Immaterial damage valuation
in the context of flood risk

Marija Bočkarjova
Piet Rietveld
Erik T. Verhoef

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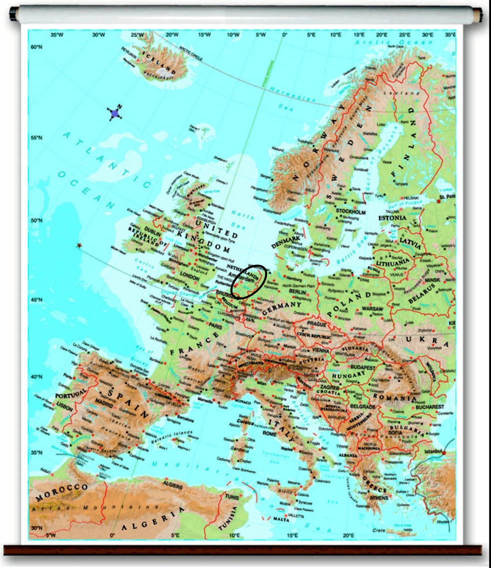
What is this study about?

The Project

- KvR: adaptation options to climate change
  - yes or no? how much? when?
- Small country, big delta:
  - how much flood protection is "enough"?

→ Cost-Benefit Analysis



Cost Benefit Analysis

Costs (-)

- Investments
- Maintenance

Benefits (+)

- Avoided damages
  - Material (households, businesses, environment, LNC …)
  - Immaterial (human victims, injuries, evacuations, …)

Avoided immaterial damages

- Do not have a price
  - To be able to make various costs and benefits comparable, they need to be expressed in the same units
- So, we have to attach some monetary value to immaterial damage
  - Different methods to achieve that
  - We use: CHOICE EXPERIMENTS: market price compatible, and thus can directly be used in CBA

Focus of the study

- Valuation of immaterial damages in the context of flood risk:
  - **VOSL** (value of statistical life saved)
  - **VOSI** (value of statistical injury)
  - **VOSE** (value of statistical evacuation)

Why a 'new' VOSL?

- Currently a VOSL of **2.5 mln €** is used in flood safety (borrowed from transport safety valuation)

→ is that adequate?

- Benefit transfer issue: VOSL appears to be different depending on…

→ context of risk – risk perception
  - qualitative (dread, voluntariness, controllability)
  - quantitative (probabilities)

→ methodology used

→ welfare

What is a VOSL?

Basically,

VOSL is a trade-off between

some amount of money (to be paid)

and a change (reduction) in fatality risk

$$\text{VOSL} = \frac{\text{amount of money (euros)}}{\text{decrease in fatality risk}}$$

What is a VOSL?

Value of statistical life (VOSL)
is a willingness to pay (decrease in wealth)
for a small decrease in fatality risk
due to a particular negative event.

$$\text{VOSL} = \frac{\Delta\,\text{Y}}{\Delta \text{P}}$$

Changes in the fatality risk level imply
expected changes in human lives saved in a particular society.

Thus, willingness to pay for a decrease in risk exposure
can be translated into the money value per one ***statistical*** life saved.

Suppose,

we want to decrease risk

(so, we know ΔP)

But:

What about $\Delta\ \text{Y}$???

What is the problem…

- Paying for reducing flood risk
  - No real markets with real, familiar goods
  - We cannot 'observe' data

What is the solution…

under controlled circumstances
ask people what they are willing to pay!

- value hypothetical goods on hypothetical markets
- collect data with the help of a survey

The survey

The survey

- TNS-NIPO internet panel (fall 2008)
  → a random representative sample

- Survey structure
  I – flood risk perception
  II – **explanation of flood and fatality probabilities**
  III – **flood risk valuation**
  IV – climate change
  V – demographics

Data collected in
4 dike-ring areas

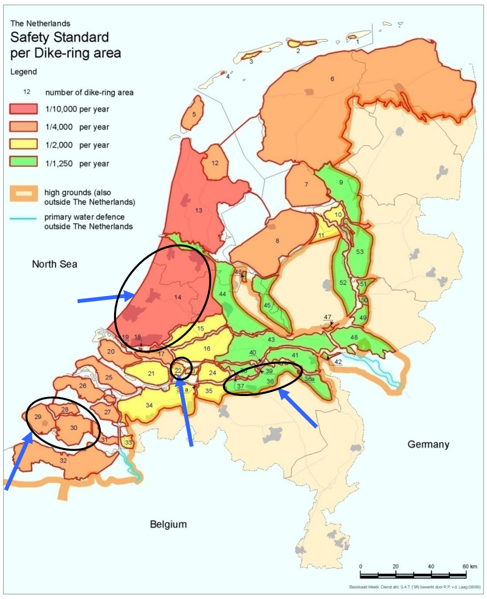
Riverside:

- ✓ Eiland of Dordrecht 110
- ✓ Land van Heusden / de Maaskant 141

Coast:

- ✓ Zeeland 151
- ✓ Central Holland 135

Total N respondents: 537



Our approach

We want:

Informed choices

So, we provide extensive information on risk :

Risk of flooding

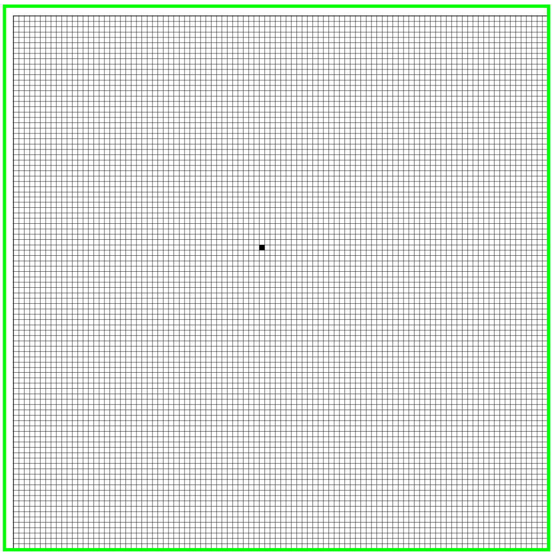
Fatality risk in flooding

Yearly fatality risk

Fatality risk due to flooding in the coming 50 years

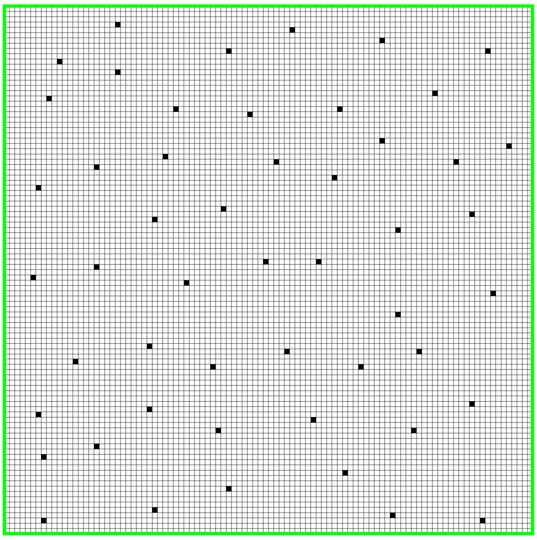
Visual aids: probability grids

– Yearly risk of flooding in Central Holland (1/10,000)



Visual aids: probability grids

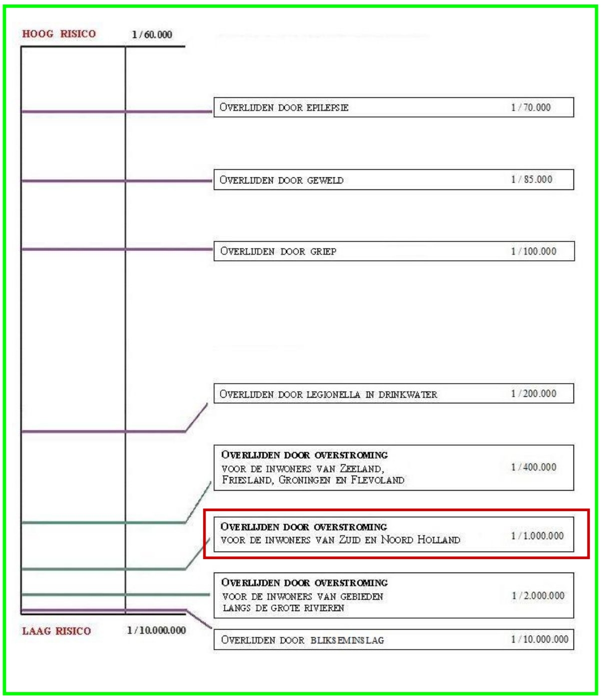
– Risk of flooding in Central Holland (50 / 10,000) in the coming 50 years



Visual aids:

Risk ladder

Yearly fatality risk due to flooding compared to other risks in the Netherlands



And now

ask about the money

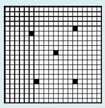
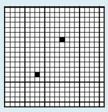
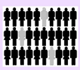
→ Choice experiment

The situation:

choice between moving two identical houses (**A** and **B**) in two polders

with varying levels of flood safety and water board taxes

Choice card CE3

	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*)	☐	☐

The method

We value:

Changes in the shown attributes

- fatality risk
- risk of injury
- risk of evacuation
- tax

Choice card CE3

	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*)	☐	☑

WE KNOW:
Changes in the shown attributes

With help of some (advanced) statistics we arrive at VOSL, VOSI and VOSE

Our main results

Estimate

Use of advanced statistical techniques
(panel data structure, heterogeneity in preferences)

Sample mean values are in the range:

VOSL	(value of statistical life)	6.30 – 6.90 mln €
VOI	(value of injury)	91,000 – 99,000 €
VOE	(value of evacuation)	2,300 – 2,400 €

→Statistically significant, robust estimates
→Comparable to other estimates found in the literature

Composite valuation of immaterial damage

Valued indicators of immaterial damage

VOSL	(value of statistical life)	6.30 – 6.90 mln €
VOI	(value of injury)	91,000 – 99,000 €
VOE	(value of evacuation)	2,300 – 2,400 €

→ There should be a relationship between the three

Value of life and value of injury

Literature offers some longitudinal studies that looked at the relationship between

the number of fatalities and the number of injuries*

in flooding for various types of floods :

Japan (Zhai, Fukuzono and Ikeda, 2006):	1 to 10
the US (Ashley and Ashley, 2008):	1 to 6

* this ratio highly depends on many factors, such as the type of flooding, type of area flooded, etc.

Value of injury relative to VOSL

Assume:

N (injuries) to 1 fatality	5-10 to 1
VOSL	7.0 mln €
VOI	100,000 €

Value of injury relative to 1 VOSL	**7% – 14%**

Value of life and value of evacuation

This relation is more area-specific,
and depends on a number of factors:

- ratio of evacuations to floods λ
- fraction of persons evacuated ε
- fraction of persons affected α
- fraction of fatalities θ

- The number of expected evacuated persons per year :

$$N_{\substack{evacuated\ \ persons \\ per\ \ year}} = N_{total} \cdot \varepsilon \cdot P_{\substack{evacuation \\ (yearly)}} \qquad [7]$$

- The expected number of fatalities per year :

$$N_{\substack{fatalities \\ per\ \ year}} = N_{total} \cdot \alpha \cdot (1-\varepsilon) \cdot \theta \cdot P_{\substack{flood \\ (yearly)}} \qquad [8]$$

- IF

$$\frac{P_{evacuation\ \ (yearly)}}{P_{flood\ \ (yearly)}} = \lambda$$

and

$$\frac{N_{evacuated\ \ persons}}{N_{fatalities}} = \eta = \frac{N_{total} \cdot \varepsilon \cdot P_{\substack{evacuation \\ (yearly)}}}{N_{total} \cdot \alpha \cdot (1-\varepsilon) \cdot \theta \cdot P_{\substack{flood \\ (yearly)}}}$$

- THEN

$$\frac{N_{evacuated\ \ persons}}{N_{fatalities}} = \eta = \frac{\lambda \cdot \varepsilon}{(1-\varepsilon) \cdot \alpha \cdot \theta}$$

Table 7. 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*	$P_{evacuation\ (yearly)}$	1 / 200	1 / 200
ratio of evacuations to floods	λ	50	6.25
fraction of persons evacuated *	ε	0.15	0.75
fraction of persons affected *	α	0.40	0.65
fraction of fatalities **	θ	1% - 5%	0.1% - 1%
Value of evacuation per one fatality (relative to VOSL) ***		0.15 – 0.80	1.03 – 10.30

*   Source: HKV (2010)
**   Source: Klijn et al. (2004)
*** Assumed VOE is 2,500 € and VOSL is 7 mln €.

