

climate changes spatial planning

Integration

Cost benefit analysis for climate change adaptation

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Contents

Introduction

1. Introduction

A fundamental problem in the context of adaptation to climate change in the Netherlands is how to assess the costs and benefits of various mitigation and adaptation options for climate change and land use. The uncertainty and irreversibilities of climate change pose new challenges for decision making and for assessing policy options. If adaptation or mitigation options are implemented too early, irreversible investments costs are made. However, if the policies are implemented too late, serious and irreversible damages will occur.

The focus of this programme was on the development of decision making tools based on cost benefit analysis under uncertainty, for analysing adaptation and mitigation options related to spatial planning in the Netherlands. The full programme focused on the methodological issues for cost benefit analysis (CBA) and multi-criteria analysis (MCA) in a spatially explicit and dynamic context, including ancillary benefits and the issue of how to allocate costs to various domains, if ancillary benefits exist . The project focused on the complicated analysis of climate change policy options and management options, and it included a number of applications for case studies that all focus on cost and benefit assessment and ranking of alternative projects, related to mitigation and adaptation projects in the BSIK programme Climate and Spatial Planning.

The novelty of the programme is the emphasis on integrated solutions for mitigation and adaptation options for climate change in the Netherlands. The integration focuses on the options to design adaptation and mitigation strategies that provide good solutions for various policy domains, for instance reduction of the risk of flooding, in combination with production of biomass, nature conservation and benefits for recreation. For the integrated analysis spatially explicit optimization and scenario models have been developed that allow to analyse the interactions between various policy options.

This implies a novel approach, because very often in traditional cost benefit analysis the focus in the design of projects is on single issues, and many impacts on other policy domains are only partially analysed. In particular the environmental costs and benefits of projects are often neglected or only partially studied. The second novel contribution is in the focus on spatially explicit analysis in the cost benefit analysis: in mitigation and adaptation strategies spatial claims play an important role, for instance in water management, coastal zone management, land use for sustainable energy (including biomass, solar and wind), adjustments in agriculture and adaptation for biodiversity conservation and restoration. Special attention has been paid to spatial claims related to agriculture and nature conservation, water management (including retention areas) and spatial claims for recreation, housing and infrastructure in river systems and coastal zones.

This report describes the original problem definition of the projects that have been funded under Climate changes spatial planning programme for the programma IC05 Cost benefit analysis for climate change adaptation, and the methods and results obtained. This concerns 1. Cost benefit analysis of flooding (WUR-ENR) subprojects 1 and 5 of the original proposal (a postdoc project at WUR-ENR and a PhD position at WUR-ENR); 2 Perception of the risk of flooding (VU-IvM) subproject 2 of the proposal (a PhD-project at VU-IVM); 3 Stated preference approaches to the valuation of flood risks: VOSL and other indicators of immaterial damages (VU-RE) subproject 3 of the proposal (a postdoc project - originally envisaged as PhD project) at VU-RE.

2. Cost benefit analysis of flooding

WUR-ENR Sub project 1 and subproject 5 of the original proposal
Postdoc: Rolf Groeneveld; PhD candidate Karianne de Bruin

2.1 Original programme description

Sub-project 1 Methodology for spatially explicit cost benefit analysis and multicriteria analysis
The method of cost benefit analysis for infrastructural projects is well defined in the Netherlands in CPB 2000. The method describes how the project alternatives and the base case can be assessed, considering the scenarios, risks and uncertainties. Next the Market and competition analysis takes place, the indirect economic effects and the national economic analysis is considered and the external effect, in particular environment and safety are analysed. Next a category of effects which cannot be expressed in monetary terms will be identified, including the distributive impacts. Finally decision making can take place on the proposed project variants. (cf. CPB 2000 and CPB/NEI, 2000).

This method will be the starting point in the project but it will be elaborated on the following aspects:

1. How to integrate simultaneous policy options and the mutual ancillary benefits in CBA analysis? 2. How to deal with the monetary benefits of environmental impacts related to climate change issues in the Netherlands. 3. How to consider the spatial competition in the various policy alternatives and how to assess the spatial implications of policy alternatives.

Ad 1. The postdoc projects will make contributions to solving these issues by elaborating on the method that should in principal be applied to integrate these aspects more consistently in project appraisal. In Schmieman et al. (2002) and Brink et al. (2001) it has been illustrated that substantial cost savings can be made if policy options and their impacts are simultaneously analysed instead of in a sequential manner. In identifying efficient options, those options can be selected that have beneficial impacts for the several target variables, and in the optimization procedure the policy and management options can be selected that provided the best results. By applying this method to the assessment of climate change adaptation and mitigation options in the Netherlands, it will become possible to identify and rank solutions that otherwise would not be considered in a systematic manner.

Ad 2. CPB 2000 notes that "it is difficult to express the effects of projects on the environment, nature and safety in monetary terms, because there are no markets, and therefore also no prices for these goods." The postdoc project will (in consultation with the project leaders of projects 3 on valuation) identify the categories of environmental benefits that are relevant for the projects to be analysed. These include the impacts on emissions of GHGs, acidifying compounds and other air pollutants, as well as emissions of toxic compounds and the impacts on nature and landscape. It will be assessed which valuation methods are most suitable for these categories and in the case studies a number of valuations will take place for these categories, based on the best valuation methods available, like CVM and hedonic pricing. For those categories that cannot be expressed in monetary terms special indicators will be used that then can play a role in a multiciriteria analysis.

Ad. 3. In adaptation option and mitigation options in the Netherlands spatial claims play an important role. The price of land is in the Netherlands not always a good indicator of the scarcity of land and space, because of the regional planning policies that prevail. This requires specific attention for the question of how to implement multiple land use for adaptation and mitigation options for agriculture, flood reduction and production of biomass, with their implications for recreation and landscape values. The post doc project will assist in finding the best solutions to deal with these issues in the cost benefit analysis of simultaneous projects.

Sub-project 5 Integrated modelling for CBA analysis and land use

The project will focus on cost benefit analysis in coastal zones in the Netherlands, in particular in those areas where competition for space prevails amongst housing and infrastructure, agriculture, recreation, and infrastructure for coastal defence against flooding. Climate change will require substantial adaptation in coastal zones for reducing the risk of flooding, for reducing the impact of salinization and for dealing with pressures of economic growth and population pressure under scenarios of climate change. This leads to the need for a revision of policies in the coastal zone and there is a need for detailed studies on how to strengthen the infrastructure for coastal defence, how to relocate greenhouse industries and how to provide space for nature conservation and recreation in the highly densely populated areas along the coast in particular in the provinces of North and South Holland. The project will focus on at least two case studies. The first deals with land use along the coast of the province of Zuid-Holland and will analyse a set of alternative projects that are dealing with reducing the impact of climate change and the adaptation to climate change impacts. It will focus on strengthening the coastal defence against flooding, and relocation of agriculture as a result of increased salinization due to sea level rise. The project appraisal will focus on opportunities for housing and recreation as a result of these adjustments. The detailed specification of the base case and the policy alternatives will be done in close consultation with the stakeholders after an in-depth analysis of the best policy options.

The second case study will focus on the socio-economic aspects of landuse in river basins in order to provide an integrated analysis of land use options and water management options, whereas at the same time the impacts on nature conservation and the potential benefits for recreations are studied. The case study, which is envisaged to be located in one of the large river systems in the Netherlands (Rhine, Meuse or IJssel) will focus on developing an integrated optimization model that includes the various policy options and the mutual impacts of these policies on land use, water management, production of sustainable energy, nature conservation and options for recreation. In consultation with the relevant stakeholders the various policy options will be analysed and assessed on their implications by means of scenario analysis. It then will be analysed how new and cost effective policy options can be implemented that consider the impacts of climate change, both for land use, river basin management, recreation and nature conservation.

The PhD candidate will focus on the modelling of the various management and policy options, their side impacts on other domains and the cost and benefits that can be obtained. The candidate will follow the method that has been applied in Brink (2003), which allows the simultaneous analysis of policy and management options that have simultaneous impacts on various policy domains. In Brink (2003) this was illustrated for options to reduce acidification and their impacts on the emissions of greenhouse gases. The study illustrated that under joint optimisation substantial costs savings can be obtained as compared to sequential optimization for various policy domains, in this case acidification and emissions of greenhouse gases. This procedure will in the present project be followed in a spatially explicit model setting for land use and river basin management, recreation and nature conservation. The model will be applied in scenarios analysis, in close consultation with stakeholders and focused on specific case studies.

2.2 Research approach and results

Research approach

The subprojects have focused on three issues. 1 The elaboration of multicriteria analysis for adaptation options in the Netherlands; 2 A cost benefit analysis for de Zuidplaspolder; and 3 The development of a model for decision making on structural and non-structural adaptation options under uncertainty and its application in the coastal town Katwijk.

Ad1. We have further elaborated the multi-criteria analysis that was developed for climate change adaptation in the Netherlands under the Routeplanner project. The method focused on the information from stakeholders and experts on the various adaptation options for the Netherlands and the ranking of these options on the basis of a set of criteria and the weights attached to these criteria. Criteria included importance, urgency, no-regret, ancillary benefits and positive effects for the mitigation of greenhouse gases.

The assessment started with the selection of a climate change scenario relevant for the Netherlands for the period up to 2050, based on the scenarios of the Royal Meteorological Institute (KNMI, 2003, 2006). The study has the character of a "what if" setting where it is assumed that the selected scenario of the KNMI represents the characteristics of climate change for average temperature change, rainfall patterns and sea-level rise for the Netherlands. Based on this starting point the assessment includes the following aspects: (1) identification of adaptation options in the Netherlands, based on literature study and consultation of stakeholders; (2) a qualitative assessment of the characteristics of the options; (3) definition of criteria used to make a ranking of the options, based on expert judgements; (4) determining the scores of the options on the various criteria; (5) determining the weights to be used in the Multi-Criteria Analysis for the ranking of the options and (6) the actual ranking and an interpretation of the results.

In addition we looked into the institutional complexities of implementing the various adaptation options, in order to be informed about the complexities that we would face when introducing adaption options in the various sectors of society. The institutional complexity was not integrated in the Multi-Criteria Analysis because we consider the issue of institutional complexity substantially different from the questions of what adaptation options would be important to consider. By combining information on the highly ranking options and their institutional complexity it becomes possible to develop an adaptation strategy that deals with the priority options and that can focus on solving the institutional barriers that may show up in the implementation.

We also identified the available information on the order of magnitude of the costs and benefits related to the introduction of adaptation options, in order to sketch the relative size of costs and benefits. However, we observed that for many options only limited information on costs and benefits was available and therefore a complete cost-benefit analysis was not possible. We made a start with compiling a database on the available costs and benefits. In more elaborated studies more complete cost-benefit analysis can be made on the most relevant adaptation options, and this process is currently ongoing in the Netherlands.

Ad 2. Secondly the study focused on the costs and benefits of adaption options in the Zuidplaspolder in the Netherlands, in order to asses which specific adaptation options and spatial patterns would be useful for the planning of a new residential area, and related agricultural activities in greenhouses. The focus has been on water retention and climate proof housing under various economic and climate scenarios.

Ad 3. Thirdly the project more fundamentally focussed on the design of an economic modelling approach to select the best adaptation strategy in a setting of uncertainty for structural and non-structural adaptation measures for protection against flooding, either from rivers, or in coastal areas. The model allows for calculating the net expected present values in a setting of uncertainty about the impacts of climate change and a setting of learning of how serious climate change will be. A two period and three period model is developed, that indicates for various ranges of discount rates and the learning process whether structural or non-structural adaptation measures would be preferred and what the optimal mix would be. We develop a model of optimal investment in flood protection measures under climate change uncertainty. Such a model allows decision-makers to cope with the uncertain impacts of climate change on the frequency and damage of river flood events, while minimising the risk of under- or over-investment. Under-investment results in a flood damage probability that is higher than optimal, while over-investment leads to sunk costs and redundant flood protection capacity.

We adapted a model by Hennessy and Moschini (2006) on costly regulatory action under scientific uncertainty to the case of flood protection. Our simplest model specification is a discrete-state two-period model which provides a crude first decision-rule for investments. In subsequent sections, this model is extended to a continuous-state two-period and three-period model, which allows us to analyse the effects of various model elements on this decision-rule. One of these elements is the trade-off between investment in structural and non-structural measures, explained below. Another element is the resolution of climate change uncertainty, which is modelled as a gradual process over time until full resolution is reached. In the two-period model the initial investment decision can be updated when full resolution of uncertainty is reached at an unknown future moment in time. The three-period model allows for an intermediate investment decision under partial resolution of uncertainty before the adjustment of the investment decision under full resolution of climate change uncertainty. The motivation for studying gradual resolution of uncertainty is that over time, additional evidence adds to the overall insight into these impacts, reducing their uncertainty. Our results show that the effect of uncertainty on the investment decision depends on the cost structure of the flood protection measures under consideration. To be precise, a combination of the discount rate, climate change uncertainty, and the cost structure of structural and non-structural measures determines the optimal mix of investments in these measures. A higher level of annual flood damage and later resolution of uncertainty in time increases the optimal investment decision. Furthermore, the optimal investment decision today is influenced by the possibility of the decision-maker to adjust his decision at a future moment in time.

