produce demand surge. Demand surge is understood to be a phenomenon of large-scale natural disasters in which the demand for reconstruction materials, labour, equipment, financing, or some combination of these, exceeds the local supply. It is believed to have occurred in several large natural disasters, resulting in additional repair costs of 20% or more. Thus, it is of particular interest to property insurers and insurance regulators (Olsen and Porter 2011).

2.1.1 DIRECT ECONOMIC COSTS

For a comprehensive review of the direct damages costing methodologies, please refer to Merz et al. (2010). In this section we build on the main findings of this work.

After the evaluation of the costs of the emergency services, the second step of any hydrological disaster assessment is to evaluate the costs of the damages to the physical properties and economic assets. In general, and especially for large-scale disasters, it is not possible to assess the damage for each single object, because there is no information on the damage behaviour of each object and/or because such a detailed assessment would require a huge effort. Therefore, elements at risk are pooled into classes, and the damage assessment is performed for the different classes, whereas all elements within one class are treated in the same way (Merz et al. 2010).

Classification of Receptors

One of the tasks of damage assessment is therefore to decide on the details of classification. In this regard the decisive aspects are:

1. the resources available for the assessment;
2. the data availability;
3. the heterogeneity of objects/classes;
4. the relevance of objects/classes.

A very detailed damage assessment based on sparse data may be misleading, since this requires a level of accuracy which may not be given. Further, a Pareto-like distribution of damages is frequently observed, meaning that, for instance, 20% of affected objects are responsible for 80% of the total damages (Merz et al. 2010). Downton and Pielke (2005) analyzed the U.S. flood damage data and found that damage estimates for small events tend to be extremely inaccurate while estimates aggregated over large areas or long time periods appear to be reasonably reliable.

Typical coarse classifications would follow socio-economic and land use categories, e.g. residential, commercial, industrial, public, agriculture. A more refined approach would consider the sub-type within these categories, e.g. flats, houses, local shops, supermarkets, warehouses, and factories (Green et al 2011).

Asset values depend on the type of the elements at risk, but also vary in time and space. The variation in time can be attributed to economic trends, e.g. inflation, new investments and innovation. Variation in space occurs because the same object type has a different asset value in one region than in another due to regional specifications or differences in material costs, wages, etc. This variation can be covered by the use of regional or local data instead of national data.

Usually the value of the building fabric (fixed assets) and the value of the contents (moveable items) are distinguished. This is particularly relevant for any assessment that aims at estimating the benefit of early waning systems, such as in this project.

In order not to overestimate the damages it is strongly recommended to use depreciated values, which means values of the damaged goods at the time of the flood, and not the replacement value, which is the value of a new good of the same type (Penning-Rowsell et al 2003).

Damage Functions

A central idea in flood damage estimation is the concept of damage functions. They relate damage for the respective element at risk to characteristics of the inundation (i.e. the flood maps and the land-use maps reflecting the type and the density of objects at risk). For physical assets such as buildings (contents and structure) two functions are commonly used: the relative (e.g. Kreibich et al 2010) or the absolute function (e.g. Prattenthaler et al 2010). The absolute function consists in establishing the damage function for a particular asset in monetary terms either in relation to the building or per unit area. The relative function provides the susceptibility expressed as a percentage of the total value of the assets. The total value of the asset has to be estimated from other data during the appraisal (Green et al 2011).

Most flood damage models have in common that the damage is obtained from the type or use of the element at risk and the inundation depth (Wind et al., 1999; NRC, 2000). Their typical output is a depth-damage curve. Other parameters, like flow velocity, duration of the inundation and time of occurrence are rarely taken into account. For example, flood damage to residential buildings is strongly dependent on the water depth of a flood, whereas for damage to agricultural crops the time of flooding and the duration of the flood are decisive (Forster et al., 2008). Further descriptors of floods are: contamination, debris/sediments load, rate of rise, frequency. In case of landslides the main descriptors are: (1) the type of material involved (i.e. rock, rock debris, earth) (2) the quantity of material (in cubic metres), (3) the type of movement (i.e. falls, topples, slides, spread, flows) (EEA 2010).

In absence of specific local flood damage data, using a national average depth-damage curve is not necessarily wrong. However, it is important to question the existing variability of asset types within the flood plain to assess if an average curve can represent statistically the average type of building on the floodplain. Using an average depth-damage curve from another country is very questionable and should generally be avoided. The use of the depth-damages curves can also be questioned when high velocity is expected, particularly in the case of dams or embankments failure (Merz et al. 2010).

Damage functions, and in general hydraulic modelling, are permeated with uncertainty (Pappenberger and Beven 2006). It is therefore very questionable to include the treatment of uncertainty in hazard mapping as a relevant risk reduction measure. It is even more so in the framework of damage estimation. For instance, Wunsch et al. (2009) concluded that it is better to invest in land use data than in more sophisticated risk mapping techniques.

When developing flood damage models two main approaches can be distinguished: empirical approaches which use damage data collected after flood events and synthetic approaches which use damage data collected via what-if-questions (Merz et al 2010). For the purpose of the project, given the objective of assessing alternative risk reduction measures, a mixed approach could be envisioned.

2.1.2 INDIRECT ECONOMIC COSTS

Indirect economic costs are those costs induced by the direct damages and spread throughout the economic system (Merz et al. 2010). These costs are attached to some form of interruption/deviation of the "business as usual" conditions of the economic system outside the flooded area (second order) and in the recovery phase (third order).

The estimation of third-order economic costs implies the understanding of the trajectory undertaken by the economic systems after the shock caused by the disaster, with regards to the baseline trajectory (i.e. without any disaster).

Compared to direct economic costs, these costs are much more difficult to estimate, mainly due to limited availability of data (Merz et al. 2010).

Macroeconomic Flood Damages

The limitation of accessible primary data have led to attempts to measure indirect damages using economic models of the type that have long been utilized for economic forecasting such as (1) simultaneous equation econometric models, (2) input-output models (I/O), and (3) computable general equilibrium (CGE) models (Rose 2004a).

Such kinds of models study the propagation of direct economic effects arriving to a total indirect cost estimate. As shown in Okuyama and Sahin (2009) different kinds of disasters have different direct-to-indirect costs multiplicators ranging from 0.86 to 0.96. The transferability of this kind of multiplicators might be considered as a way forward to more accessible estimation exercises.

However, the I/O and CGE models are most suitable for macroeconomic assessments. While the I/O models results might be seen as an upper bound estimates, because they don't account for behavioural change and input substitution, the CGE model results my be seen as lower bound estimates (Rose 2004a).

Disasters and Development -

A major part of the analyses on indirect costs have focused upon the effects of floods on income or gross domestic product (Green et al.2011). Some of the main findings are that:

1. the effects of floods on growth might be significant on the short-term but insignificant in the medium and long terms (Albala-Bertrand 1993);
2. there are positive effects after the disaster (i.e. recovery booming) if aid is provided (Merz et al 2010).

