climate *changes* spatial planning

Survey paper on economic costs of extreme events: types of damages and modelling approaches

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1. INTRODUCTION

It seems that disasters of various scales are becoming an inevitable part of modern societies. Such calamities as typhoons, vast earthquakes and strong tsunamis are taking place all over the world, endangering the lives of people and their possessions. Indeed, a disaster can be considered a disaster if a natural or manmade hazard is coming in touch with, and is devastating, human, cultural and economic assets. As an example of major events we may mention the recent earthquake and tsunami of 26 December 2004 in Asia, the hurricanes Katrina and Rita in the United States (Autumn 2005) and the vast earthquake in Pakistan (October 2005).

A wide range of effects can occur, such as loss of life; psychological traumas; devastation of property and assets, both residential and business-related causing deterioration of welfare; curtailment of human activities caused by failure of public services; interruption of business and production activities; damage to historical and cultural heritage; decay to pastures and arable land; destruction of environmental conditions, ecological imbalances, and so forth. It is important to note here that the nature and the extent of the impact of natural hazards on human society do not depend solely on the hazard, rather, on the characteristics of a system under attack, like its preparedness and the ability to react to an adversity. This makes a study of the impact of natural disasters essentially a multidisciplinary effort. Yet, in this contribution, we shall concentrate on only one perspective, namely the economic 'narrative' behind a calamity, refraining from many other aspects. However, we should be aware that influences from other fields make themselves felt in the economic sphere; occasionally we shall encounter them.

We start this paper with addressing global dynamics of climate change as one of the pressing issues in connection to extreme weather events (section 2). Next, we shall present an overview of economic damage with its conceptual underpinnings, as well as modelling efforts from the Netherlands and the international arena (section 3). That overview will cover what would often be referred to as 'material damage'. We shall also provide some insight into the 'immaterial damage' associated with hazards, in particular connected to the value of statistical life (VOSL) in flood safety in the Netherlands (section 5). Not much expertise is found in this sphere; building on the estimations of VOSL in transport, we shall outline some challenges as well as opportunities for this type of study. It will be preceded by a brief description of the Dutch water management and flood protection specifics (section 4).

2. Climate Change: Global Challenges and Local Consequences

Disasters are particularly dangerous because they are difficult to predict. Currently, a number of challenges can be identified that may be expected to contribute to the (more frequent) emergence of calamities (MunichRe, 2006). One of the broadly recognised dangers at the moment is climate change, posing additional pressure on the development of the entire global economy. We shall look at what this could mean for industrialised societies in particular.

The last decades have shown growing awareness on the increasing concentrations of 'greenhouse' gases in the atmosphere, which are believed to cause climate change. This is currently identified as global average warming (as pointed out by some experts, see the report of the International Panel for Climate Change, IPCC, 2001, p.72), and is identified by the increase in the number and severity of extreme weather events, increased precipitation and the sea level rise (Van Aalst, 2006). Following US National Research Council (2002, p.1) "Abrupt climate changes were especially common when the climate system was being forced to change most rapidly. Thus, greenhouse warming and other human alterations of the earth system may increase the possibility of large, abrupt, and unwelcome regional or global climatic events." This means that nowadays, when global environment is changing rapidly, it may be the reason why the world experiences the revelation of extreme hazards, which it has rarely seen before. As apparent from different sources (IPCC, 2001; World Wildlife Foundation, WWF, 2004; US National Academy of Sciences, 2005, *et cetera*) this trend is increasing. The consequences of this are virtually unpredictable. Although we can assume that man can hardly influence the probability of a hazard, it is becoming widely acknowledged that unscheduled extreme natural events will form part of our future. For example, following Penning–Rowsell and Peerbolte (1994, p.9), and indirectly also Van Aalst (2006, p.12), the potential for large-scale flooding exists all over Europe (see also other recent publications supporting these developments, like Van and Jansen, 2006; Stern 2006 and IPCC, 2007). Therefore, we have to take the unexpected into account when thinking about development trajectories (the argument is also supported by Benson and Twigg, 2004, and Hungarian Academy of Sciences, 2004). Identifying climate change and its effects as potential part of catastrophe emergence mechanism necessitates admitting that we are in fact forced to adapt to living in the world where hazards have high destructive potential. Schipper and Pelling (2006, p.30) point out that "the scholarly realms of disaster risk and climate change are also starting to merge". O'Brien *et al.* (2006, p.64) make an important observation:

> "Disaster policy response to climate change is dependent on a number of factors, such as readiness to accept the reality of climate change, institutions and capacity, as well as willingness to embed climate change risk assessment and management in development strategies. These conditions do not yet exist universally. A focus that neglects to enhance capacity-building and resilience

as a prerequisite for managing climate change risks will, in all likelihood, do little to reduce vulnerability to those risks".

This in fact can be seen as a suggestion to connect the issue of climate change with a more general framework of hazard management and resilience-building. Such a view is supported by Van Aalst (2006, p.5), who points out that challenges posed by climate change can not be managed separately from a broader context of development: "…the additional risks due to climate change should not be analysed or treated in isolation, but instead integrated into broader efforts to reduce the risk of natural disasters." We may ultimately notice that not only evaluations of disaster consequences themselves, but also a wider range of goals, such as studying resilience, contingency planning as well as designing development trajectories connected to climate change depend on the theoretical grounds of disaster analysis. In the next sections, we shall continue with the flood management policy in the Netherlands, pointing at the need for studies in particular directed at modelling economic damage potential, and at exploring measures of flood risk reduction.