One of the innovative elements of our study is that we explicitly distinguish between two categories of protection measures, which vary in their cost structure. The first category that we will refer to as structural measures includes those measures that have high fixed costs relative to annual costs. Examples are dike improvement and relocation. The second category that we will refer to as non-structural measures includes those measures that have low fixed costs relative to annual costs. Examples are the creation of retention areas to accommodate peak flows, and programmes to raise public awareness on flood events.

Research results

1. The multicriteria analysis

We developed a convenient tool to perform the multicriteria analysis in an excel database in order to making the ranking based on different ranking methods and criteria weighting. Results indicate that nature and water management deserves top priority in the Netherlands, followed by integrated water management and climate proof housing and infrastructure. Less important are options that focus on retreat in the short term.

The ranking is based on a weighted summation of the scores on the criteria (i) importance (weight 40%), (ii) urgency (weight 20%), (iii) no-regret characteristics (weight 15%), (iv) co-benefits (weight 15%) and (v) mitigation effect (weight 10%).
From the ranking, the following adaptation options have the highest priority:

- Integrated nature and water management (nr. 34);
- Integrated coastal zone management (nr. 35);
- More space for water: a. regional water system, b. improving river capacity (nr. 40);
- Risk based allocation policy (nr. 41);
- Risk management as basic strategy (nr. 65);
- New institutional alliances (nr. 68).

These options will emerge among the highest ranked almost regardless of the way the criteria are ordered, as their score is high on all criteria. Changing the order of the criteria will only affect options that score better on some criteria than on others. For instance, Water storage on farmland (nr. 07) scores very high on no-regret and high on urgency and co-benefits, but only medium on importance and mitigation effect. Therefore, when importance has a relatively high weight, this option has a relatively low ranking, whereas it ranks just below the top when no-regret characteristics are prioritised. It will always be below the top options mentioned above, however. There are some options that score (very) low on all criteria and therefore rank very low. These options are:

- Subsoil drainage of peatlands (nr. 08);
- Reclamation of (part of) southern North Sea (nr. 52);
- Abandoning of the whole of low-lying Netherlands (nr. 53);
- Self sufficiency in production of roughage (nr. 06).

These options have very different characteristics but are either relatively farfetched or unnecessary or very costly (for instance abandoning low-lying Netherlands!), or not directly related to adaptation to climate change.

Results have been published as Chapter 2 in the PhD thesis of Karianne de Bruin and in the internationally leading journal Climatic Change.

2. Cost benefit analysis in the Zuidplaspolder

For the cost benefit analysis in the Zuidplaspolder a number of adaptation options and their spatial aspects have been studied (see Table 1). The study showed that not all adaptation options would provide a positive net present value, but for the whole package the net present value would be positive.

Table 1.
Net Present Value of the four identified adaptation options (million euro)

Adaptation option	Location	NPV[a]
1. Water storage in residential area	Zuidplas Noord	-17.2
2. Climate robust ecological network	Zuidplaspolder	60.7
3. Climate robust design of a residential area	Nieuwerkerk Noord	-18.37
4. Climate proof construction of a residential area	Moordrecht Noord	-19.64
5. Adaptation strategy (sum of all adaptation options)	Zuidplaspolder	5.49

[a]Discount rate 2.5%

The case study shows that as the climate is changing, important decisions related to spatial planning in the Netherlands need to take this into account. It is, however, impossible to assess these changes with complete certainty. By downscaling the IPCC climate scenarios to the Dutch KNM climate scenarios, and further down to the local setting of the Zuidplaspolder, this chapter made a first step to identify the effects of climate change at a regional and local level, and to incorporate these effects in the future planning of this specific area. The spatial planning of the Zuidplaspolder needs to take into account the increased risks of flooding caused by a dike breach along the Hollandsche IJssel and the risks of inundation through increased precipitation. The net present value of four adaptation options has been calculated, using a 2.5% discount rate and a time horizon of 100 years.

The systematic application of the assessment framework presented in the study provided the inputs for an iterative planning process, where the active involvement of stakeholders has contributed to identification of costs and benefits of the adaptation options based on a detailed downscaling of the international climate scenarios to the local situation. The results of the cost-benefit analysis are an important starting point for further discussion and implementation of climate robust spatial planning. As the results of the case study of the Zuidplaspolder demonstrate, the SCBA results are not very sensitive to changes in flood probability. Moreover, varying the potential damage costs does not have substantial effects on the outcome of the SCBA. This is due to the low probability of flooding and the discounting effect of the benefits. Varying the value of landscape characteristics and investment costs does have significant effects on SCBA outcomes.

Our results show that investment decisions on adaptation to climate change related to urban development and infrastructure, and based on an integrated cost benefit analysis, should not only be focused on the benefits of flood protection, but also include the benefits of increasing spatial quality. The strength of the approach is that it provides direct input for decision-makers responsible for 'climate proofing' spatial planning policies. The framework can also be applied to other low-lying coastal areas around the world that face the challenges of climate change.

The results are published in the PhD thesis and will be submitted for publication in the book of the BSIK programme

3. The modelling tool for decision making under uncertainty

Decisions on coastal flood protection are complicated by the long time horizons, the uncertainty associated with the distribution of impacts (Tompkins et al., 2008) and local impacts of the investment measures. The investment model presented in this chapter and adjusted to the local case study on adaptation to climate-induced sea-level rise shows how an optimal investment strategy in flood protection measures reduces the risk of under-or over-investment to the decision-maker. The combination of the discount rate, climate change uncertainty, the cost structure of structural and non-structural measures and the inclusion of local costs determines the optimal mix in investment in these measures. Our results show that if climate change uncertainty is present, the ratio of costs determines the optimal investment decision with a strong emphasis on either structural or non-structural measures.

When we consider the guidelines in the Netherlands regarding the selection of the discount rate for Cost-Benefit Analysis, the risk-free rate is set at 2.5% (Ministry of Finance, 2007) and the risk premium of 1.5% when irreversible effects related to costs and benefits are evaluated to take into account long term benefits (Ministry of Finance, 2009). The results show that with a discount rate r equal to 4% when only direct investment, maintenance and damage cost are considered, the optimal investment decision at t = 0 is in non-structural measures. The fixed cost of structural measures outweighs the fixed cost of the non-structural measures. When ancillary benefits related to the tourism and nature sector are included invest in structural measures is preferred over non-structural measures. This shift is due to the inclusion of the annual ancillary benefits. The total annual costs outweigh the fixed and start-up costs, the total annual structural costs are mainly reduced due to the relative high benefits for the tourism sector related to the implementation the structural measures.

Thus, we conclude that the optimal investment decision today depends strongly on the cost structure of the adaptation measures and the discount rate, especially the ratio of fixed and weighted total annual costs of the measures. We define the optimal investment decision today as a specific mix of measures that minimizes the total expected net cost. A higher level of annual flood damage and later resolution of uncertainty in time increases the optimal investment decision.

The coastal setting, preferences of the local stakeholders and the decision-makers responsible for coastal protection have a strong impact on the preferred investment measure in coastal protection under climate change uncertainty. As the national government is responsible for the primary maintenance of the flood protection measures and upholding the flood safety standards, they are less concerned with the effects of the implementation of the coastal flood protection measures on the local stakeholders that live and work in the region. Through including the perceptions of the regional and local governmental organisations and stakeholders working and living in the area in the decision-making process, the impacts on local development of both climate change itself but also of the construction of coastal protection measures is taken into account. In this case study the impacts of the measures on the tourism sector have a high weight in the optimal investment decision. However, for this particular coastal town, at some point the benefits for the tourism sector might decrease when additional investments are made, as the effect of the disconnection between the town and the sea outweighs additional spatial benefits of the options, which is due to the unique historical link of the town with the sea. Further integrated coastal management with local development plans could also entail for example the combination of the flood protection measure with an underground parking garage.

The investment model can be applied more widely, to other coastal or river settings where different types of flood protection measures and climate change impacts can be considered, as the uncertainty with regard to climate change impacts is not likely to disappear or might even increase over time. A possible extension of the model would be to set up a multi-period model, to explore in more detail the effect of intermediate decision moments, where we model that over time partial resolution of climate change uncertainty is revealed. It would be expected that an intermediate decision moment leads to lower investments in structural and non-structural measures. However, there is a trade-off between the timing of the intermediate investment moment and the level of partial resolution revealed. An additional extension of the model framework, would be to include more specifically the uncertainty related to the different climate change effects, that impact the Dutch coastal area, such as sea-level rise, storm surge heights and peak river discharge.

3. Using choice experiments to value reductions in flood risk exposure in the Netherlands: advancing existing methodologies

IVM-VU Sub project 2 Valuation of the Environmental Costs and Benefits of Climate Adaptation and Mitigation Options
PhD candidate: Thijs Dekker

3.1 Original objectives

The main objective of this sub-project is to develop and apply methodologies for the economic valuation of environmental costs and benefits resulting from climate adaptation and mitigation options. In addition, this projects aims to examine the associated distributional issues and how project costs can be apportioned across multiple beneficiaries.

Research Questions

- How can the environmental costs and benefits of climate change adaptation and mitigation options be measured and included in societal cost-benefit analysis?

Many valuable environmental resources are not traded and priced in markets, and are subsequently left out of private and social decision making related to their conversion or conservation. In order to include environmental costs and benefits in societal cost-benefit analysis (SCBA), it is possible to assign monetary values through a range of non-market valuation methods (Ruijgrok et al, 2004). The implementation of climate change adaptation and mitigation options is likely to result in environmental impacts, which similarly need to be valued to enter a SCBA framework.

Policy evaluation based on SCBA relies on a comparison of the costs and benefits related to a specific policy. The performance of alternative policies can be compared by studying differences in their Net Present Value (NPV).[1] This study focuses on the applicability of SCBA to policies reducing

1 The Net Present Value is the difference between the (discounted) streams of costs and benefits arising from a particular policy. A policy is said to be viable when it has a positive NPV.

exposure to environmental risks and in particular flood risk reducing policies in the Netherlands. Benefits associated with reductions in exposure to environmental risks, being either a reduction in the probability of an event occurring or reductions in the consequences of such an event, arise in the form of prevented damages. For example, in our case study regarding flood risk exposure in the Netherlands, benefits arise in the form of prevented damage to property, individuals and their environment. It is, however, not clear how these prevented damages should be quantified in a monetary fashion. So far, monetary valuation of environmental risks has hardly taken place in the Netherlands (e.g. Botzen 2010;Daniel, Florax and Rietveld 2009), while in the international literature many interesting examples are available illustrating that monetary valuation can provide additional insights in the welfare implications of changes in exposure to environmental risks (e.g. Baker et al 2009;Riddel and Shaw 2006).

In the Netherlands, the Hoogwater Informatie Systeem (HIS)-damage module (Rijkswaterstaat 2005a) is currently used as the main framework to quantify the monetary costs and benefits of prevented flood events and related flood protection measures. For example, Rijkswaterstaat (2005b;2005c) estimated the damage for a flood occurring in the densely populated provinces of North- and South-Holland in a worst case scenario up to almost € 350 billion. Accounting approaches, such as the HIS-damage module, include monetary values for specific property and infrastructure damage categories. It has been argued that such estimates are incomplete, because they are based on expected property damage costs determined through 'objective' measurements of the risks involved, not the theoretically correct 'subjective' expected utility values (Brouwer et al 2009;Shaw and Woodward 2008). Moreover, the benefit-cost ratios based on property damage costs alone may substantially underestimate the total benefits, since it does not account for public risk aversion. These latter well-being effects, measured in economics through the concept of society's willingness to pay to avoid a specific risk, should be added to the expected damage costs. In addition to these issues related to dealing with risk exposure, accounting approaches can be incomplete due to excluding goods lacking a market price, so-called non-market goods. For example, the risk of loss of life is an example of an important element of flood risk reducing policies, but to date it remains unclear which monetary benefits can be assigned to a prevented fatality (e.g. Dekker et al 2011). Non-market valuation techniques, of which stated preference techniques are a special case, can be used to obtain a complete estimate of an individual's willingness to pay for a reduction in flood risk exposure or specific non-market goods. The obtained welfare measure(s) can then be used as an input in the CBA analysis of a particular policy.

3.2 Methods and results

The main objective of this study is to evaluate and advance existing stated preference methodologies for the monetary valuation of changes in flood risk exposure in the Netherlands in the face of climate change. Accordingly, this section of the report is structured along two lines of research.

First, given the time and expenses involved in performing primary valuation studies to obtain benefit estimates of specific policy decisions, there is considerable interest in developing and testing value transfer methods. A natural question that arises is to what extent results from existing stated preference studies can be used to infer values for reductions in flood risk exposure in the Netherlands. To answer this question, we conduct a meta-analysis of the Value of Statistical Life (VSL) literature and investigate whether the VSL is context dependent.

Second, we develop a choice experiment specifically designed to value reductions in flood risk exposure in the Netherlands in the face of climate change. Value estimates based on stated preference methods, such as choice experiments, have been criticized for the mismatch between the (hypothetical) predictions, based on the underlying economic framework, and (real) observed choices by respondents. Due to respondent unfamiliarity with the hypothetical survey questions or the policy involved, such as the proposed risk reduction policies investigated in this project, respondents may not behave in the expected rational fashion. Preference uncertainty potentially induces inconsistencies in choice behaviour, as respondents do not exactly know their preferences (yet) or are in the process of discovering them during the survey. This study attempts to evaluate the sensitivity of welfare measures derived through choice experiments to preference uncertainty and related learning and fatigue effects. As such, the applicability of stated preference methods to unfamiliar goods with low experience levels can be evaluated.