However, there are many well-known problems with this family of measures (EC 2009). Social costs of disaster are not accurately represented by the change in GDP. In this respect GDP is a misleading measure of welfare. For example, while flood risk mitigation expenditures are counted for in social cost assessment, at least part of them will at the same time be included positively in the calculation of GDP (EPA 2008). In fact, Rodriguez-Oreggia et al (2010) found that there is a significant impact from natural disasters on reducing the Human Development Index (HDI) and also on increasing poverty levels.

In particular in developing countries, given their different level of vulnerability, floods may have significant negative consequences. An increase in indebtedness and trade imbalances can be often observed (Albala-Bertrand 1993). Moreover, the frequency of floods is one of the main factors that impede sustained development in flood prone areas (UN 2008). Other indirect costs might include the cost of inflation due to negative effects on the supply system (Cavallo and Noy 2010).

Alternative Models

It has been argued that the aforementioned models are inappropriate for simulating natural disasters and that they must be substantially revised in order to produce reliable estimates of indirect effects (Merz et al. 2010). Conversely, computational algorithms modelling supply shocks, post-event supply constraints and time phased reconstruction in disaggregated spatial settings (e.g. van der Veen and Logtmeijer, 2005; Yamano et al., 2007) seems promising to overcome this methodological gap (Merz et al. 2010).

At the same time other semi-quantitive approaches have explored the potential of stakeholders' inclusion and expert knowledge elicitation. Pfurtscheller and Schwarze (2010) developed a simplified vulnerability score card system to raise awareness about indirect effects in regional disaster management (Merz et al. 2010). Catenacci and Giupponi (2010) used a Bayesian network approach in the context of climate change expected impact on the tourism and fishery industries.

Agent-based modelling is also a widely recognized promising methodology to integrate these alternative approaches in a context of bottom-up and local-to-regional analysis (Balbi and Giupponi 2010). Yet, the application of such a methodology to similar fields (e.g. Entwisle et al 2008) does not seem consolidated enough.

2.1.3 ECONOMIC ADAPTATION COSTS

If the aim of an assessment is to consider alternative courses of action, then adaptation costs must be included. For the adaptation costs the distinction among direct and indirect costs is not very significant because these costs do not derive from one physical event. Even though we could refer directness to the implementation process this remains a not very useful concept when non-structural measures are considered. What is much more relevant is the distinction between tangible and intangible costs of the alternative adaptation options

Tangible costs must consider: (1) the investment cost and (2) the operation and maintenance (O&M) costs.

These costs may vary a lot among structural and non-structural measure. The investment costs of flood management options involving construction receive considerable attention in project appraisal. However, any decision based on forecasting effectiveness and implications of alternatives over a typical time horizon of 50 years, should also take into account O&M costs (Green et al.2011). Non-structural options are typically reliant upon adequate O&M expenditure. For example, flood warnings depend on annual spending on maintaining a forecasting system, and on maintaining staff levels, training, and information flows for the warning services and communities at risk (Green et al.2011).

Intangible costs must at least be identified in the form of implications for the people and for the environment. These implications could also carry positive externalities (i.e. the creation of healthier ecosystems or a catchment community network) and therefore should be regarded as intangible benefits. More details on this are given in the next section.-

In assessing and comparing risk mitigation strategies costs and benefits are obviously important but not sufficient criteria. In other words a decision should be based on a wider set of values and priorities. Some of the main criteria that are increasingly applied (Green et al.2011) include:

1. effectiveness, in terms of reducing the magnitude of events and the negative consequences;
2. reliability of the measure, which depends in part on what operational actions are needed, and the frequency of problems;
3. implication of failure, including the mechanism of failure and its consequences;
4. adaptability for changing condition.

In particular, the implication of failure can only be approximated in economic terms by estimating the residual damage. A greater magnitude of damages can derive from low probability events. This can be extremely relevant for certain strategies. For example, damage functions can be used to simulate the scenario of overtopping of the structural defence. Such a kind of analysis should include the insights from the economics of catastrophic climate change (Weitzman 2009).

2.2 INTANGIBLE COSTS OR "THE NON ECONOMIC SIDE"

Intangible costs, which might be both direct and indirect, are the most difficult to estimate for two reasons: (1) it may be difficult to identify them (e.g. which is the effect of a flood on an ecosystem?) (2) it may be difficult, controversial and inconvenient to monetize them (e.g. is it acceptable to value the tribute of lives caused by a landslide in money terms?).

On the one hand, it could be accepted that these kinds of costs remain not monetized, and thus be referred to as impacts. On the other it is mandatory to identify and include them in any assessment that has the ambition of being realistic and, somehow, true. For the purpose of this section we distinguish among impacts to the people and impacts to the environment.

2.2.1 IMPACTS ON THE PEOPLE

Beside the economic loss potential impacts on individuals are: mortality, injuries, disease (e.g. diarrhoeal, vector-borne) and infections, chemical pollution, nutrition and displaced population (Few et al 2004). Only a small part of these impacts is captured by direct health costs.

Psychological or mental health impacts are also recognised and are related to various flood impacts such as the stress of the flood itself, the evacuation, the disruption to life and household and the loss of memorabilia and personal belongings (Tapsel and Priest 2009).

Loss of cultural heritage is a further potential impact which can be associated to, but it is barely approximated by the damages to historic physical assets.

However, social benefits can also arise from the redistribution of assets and income in a community after a disastrous event (McSweeney and Cooms 2011).

Mortality Risk

Indeed, the tribute of lives is unanimously recognized as the most important impact of any disaster by the public opinion. In the last ten years high losses of life due to floods have mainly concerned developing countries. In Europe the risk of dying directly by flood is low. The worst cases of death are usually related to coastal flooding, flood defence failure and flash floods. The average event mortality is estimated at 4.9*10-3 for river flood and at 3.6*10-2 for flash floods stressing a higher risk of death in flash floods (Jonkman and Vrijling 2008).

The main factors of risk are given by the high velocity and high depth associated with debris, which involve a loss of stability in the water and increase the risk of drowning. The lag of time is also crucial as it constraints the potential time of warning and evacuation. Local circumstances (e.g. presence of shelters, type of buildings, time of the day, seasonality, warnings) play a strong role (Green et al.2011).

Including mortality in a cost-benefit analysis implies the quantification of life value in monetary terms. A comprehensive review of this issue is beyond the scope of this report, and thus, we refer to the literature on the value of statistical life, which is a concept widely applied for the evaluation of many health and safety initiatives (Jonkman and Vrijling 2008; Doucouliagos et al. 2011).