3. ECONOMIC DAMAGE: CONCEPTUAL AND MODELLING ISSUES

Among a variety of consequences a disaster may bring about, damage in general is a measurable category, and represents a quantification of society's vulnerability.[1] Economic damage in particular occupies a special place in disaster consequence assessments, which bring about a whole gamut of consequences. In table 1 below (adapted from Kok *et al*., forthcoming) we provide a classification of various types of damages characterising flood events, based on the spatial distinction between direct damages inside the flooded area and indirect damages that occur outside the flooded area (see also the discussion on the types of damages below). Another distinction is made between material damages that are tangible and can be priced; and immaterial damages, for which no markets exist.

[1] We should provide some clarification here. Essentially, the study of hazards can be described by the notions of vulnerability, resilience and adaptability, which have recently become a topic of particular interest and wide debate in scholarly research. We have to stress that these notions were gained from other social and natural disciplines; this required that they also had to be given a context-specific interpretation when used in disaster analysis. We suggest interpreting economic *vulnerability* (to a hazard) in terms of a measure to incur damage. Economic *resilience* is then the ability (of the system) to cope with a disturbance, adjusting to the new circumstances and conditions and maintaining its vital functions. *Adaptability*, in turn, is seen as the ability of the system to prepare for potential hazards, thereby aimed at decreasing its vulnerability and improving its resilience capacity. The difference with the widely used *mitigation* strategies is that, contrary to adaptation (which is aimed at the system under attack), mitigation is seen as the entirety of strategies, aimed at preventing or limiting the adversity. In connection with *sustainability* notions (broadly interpreted), adaptability and resilience-theory applications could yield their best potential – thereby obtaining a certain normative contents. In the context of changing natural environment under the pressure of climate change, modern complex economic networks seem to be less predictable, in terms of both their vulnerability and resilience to a major hazard. In-depth studies of such systems are needed to gain insight into the processes behind a disaster.

	Material	Immaterial
Direct	• Residences • Capital assets and inventories • Business interruption (inside the flooded area) • Roads; utility and communication infrastructure • Agricultural land and cattle • Vehicles • Assets of historical and cultural value • Damages to the nature and the environment	• Fatalities • Injuries • Discomfort
Indirect	• Production interruptions for businesses outside the flooded area • (Temporary) substitution of production and consumption outside the flooded area • Evacuation and rescue operations • Reconstruction of (flood) defences • Temporary housing for evacuees • Clean up costs	• Societal disruption • Psychological traumas • Loss of trust in public authorities

Table 1. Dimensions of flood damages (adapted from Jonkman *et al*., forthcoming).

The purpose of an *a-priori* assessment of economic damage is gaining insight into the damage potential that a hazard may bring, as well as exploring the options that are open for mitigation and adaptation measures. In this section, we shall touch upon some of the crucial conceptual and modelling aspects of a part of 'material damage' category, economic damages that include business interruption and production losses for companies outside the flooded area.[2] We shall return to the discussion of immaterial damages in the next sections.

3.1. The Concept of Damage

The concept of (economic) damage remains one of the most controversial and multifaceted terms in hazard analysis; one rarely finds the same definition of damage in publications from different sources, such as authors, research institutes, or government agencies. Current attempts at studying calamity consequences are highly diversified; varying by country, type of (natural) hazard, modelling type or purpose. This means that a set of *commonly* accepted concepts used in disaster research and their definitions are still missing. Loss definition suffers from the fact that in various studies the delimitation of the various categories of loss is unclear. Various studies use notions such as direct,

[2] We know, that in the Netherlands approaches exist focusing on estimating physical damages (Vrisou van Eck and Kok, 2001), environmental damages (Stuyt *et al*., 2003), loss of life (Jonkman and Kelman, 2005; Jonkman, 2007), public health impacts (Ahern *et al*., 2005) and economic impacts (Van der Veen *et al*., 2003, 2004; and Steenge, *et al.*, 2007).

indirect, primary, secondary, induced damage; yet, lately in the literature we notice a trend in the use of damage concepts towards the convergence to the direct-indirect loss distinction. Here, two main approaches can be distinguished. Some authors support the division of costs based on the spatial criterion (i.e., all losses attributable to the affected area are direct, losses incurred elsewhere are indirect), or based on the stock-flow differential (all physical damage is stock, and considered direct; all losses associated with production curtailment, whether within or outside the affected area, measured as flow, are indirect). In this, however, each scientist is free to choose.

Estimation of damage, however, requires some caution. It is important to realise that some of the physically damaged assets, like machinery and equipment, are involved in the production of goods and services in an economy, and thus are (indirectly) part of a complex economic network of production and consumption flows. Essentially, such direct damages would give rise to the interruption of output flow in the damaged facilities themselves (sometimes referred to as business interruption), but also disruptions in the business supply-demand chains on a bigger scale, like regional or even national economy. This way, all businesses that would suffer losses because their suppliers or customers are not there anymore, will incur indirect damages. Disaster consequences and therefore damage in the industrialised society are directly connected to the complexity of the economic system under attack. Due to high interconnectedness of various elements within a system, any direct damage would most likely imply a relatively high extent of indirect damage. Because in the contemporary world system constituents depend on the array of conditions and the state of other constituents, major calamities are likely to resonate far beyond the borders of their direct impact through a complex circle of indirect chain effects.[3]

So, while convergence seems to emerge among scholarly authors in distinguishing two main elements of damage, direct and indirect effects, many discrepancies still appear on the operationalisation and application levels. The difficulties experienced usually are fourfold. Firstly, there is no agreement on the economic points of departure; financial appraisals are mixed with economic cost-benefit analyses (CBA). Where a financial appraisal is often the basis for investigating the sum of money to be recovered from insurance companies, CBA is a helpful means to weigh alternative measures to prevent or to prepare for a calamity. When the two are used simultaneously, methodologically inconsistencies may well be the results.