Benefits transfers: context dependency of the Value of a Statistical Life

A key advantage of using meta-analysis based 'function transfer' over 'direct transfer' in estimating values for environmental risks is that differences in physical and socio-economic characteristics between risk areas can be explicitly modelled and controlled for (Bateman and Jones 2003)(Bateman and Jones, 2003; Rosenberger and Phipps, 2002). Benefits Transfer (BT) practices in the field of mortality risk reduction often involve the transfer of 'out of context' values. That is, due to the limited availability of context specific values, values elicited for one risk source are applied in another risk context. For instance, the US Environmental Protection Agency (EPA) combines economic valuation studies on occupational and traffic related mortality risks to derive a value for prevented premature deaths in environmental contexts (US EPA 2000). The latter value for reductions in mortality risk, commonly referred to as the value of a statistical life (VSL), forms a significant share of the total benefits in many environmental programs (Alberini 2005). The psychology literature puts forward a number of arguments why willingness to pay (WTP) for risk reductions of similar size and therefore the VSL may differ between risk contexts (Slovic 1987). In particular, differences in risk perception and the population at risk across contexts are expected to result in diverging VSL estimates. Hence, not or arbitrarily adjusting VSL estimates in BT practices for the context in which values have been elicited may have serious implications for policy evaluation.

Thus far, only four primary valuation studies have developed surveys in which WTP estimates were directly contrasted across mortality risk contexts, resulting in ambiguous results. In a contingent valuation study Vassanadumrongdee and Matsuoka (2005) find comparable WTP estimates for mortality risk reductions in distinct subpopulations for air pollution and road safety after controlling for personal exposure. Tsuge et al. (2005) observe similar negligible intra-respondent context effects in a choice experiment and show that the timing of the risk reduction and personal characteristics are the main determinants of stated WTP. On the other hand, Alberini and Scasny (2011) find in an Italian choice experiment that mortality risk reductions in the road safety context are valued less compared to similar risk reductions in fatal diseases associated with air pollution, in particular cancer. Beattie et al. (1998) find an intra-respondent discrepancy between WTP for mortality risk reductions from road safety and domestic fires. To date there does not yet exist a meta-analysis with the explicit aim of identifying contextual effects, despite the large number of VSL surveys in various contexts and limited number of primary studies addressing this issue. Several existing VSL meta-analyses acknowledged the potential presence of context effects and adopted control variables. Elvik (1995) and Miller (2000) observe, on average, a higher WTP for occupational safety than for road safety. Another meta-analysis by Takeuchi (2000) reveals that VSL estimates in the environmental context are significantly lower compared to road safety. The primary focus of these meta-analyses was, however, on variations in VSL across countries and sensitivity to scope effects. The meta-analysis presented here differs in scope and attempts explicitly to identify aggregate context effects, such that correction factors of WTP for out of context BT purposes can be estimated. The difference in scope is reflected in the underlying study selection criteria and the study presents the first test of the reliability of out of context BT.

To test whether the VSL is context dependent we combine the results of 26 international contingent valuation studies covering three alternative mortality risk contexts, respectively road safety, air pollution and general mortality risk. Key differences between the risk contexts are that mortality risks in the air pollution context are perceived less controllable by the individual himself relative to the road safety context. In total 77 VSL estimates are included in the database. Five address air pollution, 52 road safety and 20 estimates 'context free'. A detailed description of the search and selection process is provided in Dekker et al. (2011). A Bayesian regression framework is adopted to facilitate comparison of non-nested models and its better suitability to work with small sample sizes. In total four alternative regression models are tested controlling for risk and methodological characteristics of the underlying studies. Additionally, we control for unobserved study effects and variations in sensitivity to scope across studies by including random parameters in the regression model.

In all four models the posterior means for the context dummies AIR and GENERAL are positive, indicating a WTP premium for mortality risk reductions in the air pollution and general mortality risk contexts compared to road safety. At the mean, our results imply that WTP (and VSL) estimates from the road safety context should be multiplied by a factor 1.8 to be applicable in the air pollution context. This correction factor is close to the proposed correction factor by Rowlatt et al. (1998). Statistical tests provide no support for the conjecture that WTP measures for mortality risk reductions in the air pollution and general mortality risk context are equivalent. Consequently, transferring WTP estimates based on the general mortality risk study design to either the road safety or air pollution context is likely to result in overestimation of the policy benefits. Policy makers should therefore control for risk context in an 'out of context' BT exercise. Regression results show that VSL estimates are not only sensitive to context variables, but also to methodological characteristics of the underlying contingent valuation studies. Bayesian estimation methods offer a convenient way to average out these study characteristics and provide context specific VSL estimates comparable across context. Table 1 provides an overview of context specific VSL estimates in a hypothetical transfer scenario where the probability of a mortality risk is reduced from 100 over 100,000 to 90 over 100,000. In the presented case, mean VSL in the road safety context is 2.43 million dollar, which is respectively 50 and 31% of the mean VSL in the air pollution and general mortality risk context. The values covered by the confidence intervals are comparable to other empirical studies and the limited overlap in the underlying densities should warn policy makers that ignoring contextual effects in VSL BT exercises comes at a price of higher transfer errors.

Table 1.

Benefits Transfer scenario across risk contexts. Baseline risk probability 100 / 100,000, size of risk reduction 10 / 100,000. Values in US dollars (2004 PPP corrected)

	Mean	St. dev.	Pct 2.5	Pct 97.5
WTP				
Road	243.68	93.25	112.35	470.70
Air	437.75	199.12	168.08	925.88
General	752.05	321.11	303.90	1,534.16
VSL				
Road	2,436,785	932,486	1,123,524	4,706,951
Air	4,377,508	1,991,229	1,680,775	9,258,778
General	7,520,514	3,211,124	3,039,005	15,341,577

The contributions of this study are twofold. First, it clearly illustrates that 'out of context' benefits transfers of VSL values should be conducted carefully. Estimation results highlight that the variation in VSL values across studies can be explained by controlling for risk context in combination with other risk and study specific characteristics. Substantial risks of over- and underestimation arise when policy makers do not appropriately control for the risk contexts associated with both the source studies and policy site(s). The limited overlap observed in our context specific predictive VSL distributions in a BT exercise highlights that there exists little support for 'out of context' transfers. This result confirms generally mentioned concerns in literature reviews and empirical studies that the VSL may vary across risk contexts due to differences in risk perceptions and the population at risk. Second, this paper is the first meta-analysis that explicitly estimates a correction factor to transfer VSL values from the road safety context to air pollution policies. Evaluated at the mean, values from the road safety context should be multiplied by a factor 1.8 in order to be applicable in the air pollution context. This value is close to the previously proposed correction factor 2.0 by Rowlatt et al. (1998). The limited availability of VSL estimates in specific risk contexts forces policy makers to engage in either risky BT exercises or conduct a costly new original valuation study. Correction factors are needed to reduce the size of 'out of context' transfer errors in BT exercises. Additional research is, however, required to reduce the uncertainty surrounding the correction factors and VSL values in general.

The results from the VSL meta-analysis are published in a journal article in Environmental and Resource Economics. See Dekker et al. (2011).

Primary valuation study: a choice experiment

As mentioned above, the number of flood risk valuation studies conducted in the Netherlands is limited (Bočkarjova, Rietveld and Verhoef 2010;Botzen and van den Bergh 2009;Brouwer and Schaafsma 2011;Daniel, Florax and Rietveld 2009). Moreover, similar studies in other countries mainly focus on flood risk insurances and don't match with the Dutch case of public provision of flood risk safety (Botzen and Van Den Bergh 2008). Accordingly, the possibilities of conducting a successful and reliable benefits transfer exercise is limited. Therefore, a primary valuation study is conducted in the form of a choice experiment.

Choice experiments are a survey based method in which respondents are presented with a series of choice tasks. In each choice task the respondent is shown a card with a set of policy alternatives. The presented policies vary in their characteristics. For example, one policy may provide additional reductions in flood risk probabilities, while another may put more emphasis on reducing the consequences of a flood by providing compensation in the aftermath of a flood. Each policy comes at a cost, for instance through increased general income taxation or local taxes paid to water boards. The respondent is requested to select the most preferred alternative in each choice task. By making a trade-off between the policy characteristics, including cost, in each choice task, it is possible to derive a WTP estimate for changes in a specific policy characteristic or estimate public WTP for an entire flood protection policy.

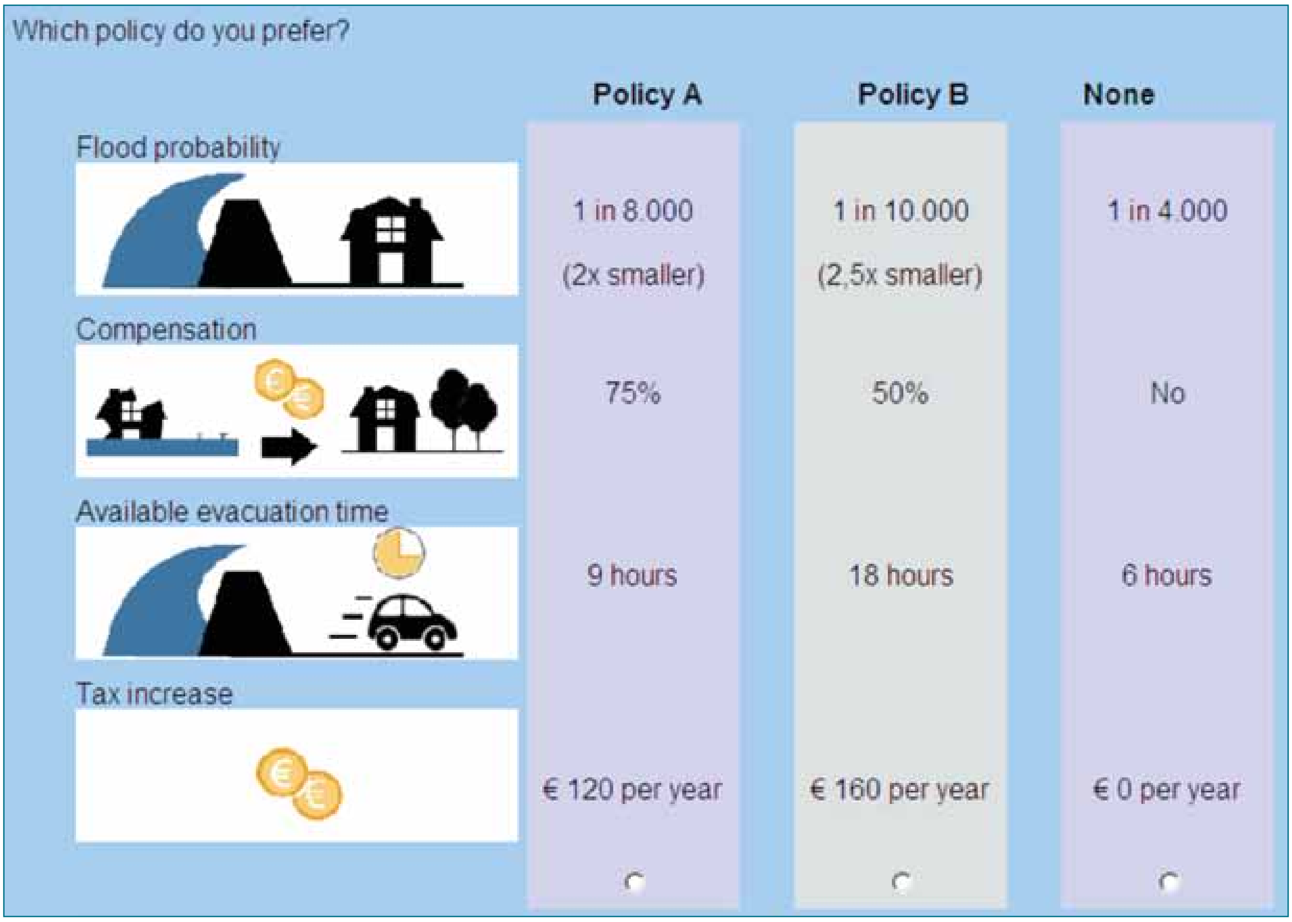


Figure 1.
An example of a choice card used in the choice experiment.

In the choice experiment respondents are confronted with ten choice tasks. In each choice task a set of three policy alternatives is presented, including a status quo option. The experiment frames reductions in flood risk exposure in the form of a public good provided by the local water boards. The status quo alternative describes a situation of no public action to reduce exposure to flood risks. Reductions in flood risk exposure are provided by means of reduction in the probability of flooding, financial compensation in case a flood occurs or additional evacuation time before a flood. Improvements in these policy attributes come at the cost of additional annual water board taxes for each household. Figure 1 provides an example of a choice card used in the choice experiment.

The choice experiment was embedded in an online survey regarding flood risks and flood risk perceptions in the face of climate change in the Netherlands and conducted in the period February – March 2010. In total 1520 respondents participated in the survey. The selected case study area covers two so-called 'dikerings' in the provinces of North- and South-Holland.[2] Dikerings 13 and 14 are situated along the Dutch west coast and are threatened by flood risks from the North Sea, major rivers like the Rhine and lakes. Here, the designated flood probability is set at the lowest level, i.e. once every 10,000 years, and impacts of a flood will be substantial as most of the country's economic activity and population is located within these dikerings. Most of the surface within the study area is situated below sea level and major cities like Amsterdam, Den Haag and Rotterdam are found here, contributing to the large damage potential. As such, the case study area matches with our focus on low-probability-high impact events with which respondents lack experience.