However, it is worth noting that the US EPA estimated the value of a statistical life for an American citizen around U.S.$ 6.9 million in 2008. The primary reference for this data is the National Morbidity, Mortality and Air Pollution Study (NMMAPS). It is also important to note that this value is not supposed to represent lifetime earnings/contributions to society or the moral and emotional worth of a human being. The figure is calculated to approximate how much people are theoretically willing to pay to save a life.

Long Term Effects And The Society

Mental health impact includes common mental disorder such as anxiety and depression, and post-traumatic disorder (PTSD). The immediate mental impacts also include the anxiety of being out of one's home, the discomfort of living in temporary accommodation and the time and effort in dealing with insurers and builders (Werritty et al 2007).

Long-term effects of floods are mainly related to low-income and medium-income countries. European citizens are primarily subjected to headaches, colds coughs and flu (Ahern et al 2005).

Health effect can be increased by socio-demographics factor (e.g. age, illness, income, house type), by floods characteristics and by post-floods factors (e.g. problems with insurers and builders, evacuation). In addition to an individual might be influenced by: (1) his personality and life experience (2) his network of relations and the social context (DEFRA 2005).

Social Adaptation Costs (and Benefits)

Current economic approaches limit the assessment of social capital to the level of the individual. Typically the number of flooded households is considered and eventually a specific factor is applied to adjust the number to the population size. However, negative effects can also result from floods such as social disorganization due to the loss of life, refugees, loss of trust on the authorities leading to the ruin of local economy, even to political instability and change (Green et al.2011).

However, social capital is far more than that. It is also based on networks, norms, cohesion and trust. The quest for stakeholders engagement, as supported by the EU policies (EC 2000; EC 2007), may improve social capital through the creation of catchment communities and flood action groups, which could act as social safety nets, reducing the social system vulnerability.

At the same time any flood mitigation strategy and associated measures will have implications for the social relationships and for the individuals risk perception and managing. For instance, leaving a floodway that includes flood-prone properties may not encourage social cohesion from the owner's point of view (Green et al.2011). Moreover, a repeated "false positive" flood alerts may undermine the trust on local authorities and impose an evitable load of stress to the population.

2.2.2 IMPACTS ON THE ENVIRONMENT

Floods are natural phenomena that are related to characteristics of the catchment. The environment of a catchment is a mosaic of interdependent ecosystems, which develops around the prevailing water regime. Ecosystems and species can also be considered as hazards' receptors. Thus, floods (and landslides) also have ecological effects, which might be favourable or adverse.

The favourable effects would include, for example, the benefits from the water and sediments that floods bring to wetland areas, thereby enhancing these locations as bird habitats. Floods thus help to maintain the natural character of these areas and the biotic diversity that they support. (FLOODsite 2009)

The unfavourable effects will occur where floods invade areas with water intolerant ecosystems, or where floods lead to erosion or deposition of sediments to the detriment of the species normally based there, or where flood waters disperse pollutants that adversely affect floodplain habitats and/or their species (FLOODsite 2009).

Floods may move good soil from one place to another or burry a cropland under several meters of sand, significantly affecting its fertility. For plants, the seasonality is the most critical factor. Regular flooding of dryland during the growing season is undesirable but outside the growing season is relatively unimportant. Further, if a flood increases the availability of a nutrient in an area where naturally the soil is nutrient poor, then the result may be to change the species composition (Green et al 2011).

Ecosystem Services

So the question is to determine when and where a flood will have beneficial effects on the existing ecosystems and when it will have harmful effects. Many decisions will involve environment to environment trade-offs such as the preservation of a dryland ecosystem or the enhancement of a wetland ecosystem (Green et al 2011). This might imply the evaluation of the ecosystem services.

The Millennium Ecosystem Assessment (Alcamo et al 2003) defined the value of ecosystems in terms of four services:

1. supporting (e.g. nutrient cycling, soil formation, primary production);
2. provisioning (e.g. food, freshwater, wood and fibber, fuel);
3. regulating (e.g. climate regulation, flood regulation, disease regulation, water purification);
4. cultural (e.g. aesthetic, spiritual, educational, recreational).

Without the supporting services, the other three functions can hardly be provided. Thus, it is necessary to maintain and preferably enhance the supporting services but direct means of evaluating this function are not likely to be available. In contrast, provisioning and regulating services can be evaluated in economic terms, which happen very often in the cases of flood regulation (Leschine et al. 1997). The estimation of the cultural services is much more problematic, but it could be extremely relevant in the case of hydrologic disasters which significantly affect the landscape. In this context contingent valuation is a widely applied methodology (Daun and Clark 2000).

Primary sector activities such as agriculture, forestry, fisheries and hunting depend on a wide range of provisioning and regulating services that together shape the natural capital on which these sectors depend (Chiabai et al. 2009).

Impacts on Agriculture

The disruption of production and services can also be used to assess losses to the environment including the agro-environmental component. Arable farming is the more obvious example as the products are marketed as other economic activities. However, while the losses of agricultural products, farm houses and farm infrastructure, which are direct tangible costs, are very much linked to the economic part of our framework, the potential decrease in the quality of soil and the loss of soil structure are definitely to be included among the intangible environmental impacts (Green et al 2011).

Arable farming can be interpreted as a highly simplified ecosystem and the effect of flooding depends on when it occurs in relation to the growing season. Thus, crop losses in the northern hemisphere are most pronounced in the summer period. Except where multi-cropping, in the form of horticulture is practiced, flooding in winter generally has little or no effect (Penning-Rowsell et al 2003).

The Total Economic Value

In evaluating environmental goods, a slightly diverging approach to the Millennium Ecosystem Assessment is given by the theory of the total economic value (Krutilla and Fisher 1985). Here the distinction is among use and non-use values.

Use values include: (a) direct values (which correspond to the provisioning services but include also the recreation value), (b) indirect values (which correspond to the regulating services), and (c) the option value, which is the premium placed on maintaining resources and landscapes for future possible direct and indirect uses, some of which may not be known yet. The option value might be substantial for hydrologic disasters that imply a significant loss of biodiversity.

Non use values, or existence values, correspond to cultural services with the exclusion of the recreation value. More emphasis is put on the significance and on the bequest value of the resource, which is the value of the satisfaction from preserving a natural environment. The estimation of this kind of values is challenging because it is subjected to a high degree of uncertainty (Akter and Grafton 2009).

Environmental Adaptation Costs

Considering the environmental implications of catchment and floodplain management options for hydrological disaster risk reduction, may also be relevant. These could include changes in run-off and flood characteristics in each compartment or reach of the catchment associated with different structural risk mitigation options. There might also be significant implications in terms of land use patterns expected to arise over a certain time horizon (e.g. induced urbanisation and) (Green et al 2011).