Secondly, there is confusion on the temporal and spatial scales. While financial appraisal limits itself to a single organisation, like a company or sometimes a state; economic analysis can be carried out at multiple spatial scales, ranging from local to regional, national or global. Here, choices have to be made. Also, it is important to have

[3] The role of adaptation in this situation is to minimise direct losses, decreasing economic system's vulnerability; and through resilience to neutralise indirect losses, adjusting in the face of a disaster.

a well-defined temporal scale of analysis as, expanding the time span beyond the immediate calamity aftermath, multiple indirect effects would reveal themselves, as well as adjustment of a system to new circumstances in terms of changes in relative prices and in consumption or production requirements. Especially for major adversities, such indirect (both positive and negative) effects can appear on a grand scale, and have to be carefully considered. In principle, there is no general convention in the literature on the optimal or appropriate scale to be adopted. Yet, the choice of temporal and spatial scales for a particular study should apparently be made in agreement with the purpose of the inquiry, followed by the choice of the appropriate theoretical framework (more on that can be found in Messner *et al*., 2007).

Thirdly, there is the issue of double counting. It often appears due to the confusion between stock concepts and flow concepts. We will clarify briefly. When conducting an economic appraisal of damage incurred within an economic system, it is important to make the essential distinction between two measures of asset value: stocks and flows. While stocks reflect quantity measured at a given point in time, flows reflect quantity per unit of time. Usually, stocks and flows are related. That is, stock is often considered as an accumulation of flows, and flows represent the change in stock (in a given period of time). Because stocks are often generated by flows, in economic theory it is generally accepted that a stock value of an asset equals the discounted value of future flows, generated by this asset. This has direct implications for the accounting of business interruption as a result of property loss. Economically speaking, one of the manners of thinking about the value of machinery or equipment used in the production of goods is actually considering the present value of all the goods the machine will expectedly produce during its lifetime. In terms of assessing disaster-imposed damage, this means that one can include either the market value of lost equipment (which is essentially *stock* based), or evaluate the expected *flow* of output that will not be produced because the machine is lost. Consequently, including both measures can not be done, because they both represent the same value of a single asset. If stocks are counted together with flows (for the same asset), one should guard against double counting (MAFF, 1999; Messner *et al.*, 2007). Thus, depending on the type of loss, stock or flow concepts can be applied (for example, it is more appropriate to measure property damages as a loss of stock, while it is more appropriate to measure business interruption in terms of losses of flow). To keep the appraisal consistent, as pointed out in the literature, it is essential to measure each loss category either in terms of lost stock, or in terms of lost flow, but not both.

The other possible source of double counting is accounting for both loss of income and expenditure. Although this aspect does not come up often in the studies, we find it important to address this possibility as well. Cochrane (found in National Research Council, 1992, p.101, also cited by Chang, 1998), provides a thorough explanation on this account:

> "…the level of economic activity can be measured by counting expenditures, or incomes, but not both. Income […] must be equivalent to value of the products produced. This is because the price of a product reflects all the costs incurred in its creation, which in this case is the sum of wages, interest, and profits. This simple result provides an important loss-accounting guide: damage assessment should focus on incomes lost or spending lost, but not both. Either should yield the same result."

This statement should be borne in mind by researchers performing financial, as well as economic appraisals.

Finally, there is a multiplicity of parties that have a stake in damage estimation, like governments, insurers and their associations, re-insurers and government insurance regulators, private businesses, industry representatives, individuals, academic researchers and experts; and each is interested in a specific damage aspect. The various purposes and destinations that damage assessment serves are an obstruction to the wide cross-study comparisons.

3.2. Discussion of Literature on Damage Modelling

In this section, we shall discuss methods and models now being used in disaster consequence analysis for modern economies. In fact, we are equally interested in the discussion of the methodologies for the study of economic inferences connected as to minor, as to major calamities (we shall return to this point later in this section). We offer a brief overview of the selection of authors contributing to the field with studies on the economic impacts of disasters on contemporary societies. We signal a missing convergence in the scholarly disaster community concerning methodological issues of disaster analysis.

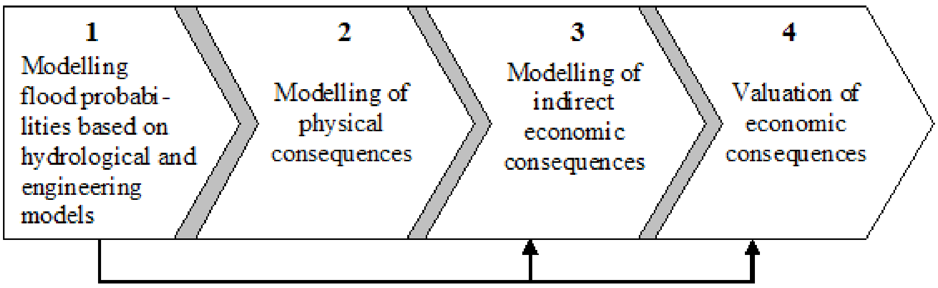

Figure 1. Damage modelling scheme.