Due to climate change, flood risk exposure within the selected dikerings is expected to increase (Maaskant, Jonkman and Bouwer 2009). In absence of additional preventive measures, flood probabilities in dikerings 13 and 14 are predicted to increase to once every 4,000 years by 2040 due to higher discharge levels in rivers and a sea level rise of 30cm (Maaskant, Jonkman and Bouwer 2009). To prevent an increase in the frequency of flooding and its related damages, additional investments in flood defence structures or alternative adaptation mechanisms are required. Kabat et al. (2005) label this as 'climate proofing' the Netherlands. The latter increase in flood probability to once every 4,000 years in case of no action, was taken as the status quo scenario in the choice experiment.

Methodological advances

The main goal of the choice experiment was not to obtain a value estimate for reductions in flood risk exposure, but to test the extent to which choice experiments are a suitable method to obtain welfare measures for complex environmental goods like flood risks. The complexity arises due to the unfamiliarity of respondents with floods on itself and a lack of experience in making trade-offs regarding flood risk safety. Moreover, the low-probability characteristic of floods increases the cognitive burden on respondents. Together these characteristics of flood risks may have an impact on the degree of confidence respondents have in making decisions during the choice experiment, i.e. preference certainty.

In Dekker and Brouwer (2010) we highlight, as first in the literature, that preference uncertainty can arise at two levels in choice experiments. First, respondents may be uncertain about the extent to which they are willing to give up one policy attribute for another. The latter is reflected in uncertain marginal rates of substitution, including marginal WTP. We label the latter form of preference uncertainty as trade-off uncertainty. Both forms of uncertainty are complementary to each other. Thus far, the literature has only focused on preference uncertainty arising at the level of the alternative, i.e. package uncertainty (e.g. Vazquez, Arana and Leon 2006). In the latter case respondents are uncertain about which alternative in the choice set they prefer most. Package uncertainty is generally modeled through the scale parameter of the underlying random utility model. Dekker and Brouwer (2010) show that individual specific conditional distributions can be used to reveal trade-off uncertainty by defining confidence intervals on an individual's marginal WTP. However, this measure is confounded with the properties of the experimental design and conditional on the assumption that respondents answer the choice experiment in a constant

2 The Netherlands is divided into 53 dikerings, each with a designated flood probability. A dikering is defined as a connected series of water defence structures, e.g. dikes, dunes or high ground, protecting a specific geographical area from flooding. The protection levels within a dikering indicate that embankments should be high enough to withstand water levels that occur only once every X years, where X refers to the defined flood return period in the dike ring (de Moel, Aerts and Koomen 2011). These flood probabilities don't account for the possibility of failing of particular safety structures by collapsing, piping or erosion (Rijkswaterstaat 2005b).

fashion. Rouwendal et al. (2010) show that the informational content of choice experiments is simply not high enough to obtain narrow confidence intervals by analyzing individual choice tasks. Since respondents need to make a trade-off between multiple attributes over multiple alternatives, while researchers only observe a single choice, it is not surprising that trade-off uncertainty on itself is hard to identify in choice experiments. Nevertheless, Dekker and Brouwer (2010) show that the distribution and degree of uncertainty associated with marginal WTP estimates may vary substantially across respondents. The paper also stresses that appropriate measures to take trade-off uncertainty into account are required, but that their identification may be hampered by the informational content of choice experiments.

Preference uncertainty is not a static phenomenon; respondents are likely to experience learning and fatigue effects while progressing through a sequence of choice tasks as they learn about the properties of the non-market good and the institutional setting of the choice experiment (Braga and Starmer 2005). It is therefore frequently argued that respondents can make better informed decisions at the end of a choice sequence. Brouwer et al. (2010) forms a first step in analyzing preference dynamics in choice experiments. In a survey on water quality changes in Australia the paper studies changes in preferences and package uncertainty over the choice sequence. More specifically, we test different hypotheses related to preference refinement and asked respondents at the same time to also report their own experienced certainty when going through the choice tasks. This comparison between random utility preference dynamics and self-reported choice certainty has to our knowledge not taken place in the CE literature before. We show that asking respondents how certain they are about their choice does not affect choice behaviour, taking away concerns expressed in the literature about the impact of such follow-up questions on procedural variance, and providing legitimacy to our comparison. The results of a regression on self-reported choice certainty in Brouwer et al. (2010) suggest that a learning process takes place during the course of the choice experiment, with self-reported certainty increasing across repeated choice tasks. This confirms a priori expectations that learning effects do occur. Respondents felt significantly more confident and certain about their choice at the end of the choice experiment than they were at the beginning. However, whilst controlling for both experimental design and respondent characteristics, we have to reject the hypothesis of preference refinement based on the self-reported choice certainty results. Moreover, econometric testing procedures did not identify any significant impact of learning effects on parameter estimates or variance (i.e. package uncertainty) across the choice tasks. Hence, the lack of econometric evidence of significant reductions in utility variance during the choice sequence is confirmed by respondent stated choice certainty. Based on the outcomes of this study, we conclude that choices and underlying preferences are stable and coherent in this specific water conservation case study.

It is hard if not impossible to generalize our results to other decision-making contexts or environmental domains. Rose et al. (2009) show that choice complexity is context dependent and varies across countries and cultures. However, an important explanation for the results found in Brouwer et al. (2010) may have been that the choice task in the experiment presented here was not too complicated (Hoeffler and Ariely 1999). The number of alternatives and attributes was limited to three, and respondents were only submitted to five repeated choice tasks. In the main choice experiment conducted in this study the number of attributes was extended to four and respondents were presented with ten choice tasks each. In Dekker, Koster and Brouwer (2011) we continue on the line of research discussed in Brouwer et al. (2010). Two specific samples of the choice experiment are used to contrast two alternative hypotheses regarding preference learning, respectively Coherent Arbitrariness and the Discovered Preference Hypothesis (Ariely, Loewenstein and Prelec 2003;Plott 1996). The two representative subsamples are presented with exactly the same choice experiment. The only difference is in the first choice card, where exactly the same policies are presented at respectively a set of high and low prices. Contrary to Brouwer et al. (2010) we find based on the Swait and Louviere (1993) test procedure that preference dynamics exist over the choice sequence. That is, in one sample preferences are found to vary over the choice sequence, while in the other sample a reduction in package uncertainty is observed. Based on the Swait and Louviere (1993) test a set of stable preferences is found at the end of the choice sequence in both samples. However, we can't find any convergence in preferences between the two samples. As such, Dekker, Koster and Brouwer (2011) show that WTP estimates appear to be sensitive to arbitrary initial value clues. This seriously questions the applicability of choice experiments to complex environmental goods as flood risks. In addition, Dekker, Koster and Brouwer (2011) also apply a novel econometric approach to identify preference dynamics, which also does not detect convergence of preferences within and between the two samples over the choice sequence. In fact, test results show that stability of preferences is questioned, also at the end of the choice sequence. The new (semi-parametric) method thereby reveals a short coming of the Swait and Louviere (1993) test in testing for preference dynamics. The proposed local logit model allows for substantial increases in estimation efficiency due to smoothing of parameter estimates.

Results regarding preference uncertainty and related preference learning and fatigue effects are discussed in Dekker and Brouwer (2010), Brouwer et al. (2010) and Dekker, Koster and Brouwer (2011).

Apart from the issue of preference uncertainty and preference dynamics, preferences for flood risk reductions are also likely to vary across respondents. Thus far, random parameter logit models have been commonly used to take unobserved preference heterogeneity across respondents into account. Dekker and Rose (2011) show that standard applied mixing distributions are likely to result in biased welfare estimates, since they are inconsistent with the true distribution of preferences over the sample. In selecting a mixing density, researchers face a trade-off between behavioural relevance, shape flexibility and ease of estimation. The former implies that economic theory predicts that particular attributes have a strict positive (or negative) impact on individual utility. The mixing density needs to be in line with these predictions; this is not the case for the commonly applied normal distribution. Alternative and more flexible distributions, like the lognormal distribution confine with behavioural predictions, but are frequently associated with convergence issues during estimation. As a potential solution to this problem, Dekker and Rose (2011) introduce the asymmetric triangular distribution in the random parameter logit framework. The simple specification in combination with the flexible form of the triangular distribution is able to overcome drawbacks of more commonly applied distributions. To facilitate non-nested model comparison alternative distributional specifications are tested in a Bayesian estimation framework. Results show that marginal WTP estimates for flood risk reductions are highly sensitive to the selected mixing density. Dekker and Rose (2011) highlight that standard mixing densities, including the asymmetric triangular, are highly unlikely to be consistent with the true distribution of preferences over the sample of interest. More flexible mixing densities are therefore required to derive unbiased welfare estimates. The developed semi parametric estimation method in Dekker, Koster and Brouwer (2011) can also turn out to be useful in controlling for heterogeneity in preferences across respondents. Additional research on this topic is, however, required.

3.3 Conclusions and recommendations

This study has shown that conducting a primary valuation exercise is important on itself. First of all, 'out of context' benefits transfers can result in significant biases in transferring monetary value estimates from one application to another. The latter problem can be solved by additional studies on appropriate correction measures or by conducting a primary valuation exercise. A second advantage of a primary valuation exercise is that the policy and related environmental risk can be communicated to a respondent in a clear and direct fashion. As such, the survey development already plays an important role in preventing biased welfare estimates. However, environmental risk, and in particular flood risk exposure in the Netherlands, can be characterized as events with which the respondent is unfamiliar and has limited experience with the event itself and the related trade-offs. Preferences are therefore likely to be ill-defined for preventive public flood risk safety measures reducing the exposure to flood risks. The underlying economic framework therefore needs to take into account that respondents may suffer from preference uncertainty, due to a lack of experience with the presented trade-offs, and that preferences may change over the course of a choice experiment due to learning effects. In a carefully set-up choice-experiment we have shown that value estimates derived from choice experiments are highly-dependent on the first choice task and unlikely to become stable over a short sequence of choices, i.e. 10 choice tasks. Moreover, we have shown that welfare estimates are likely to be biased when standard mixing densities are used in random parameter logit models. Overall, choice experiments provide a suitable framework to obtain a monetary value estimate for flood risk reducing policies, which can serve as an input for cost-benefit analysis. However, much work is still needed to bring the underlying economic framework more in line with existing variations in response patterns by respondents.

4. Stated preference approaches to the valuation of flood risks: VOSL and other indicators of immaterial damages

VU-RE Sub-project 3
post-doc: Marija Bočkarjova

4.1 Original programme description

Problem definition

The concept of Value of statistical life, as the expression of personal or societal valuation of the marginal increase in safety or decrease in risk exposure to a particular negative event, is one of the issues that is not extensively studied in the field of natural hazard. The background of VOSL is rooted in changes of the risk level that imply changes in human lives saved, which means that expenditure directed at the decrease of risk exposure can be translated into the money value per statistical life saved.

VOSL can also be seen as a measure of immaterial loss to be compensated in connection to fatality due to flooding, and so it occupies a place among other measures of potential costs connected to a flooding event. Furthermore, VOSL fits in the context of the observed shift of thinking about

major floods in the Netherlands from probability to risk management (where risk is seen as the product of flooding probability and its effects), recalibration of balances between private and public responsibility regarding flood safety; and efforts directed at adaptation to climate change. The challenge of estimating VOSL in flooding for the Netherlands is the specificity of the situation in the country with regard to water management and flood protection, characterised by high group risk. This has a potential for a free-rider problem, leading to biased VOSL estimation.
Current inquiry into VOSL related to flooding shall capitalise on the approach and findings of De Blaeij et al. (2003) analysing VOSL in the context of traffic safety in the Netherlands. The method applied is a stated preference type of study (namely, conjoint analysis in combination with contingent valuation). This calls for the use of questionnaires where respondents are provided with information on possible risks related to natural disasters, like a major flood, and are asked to provide their willingness to pay to reduce these risks. For reviews of approaches see Viscusi (1993) and Schwab Christe and Soguel (1995). The conjoint analysis type of questions will entail the use of various standard and advanced logit models, including the mixed logit model, to arrive at appropriate estimates (see De Blaeij, 2003). This should lead to a direct estimate of Dutch residents valuating risks of climate change. Attention will not only be paid to fatal risks, but also risks of getting an injury and the psychological costs of preventive measures such as evacuation.

4.2 Research approach

One of the elements in cost-benefit analyses that as yet remains a subject of debate is the benefit of avoided immaterial damages, such as human losses (that is often monetized as the value of statistical life, VOSL or VSL). Flood risk context in the Netherlands is characterized by the presence of correlated risks. For example, on individual level, risk of evacuation, risk of getting an injury and risk of fatality are related and cannot be realized all at once; so if someone is evacuated from a flood-prone area, she cannot get an injury or die as a result of a flood; also, if someone could not get evacuated, then she runs a risk of getting an injury and a risk of becoming a fatal victim, as yet only one of the two can get realized. The problem in the elicitation of such risks is that risk valuation may be confounded if only fatality risk is valued.[3]

The objective of this project is to estimate three immaterial damage indicators in the context of flood risk in the Netherlands and to provide composite valuation of immaterial damages.[4] We consider value of statistical life (VOSL), value of statistical evacuation (VOSE) and value of statistical injury (VOSI). This research is novel in a number of aspects. First, we provide an estimation of VOSL in flooding. VOSL is one of the essential components entering cost-benefit analyses as a (best available) approximation of value of benefit of an avoided (or, rather, delayed) fatality in a particular risk context. This is one of the first efforts to elicit VOSL in the estimation context of natural hazards. This research can also be positioned in the row of literature addressing monetary valuation of immaterial damages due to global warming (see for example Frankhauser and Tol, 1996; Frankhauser, Tol and Pearce, 1998).