Further environmental implications include carbon capture and emission of greenhouse gasses associated with different adaptation options. For instance, catchment management that seeks to enhance runoff absorption/retention in upper catchment peatlands by restoring peat habitats would have positive implications, whereas structural measures that require imported equipment and consume more energy would have negative implications. In this regard, “non-structural” options such as warnings and flood proofing on average are benign or neutral (Green et al 2011).

3 STATE OF THE ART OF ECONOMIC VALUATION METHODOLOGIES

In the first section of chapter 3 we briefly review the main cost estimation methodologies which have been applied to disasters caused by floods and landslides. The methods reported here, and summarized in Table 1, could be divided into four main groups, related to their capacity of addressing the different types of costs. They also belong to three main families of valuation techniques: (1) market-based (MB), (2) system approaches (SA), and non-market-based (NMB).

Table 1. Review of the main cost estimation methodologies (adapted from Logar and van den Bergh 2010).

Costing Methodology	Family	Direct Tangible	Indirect Tangible	Direct Intangible	Indirect Intangible	References
Contingent Valuation	NMB			X	X	Brouwer et al 2006; Ahlheim et al 2008.
Choice Modelling	NMB			X	X	Zhai et al 2007
Life Satisfaction	NMB			X	X	Luechinger and Raschky 2009
Market Valuation	MB	X	X			Yoshida, K., 2003; Brander et al 2006; Sterlacchini et al 2007.
Surrogate Market	NMB			X	X	MacDonald et al 1990; Hromádka et al 2009; Dassanayake et al 2010
Computable General Equilibrium	SA	X	X			Bucher et al 2009
Input-Output	SA	X	X			Okuyama and Sahin 2009
Regional Econometric Models	SA	X	X			Takasaski et al. 2004 Liu et al 2007
Hybrid and Optimization Models	SA	X	X			Windsor 1973; Lall and Miller 1988; Needham et al 2000.
Benefit Transfer	-	X	X	X	X	Eade and Moran 1996

3.1 CONTINGENT VALUATION

The contingent valuation method (CVM) is used to evaluate non-market resources with a structured survey. More details are given in Brouwer (2006), Brouwer and Stavros (2007) and Logan and van den Bergh (2010). This method, together with choice modelling, belongs to the family of the stated preference methods, which are applied to estimate economic values where there is no market-based price and consumer behaviour data (Ozdemiroglu et al. 2010).

CVM uses questionnaires which are functional to state respondents' willingness to pay (WTP) and/or willingness to accept compensation (WTA) with respect to an environmental damage (Green et al. 2011). The economic values estimated via the CVM are contingent upon a hypothetical market (Brouwer and Stavros 2007). Thus, the data generated in this way is only hypothetical.

Some of the main problems with this method are:

- strategic bias, when respondents intentionally give responses that do not reflect their "true" values (Brouwer 2006).
- the costs of the studies (Brouwer 2006);
- time constraints, the practical implementation of the CVM could require six months to a year (Brouwer and Stavros 2007).

3.2 CHOICE MODELLING

This group of methods is based around the notion that any good can be described in terms of its characteristics and attributes (Brouwer and Stavros 2007) and includes: choice experiments, contingent ranking, contingent rating, and paired comparisons.

In the experiments the individuals have to compare different alternatives described with an array of attributes, including the price (Logar and van den Bergh 2010, Green et al. 2011). The set of possible choices have an important impact on the results and are often difficult to handle for the respondents (Mc Fadden et al., 2005). As for CVM, it is required to have a substantial knowledge of econometric analysis (Brouwer 2006).

3.3 LIFE SATISFACTION ANALYSIS

Life satisfaction analysis is a typical multidisciplinary approach (Logar and van den Bergh 2010). This method makes use of surveys to ask people to assess their current level of happiness (Logar and van den Bergh 2010). Economic values are produced on the basis of the respondents' answers and some socio-economic indicators such as: capital income data, and environmental conditions. This data is processed with econometric modelling techniques (e.g. regression analysis) (Logar and van den Bergh 2010).

3.4 MARKET VALUATION TECHNIQUES

Economists generally prefer to use direct, observable market interactions for placing a monetary value on goods and services (NOAA, 2011).This set of methods uses market-based indicators in the cases where the environmental goods and services can be associated with competitive markets (Ozdemiroglu et al. 2010; Green et al. 2011).

Market price

The market-based transaction method is mainly used to estimate the demand for an environmental resource traded in the market, such as water (Brouwer and Stavros 2007). This method uses observed prices from transactions for leases or sales of water rights. It may require shadow pricing.

Dose-Response

The dose-response method considers the physical and ecological links between pollution (i.e. dose) and impact (i.e. response) and evaluates the final impact in terms of market price or WTP (Brouwer 2006).

Production Function

A production function approach estimates a function that specifies the output of a company, an industry or the whole economy based on the combination of inputs (Logar and van den Bergh 2010). Econometric analysis is used to relate output to inputs. The same approach can be used to derive inverse demand functions based on the observation of consumers' behaviour.

Replacement Cost

With the replacement costs method the cost of restoring the environment to its original state is estimated (Brouwer 2006). A replacement or repair cost approach assumes that the costs of replacing or repairing an ecosystem good or service represents a reasonable estimate of its value. Nevertheless, it is best seen as a lower bound to the real value of the good or service, certainly in the case of replacement (Logar and van den Bergh 2010).

Opportunity Cost

Opportunity cost approaches are very useful where a policy precludes access to an area, for example estimating forgone money and in-kind incomes from establishment of a protected area (Brouwer 2006).

3.5 SURROGATE MARKET

These methods are also known as revealed preference methods, because while most environmental goods and services are not traded in markets, their characteristics affect demand of other goods and services that are traded in markets (Ozdemiroglu et al. 2010, Green et al. 2011).

Avertive Behaviour

The avertive behavior and defensive expenditures technique focuses on averting inputs as substitutes for changes in environmental characteristics (Brouwer and Stavros 2007; EPA 2008; Green et al. 2011).

Travel Cost Method

Travel cost method uses questionnaires to elicit the transport costs and the time value for implicitly assessing the price of an environmental service (Brouwer 2006, Brouwer and Stavros 2007 and EPA 2008). The demand curve is estimated by regressing the rate of visits against selected socio-economic factors, such as the travel costs of visiting the site and some indicator of the site quality (Brouwer and Stavros 2007). For hydrological disasters this method is well suited to estimate the costs of traffic disruption (Green et al. 2011).

Hedonic Price Method

The hedonic price method is applicable only to environmental attributes likely to be capitalized into the price of housing and/or land (Brouwer 2006). This method employs the differences in the prices of marketed goods to derive the value of environmental characteristics (Brouwer and Stavros 2007, EPA 2008). Thus, market distortions can bias the obtained prices.