We find:

Value of injury per 1 fatality is **7-14% of VOSL**

Value of evacuation per 1 fatality:

For the coastal area: 15-80% of VOSL

For a riverside area: 1 to 10 times VOSL

Conclusions

Conclusions (I): **NOVELTY**

- Risk valuation in the context of flooding
  - new in the Netherlands
  - new in hazard literature

- Simultaneous valuation of risk of fatality, injury and evacuation (**VOSL**, **VOSI** and **VOSE**)
  - new in economic valuation literature

- Very low levels or risk valued
  - practically challenging

Conclusions (II): **RESULTS**

- Elicited values:
  - **VOSL** (value of statistical life) **7 mln €**
  - **VOSI** (value of statistical injury) **100,000 €**
  - **VOSE** (value of statistical evacuation) **2,500 €**

Significant
Robust
Plausible

Conclusions (III): **POLICY IMPLICATIONS**

- Composition of immaterial damage in the context of flooding
  - is area-specific (coast vs riverside)
  - taking only valuation of avoided fatalities (VOSL) in CBA may substantially underestimate TOTAL immaterial damages
- Higher obtained value of VOSL, and new values for VOI and VOE mean that:
  - balances in CBA on the "benefits" side are changing: immaterial damage is gaining more weight
  - higher costs may be tolerated for flood protection measures

Thank you!

The method

(a little bit of economics and statistics)

So how do we do it?

Respondents make choices between 2 shown alternatives depending on their level of U, utility (satisfaction).

However, we cannot control / observe all aspects of individual "utility", but only the attributes that we have shown in the choice cards.

Therefore, individual utility of each alternative can be thought of as consisting of 2 parts: observed utility (V) and unobserved utility (ε):

$$U = V + \varepsilon$$

Choice card CE3

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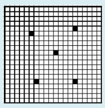
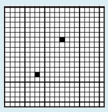
Probability of **flooding** in your place of residence (*in the coming 50 years*) 	5 : 400 	2 : 400 
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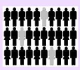
Probability that you become a **flood victim** (*in the coming 50 years*) 	0	2 : 40.000
Probability of getting an **injury** (*in the coming 50 years*) 	0	10 : 40.000
Water board tax (*yearly*) 	€ 25	€ 55
Your choice (*please mark **one** box*)	√	☐

Utility…

As researchers, we hope – and we can test that – that choices offered to the respondents were governed by the attributes that were shown on the cards (i.e. safety and payment).

Therefore, we model observed utility (V).

We assume a linear form of the observed part utility (V), so that utility of safety and utility of money are additive:

$$\begin{cases} V_{evac.} = ASC + \beta_{P(evac.)} * x_{P(evac.)} + \beta_{Tax} * x_{Tax} \\ V_{no\ \ evac.} = \beta_{P(fatal)} * x_{P(fatal)} + \beta_{P(inj.)} * x_{P(inj.)} + \beta_{Tax} * x_{Tax} \end{cases}$$

And how do we get to VOSL?

We can take partial derivatives of the utility function with respect to risk and money to obtain the "marginal utilities":

$\partial V / \partial x_{P(fatal)}$ and $\partial V / \partial x_{Tax}$

Recall VOSL is defined as: $\mathrm{VOSL} = \frac{\overline{\Delta \mathrm{Y}}}{\Delta \mathrm{P}} = \frac{\overline{\mathrm{WTP}}}{\Delta \mathrm{P}}$

And therefore: $VOSL = \frac{\partial V / \partial x_{Tax}}{\partial V / \partial x_{P(fatal)}}$

And finally…

valuation of immaterial damage (VOSL)

If observed utility is:

$$\begin{cases} V_1 = ASC + \beta_{P(evac.)} * x_{P(evac.)} + \beta_{Tax} * x_{Tax} \\ V_2 = \beta_{P(fatal)} * x_{P(fatal)} + \beta_{P(inj.)} * x_{P(inj.)} + \beta_{Tax} * x_{Tax} \end{cases}$$

VOSL is a trade-off between money and the level of risk, on the margin.

$$VOSL = \frac{\partial V / \partial x_{Tax}}{\partial V / \partial x_{P(fatal)}} = \frac{\partial x_{P(fatal)}}{\partial x_{Tax}} = \frac{\beta_{P(fatal)}}{\beta_{Tax}}$$

Valuation of immaterial damage

(VOSE and VOSI)

Similarly to VOSL,

VOSI (value of statistical injury**)** is determined as:

$$VOI = \frac{\partial U / \partial x_{Tax}}{\partial U / \partial x_{P(inj.)}} = \frac{\beta_{P(inj.)}}{\beta_{Tax}}$$

VOSE (value of statistical evacuation**)** is determined as :

$$VOE = \frac{\partial U / \partial x_{Tax}}{\partial U / \partial x_{P(evac.)}} = \frac{\beta_{P(evac.)}}{\beta_{Tax}}$$