In figure 1 above a conceptual scheme is presented, where it is shown how various assessments of damage are connected. The scheme consists of four blocks; the grey areas between the blocks symbolise the overlap of the approaches. The first block, modelling of flood probabilities with the combination of hydrological and engineering approaches, reflects the modelling expertise on the 'physical' side of the flood phenomena and is found in the domain of exact sciences. At this stage, flood probability and extent are modelled based on the geographical characteristics of the area, combined with the knowledge about its protective infrastructure (like dikes, levees or locks), see for example Asselman and Heynert (2003). This stage may be seen as the point of departure that provides basic input information on flood characteristics for any other model exploring the consequences of the hazard. Block two stands for modelling direct damages that result from the direct interaction with a hazard, and may in general include various models ranging from the assessment of physical damages to the built infrastructure and various types of assets (Vrisou van Eck and Kok, 2001); to environmental pollution (Stuyt *et al.*, 2003); or the number of fatalities (Jonkman and Kelman, 2005; Jonkman, 2007), see also table 1 for damage classification. Next, block three represents models that take a wider span of consequences of a calamity into account, i.e. what we refer to as higher-order effects, including indirect economic effects of disturbances of the circular flow within a bigger area, like a province or a country; macro-economic effects of a calamity on the longer-term budgetary planning and investments in hazard prevention (on both of which we will follow in the remainder of this section), and so on. Such models often use the results of the models from the blocks one and two as input information in their assessments. For example, the data on the extent of flood and the value of direct damages to economic assets are necessary for the modelling and analysis of indirect (economic) damages in a broader context. Finally, valuation approaches comprising block four are the ones that are attempting to establish values for immaterial damages using various methods (on which we shall follow in section 5). Also here the background information on the flood probability and characteristics remains an important input.

In this section, we shall pay attention in particular to the models from block three in figure 1, discussing selected literature on international expertise in modelling of economic damage, followed by the Dutch modelling exercises available by now. In the international arena, the topic of a methodology dealing with economic disaster consequence estimation remains a continuous subject for expert as well as scholarly debate. For example, the international (IMF and World Bank) and national bodies (like responsible national Ministries or agencies) involved in disaster protection and preparedness are sometimes the same ones providing broad guidelines or frameworks for broad damage estimation, although they rarely offer a model (see, MAFF, 1999; BTRE, 2001; ECLAC, 2003; Benson and Clay, 2004). Macro-models offered by IIASA (Freeman *et al*, 2004; Mechler, 2004 and 2006; Linnerooth-Bayer, Mechler and Pflug, 2005) are much more tangible and usable. However, these mostly deal with macro-effects and risk financing in and for developing countries, which provides a different focus than the one we are studying here.

Typically, in disaster economic modelling among academic scholars, one can see that opinions are divided on the use of models; the ones most frequently used are Input-

Output based approaches and CGE approaches. Rose and colleagues use both frameworks and offer extensive methodological accounts. For example, Rose and Benavides (1998) and Rose and Liao (2005) provide an input-output analysis of a lifeline breakdown and its effects on the disruption of production activities. At the same time, Rose (1995, 2004b), and Rose and Lim (2002) provide methodological insight into economic disaster modelling and challenges associated with this. Furthermore, Rose (2004a, 2006), Rose and Liao (2005) choose to concentrate on the issue of economic resilience in a disaster context and its quantification with the help of a CGE modelling. Ultimately, Rose and colleagues claim that analysis of large-scale disaster phenomena is essentially different from the 'usual' modelling based on equilibrium with distortions at the margin. Rather, modelling of major calamities and economy's response to those, which often mark a break in the established development path, requires that regular models are adjusted to better suit the purposes of major shock analysis. Such an approach to catastrophes, when they are seen as discontinuities, to which marginal analysis principles are not straightforwardly applicable anymore, is also supported by Steenge and Bočkarjova (2007).

There is a whole range of authors who favour the input-output approaches as a leading modelling framework. The approach of Cochrane (1997a,b and 2004) and HAZUS (FEMA, 2001), for example, are based on manipulating an input-output table to account for disaster losses, after which balancing takes place by adjusting inventories, imports, exports and existing substitution capacity within sectors to take over part of the lost production. Although this is an attractive usable module, the approach seems to be less transparent and is in a sense ad-hoc, where the opportunities for rebalancing are determined by the user. Cole and colleagues (Cole, 1998, 2004b; Cole, Pantoja and Razak, 1993) offer several works based on the input-output approach and social accounting matrices (SAMs), presenting the possibilities for analysis, by means of what they call an event accounting matrix, the EAM. The EAM, an innovative element that captures the essence of post-disaster disorder and later recovery planning, is a concept which has not yet reached its definitive shape, but which is an excellent departure point for further research. In his later studies, (Cole, 2003, 2004a) extends his modelling to an insurance accounting matrix approach, introducing protection investments as a 'buffer' for an economy to be used when disaster strikes.

Furthermore, Santos and Haimes (2004) offer the so-called inoperability input-output model for analysing the repercussions of a terrorist attack, although they do not include disequilibrium modelling. Finally, Okuyama, (2004) and Okuyama, Hewings and Sonis (2004) provide a time-adjusted input-output based sequential interindustry model, the SIM. The advancement of the model into the analysis of production chronology and recovery planning are worth noting, but the disequilibrium stage as a starting point for recovery modelling is not explicitly reflected upon.