3.6 COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

CGE analysis examines the economy-wide impacts of a change in a policy, technology, exports, or other exogenous factors (Logar and van den Bergh 2010). More detailed descriptions can be found in Cochrane (2004) and EPA (2008).

CGE addresses the problem of uneven supply shocks and simulates the price system in a market economy. The main shocks can be: a decrease in the initial endowment of production factors; a fall in the sectorial marginal productivity of production factors; a combination of both (Sahin 2011).

CGE models are useful to reproduce the economic losses as a percentage of GDP (Sahin 2011). However, the main purpose is to analyze the interactions between many and different economic agents each of whom is represented by an equation (Greenberg et al. 2007; Logar and van den Bergh 2010; Sahin 2011).

This method is suitable for macroeconomic assessments and for long-run equilibrium analysis, but it is based on many assumptions, such as: (1) optimizing behavior of consumer and producers (which is questionable under disaster situations); (2) market clearing; (3) competitiveness of product and factor markets.

3.7 INPUT-OUTPUT ANALYSIS

This group of models is built around a matrix that describes how the sectors of an economy interact with one another (Greenberg et al. 2007). Thus it is possible to reflect the economic interdependencies within a regional economy (Okuyama and Sahin 2009), using a table that describes the interrelated flows of goods and factors of production over the course of a year (EPA 2008).

I/O econometric models integrate the conventional IO models with econometric macroeconomic models (EPA 2008). These models are often used to estimate the policies and regulations regional impacts, and also long-run impacts (EPA 2008).

Social Accounting Matrixes

Social accounting matrixes (SAMs) are widely used in the international development community. SAMs are used to examine the indirect effects across different socio-economic agents, activities and factors at a very aggregated level (Okuyama and Sahin 2009)

These models assume that technology and productivity are fixed, so that the future transactions patterns are identical to the current one (Greenberg et al. 2007). Further, they are incapable of capturing the price changes effects due to a disaster. The linearity and the rigid structure, may lead to overestimation of impacts (Greenberg et al. 2007; Rose 2004a; EPA 2008).

3.8 REGIONAL ECONOMETRIC MODELS

These models reflect historical trading patterns and are useful only when they reflect balanced and undistorted economies. Regional econometric models are based on time series of panel data (Greenberg et al. 2007). These models include estimates on employment, wages, incomes, population and prices of a specific region, and assume equations that represent the interregional trade of the industry and the in-and-out migration flows (Greenberg et al. 2007). They are capable to explain how an economic change in one region spills over to other regions and creates a feedback effect in the original one (Greenberg et al. 2007).

3.9 HYBRID AND OPTIMIZATION MODELS

Linear Programming

Linear programming provides guidance regarding optimal (maximum value added) allocation of scarce post-event production capacity (Cochrane 2004). It minimizes, or maximizes, an objective function by choosing a set of decision variables, under a set of constraints (like available technologies, productive capacities, fuel supplies and regulations) (EPA 2008).

Optimization Models -

Optimization models are used to provide mathematical solutions to problems that entail maximization or minimization of an economic objective subject to specified constraints. Given the problem’s optimal solution, the model reveals the inputs’ economic value (Brouwer and Stavros 2007).

There are two types of optimization models: mathematical programming and dynamic optimization models. The mathematical programming models are static and one period structured. The economic agents tend to optimize a single economic objective function in a specific time period. Dynamic optimizations models indicate the optimal outcomes for separate periods. Both can calculate WTP and marginal values for all the considered constraints (Brouwer and Stavros 2007).

Biophysical-Agro-Economic Models

Biophysical-agro-economic models provide a comprehensive insight on the feedback effects between human activities and natural resources (Logar and van den Bergh 2010). They produce biophysical estimates of crop responses to climate events, with the use of spatially explicit models on different geographical scale (Logar van den Bergh 2010). The obtained estimates are incorporated into socio-economic models, to predict farmers’ decisions, and then to aggregate these decisions at the market level to forecast changes in supply prices (Logar van den Bergh 2010);

Coupled Hydrological-Economic Models

Coupled hydrological-economic models have three components: (1) a hydrological component, (2) an economic optimization model, and (3) an institutional factor (Logar and van den Bergh 2010). These models are mainly used to analyze the impacts of water allocation and use by different sectors under alternative policy scenarios (Logar and van den Bergh 2010).

3.10 BENEFIT OR VALUE TRANSFER METHOD

This method was developed for situations in which the funds and/or time available for data collection are constrained (EPA 2008; Logar and van den Bergh 2010). The monetary environmental values estimated in one site are spatially, or temporally, transferred to another one, which requires some statistical similarity with the original study (EPA 2008, Logar and van den Bergh 2010, Green et al. 2011).

Logar and van den Bergh (2010) describe that the transfer might work using a study area similar to the targeted one, and applying the new characteristics within an existing econometric model. The simplest option is the unit value transfer method, which directly exports a WTP point estimate.

4 METHODS FOR THE APPRAISAL OF MEASURES AND PROJECTS

There are several instruments available for processing the complex relations between the different categories of costs and impacts as described in chapter 2 and 3. The results of such analyses can contribute to a scientific based recommendation in the political process and to the development of a novel risk prevention culture.

In this chapter we focus on cost-benefit analysis, cost-effectiveness analysis and multi-criteria analysis. In case that objectives and impacts can be formulated on the basis of economic theory and can be stated in monetary terms, the classical cost-benefit analysis (CBA) can be applied. However, in case that multiple objectives are involved and/or impacts cannot be reported in monetary terms, cost-effectiveness analysis (CEA) and multi-criteria analysis (MCA) are often used for evaluation purposes. Further, while CEA and MCA can incorporate monetary values, CBA cannot incorporate non-monetary values.

4.1 COST-BENEFIT ANALYSIS

Cost-benefit analysis is an instrument to give political advice and is used to evaluate public projects from the viewpoint of economic efficiency. It can be described as the public counterpart to the investment analysis of a private firm and it is intended for those projects, which are not driven by price mechanism on markets but by political decisions, as e.g., the production of public goods such as prevention from natural hazards (Mishan 1988).

The theoretical background of CBA can be found in welfare theory (Just et al 1982). CBA is also called "practical arm" of welfare theory. Given that market mechanism fails or there simply are no markets for certain goods, public intervention is required. In these cases, CBA has the purpose to check projects for efficiency and to facilitate rational decisions against the background of economic scarcity.

Investment analysis of private firms and cost-benefit analysis fulfill the same task in different areas of decision making. They differ in the manner of resource allocation (market versus political decision), but also in the way of evaluating the project effects. The private calculation uses market prices; CBA requires the determination of opportunity costs and WTP (Gregersen and Contreras 1992).