Another important contribution of this project is a separate valuation of a fatality risk and a risk of getting an injury on the one hand, and valuation of a risk of getting evacuated on the other hand. It is sometimes being suggested that VOSL estimates might be biased, or confounded, due to sensitivity of willingness to pay (WTP) to the scope of goods valued (see for example Svensson,

3 We address the issue of confounded risk valuation in Bočkarjova et al. (2010) where we confirm VOSL sensititvity to the presence of correlated risks for some sub-groups of respondents.

4 Also studies on valuation of material damages connected to flood hazard in the Netherlands have become available recently (Botzen et al., 2009 and Daniel et al., 2009).

2009) as respondents implicitly include the valuation of a other risks related to a calamity when only VOSL is being measured. Explicit valuation of injury (VOSI) and evacuation (VOSE) alongside with VOSL helps addressing this issue. This means that we are able to arrive at indicators that are closer to the 'true' values of VOSE, VOSI and VOSL, which in turn will facilitate taking better public decisions concerning risk reduction measures and therefore should result in increased collective welfare.

The methodology

Stated preference modeling (SP), and in particular choice experiments, is one of the state-of-the-art techniques that is currently widely used in valuation of intangible goods for which (directly or indirectly) no markets exist. Because of non-existent markets, realized choices of consumers cannot be observed, and therefore their '*revealed preferences*' cannot be measured, at least not directly. Using SP methodology, researchers create a setting where, depending on the context, (artificial) goods are traded in artificial markets. By asking respondents to make choices in such situations, their intended behaviour is obtained, from which '*stated preferences*' can be derived. The areas where SP is widely used include environmental studies, health care, transport and labour economics (see for example de Blaeij et al., 2003; Dekker et al., 2011; Kluve and Schaffner, 2008; Bellavance et al., 2009). The VOSL that is derived by means of these techniques is often used in cost-benefit analyses as a (best available) approximation of value of an avoided fatality in a particular risk context (see Viscusi and Aldy, 2003).

When a choice experimental setting is applied, respondents usually receive some general information about the nature of risk, as well as some explanation of the present average risk level. This is done in an effort to obtain well-informed choices in a clearly defined situation. Choice cards usually present a number of alternatives defined by the researcher. The choice cards are constructed in such a way that there is enough variation in attribute levels (such as risk and monetary payment) to be able to value individual choice parameters.

4.2.1 The choice experiment

Our study was carried out using an internet survey conducted in October-November 2008 among about 530 respondents located in four regions of the country (see Figure 1): coastal areas of Central Holland and Zeeland; and riverside areas of island of Dordrecht and the Betuwe (Land van Heusden / de Maaskant). The overall sample as well as regional sub-samples are representative and were drawn from a commercial respondent panel (TNS-NIPO).

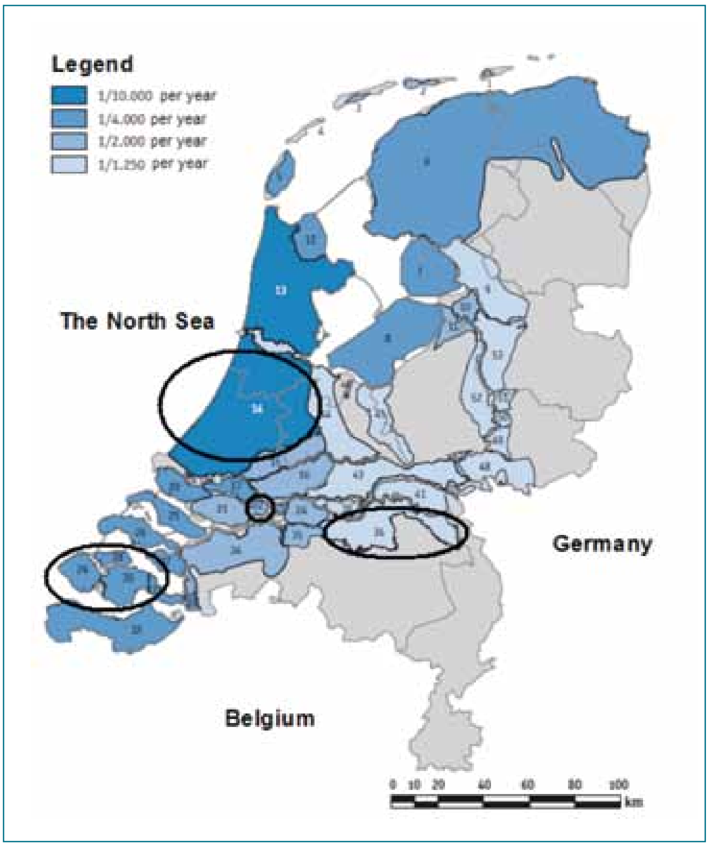


Figure 1.
Map of the Netherlands with dike-rings. Surveyed areas circled.

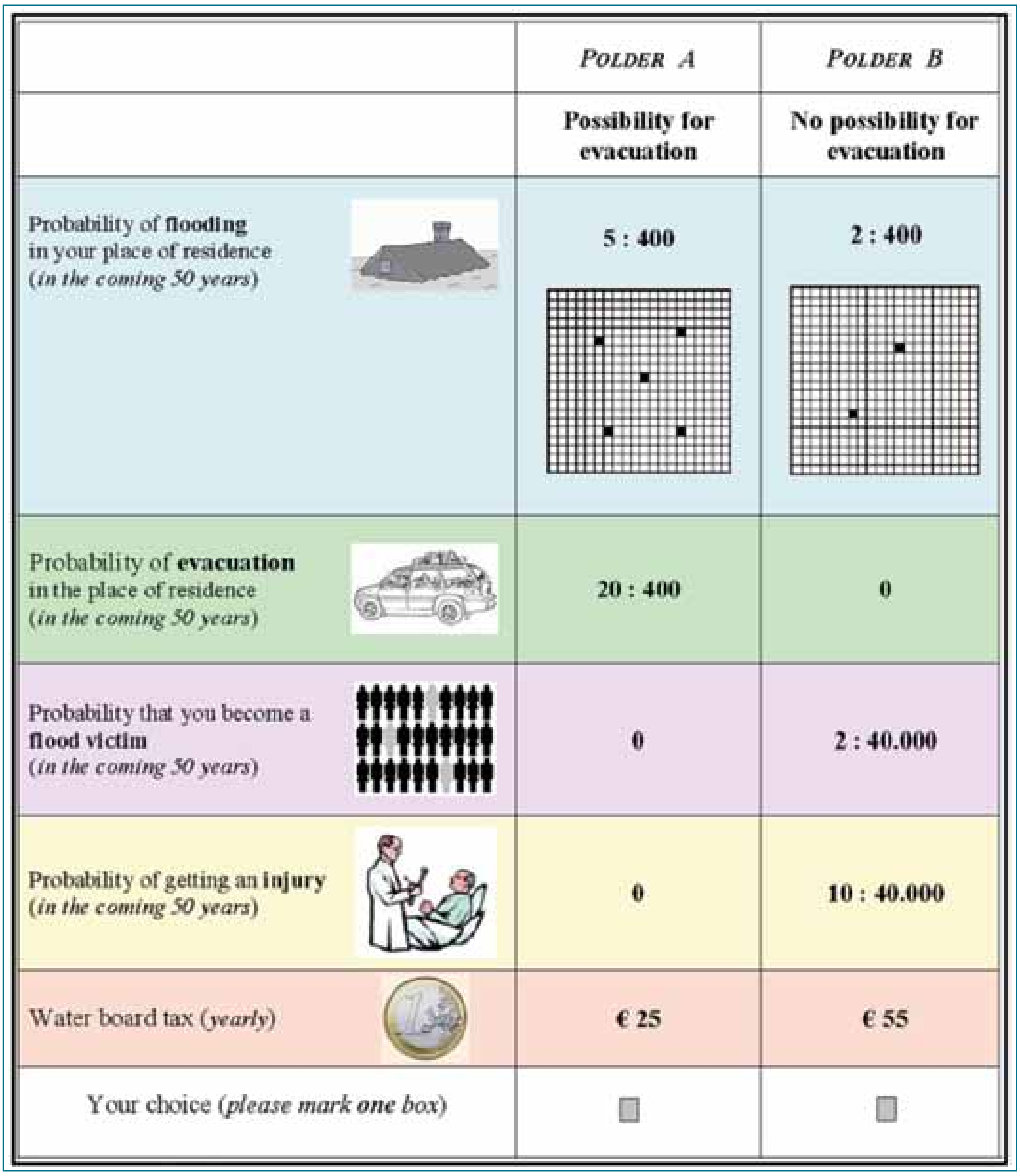
Table 1.
Average assumed probabilities per dike-ring area.

	Overtopping probability (yearly)	Probability of dying in an event of flood [a,b]	Probability of fatality due to flooding (yearly)
dike-ring 14 (Zuid Holland)	1 : 10,000	1%	1 : 1,000,000
dike-rings 28, 29, 30 (Zeeland)	1 : 4,000	1%	1 : 400,000
dike-ring 22 (Dordrecht)	1 : 2,000	0.1%	1 : 2,000,000
dike-ring 36 (Land van Heusden / de Maaskant)	1 : 1,250	0.1%	1 : 1,250,000

[a] Mortality rates per dike-ring in the Netherlands were defined based on Klijn et al. (2004), WL|Delft Hydraulics (2007) and Jonkman et al. (2009).
[b] While explained probabilities of dying given an event of flooding do vary by dike-ring (1% for the coastal areas and 0.1% for the riverside areas), shown yearly probabilities of dying due to flood in the choice cards are the same for all respondents, and are fixed in this choice experiment to 1% of the yearly probability of flooding.

Before presenting respondents with hypothetical choices on their flood safety, we first provided them with extended textual and visualized information about the actual average yearly probability of flooding, the probability of dying in an event of flood, and the yearly probability of fatality due to flooding in their place of residence. The probabilities varied depending on the specific dike-ring (see Table 1).

In addition to explaining actual probabilities also visual aids such as probability grids and a risk ladder were provided. In a so-called risk ladder the probability of fatality due to flooding was brought in perspective with other average yearly risks of dying in the Netherlands.[5] After that, the choice situation was explained and respondents were offered the choice cards. We have used an orthogonal design with 15 blocks, so that each respondent was presented with 5 cards containing two (labeled) alternatives.



	POLDER A	POLDER B
	Possibility for evacuation	**No possibility for evacuation**
Probability of **flooding** in your place of residence (*in the coming 50 years*)	5 : 400	2 : 400
Probability of **evacuation** in the place of residence (*in the coming 50 years*)	20 : 400	0
Probability that you become a **flood victim** (*in the coming 50 years*)	0	2 : 40.000
Probability of getting an **injury** (*in the coming 50 years*)	0	10 : 40.000
Water board tax (*yearly*)	€ 25	€ 55
Your choice (*please mark one box*)	☐	☐

Figure 2.
Sample choice card.

5 Before the final version of the questionnaire was administered, it went through a pilot testing in a focus group. Report on the pilot survey is found in Bočkarjova et al. (2008a).

Our respondents were asked to make a choice – a 'purchase decision' – between two hypothetical houses that were suggested to be similar in any other respect, yet different in terms of flood safety characteristics. These characteristics, or choice attributes, describing the place of residence depended on the type of alternative. In one of the locations (alternative A) there was a possibility for a timely evacuation from the area before a flood, and thus this alternative was described by a flood risk (in the coming 50 years), *evacuation risk* described by a probability of preventive evacuation (in the coming 50 years) and the level of water board tax, or yearly *payment*. The other alternative did not presuppose evacuation (area B) and therefore it was described by a flood risk (in the coming 50 years), *fatality risk* described by a probability of dying due to flooding (expressed in terms of average number of fatalities per 400.000 inhabitants in the coming 50 years), *risk of injury* (expressed in terms of average number of injured persons per 400.000 inhabitants in the coming 50 years) and *payment* described as the respective level of water board tax per year in euros. The following numbers of attribute levels were considered in this choice experiment: P(evacuation): 5 levels; P(fatality) attribute: 5 levels; P(injury): 5 levels; Tax attribute: 3 levels. This was a second experiment in a row for these respondents (see Bočkarjova et al., 2010 for an analysis of the other experiment).

4.3 The model

In discrete choice modeling it is assumed that respondents attach some particular level of utility to each presented alternative, and that the choice is made in favour of an alternative with higher utility. Usually (Henscher et al., 2008), a respondent's *m* utility of alternative *i* is defined as $U_{im} = V_{im} + \varepsilon_{im}$, where Vim part is observed (and thus can be measured) by the researcher via the predefined attributes of the alternative, and V_{im} is the unobserved part of respondent's utility of alternative i, which accounts for all other properties of the alternative not included by the researcher.