There is also some Dutch modelling experience available to conduct flood damage assessments. Historically, much knowledge was accumulated in the Netherlands within the scope of physical damage evaluation and prediction, as the field was dominated by civil engineering advances and expertise. However, until recently, little was known about the economic repercussions of a major flooding of the country. Probably the first effort to arrive at an integrated assessment of damage was the so-called 'standard method' (Vrisou van Eck, Kok and Vrouwenvelder, 1999; and Vrisou van Eck and Kok, 2001), which was recently upgraded in one of the government reports "Flood Risks in the Netherlands" (see MTP, 2005b). However, the method does not have a profound indirect loss estimation module, and it presumably involves double counting of losses for businesses (based on the distinction between stocks and flows as we discussed in section 3.1). Two later reports from NEI and Tebodin (Briene *et al.*, 2003; Van den Berg *et al.*, 2000) include a better description of the indirect effects of a potential flooding, which is estimated based on the input-output multipliers, adjusted for substitution effects between and within the sectors. Furthermore, Eijgenraam (2005) suggests a model to support economic decision-making for the problem of investing in protective dike improvements. Here, the author takes into account the amount of direct and indirect effects of potential flooding, to provide the optimal level of protection, but the economic damage is borrowed from High Water Information System, HIS[4] (see Meulepas and De Klerk, 2004; MTP, 2005a), which is in turn based on the standard method. All these works are characterised by micro- and meso-approaches, based on the calculations per dike ring.

On the meso-macro level, the team of the Erasmus University of Rotterdam (Van Ast, Bouma and Francois, 2004) has developed what they refer to as the risk assessment approach, where attention is paid to the methodological side of the problem. Furthermore, the work of the Twente group resulted in a number of project reports and publications. Van der Veen *et al* (2001) instigated the discussion on the societal and economic effects of large-scale calamities on the national level, stressing the importance of a theoretically sound approach. Delft Cluster reports then followed (Van der Veen and Logtmeijer, 2003; Van der Veen *et al*, 2003a,b), explicitly focusing on indirect economic damage methodology and mapping of important economic activities. Later, the methodological developments in the disaster analysis of disruption, recovery and policy were continued, offering the building blocks for a three-step procedure within an input-output framework (Bočkarjova, Steenge and Van der Veen, 2004b and 2007). Inferences in the economic hotspot determination and mapping can be found in Van der

[4] The High-water Information System in the Netherlands is designed to monitor flood defences, to present inundation and loss calculations, providing information about high water developments in the primary dike system to professionals and policy-makers. Several stakeholder organisations are involved, with a central role for the Ministry of Transport, Public Works and Water Management (MTP).

Veen and Logtmeijer (2005). However, the debate on the approach most suited to the Dutch situation and flooding disasters is open and further advances are being made.

In the next section we shall look closer at the current developments in the Dutch water and flood management system, which will preclude the discussion around the possibilities to estimate the value of statistical life for flood safety.

4. THE SPECIFICITY OF DUTCH SITUATION WITH REGARD TO WATER MANAGEMENT AND FLOOD PROTECTION

It has been noticed (see for example Mitchell, 2003) that flooding threats are becoming a matter of increased concern in Europe. Mitchell distinguishes a number of driving forces behind these developments embedded in a dominant consumer-oriented economy, which in fact also contributes to the increased risks of flooding. Among others, he is mentioning such factors as the movement of exporting industry to waterside locations; the phenomenon of North to South industrial migration; shift towards transportation infrastructure, watershed protection and water supply, nature conservation, and recreation as more important floodplain land uses than traditionally dominant agriculture; landscapes and ecosystems that become extensively modified by humans; growing urbanisation, and others. Mitchell notices that these processes are in particular characteristic of Europe, and are even more intensified by the decreasing willingness of European nations to tolerate floods, imposing high flood-protection standards, probably pioneered by the Netherlands which seems to become a 'zero-risk' society (see also Tol *et al.*, 2003, p.579). These developments together with the pressures posed by the ongoing climate change as we discussed in section 2, as never before, point at the need for thorough research, exploring the damage potential in the areas at risk, weighed against preventive measures that can be taken to provide better protection to such flood-prone areas to support policy and action.

One of the important issues observed in Dutch water management and policy signal recently is a shift in thinking about flood threats. For centuries, both sea and rivers have continuously been a source of danger. The Delta Plan, which came into being after the disastrous 1953 flood, has for decades set the stage for flood protection in the Netherlands. This was based on the concept of very strong primary defences, organized to withstand extreme water levels. For the highly developed and populated central part of the Netherlands, this amounted to a chance of a flood up to once per 10.000 years. We can notice that this permitted a spectacular economic growth in the provinces below sea level, which ultimately made the country a world player on many markets. However, the discrepancy between the infinitesimal dike overtopping probability, and the alarmingly increasing expected losses resulting in a high and ever growing risk of flooding (we shall clarify shortly), demand a different type of approach. It means that the country has to prepare itself for future challenges connected to the rising *risk*, in this context finding a balance between expected probability and potential losses, and growth and development agendas.