Table 2. Structure of a cost-benefit analysis (Hanusch, 1994, p. 6)

1. Identifying the relevant constraints

a) Physical constraints

b) Financial constraints

c) Juridical constraints

d) Administrative constraints

e) Political constraints

2. Selecting feasible alternatives

3. Determination of project impacts

a) Project impacts have to be determined referring to duration, area and individuals concerned

Structure of a Cost-Benefit Analysis -

CBA is used as the basis for decision making in the political process. Therefore, the procedure and the result should be made transparent and clear, also for non-experts. Third parties should be able to understand all steps of the final report as well as problems, which occurred during the analysis. The structure of a CBA shown above gives an impression of the wide range of knowledge that is needed to carry out a CBA. It includes the theoretical background of welfare theory as well as private investment calculations. Furthermore, political, social, technological, and natural sciences can provide input in order to conduct a comprehensive CBA (Pearce et al 1994).

When selecting alternative projects, it has to be taken into account, that natural and social constraints can prohibit certain parts of a project or projects as a whole. These constraints can vary in time and from country to country (Hanusch, 1994, p. 10).

The determination of project impacts is the central issue of a cost-benefit analysis and often very difficult to handle because of the wide range of impacts to be considered. The first task is to report the positive and negative effects generated by a public project. The important thing here is to realize that every use of production factors in order to produce certain goods means a withdrawal of factors and reduced production elsewhere (Bergen et al 2002). How can this shortfall in output on the one side and the extra production on the other be evaluated? This happens by comparing the WTP for a certain good with the price that has to be paid and then adjusting the amount demanded to the given price (price taking behavior).

Discounting Costs and Benefits

In general, public projects and especially forest projects cover more than one period and costs as well as benefits can occur at different points in time. To make sure that they can be compared, costs and benefits must be “homogenized” in time (Hanusch, 1994, pp. 97ff.). This can be achieved by discounting the advantages and disadvantages of different time periods to a basic period, e.g. the year when the project starts. Using financial mathematic formulas the so-called present value can be calculated. By discounting, costs and benefits that occur in the future get a lower value. The approach of estimating the present value corresponds to the procedure used in dynamic investment calculation. The letter d stands for the discount rate. On the next page examples for the calculation of present and future values are given. When evaluating projects, no a priori decision on the “right” discount rate can be made. Depending on different viewpoints, several discount rates are preferable (Boardman et al. 2001). In the following, the different arguments are presented and explained.

When an individual time preference (ITP) of a household or an individual is used then the assumption holds that individuals have a positive time preference due to uncertainty about the future. To get more information about the level of ITP, the behavior of households on the capital market can be analyzed. It is observable, at which interest rate households are willing to save (to postpone today’s consumption, if ITP is lower than the interest rate to be earned) or to get a credit (to shift future consumption to present, if ITP is higher than the interest rate to be paid). On a perfect market only one interest rate would occur and bring the market into equilibrium. This interest rate could be used as discount rate for the calculation of the present values. In reality the conditions for a perfect capital market are not fulfilled. Thus, a variety of different interest rates exists (e.g. interest owing and interest on credit) and the problem determining the accurate interest rate remains unsolved.

The opportunity cost rate is not based on the households´ preferences concerning todays and future consumption, but focuses on the possibilities to facilitate consumption in the future by renunciation of today’s consumption (Mühlenkamp, 1994). The opportunity cost rate indicates how many additional consumption units in the future are made available by the withdrawal of one consumption unit in the present and using this unit for investment purposes. This can also be called marginal productivity of the capital unit used (Hesse, 1980).

This concept is based on the fact that no uniform interest rate exists for time preference rate and opportunity cost rate. Discounting monetary flows by only one interest rate would cause no distortions only if production factors are withdrawn exclusively either from consumption or from investment. This cannot be supposed a priory and thus, it is suggested to use a combined rate of time preference rate and opportunity costs rate that considers consumption as well as investment aspects.

Advocates of a social time preference rate assume that households are shortsighted and that they focus too much on their own interests. This leads to a relative high discount rate and means that effects concerning future generations are not sufficiently taken into account. It is argued, that especially for afforestation projects and big infrastructure projects with a long duration the individual time preference rate is too high and a lower 'social' time preference rate should be used for discounting. This approach can be justified by the fact that society has an infinite time horizon.

Decision Criteria

Assuming that all positive and negative affected households have been identified and the respective project impacts are determined, evaluated and discounted, what follows is the comparison of costs and benefits. There are three main criteria of decision that have their origin in private investment analysis: net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR) (Kruschwitz, 2003).

The net present value (NPV) is defined as the difference between the discounted benefits and the discounted costs of a project. A positive difference indicates that the benefits generated by the project exceed the costs. The project is advantageous and recommendable. Implementing the project leads to a welfare increase for society as a whole. The amount of the net welfare effect is given by the NPV.

The ratio of discounted benefits and discounted costs of a project is called benefit-cost ratio (BCR).

A BCR higher than one indicates that a project is advantageous (Bründl et al. 2009). The basic terms for the calculation of BCR are the same as for NPV, but the informative value is restricted, due to effects that occur when classifying cost and benefits: costs can be interpreted as negative benefits and benefits as negative costs. While NPV is not influenced by different classifications, BCR provides different results, depending on varied interpretations of costs and benefits. Only if it is possible to separate costs and benefits exactly, both criteria can be considered to be equal. This cannot be stated as a rule. If netting out benefits and costs is not avoidable, NPV is the superior criterion of decision.

The third investment criterion is the internal rate of return (IRR), which is the rate of return that renders an NPV equal to zero. The internal rate of return is that interest rate, at which discounted benefits and costs of a project are equal. A project is recommendable, if the IRR is higher than the level of a certain reference interest rate.

Considering Risk and Uncertainty

Perfect information about all project impacts is not available. Thus, the determination of costs and benefits is based on uncertainties. These uncertainties may have two characteristics. If data is available that allows calculating probabilities for the occurrence or non occurrence of certain project effects, one can speak of a decision under risk. These probabilities can be objective or subjective ones. If a probability calculus is not possible, the decision has to be made under uncertainty in the narrow sense. Referring to a decision under risk, the present values of costs and benefits can be interpreted as random variables. They can be characterized by a probability distribution on basis of objective data or according to subjective judgments (Boardman et al. 2011).

Uncertainty in the narrow sense means that no information exists on probability of occurrence for future events. In this case literature provides a wide range of decision rules (Hanusch, 1994, pp. 133ff.). The maximax-rule is based on an optimistic philosophy. It asks for the maximum achievable benefit of each alternative and then chooses the one with the highest maximum benefit. The more pessimistic maximin-rule compares the minimum benefits to be reached by alternative projects and recommends the one that generates the highest minimum benefit. The Hurwicz-rule combines the two former concepts. The highest and lowest benefits are weighted by numbers between 0 and 1 and then aggregated to an overall measure.