In this choice experiment we offered respondents a choice between two houses, similar otherwise, but different in terms of flood safety: one is located in an area where preventive evacuation is possible, and another area where no evacuation is possible, and therefore all inhabitants run some risk of being injured during a flood or of dying in a flood. Thus, we have two labeled alternatives, different in 4 attributes: the first alternative includes the probability of evacuation in a polder -x_{Pev} and the municipal tax level, x_T. The second one with the probability of injury -x_{Pinj}; the probability of fatality due to flooding -x_{Pf}; and the respective level of local tax per year in euros -x_T.[6] The second alternative includes the ASC, the alternative specific constant. Therefore, respondent's *m* utility function can be written for each alternative as:

$$V_m(evacuation) = ASC + \beta_{Pev} \cdot x_{Pev} + \beta_T \cdot x_T \quad [1a]$$

$$V_m(no \quad evacuation) = \beta_{Pf} \cdot x_{Pf} + \beta_{Pinj} \cdot x_{Pinj} + \beta_T \cdot x_T \quad [1b]$$

Note that ASC in [1a] captures the difference in individual utility between the two labeled alternatives (in our case, the alternative that provides a possibility for evacuation compared to the one that does not). Inclusion of *ASC(evacuation)* also means that respective coefficients of choice attributes will capture the marginal valuation of the particular attribute. Also note that the monetary attribute in the two utility equations has the same coefficient, β_T, which presumes the same marginal utility of

6 For reasons of ease of explicability, also P(flood) was shown on the card for each alternative, which was 100 times greater than P(fatality), corresponding to 1% fatality rate at the event of a flood.

money for all respondents across both alternatives.

When beta coefficients in the utility functions are estimated, our indicators of interest can be obtained. In a basic model as defined by [1a,b], the VOSL, which is a trade-off between money and a decrease in risk level at the margin, is determined as the marginal utility of fatality risk divided by the marginal utility of money to the respondents, so that:

$$VOSL = \frac{\partial U / \partial x_{Pf}}{\partial U / \partial x_T} = \frac{\beta_{Pf}}{\beta_T} \qquad [2]$$

Similar to the VOSL, the value of a statistical evacuation, VOSE, is the monetized benefit of an avoided inconvenience associated with a preventive evacuation when flood is expected. It is determined as the marginal utility of evacuation inconvenience divided by the marginal utility of money to respondents, so that $VOSE = \beta_{Pev} / \beta_T$. Furthermore, this experiment allows computing the value of a statistical injury, VOSI, which is a trade-off between money and a decrease in the probability of an injury risk at the margin, is therefore determined as the marginal utility of inconvenience due to injury divided by the marginal utility of money to respondents: $VOSI = \beta_{Pinj} / \beta_T$. This means, that the goal of running model [1a,b] is the estimation of respective attribute beta's, where the ratios (β_{Pf} / β_T, β_{Pev} / β_T and β_{Pinj} / β_T) provide an estimate of the indicators in question, VOSL, VOSE and VOSI, respectively.

4.4 Results

4.4.1 Valuing flood risk: MNL estimations

A basic multinomial logit (MNL) model run for this experiment showed that respondents' choices between the suggested alternatives were governed by the changes in the risk of evacuation, the risk of flooding and the tax; the risk of injury remained statistically insignificant in all basic estimations. Moreover, the statistically significant alternative-specific constant testifies of systematic preferences of respondents towards the alternative with an evacuation possibility provided the assumption on linear coefficients. Alternatively, ASC may be reflecting the non-linearity of the marginal utilities of risks.

Table 2.
Overview of main MNL estimates (standard deviations in parenthesis[a]).

	Basic MNL model	Extended MNL model[b]
VOSL (value of statistical life)	6.84 mln € (4.126 – 9.543)	7.04 mln €
VOSI (value of stat. injury) [b]	92,183 € (-30,092 – 214,458)	95,689 €
VOSE (value of stat. evacuation)	2,517 € (1,116 – 3,919)	2,554 €

[a] calculated using the delta method.
[b] indicators are weighted at covariate sample means.

The average value of statistical life, VOSL, in our basic MNL logit estimations is about 6.8 mln € - see Table 2 (which is within an expected range of 2 to 14 mln € for European studies, see Kluve and Schaffner, 2008[7]); the average value of evacuation inconvenience, VOSE, is 2,500 €; the average value of injury, VOSI, is 92,200 € (which might be seen as slightly high for a middle-range injury, but yet in the range of values found elsewhere in the literature, like Viscusi and Zeckhauser 1994[8] and Shanmugam 2000, as well as de Brabander 2007). Statistical insignificance of risk of injury parameter might be due to variations in individual interpretations of the term 'injury', which due to the character of possible injuries received in flooding was not described explicitly as a light or a heavy injury, but rather as a middle-range injury (see Ahern et al. 2005). Another possibility is correlations in valuation with other experiment attributes. This will be captured by estimating mixed logit models discussed in the following sections. Split-sample analysis (basic model) revealed significant differences in valuation of flood risk among respondents with various education levels, age and health condition.

An extended model was run to test the main effects of the independent covariates of our interest, such as income, age, education, gender, health condition, prior water-calamity experience and place of residence. The utility functions in the model then take the form:

$$V_m(evacuation) = ASC + \beta_{Pev} \cdot x_{Pev} + \beta_T \cdot x_T + \sum \beta_{Yi} \cdot (x_{Yi} \cdot x_T) \qquad [3a]$$

$$V_m(no \quad evacuation) = \beta_{Pf} \cdot x_{Pf} + \beta_{Pinj} \cdot x_{Pinj} + \beta_T \cdot x_T + \sum \beta_{Yi} \cdot (x_{Yi} \cdot x_T) + \sum \beta_{Zi} \cdot (x_{Zi} \cdot x_{Pf}) \qquad [3b]$$

Where the three summation terms represent independent variable interactions with one of the experiment attributes: $\sum \beta_{Zi} \cdot (x_{Zi} \cdot x_{Pf})$ stands for interaction terms of covariates x_{Zi} with risk attributes P(fatality).[9] The other term, $\sum \beta_{Yi} \cdot (x_{Yi} \cdot x_T)$, stands for interaction terms of covariates x_{Yi} with the monetary attribute Tax.

7 In the view that our estimated VOSL excludes a part of immaterial damages that might otherwise be implicitly included in the valuation, such as the value of evacuation or value of injury due to flooding, it might be considered slightly high. This may be caused by money-risk trade-offs that involve unusually small changes in probability used in our experiment (in the order of $1{,}5 \cdot 10^{-6}$ to $9 \cdot 10^{-6}$) – as found by de Blaeij et al. (2003), VOSL decreases under-proportionally as the valuated change in risk decreases. Another cause may be perhaps the willingness to avoid flood catastrophe as a no-'rival rationality' condition for valuation (following Sustein (2000, pp.30-31), other no-'rival rationality' conditions for people to be willing to pay a higher premium are: i) to avoid deaths that involve a high degree of pain and suffering; ii) to protect children; iii) to devote more resources to protect against dangers when the costs of risk avoidance are high; iv) to protect vulnerable or traditionally disadvantaged groups against certain risks).

8 Viscusi and Zeckhauser (1994, p.35) in their revealed preference study of injury valuations use a similar definition of injury, and also find similar monetary valuations of injury: "In the case of injury valuations, the midpoint estimate for an injury severe enough to lead to a lost workday (which of course includes much more severe injuries as well) is 50,000USD. ... Empirical estimates suggest that the social value of injuries may be 50% larger than this amount."

9 In the process of selection of the preferred model, we have also tested MNL models where covariate interactions were included with the other two risk attributes, P(injury) and P(evacuation). These interaction, however, remained insignificant and are therefore not considered in the preferred model [3a,b].

In the extended model where multiple covariates were included simultaneously, only effects of age and health condition prevailed (with education effect faded away), and the effect of own prior experience with flood or evacuation gained prominence. While the age and health condition relations with willingness to pay for decreases in risk were not unexpected (WTP increases with age, and decreases as the individual's estimation of the own health condition improves),[10] the association between prior experience with floods and WTP turned out to be somewhat surprising. The negative sign of this coefficient may be due to either 'adverse availability heuristic' (underestimation of individual future probability of getting repeatedly involved in similar events), or 'calamity impact discounting' (underestimation of future calamity impact due to minor damages incurred in a similar event in the past), see Bočkarjova et al. (2009).

4.4.2 Valuing flood risk: mixed logit estimations

We use the mixed logit model to estimate the models of the type [1a,b] and [3a,b] (basic and extended versions, respectively). This means that one or more of the choice attributes will be assumed to vary randomly following a specified distribution, in order to capture individual heterogeneity in risk valuation, such that $\beta \sim f(\beta \mid \theta)$, where Θ stands for characteristic parameters (such as mean and variance) of the respective distributions of the random coefficient β over the population. The assumed mixing distributions were normal, uniform, triangular or lognormal. For all models we have included a panel structure, and the models were estimated using Limdep 4.0 software.

Based on the results of a number of tested mixed logit model formulations, we selected preferred models (basic and extended) to be estimated, where we have left two random parameters with significant heterogeneity in taste: fatality risk (β_{Pf}) and the evacuation alternative constant *(ASC(evacuation))*. The constant was assumed to be normally distributed, while the coefficient of fatality risk attribute was assumed to have normal, triangular, uniform and log-normal mixing distributions. The models were estimated accounting for the panel structure, and assuming correlation between the two random coefficients. The short models A (with choice attributes only) were estimated using 500, 1,000 and 5,000 Halton draws, and we can see that estimated parameters (and thus VOSL as well as VOSI and VOSE) are sufficiently stable. The improvement in the log-likelihood function for all estimated models, compared to MNL models, is substantial and is statistically highly significant.

Mean VOSL values for the basic model (A) are about 6.7 mln € with normal, uniform and triangular mixing distributions of fatality risk coefficient; for the log-normal distribution VOSL is about 6.3 mnl €. All these values remain fairly close to the multinomial estimate of 6.8 mln €.

Extended models (B, where also socio-economic covariates were included in the utility function defined as in [3a, b]) were estimated with 1,000 and 5,000 Halton draws, and also show robust results. Among the covariates, only interaction terms with the dummies for age, health condition and residence in the rural areas turned to be statistically significant. We can see that younger respondents (between 18 and 35), urban residents as well as respondents with very good self-reported health condition (8 to 10 on the scale of 0 to 10) have a lower willingness to pay for the improvements in flood safety compared to older respondents, rural residents and respondents in a less good health condition, all other things held constant. The positive effect of age on WTP might initially seem somewhat counterintuitive (Bočkarjova et al. 2009), provided the arguments on fewer

10 In the test phase, age, health and gender dummies were also interacted with the risk attributes, but this did not yield statistically significant results. So, in the preferred extended MNL model, as shown in Table C2, the covariates that are interacted with the tax attribute are: high income, no income stated, age, health condition, gender and own property; the covariates that are interacted with the P(fatal) attribute are: rural, coastal area and prior experience.

expected life-years for older respondents. However, empirical studies provide mixed results on the age-VOSL relationship (Alberini et al. 2004 and 2006, Krupnick 2007, Kim et al. 2009, Cameron et al. 2010).[11] A possible explanation for increasing WTP with age in our case may come from the side of altruism argument (also found by Grolleau et al. 2009), when older people are in fact paying not only for their own decrease in the risk of premature fatality, but rather for that of the following generation that should be 'secure' of flood safety (this position of older respondents was also observed during the pilot).

Results of the extended model (B) estimations show that mean VOSL estimates are about 7.2 mln € for the normal, triangular and uniform distributions, and 7.0 mln € for the log-normal, compared to the VOSL of 7.0 mln € from the multinomial logit estimation (all values are weighted at sample average values of the covariates).

The valuations of evacuation and of injury follow the same pattern as VOSL and also resemble a robust pattern. So, mean VOSI for the basic model is found in the range of 91,000 to 92,000 €, while the reference multinomial point estimate of VOSI is 92,200 €. For the multivariate model these values are slightly higher, mean VOSI for the mixed models varies between 101,200 and 101,800 €compared to the MNL estimate of VOSI of 95,700 €.

The estimation of the mean value of evacuation is about 2,400 € for both basic and extended models, for all distributions of the fatality risk coefficient, which is meticulously close to the VOSE of 2,500 € from the MNL estimates.

4.5 Composite valuation of immaterial damages

So far we have presented separate measures of immaterial damages in this project, namely VOSL, VOSI and VOSE. However, it is just as important to know how each of the indicators contributes to the entire picture of immaterial damages, in case all of which are going to be used in cost-benefit analyses. This means that we need to establish relationships between the expected numbers of fatalities, injuries and evacuated persons (see also Zhai et al. 2003, and Penning-Rowsell et al. 2005).

4.5.1 Injuries vs fatalities

The number of injured persons per one fatality depends on the type of flood, and might be different for various types of injuries (for example, a flash flood opposed to a dike overtopping). However, a number of longitudinal studies have shown that this ratio is pretty stable if we take a historical average of multiple events and various types of injuries. For example, in Japan the ratio of deaths to injuries is 1 to 10 (Zhai et al. 2006), for the US it is 1 to 6 (Ashley and Ashley 2008). This means that it would be reasonable to assume for our case an approximate ratio of deaths to injuries between 1 to 5 and 1 to 10. In relative terms, given the level of VOSI of 92,000 € and VOSL of 6.8 mln €, the mark-up factor of the value of injuries per 1 fatality make about 0.07 to 0.14 of VOSL. So, in monetary terms, it would take about 74 expected injured persons to add to the total immaterial damage amount as much as 1 expected fatal incident.