These recent changes in the view on water management in the Netherlands have led to a change of approach from one based on probability, to one based on risk assessment. Risk, in turn, is the concept including the interaction between the probability of an event to happen (like a major flooding) and the consequences that this event may bring about. In other words, risk is the product of probability and the effects of the expected calamity. Adopting a risk management approach in fact requires a framework that takes the multifaceted effect side of a disaster explicitly into account. At the same time, there is a need for the assessment of the potential economic (material and immaterial) damage that a flood may cause. If taken on board, this new initiative may in the long run lead to direct implications, like even more differentiated protection standards (see for example Duits, 2007) or implications for spatial planning and physical asset and population re-distribution in the long run, accompanied by a further chain of reactions throughout various facets of contemporary society.

A wealth of issues surrounds the spatial dimension. First, many of the issues on today's agenda are a consequence of how Dutch spatial structure has developed. The country is basically a patchwork of interconnected polders, which each has different characteristics such as population, economic value, and different safety standards. Some figures on the potential damage per dike ring could illustrate further the differences between the units of protected areas (from Floris report (MTP, 2005c) on flood risks and safety in the Netherlands, providing maximum direct physical damages) which range from €160mln for Terschelling (an island with limited amount of economic activity located there) to €290 bln for Zuid-Holland (one of the western coastal provinces with high concentrations of inhabitants and economic assets). Taking into account the varying protection standards, expected *yearly* damages (i.e., risk) are €0,1 mln for Terschelling; €116 mln for the provinces of Zuid Holland and Noord Holland; and almost €200 mln for Land van Heusden/De Maaskant and Betuwe, Tielerand Culemborgerwaarden. Number of expected victims of a flooding varied greatly by dike ring, depending on the assumptions about flood characteristics and evacuation capacity; for example, in Noordoostpolder are estimated to vary between 5 and 1400, and in Zuid Holland – between 30 and 6100 (see MTP, 2005c and 2006, as well as Jonkman, 2007 for more detail concerning methodology for the estimation of the number of fatalities). Expected yearly number of flood victims are estimated at 0,042 for Noordoostpolder; 0,28 for Zuid Holland, and 1,31 for Land van Heusden/De Maaskant.

We have to note at once that the figures provided above are rough estimates yet; tailored flood probability and damage calculations should be based on the much more complex concept of systemic risk where a number of dike rings should be seen as an interdependent system. Connected to this is the issue concerning the present spatial distribution of activities, in particular the question whether or not the Western part of the country can remain as prominent in Dutch society as it is now. Systematic factors do not look favourable: sea level rise, subsiding ground level, increased precipitation and the expectation of more extreme peak river discharges. The Netherlands has to decide how it will develop in the next decades. Second, there is another issue specific of Dutch situation, which concerns the role of government, namely its increasing willingness to share the responsibility of flood risk management (Wouters, 2006a,b). One of the aims of this trend, which may eventually become a policy vision, is to make the public more aware of flood risks by means of involving private actors in decisions connected to water management and flood protection on the basis of sharing a part of associated costs. Connected to that is the topic of insurance that tends to reappear more often on the public debate agenda (Botzen and Van den Bergh, 2006a,b). It is yet complicated by the presence of catastrophic losses, interdependence and ambiguity, all of which makes it troublesome for private insurers to define the amount of premiums, as well as to ensure the presence of capital to satisfy all disaster-related claims simultaneously.

Given the increasing complexity in which modern societies like the Netherlands are operating, it is nearly impossible to solve water management and (large-scale) flooding problems without embedding them in the broader context of economic development as was the case in earlier times. The seamless interaction between water and economic networks offers rich grounds for debate, which we believe should improve our vision on the water and flood protection problems in future. We can see that a number of questions appear following the issues discussed above, like: Should the core economic activities be located in the areas directly behind the dikes be still protected, or should a policy of spreading these activities to the higher areas in the Eastern and Southern parts of the Netherlands be adopted? Also, what is a possible mix of private and public solutions that could ensure countries adaptability in the long run to the threats of climate change? In this context, further research on the economic dimension of disaster consequences will be needed as an essential part in understanding, explaining and steering contemporary economies in the direction of the desired development trajectories. Here, a cost-benefit approach from welfare economics is a good candidate to analyse various adaptation measures and policies.

5. VOSL IN THE CONTEXT OF FLOOD SAFETY

In this section, we shall discuss the value of statistical life (VOSL) as one of the aspects of immaterial damage in the context of flood safety in the Netherlands. VOSL is one of the common ways to evaluate the risk of a fatality. It signals how much an individual or a group of individuals are willing to give up in order to decrease the expected number of fatalities in a given context (like traffic accidents, or industrial accidents) by one. It is important to clarify that in this case, the average number of victims or fatalities is being decreased, and thus it is not known in advance whose live will ultimately be saved. That's why the term 'statistical life' is used. Moreover, a VOSL reflects essentially the willingness to pay for a reduction in risk (rather, probability of an adverse event with a lethal outcome), and therefore is not intended to determine the value of a human life.

For example, in labour economics, the differences in wages between 'safe' and 'unsafe' jobs can be compared (using appropriate econometric methods, to which we shall return later in this section) to the differences to fatality rates, and in this way monetary values that employees attach to the safety at the workplace can be translated into the value per fatality. In the studies of VOSL in transport safety (see, e.g., De Blaeij, 2003), the willingness to pay for a safer or less safe car; or the willingness to pay for a safety device reducing driver's chance of a fatality are related in a similar way to the number of reduced expected fatalities. This way, the compensation for risk is transformed into the value of statistical life, which in turn can be used as a threshold to value changes in risk of a fatality in general.