Other suggestions range from the Laplace-rule, that - according to the 'principle of insufficient reason' - gives all events the same probability, over rules of thumb, that cut costs and/or benefits using a certain arbitrary flat rate, to the implementation of risk premiums, that are put on the discount rate. In the end, all these procedures influence arbitrarily the result of the cost-benefit analysis.

Another possibility is to conduct a sensitivity analysis. Here the question is how sensible output variables react on changes of one or several input variables. This is not the solution for the decision problem under uncertainty in the narrow sense, but it gives indication, whether this state of uncertainty has important impact on the CBA result. If output variables react only to a small extend, the final result of the CBA is not decisively influenced by uncertainty, either.

4.2 COST-EFFECTIVENESS ANALYSIS

Like CBA, cost-effectiveness analysis (CEA) is an instrument for the evaluation of public projects with the aim to determine the best one. But comparing CBA with CEA several differences can be observed. The traditional CBA as described above wants to measure project impact by overall monetary welfare changes. Thus, it can be called a one-dimensional analysis. Cost-effectiveness analysis may have more than one dimension (Dickie & List 2006). The overall goal "welfare" can be split up into several sub-goals and evaluation takes place on a lower, project specific level. This extension of the possibilities for project evaluation means a change of the viewpoint from which the analysis is conducted and reveals a fundamental difference between CEA and MCA (Boardman et al. 2011).

Furthermore, CEA does without a monetary evaluation of project effects and is already satisfied with estimating the physical impacts in their respective dimensions. For each sub-goal the efficiency rule is applied on the condition that each project outcome is produced at lowest costs. Referring to costs, it has to be emphasized that CEA as well as CBA are based on the concept of opportunity cost calculation, i.e. both consider efficiency aspects. In contrast to CBA, CEA does not strive for an overall impact measure, as for example the net welfare effect. In the final report of a CEA, all partial effects stand side by side. A later interpretation or possible combination of the determined effects is exclusively left to the political decision-makers.

Table 3. Structure of a cost-effectiveness analysis (Hanusch, 1994, p. 160)

1. Goal analysis

The goals to be analyzed are project specific. They have to be complete, consistent and capturable in an operational form.

2. Identifying the relevant constraints

As in the case of CBA, the relevant constraints of the projects have to be identified.

3. Selecting alternatives

All possible project alternatives have to be selected, considering the relevant goals and restrictions.

4. Analysis of costs

All costs related to the respective projects have to be determined, based on the concept of opportunity cost calculation.

5. Analysis of effectiveness

All positive and negative partial effects on the output side of the alternative projects have to be determined based on suitable measures or indicators with regard to the goals determined under 1.).

6. Discounting costs and effects

As a rule, costs and effects occur in different periods during project duration. They have to be made comparable by discounting.

Structure of a Cost-Effectiveness Analysis

The typical structure of a cost-effectiveness analysis is presented in Table 3. The first three points might be called "high level analysis". The cost-effectiveness analysis in the narrow sense ("low level analysis") contains the points 4 to 8 (Hanusch, 1994, p. 160). It is obvious that in comparison with CBA the only differences lie in point 1 (goal analysis), point 5 (effectiveness analysis) and in drawing up a cost-effectiveness matrix (point 8). In the following, these points are to be considered in detail.

A cost-effectiveness analysis can be carried out for projects that either have one or several goals. In a simple case, there is merely one goal to be reached, which is already determined by law, as for example the absolute protection of a settlement. Here, CEA compares the costs of alternative projects, which have the same effectiveness with regard to this aim.

In case that no objective is formulated, a goal analysis has to be carried out before proceeding with a CEA. This analysis starts either at a project specific level and the respective problem(s) to be solved or begins at an overriding category as e.g. welfare and then tries to identify operational sub-goals at the project level. In both cases, the goal system has to be complete and logically consistent.

Only if the goal system is complete, consistent and formulated in an operational way, the effectiveness of different project alternatives can be determined. First, the variables that might serve as a benchmark for effectiveness have to be identified. They must indicate, in how far particular projects contribute to the achievement of the determined partial goals.

Later it must be checked, how the partial effects can be measured. Using a nominal scale results in categories like “yes/no” or “satisfying/unsatisfying” and has only limited meaningfulness. Measuring at an ordinal scale admits comparing statements about the different degrees of goal achievement, like “higher/equal/lower” or “better/equal/worse”, but still without providing information about the concrete difference of alternatives’ effectiveness. This can only be achieved by using a cardinal scale. A cardinal scale has the highest meaningfulness. It permits the determination of numerical differences, like for example the statement that alternative A’s goal achievement is 15, 50 or only 5 units higher or lower than that of alternative B.

Cost-Effectiveness Matrix

The results of the CEA can be summarized in matrix form. Here, the different alternatives are presented, showing the costs and respective effectiveness with regard to the partial goals. A definite recommendation can only be given, if one project turns out to be superior to all other alternatives concerning costs as well as effectiveness. If a project is better (higher effectiveness and lower costs) in all other aspects but one, it cannot be characterized as superior to all alternatives any more. In this case, two or more alternatives are dominant. A recommendation is easier, if only one goal is to be achieved and thus, only one benchmark for effectiveness has to be chosen. Here, alternatives can be ranked on the basis of cost-effectiveness ratios. Such an approach ignores the absolute level of effectiveness of a project. Furthermore, the area of application is restricted due to the one-dimensional goal.

A further possibility to achieve clear results of a CEA is the setting of preconditions that have to be fulfilled by the projects in question, as for example minimum degrees of effectiveness (“fixed effectiveness approach”) and or maximum cost limits (“fixed cost approach”) (Hanusch, 1994, pp. 169ff.).

4.3 MULTI-CRITERIA ANALYSIS

The third instrument for evaluation of public projects that will be mentioned here is the multi-criteria analysis (MCA). Like cost-effectiveness analysis, benefit analysis aims at a multidimensional goal system and tries to rank alternative projects in order to give recommendations in the political decision making process. In contrast to CEA, MCA is not restricted to the presentation of certain degrees of partial effectiveness in matrix form, but goes one step further: aggregating the respective degrees of effectiveness to one single number, that indicates the overall effectiveness or utility value. In this respect, MCA can be characterized as a further development of CEA.

Table 3. Structure of a multi-criteria analysis (Hanusch, 1994, p. 173)

1. Goal analysis

The goals to be achieved by implementing public projects have to be determined completely, consistent and in an operational way.

2. Identifying the relevant constraints

3. Determining the feasible alternatives

All alternatives that seem to be feasible for the realization of the determined goals and do not contrast with the identified constraints are to be reported. Possibly, the relevant alternatives are already determined in the political decision making process.