11 Also other literature in health studies (like Gyrd-Hansen 2003, Olsen and Donaldson 1998) support the decreasing WTP with age due to the decreasing quality-adjusted life-years. However, also studies on the value of statistical life-years, VOSLY, (Hammit 2007) provide mixed results on the age-WTP relationship.

4.5.2 Evacuations vs fatalities

Further, we need to establish the number of evacuated persons per one fatality. This requires more information, as evacuation and flood events have different frequencies and involve various groups of people. The number of expected evacuated persons per year would depend on the number of residents of an area at risk (in the Netherlands these are dike-rings), fraction of evacuated persons per event (η) and the yearly probability of evacuation ($P_{evacuation\ (yearly)}$), or:

$$E(N_{\substack{evacuated\ persons \\ per\ year}}) = N_{total} \cdot \eta \cdot P_{\substack{evacuation \\ (yearly)}} \qquad [4]$$

The expected number of fatalities per year in an area at risk would depend on the extent of flood in terms of affected persons (α, if not the whole area is flooded), the fraction of non-evacuated persons (1-η) – assuming it is the same throughout the whole area as the extent of flood is not known beforehand; the fraction of fatalities per flood event (ϕ) and the yearly probability of a flooding (Pflood (yearly)), or:

$$E(N_{\substack{fatalities \\ per\ year}}) = N_{total} \cdot \alpha \cdot (1-\eta) \cdot \varphi \cdot P_{\substack{flood \\ (yearly)}} \qquad [5]$$

We define that the ratio of frequency of evacuations to the frequency of floods as λ:

$$\frac{P_{\substack{evacuation \\ (yearly)}}}{P_{\substack{flood \\ (yearly)}}} = \lambda \qquad [6]$$

Combining expressions [4]-[6], the ratio of evacuated persons to the number of fatalities, ν, is:

$$\frac{E(N_{evacuated\ persons})}{E(N_{fatalities})} \equiv \nu = \frac{\lambda \cdot \eta}{(1-\eta) \cdot \alpha \cdot \varphi} \qquad [7]$$

Expression [7] shows that ν depends on the number of evacuations per flood (λ), the extent of flood in the area (α), the fraction of residents evacuated (η) and those who remain in the area at risk (1-η), and the fraction of deaths per flood event (ϕ). So, the more frequent the evacuations, the more people get evacuated and the fewer fatalities are expected per flood event, the higher the ν indicator.[12] This means that in the areas where extreme water levels can be predicted well in advance (like riverside) most residents can be evacuated and few die, the ratio of evacuated persons to fatalities will be high. In other areas, where flood warnings are short (often, in the coastal areas), and few people can preventively be evacuated, the ratio of evacuated persons to fatalities will be low, also because more fatalities could be expected.

12 Note that in cost-benefit terms, the optimal evacuation frequency is the one where the inconvenience costs of another evacuation is equal to the probability that an accident occurs times the expected value of immaterial damage. *Material* damage does not matter in the determination of the optimal frequency of evacuation, because it remains unaffected by the evacuation.

Table 3.
Main parameters for the analysis of evacuation inconvenience.

	Parameter	Coastal area	Riverside
Probability of flooding	$P_{flood\ (yearly)}$	1 / 10,000	1 / 1,250
Probability of evacuation [a]	$P_{evacuation\ (yearly)}$	1 / 200	1 / 200
ratio of evacuations to floods	λ	50	6.25
fraction of persons evacuated [a]	η	0.15	0.75
fraction of persons affected [a]	α	0.40	0.65
fraction of fatalities [b]	ϕ	1% - 5%	0.1% - 1%
Number of evacuated persons to one fatality [c]	ν	441 – 2,206	2,885 – 28,846
Mark-up factor for the value of evacuation per one VOSL [d]	κ	0.16 – 0.78	1.02 – 10.18

[a] Source: HKV (2010)
[b] Source: Klijn et al. (2004)
[c] The ratio of evacuated persons to the number of fatalities is calculated following the formulae [7].
[d] Mark-up factor for the value of evacuation per one VOSL is calculated following the formulae [8].
Assumed VOSE is 2,400 € and VOSL is 6.8 mln €.

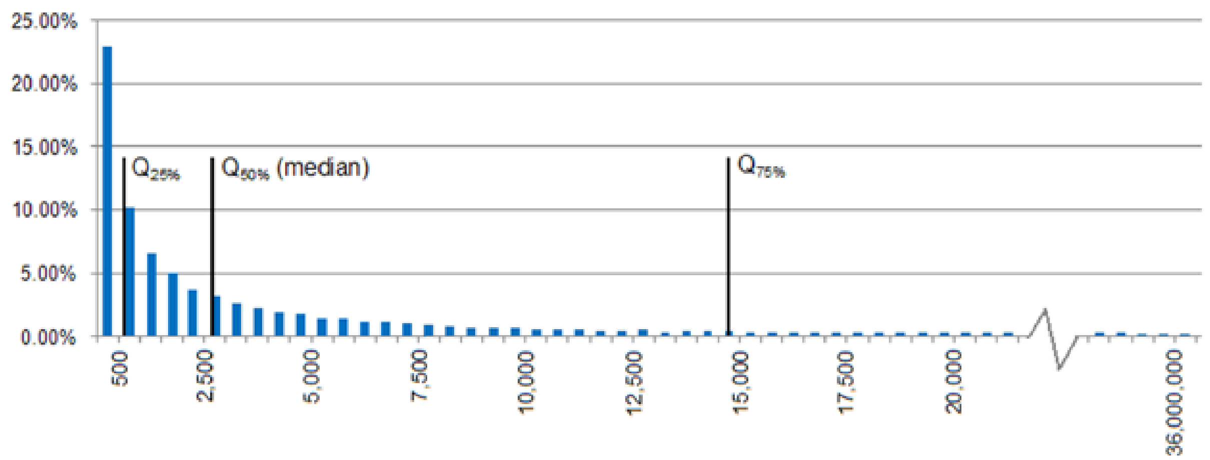


Figure 3.
Simulated frequency distribution of the the ratio of evacuated persons to the number of fatalities, ν (in intervals of 500).

In order to have a better idea about the spread of the ratio of evacuated persons to the number of fatalities, we have constructed a simulated distribution for the ν parameter. Assumed ranges of parameters, uniformly distributed: 5% to 95% in 10 steps of 10% for the number of evacuations per flood (λ), the extent of flood in the area (α), the fraction of residents evacuated (η); and a restricted range of 0.1% to 10.1% (with 10 steps of 1%) for the fraction of deaths per flood event (ϕ). Depicted quartiles on Figure 3: $Q_{25\%}$=580; $Q_{50\%}$(median)=2,716; $Q_{75\%}$=14,357. The 90% confidence interval for this distribution of ν is found between 67 and 190,900.

Due to the fact that ϕ, the fraction of deaths per flood event,[13] is directly and inversely related to ν, the ratio of evacuated persons to the number of fatalities, the final value of ν is highly sensitive to the assumed range of ϕ (we shall see it illustrated in the sample calculations for two typical areas below). So, the lower the ϕ, the higher the ν.[14]

Because the ν indicator has a relatively wide spread, we may expect that composition of immaterial damage varies across the areas different in terms of flood characteristics. We shall illustrate this by taking examples of two typical regions in the Netherlands. Let us start with an example of a dike-ring on the **riverside**. For the estimates of the parameters λ, α and η from formulae [7] we rely on the calculations done by HKV (2010) – see Table 3. Here, the projection is that evacuations will take place 6.25 times more often than floods (respective probabilities are once in 200 years vs once in 1,250 years). Experience shows that extreme water levels here can be forecasted at least 1 week beforehand, and therefore there is enough time for evacuation from the area for most of its residents. In most of the riverside areas about 65% of the inhabitants will get affected by a flood; and three quarters of the inhabitants would get evacuated per event. More uncertainty exists, however, with regard to the fraction of fatalities per event, as it depends on such factors as the type of flooding (overtopping or breaching of dikes), time of the year and time of the day, and on the weather conditions. It would, however, be reasonable to assume that the fraction of fatalities per flood event (ϕ) for the riverside areas would be found between 0.1% and 1% (Klijn et al., 2004). This means that we can obtain various ratios of evacuated persons to the number of fatalities: for $\phi_1 = 1\%$, $\nu_{river(\phi1)}$ will be 2,885. If this percentage decreases to $\phi_2 = 0.1\%$, then $\nu_{river(\phi2)}$ will proportionately increase to 28,846.

A different picture would be observed in the **coastal areas** in the Netherlands, where storm surges from the sea pose flood danger. The dike-ring of Central Holland is a typical coastal area with high population density and the highest protection level in the country, 1 in 10,000 per year. Here, HKV (2010) calculations show that evacuations are expected to be as frequent as at the riverside, 1 in 200 years (Table 3). This means that here the ratio of evacuations to floods is 50 to 1. Provided a relatively short warning time for coastal storm surges (24 to 48h), high population density, the extent of the area, and limited escape capacities, evacuation fraction would be expected to be low, reaching on the average 15%. It would be very unlikely – if not impossible – that the entire area of Central Holland is flooded; most floods would probably cover only a part of the dike-ring (depending on the place and the number of breaches), so that α would expectedly be about 40% in most scenarios. However, if a flood takes place, it would probably be a severe event characterized by high water depths, reaching in some places 4 to 6m. This means that we may expect a high fraction of human victims: 1% to 5% of people found in flooded area might die (Klijn et al., 2004). So, the ratio of evacuated persons to one fatality (ν_{coast}) would range in such coastal area between 440 and 2,200.

Positioning the obtained ranges of ν_{coast} and ν_{river} for the two typical dike-ring areas in the Netherlands in the simulated distribution for the ratio of evacuated persons to one fatality (Figure 3), we can see that the range of ν_{coast} (440; 2,200) is found below the median (2,716); and the range of the ν_{river} (2,880; 28,850) is found just above the median. Both ranges fall within the $CI_{90\%}$ interval of ν.

13 The same is true for parameter α, the extent of flood in the area. However, on a more practical level, the expected value of α should not vary greatly across various regions. Alternatively, parameter ϕ, the fraction of deaths per flood event, may differ by factor 10 or even 50 across the regions (as we shall see, expected fraction of fatalities at the riverside may be as low as 0.01% of affected population, and reach up to 5% in the coastal areas).

14 For comparison, we have simulated another distribution of the ratio of evacuees to fatalities (let's call it ν_1) for the values of ϕ found between 5% to 95% in 10 steps of 10%, just as the assumed ranges of the other three indicators, λ, α and η. Now, the distribution of ν_1 has 'moved leftwards' with a median of 33, the 90% confidence interval between 1 and 90,000, and a maximum of 361,000.

4.5.3 Composition of immaterial damages

The relationship between the expected number of evacuees and fatalities can easily be translated in value terms, and represented as a mark-up factor, or perhaps a 'surcharge', for the value of evacuation per one VOSL, κ:

$$\kappa = \frac{\nu \cdot VOSE}{VOSL} \qquad [8]$$

Applying formulae [8], and assuming typical values of VOSL and VOSE (6.8 mln € and 2,400 €, respectively, see Section 4), we can also construct a distribution for this mark-up factor. So, in about half of the cases, value of evacutation will contribute up to a one VOSL to the total immaterial damages. In the other half of the cases, however, the mark-up factor κ will be higher than a single VOSL; for the last 10% of cases κ will lie above 25, up to almost 13,000 at the extreme. This explosive increase in κ is traced back to the long thin right-hand-side tail that we have observed by the ν distribution (see Figure 3).

Finally, to provide a ready-to-use overview, the injury, evacuation and fatality components can be expressed in percent of the total composition of immaterial damages. Because the value of evacuation can result in highly varying mark-up factors per one VOSL, the final composition of immaterial damages will depend on the particular values of ν and κ. For the sake of illustration, we shall pick the middle points of the ranges for κ_{river} and κ_{coast} (5 and 0.5, respectively), and see with which composition we will end up for the riverside and the coastal areas. From Figure 4 we learn that injuries make up the smallest portion of total immaterial damages in both cases; for the rest the two pictures are chalk and cheese. So, for the **coastal areas**, fatalities make up almost two thirds of the total immaterial damages (62.5%), and evacuation – about a third (31%). In the **riverside areas,** almost 82% of all immaterial damages are made up by the evacuation inconvenience and about the sixth (16.4%) – by fatalities. We recall that the two charts on Figure 4 are based on the mid-point values of κ_{river} and κ_{coast}. For more extreme, though not unrealistic, cases of κ_{river} = 10 and κ_{coast}, = 0.15, the relative composition of the immaterial damages would get even more skewed to the side of evacuations for the riverside areas (up to 90%), and to the side of fatalities for the coastal areas (up to 80%). Clearly, the final composition of immaterial damages will depend on the number of factors connected to the nature of flood in the area.