However, in practice the valuation of a VOSL, as found by Daniel *et al*. (2005b) most probably reflects not only immaterial damages, but also includes loss of consumption. Also De Blaeij (2003) reflects that VOSL estimates are based on the respondents' maximum WTP, which presumes that measured VOSL includes total benefits, for which agents are willing to pay, i.e. as for the reduction of risk of suffering, as for the reduction of risk of foregone future utility of pleasure through consumption. In addition, numerous studies have shown that a VOSL is not a constant, but rather varies dependent on the personal characteristics of the surveyed population and the context in which VOSL is measured. For example, the higher the level of income, the more people are willing to pay for extra increase in safety, which pushes VOSL up. Another aspect that can be of importance in VOSL estimations is the initial level of riskiness. Namely, the higher the initial risk, the more people are willing to pay to contribute to its decrease; the lower the initial risk level, the more VOSL tends to decrease.

5.1. Some Background on Valuation Approaches

To evaluate various measures directed at improvements of flood safety, a cost-benefit approach (CBA) is often used. Essentially, it compares alternative options in terms of streams of benefits against respective costs (including initial investment and maintenance).[5] In this way, several considered alternatives can be compared. To be able to account for all or at least as many as possible costs and benefits, these should be

[5] For an overview of issues connected to CBA appraisals, see *inter alia* Nijkamp, Ubbels and Verhoef (2002).

expressed in the comparable units, which are often assumed to be money terms. Yet, it is not equally straightforward or easy to provide a monetary value to assets of different nature. Probably, the simplest assets to value are market goods; they have a price determined on an existing (competitive) market. Although shadow prices may still differ, this provides a first starting point for determining the unit value. Non-market goods often need to be valued indirectly, as they are not directly traded, and thus do not have an established price. These are, for example, environmental goods, where extensive valuations are well documented.

Valuation methods aim to estimate the individuals' marginal 'willingness-to-pay' (WTP) (in monetary units) for improvements in the quantity or quality of a non-market good concerned, and are therefore consistent with the general philosophy of CBA, in which relevant welfare effects are expressed in monetary units. Economists have developed a number of procedures, which, at least in the case of some externalities, do provide reasonable guidance to the monetized value of these effects, despite the remaining uncertainty and dispersion in values produced (Button, 1993a). In recent years the level of sophistication used in this process has risen considerably. Two types of approaches to value environmental goods exist (see table 2), namely, behavioural and non-behavioural ones.

Valuation approaches			**Short-cut approaches**	
Behavioural		Non-behavioural		
Surrogate markets (Revealed preference)	Hypothetical markets (Stated preference)			
• *Hedonic techniques* • *Travel cost methods* • *Household production functions*	• *Contingent valuation in various forms* • *Conjoint analysis*	• *Damage costs (buildings, crops, etc.)* • *Costs of illness*	• *Prevention costs: hypothetical defensive, abatement or repair programmes*	• *Actual defensive, abatement or repair programmes*

*Table 2. A classification of different valuation approaches (*Adapted from Verhoef, 1996)

While non-behavioural techniques are used widely in practice, providing 'hard' estimates, following Nijkamp, Ubbels and Verhoef (2002), they are not taking into account non-use value of assets, as well as they fail to relate valuations to consumer utility functions. Behavioural approaches, alternatively, are preferred on theoretical grounds, as they provide directly consumers' valuation of the selected asset. Two main categories of behavioural techniques are distinguished here, revealed and stated preference methods.

Revealed preference techniques can be applied when surrogate markets for the environmental good to be valued exist; that is, when consumers' marginal willingness to pay for changes in the effect can be measured by looking at their behaviour on other, related markets. Such other markets may be housing markets and labour markets when hedonic techniques are used to statistically infer the value of, for instance, noise annoyance as an attribute of housing services, or safety as an attribute of jobs. In Daniel *et al*. (2005a, 2006a,b) the effects of the flood risk on the property values in the Netherlands along the river Meuse (including the so-called emergency inundation areas, in Dutch, '*noodoverloopgebieden*') are explored with the help of hedonic pricing model based on the actual data of housing transaction prices. The so-called travel cost method would typically seek to measure the valuation for, e.g., natural parks by looking at the expenses that visitors make in order to see the park. Household production functions can be used then to infer how households, in their 'production of utility', try to defend themselves from the impacts of certain externalities.

When the goal is to value non-use values, or when no surrogate markets exist, stated preference techniques can be used to infer consumers' willingness to pay by confronting them with hypothetical markets or goods. Contingent valuation studies try to ask for a willingness to pay directly, possibly by confronting respondents with various bids for a certain good. Conjoint analysis techniques typically confront respondents with two (or more) scenarios in which the quantity or quality of an environmental good and some financial transfer vary, and ask them to indicate the most preferred option. Essential to stated preference methods of valuation are the explanation of known probabilities, which aims at the collection of objective valuations from the respondents based on the realisation of factual information instead of subjective perceptions. Yet, because the above-mentioned methods are always indirect or induced values, valuation of non-market goods will always remain an approximation.