4. Analysis of effectiveness

Positive and negative effects of the respective projects are to be reported. In order to quantify these effects, suitable benchmarks for effectiveness have to be developed with regard to the partial goal performance.

5. Determining the degree of goal performance

After analyzing the degrees of partial effectiveness, they have to be transformed into degrees of goal performance. For this purpose nominal, ordinal or cardinal scales can be used.

6. Weighting the degrees of partial goal performance

The degrees of goal performance are weighted according to the relative importance of the respective

Structure of a Multi-Criteria Analysis

The items 1 to 4 have already been mentioned when dealing with CBA and CEA, respectively. In the following, the points 5, 6 and 7 are to be analyzed in detail.

The methodical approach of MCA, i.e. aggregating all partial degrees of goal performance to one single utility value, requires all partial effects to be measured at one uniform scale. Here, a nominal scale turns out to be of very restricted suitability, because it uses terms like “satisfying/non satisfying” or “yes/no”. Only a project that is characterized as satisfying in all aspects can be judged as satisfying. In all other cases, where satisfying as well as non satisfying aspects occur, no definite judgment of the project can be made, because a setoff/counterbalancing of different values is not possible at a nominal scale.

If an ordinal scale is used (e.g. “higher/equal/lower”), a total value can be calculated applying the majority rule. According to this rule, a project is to be recommended, if it performs better than others in most of the partial effects. Another procedure to get an overall judgment follows the “rank summing rule”. Here, alternatives are evaluated according to the sum that is given by aggregating the ranks that the alternatives achieve with regard to the respective partial degrees of effectiveness.

Difficulties might occur as well, if project effects are valued using a cardinal scale, due to different benchmarks with regard to the respective partial degrees of goal performance. These problems can be avoided, if one uniform scale is used from the beginning. If this is not possible, a transformation of the different scales into a uniform scale is necessary. In order to do this, a suitable ratio of values has to be found, taking into account that the prevailing ranking of the alternatives is maintained.

In practice a simple absolute measure is used, e.g. distributing points of a scale from 1 to 5 or from 1 to 10 points. A modified procedure consists in assigning 100 points to the highest partial degree of goal performance. If a project generates a lower degree, the points to be assigned result from the percentage share achieved in comparison with the highest degree (e.g. 50 % of the highest effectiveness correspond to 50 points).

Weighting the Degrees of Goal Performance

MCA aims at a multidimensional goal system. Within this system certain sub-goals may have more or less importance (Boardman et al. 2001). Thus, the degrees of partial effectiveness or goal performance have to be weighted according to the priority assigned to them by the principal and/or agent of the MCA. In order to get information about the importance of the respective sub-goals, direct or indirect approaches can be used.

Table 4. Different approaches to determine goal weights (Hanusch, 1994, p. 178)

Direct approaches

1. Questioning of members of parliaments as well as civil servants of the appropriate executive body/organ
2. Questioning of other political responsible representatives (chambers of industry and commerce, unions, federation of commercial or industrial enterprises)
3. Questioning of population in form of a complete survey
4. Questioning in form of a representative sample survey
5. Public hearings in form of questioning experts

In practice, indirect approaches oriented to the past as well as direct approaches are used, to get a wider basis for decision-making with regard to the weighting of the goals. As shown above, the focus lies on the judgment of political decision-makers and experts. The opinion of the population concerned, which is the only benchmark for evaluation by CBA, seems to be of little importance.

After reporting all information that is considered important, the goal performance has to be weighted. In many cases the “100 points rule” is applied, i.e. a fixed number of 100 points is assigned to the partial goals according to their respective importance. A score of “0” means “absolute unimportant”; a score of “100” signifies that this partial goal is the only relevant aspect for the decision-maker. This approach is based on the assumption that the importance or priority of the partial goals can be determined independently from the degree of goal performance. It is true that this condition simplifies the analysis, but on the other hand it might lead to a rejection by decision-makers or the population impacted by public projects.

After weighting the degrees of partial goal performance, the interim results can be presented in a “partial utility value matrix”, which forms the basis for the calculation of the “overall utility value”. A utility value comparison of different projects is only possible, if they refer to the same goal system. If a cardinal scale is used, even a ranking of the projects is possible including recommendations of the best project. Note that the result of a utility analysis depends heavily on the weights given to the respective sub-goals.

5 CONCLUSION

The concept of total cost is much more ambitious than what has been traditionally provided in the existent assessment exercises, because it aims at describing the total burden imposed by a disaster to a socio-ecosystem. The true costs of disasters include costs (and benefits) which are difficult to identify and quantify. It comprises all direct, indirect, tangible and intangible costs.

Tangible costs derive from the impacts on the economic system. Economic costs can generally be broken down into damage costs (or losses), adaptation costs, and residual damage costs. A central concept for flood damage estimation is the damage function. It relates the damage for the respective element at risk to the characteristics of the inundation (i.e. the flood maps and the land-use maps reflecting the type and the density of objects at risk).

Intangible costs, which might be both direct and indirect, are the most difficult to estimate for two reasons: (1) it may be difficult to identify them (e.g. which is the effect of a flood on an ecosystem?) (2) it may be difficult, controversial and inconvenient to monetize them (e.g. is it acceptable to value the tribute of lives caused by a landslide in money terms?). On the one hand, it could be accepted that these kinds of costs remain not monetized, and thus be referred to as impacts. On the other hand, it is mandatory to identify and include them in any assessment that has the ambition of being comprehensive and realistic.

The main cost estimation methodologies which have been applied to disasters caused by floods and landslides belong to three main families of valuation techniques: (1) market-based, (2) system-based, and (3) non-market-based approaches.

Intangible costs have been largely neglected in the field of economics of natural disasters even though there is huge body of work on the value of statistical life and on the evaluation of environmental goods. This might be due to the fact that:

1. including all these costs in a single economic assessment is considered to be too challenging and resource consuming;
2. a one dimensional result is not considered to be acceptable by a decision maker, especially when ethical implications are strong;
3. to estimate the total cost could lead to the justification of every adaptation investment in a cost-benefit analysis context.

There are several instruments available for processing the complex relations between the different categories of costs and impacts. In case that objectives and impacts can be formulated on the basis of economic theory and can be stated in monetary terms, the classical cost-benefit analysis (CBA) can be applied. However, in case that multiple objectives are involved and/or impacts cannot be reported in monetary terms, cost-effectiveness analysis (CEA) and multi-criteria analysis (MCA) are often used for evaluation purposes. Further, while CEA and MCA can incorporate monetary values, CBA cannot incorporate non-monetary values.

Given the significant limitations concerning the monetization of intangibles, a comprehensive assessment of risk prevention measures should adopt a cost-effectiveness approach. A cost-effectiveness approach shifts the focus to the analysis of the alternative measures which are considered to achieve a certain level of risk reduction, to be defined specifically for each case study.

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