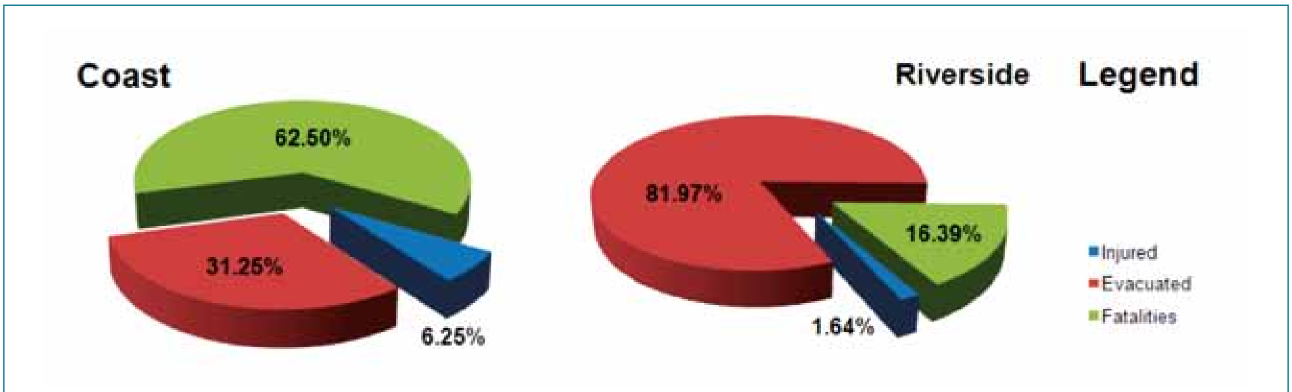


Figure 4.
Composition of total immaterial damages per dike-ring area (in percent).
Assumptions: average expected mark-up factor of value of injuries per 1 fatality (coast and river: κ_{INJ} = 0.1), average expected mark-up factor of value of evacuation per 1 fatality ($\kappa_{EVAC\text{-}.coast}$ = 0.5; $\kappa_{EVAC\text{-}.river}$ = 5). Typical values of VOSI = 92,000 €, VOSE = 2,400 €, VOSL = 6.8 mln €.

We note that when using this approach for policy assessments, a researcher should beware of the effects that policy measures themselves may have on the composite valuation of immaterial damages. So, some proposed measures aiming at reducing total expected immaterial damages, such as raising the dikes, would lead to a more or less proportional reduction in the expected numbers of fatalities, injuries and evacuations, so that ν and κ are expected to stay fixed for flood conditions dominating in a particular area. Alternatively, other measures, such as introduction of more stringent rules for evacuation result in a higher expected number of evacuations, but lower expected numbers of fatalities and injuries. So, this will lead not only to the decrease in the total expected immaterial damages, but also to a change in the relative weights of the immaterial damage components, such as increase in the relative contribution of evacuations costs.

To summarise our findings, we observe that while it seems that obtained VOSI in absolute terms is a sizeable indicator (92,000 €), on the aggregate level the value of injury is a relatively minor contributor to the composite valuation of immaterial damages. This has to do with a relatively low expected number of injuries per one fatality in the event of a flood. Alternatively, a relatively moderate estimate of VOSE (2,400 €), perhaps somewhat unexpectedly, has on average proven to add a substantial contribution to the total amount of immaterial damages. Due to high variability in parameters that are necessary to determine the relation between the number of evacuated persons and one fatality, this ratio has a distribution with a wide range. So, the particular height of evacuation mark-up factor per VOSL depends on the area in question and is directly related to the nature of flood risk. Namely, in areas where floods can be forecasted well in advance (like in the case of river floods) and the majority of residents can be evacuated on a regular basis, the total value of evacuation can be a number of times higher than the total value of fatalities. At the same time, in the areas where flood warnings are short (like in the case of storm surges in the coastal areas), evacuations are less massive and expected fatalities are relatively high, the contribution of value of evacuation would make up less than that of fatalities.

4.6 Conclusions and policy implications

This study is based on a survey on the valuation of flood risk conducted in 2008 in four flood-prone areas in the Netherlands. The proposed level of fatality risk was small (in the range of 10^{-6} to 10^{-5}) compared to a range usually valued in similar studies. The current study has also offered a separate simultaneous valuation of fatality risk, VOSL, value of statistical injury and value of statistical evacuation, which presumably also resulted in unconfounded VOSL estimate (see Bočkarjova et al. 2010). It is also new to the valuation literature that VOSL is estimated in the natural hazard context. Moreover, simultaneously estimated and well validated VOSI and VOSE in the context of flooding are not known to the authors.

Our following conclusion is that numerically, our obtained indicators are plausible and reflect findings elsewhere in the literature. The resulting mean VOSL is about 6.3-7.2 million euros per additional statistical life saved, or fatality avoided; the value of evacuation inconvenience, mean VOSE, is between 2,300-2,500 euros per evacuation; and the value of inconvenience associated with injury, VOSI, is 91,000-102,000 euros per injury. Concerning the technical part of this study, we can conclude that, first, in all mixed logit models (basic and extended) the estimated risk parameters, and thus the indicators of our interest – VOSL, VOSE and VOSI – remain robust across the various assumed distributions. Second, all average parameter estimates from mixed logit models are also found within narrow margins from the respective point estimates obtained in the multinomial logit models. Both these findings provide evidence in favour of a fair degree of reliability of our estimates.

Our final conclusion is that it is important to consider other indicators (such as VOSI and VOSE suggested here) alongside with VOSL to obtain the total value of immaterial damages. The total composition of immaterial damages would further depend on the nature of flood risk in a particular area. So, if we take a look at the composition of immaterial damages in the Netherlands, adding together the costs of fatalities, injuries and evacuations, we can see that value of injuries would contribute no more than 10% to the total immaterial damages. The value of evacuation, however, appears to be less predictable, and varies depending on the area and the nature of flood danger. For example, in the **riverside areas** in the Netherlands where extreme water levels can timely be predicted and the majority of residents can be evacuated, the value of evacuation would be relatively high, making up 3/4 to 9/10 of the total immaterial damages depending on the assumptions about the frequency of evacuations, fraction of evacuated persons per event and fraction of fatalities per flooding. For the **coastal areas** where storm surges are less predictable and where only a small fraction of inhabitants can timely be evacuated, evacuations surcharge per one fatality would be substantially lower and vary, again depending on the circumstances, from 1/3 to 1/2 of the total immaterial damages. Fatalities, on the other hand, would make up here at least a half of the total costs.

Our findings on the magnitude and composition of valuated immaterial damages have a number of **implications for policy** that are of general character as well as specific to the situation in the Netherlands. First, valuation of fatality risk in flood (a typical VOSL of 6.8 mln €) is higher than the respective indicator obtained in the context of transport safety (VOSL=2.2 mln €, see Wijnen et al. 2009) and that is currently adopted in CBA of flood protection measures in the Netherlands. This pleads for a higher monetary value of benefits in relation to avoided fatalities connected to better flood protection measures. Second, composite valuation of immaterial damage shows the importance of including differentiated indicators of immaterial damage alongside with valued fatalities (VOSL) in cost-benefit analyses, such as value of statistical injury (VOSI) and value of statistical evacuation (VOSE), which can substantially contribute to the composite value of avoided immaterial damages. As we have shown, under some risk conditions the VOSL might make but a fraction of total immaterial damages, and so inclusion of the VOSL alone in a cost-benefit analysis may not be representative of total immaterial damages, and in some cases even significantly underestimate these. Finally, the observed discrepancy in the relative weights of various components of immaterial damage (and we have considered only three of them in this study) between various areas with differing flood risks points at the necessity to consider area-specific immaterial damages when conducting CBA, also provided the effects that particular policy measures may have on the expected height and composition of immaterial damages.

5. Conclusions

Adaptation to climate change requires a detailed analysis of the cost and benefits of the various adaptation options. As adaptation involves many sectors of the economy the various adaptation options are very specific in terms of the cost and benefit structure, and in many cases ancillary benefits exist.

In practice a cost benefit analysis for adaptation requires at least the following considerations:

- Identify the projected impacts of climate change (e.g. expected sea level rise, change in temperature, or change in precipitation patterns) and their timing.
- Investigate whether current facilities and planned policies are adequate to deal with the changed circumstance. If so, one might argue that then no action is required.
- If not, make an inventory of potential adaptation options and assess in a qualitative manner whether these options need to be implemented in the short term, the medium term on the long run.
- Assess the uncertainties involved by estimating what the probabilities are that the expected climate impacts will happen and to what degree. In doing so also assess when the impacts are expected to occur.
- If sufficient certainty exists on the occurrence of the climate impacts (i.e. it is almost certain the impact will occur and to what extent) then the optimal policy can be identified in a deterministic setting, and the issue is to select the most efficient strategy from the range of alternatives.
- However, if uncertainty exists on the climate impacts then this uncertainty needs to be included in the analysis. If a risk neutral policy is followed, the cost benefit analysis needs to be based on the expected net present value of the net benefits of the various adaptation options. These can be calculated based on the probability distribution of the climate impacts and the costs and benefits of adaptation options. For instance for sea level rise it is possible to calculate the optimal timing of the dike heightening and the step size if a probability of sea level rise is made explicit.
- In the analysis it can be considered whether structural measures are preferred or whether non-structural measures will do a more efficient job, or whether a combination of measures can be applied. As was demonstrated in the model analyses, it depends on the cost and benefit structure, and the moment on which certainty will be obtained about the climate impacts (the learning rate) and the discount rate which measures will be preferred. This requires an advanced cost benefit analysis that can be done in close consultation with experts.
- If risk adverse policies are preferred then of course more strict measures will be required, depending on the degree of risk averseness.
- In all cases it is essential to include in the analysis the potential ancillary benefits of adaption policies and to search for integrated solutions, because specific measures that may not be beneficial by themselves, can become attractive if the ancillary benefits (for instance in terms of improved quality of landscape or scenery) are considered.
- Decide about the discount rate to be used in the analysis. For public investment projects the officially recommended discount rates should be applied with an appropriate consideration of the risk factor to be applied. For private investment projects the investors can decide about the desired discount rate or internal rate of return to be obtained.

Whether adaptation actions need to be implemented in the short run or whether actions can be postponed depends on the costs of the measure and on the expected damages costs of doing nothing and the reduction in the expected damage costs that can be obtained by taking action. In a risk neutral setting the general rule would be as follows: If the net present value of the additional costs of action are outweighed by the net present value of the expected reduction in damages, then it is generally speaking worthwhile to start adaptation.

The optimal timing of adaptation is a complex issue because of the uncertainties involved in the climate projections, in the costs and benefits of the various options, and in the development of technologies, which may lead to lower costs in the future. Particular uncertainty exists on when exactly we will learn more about how serious the issue of climate change actually will be and how much adaptation will be required. For economic decision making it is essential to obtain better information on the probability distributions of the various aspects of climate change, such as changes in precipitation, changes in temperature and sea level rise. Based on these improved probability distributions a more rational adaptation strategy can be developed as compared to a strategy that aims at being robust for the very wide range of possible impacts.

The research programme has provided detailed insight in the selection of adaptation options. The choice will depend on the discount rate that will be selected and on the resolution of the uncertainty. Depending on the cost structure of the adaptation options, and on the discount rate to be applied, a choice will be made on the optimal mix of structural and non-structural adaptation options. We have also shown that ancillary benefits may play a dominant role in the final selection of the adaptation option.

For the valuation of a statistical life in the context of flooding we have shown that the value based on a choice experiment is substantially higher than similar values in the context of other domains of safety, such as traffic. In addition, it is crucial to consider a number of indicators of immaterial damage alongside with valued fatalities (VOSL) in cost-benefit analyses. Composite valuation of immaterial damage performed in this project has shown that such indicators as value of statistical injury (VOSI) and value of statistical evacuation (VOSE) can substantially contribute to the total value of avoided immaterial damages. We have further observed differences in the relative weights of various components of immaterial damage between various areas with differing flood risks such as coastal and riverside areas. These issues point at the necessity to consider area-specific immaterial damages when conducting CBA, also provided the effects that particular policy measures may have on the expected height and composition of immaterial damages.

The scientific innovation of the research programme is manifold. The study has not only contributed to a much more detailed understanding on how to deal with the value of a statistical life in the context of flooding and how to measure this value in the context of choice experiments. In the costs benefit analysis for structural and non-structural measures it has also been demonstrated which factors play a dominant role in the choice between structural and non-structural measures in the context of decision making under uncertainty and learning. The learning rate, the discount rate and the relation between the fixed and variable costs of the measures turn out to be crucial in this respect. The scientific results of the program have been published in the international literature and will also be disseminated through the participation in international research projects on adaptation, such as the EU-funded programme Mediation.

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Climate changes Spatial Planning

Climate change is one of the major environmental issues of this century. The Netherlands are expected to face climate change impacts on all land- and water related sectors. Therefore water management and spatial planning have to take climate change into account. The research programme 'Climate changes Spatial Planning', that ran from 2004 to 2011, aimed to create applied knowledge to support society to take the right decisions and measures to reduce the adverse impacts of climate change. It focused on enhancing joint learning between scientists and practitioners in the fields of spatial planning, nature, agriculture, and water- and flood risk management. Under the programme five themes were developed: climate scenarios; mitigation; adaptation; integration and communication. Of all scientific research projects synthesis reports were produced. This report is part of the Integration series.

Integration

The question is how to increase the 'adaptive capacity' of our society. Analysis of the adaptive capacity is related to the physical component (the feasibility of physical spatial adaptation) and to the existing institutional structures. Areas Climate changes Spatial Planning dealt with are: uncertainties and perceptions of risk; institutional capacity to deal with climate change; the use of policy instruments; and cost benefit analysis. Adaptation strategies must be in line with the current institutional structures of a policy area. For a proper decision process we developed decision support tools, such as socio-economic scenarios, the Climate Effect Atlas and other assessment frameworks.

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