5.2. Valuation of VOSL in Flood Safety in the Netherlands

In the above we have briefly introduced the concept of the value of statistical life, and the valuation methods that can be applied for its determination in the framework of a cost-benefit analysis. In this subsection we shall follow the discussion around the stated preference method for the valuation of VOSL in the Netherlands, illuminating a number of issues that are of importance for the determination of VOSL within an SP approach. One of the first issues that comes up to the surface is the general level of flood protection that exists in the country. Legal standards for dike construction are defined at the tolerated level of dike overtopping mounting to once in 500, 1250, 4000 years and even once in 10.000 years for the Western part of the country, which are extremely strict comparing to other flood-prone places around the globe (where often once in 100 years is considered as enough protection). This means, that we are dealing with small, and provided the experience of other SP studies, very small probabilities, which often proves to be a difficult task to explain to the respondents.

The issue is complicated by the fact that the probability of a fatality due to flooding is of composite nature. First of all, in the Netherlands, which consists of dike rings and polders as we mentioned in section 4, this means that the probability of a flooding should be determined for each specified locality, based on the information about various dike failure mechanisms (see MTP, 2005c), including overtopping. This aspect is being studied and attempts at modelling it are made (see, for example, Cappendijk and Jonkman, 2006), however, extensive standardised information on flood probabilities per dike ring, though available, requires more underpinning with localised information to obtain reliable estimates. Second, the probability of a flooding, even if to be roughly substituted by the legal standard for dike ring safety, should be multiplied by a probability of the emergence of a fatality in case a flooding takes place. The problem is that the latter probability has to be modelled separately, too, while a constant number, or a known proportion for the determination of a number of fatalities in flooding, do not exist. Jonkman (2007) offer such a model, yet it remains sensitive to the underpinning assumptions; which should in turn be strictly controlled for in an SP environment. One of the aspects that surfaces in this respect is the issue of evacuation. Here, a threefold of points are important, namely, the reach of the warning message throughout the population, perception of flood warning and compliance to evacuation, i.e. response in terms of factual behaviour. Each of these points is crucial for the determination of flood mortality. If a warning message has not physically reached a fraction of population, it will potentially increase the number of those exposed, as will the disbelief in the warning (with numerous examples from the literature). Finally, decision to evacuate may not realise in actual movement from the threatened area due to inability or lack of means to evacuate or escape, or the restricted capacity of the exit roads (including congestion) to allow all those willing to evacuate to do so. This means, that when confronting the respondents with information or questions concerning evacuation, we need to keep in mind that these are issues of personal preference (like risk-taker or a risk averse person), which may, due to a dominated perception of flood consequences (mostly, underestimated) including personal risk of mortality, if uncontrolled, influence the respondents' valuations of changes in the safety level.

As a threshold case, we may use one of the accepted 'rules of thumb' as a starting proxy (following Jonkman, 2007) for the determination of the probability of a fatality in flooding; suggesting that 1% of the affected population becomes a victim of a major flood. A second proxy to be used is the legal safety standard in the Netherlands for dike overtopping, which will bring us to the expected yearly probability of a fatality due to a flooding for the inhabitants of some of the dike rings in the West of the Netherlands to one in a million (i.e., 10^{-6}), which is an extremely low indicator.[6] We may expect to

[6] For comparison, RIVM report on the management of risk (2003) provides some estimations of yearly number of deaths for various incidents. Translating those numbers into ratios we obtain that, for example, the probability of dying from smoking is one in 700; being a victim of a traffic accident is on average 6 in

have difficulty in explaining such low probabilities to the respondents (also stressed by Brouwer and Schaafsma, 2006), and should look for an appropriate manner to present this information as much comprehensive as possible. Here, often risk ladders and colour grid representation are used, which we may adopt for our purposes.

Another question connected to the initial level of risk is the existence of a positive VOSL (as we mentioned in the previous sub-section). Here, possibly, also the status of flood safety as a public good may play a role. Already at this early stage of research, it becomes apparent that the usual practice in SP approaches of providing the respondents with alternatives, asking to make a trade-off between a sum of money and the level of *individual* risk reduction, becomes troublesome. On the one hand, the trust in government as a provider of public safety might create a bias in personal perception of flood safety, which may be difficult to influence even by providing the explanation of objective levels of risk. Besides, the interpretation of flood safety as a public good might give rise to a free-rider problem and result in the underestimation of VOSL. On the other hand, if the changes in safety cannot be attributed to a single person, then it has to be attributed to a known size of a group of individuals, which is not certain in our case.

Atop of the points that we have outlined above there are known biases that accompany SP valuations, like the (in)sensitivity to the scope of the good - embeddedness; hypothetical nature of choices; yeah-saying; choice of payment vehicle; reference point and others (see, for example, De Blaeij, 2003, for an outline of biases associated with SP methods). All this signals that we should exercise caution in setting up an SP questionnaire, designing our experiment. Formulation (i.e., wording) of questions, the presentation of information on risk[7], the order of questions and the amount of questions presented appear to play a role, and ultimately affect the VOSL estimate, in this type of 'experimental' setting.

To conclude, we should point out to the different sort of problem that we have at hand with the estimation of VOSL for flood safety in the Netherlands, compared to the earlier studies of VOSL in the Netherlands (for example, see De Blaeij, 2003 for the methodological and empirical issues of VOSL estimation in transport). The different nature of risk, and the context of the problem promise to suggest some challenges; yet it also suggests opportunities that we have to utilise in approaching these challenges.

10.000; fatality due to consumption of drinking water containing legionella bacteria – about 4 in 100.000; and being hit by a lightning – just slightly lower than one in a million.

[7] Literature suggests that respondents might differently perceive different, mathematically equivalent, probability expressions, like 1 in 100 and 10 in 1000.

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