Evaluation of effectiveness and efficiency of non-structural measures

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Contents

1) Objectives and approach
2) Systematisation of structural and non-structural measures
3) Effectiveness and efficiency of measures
4) Context conditions for balancing measures
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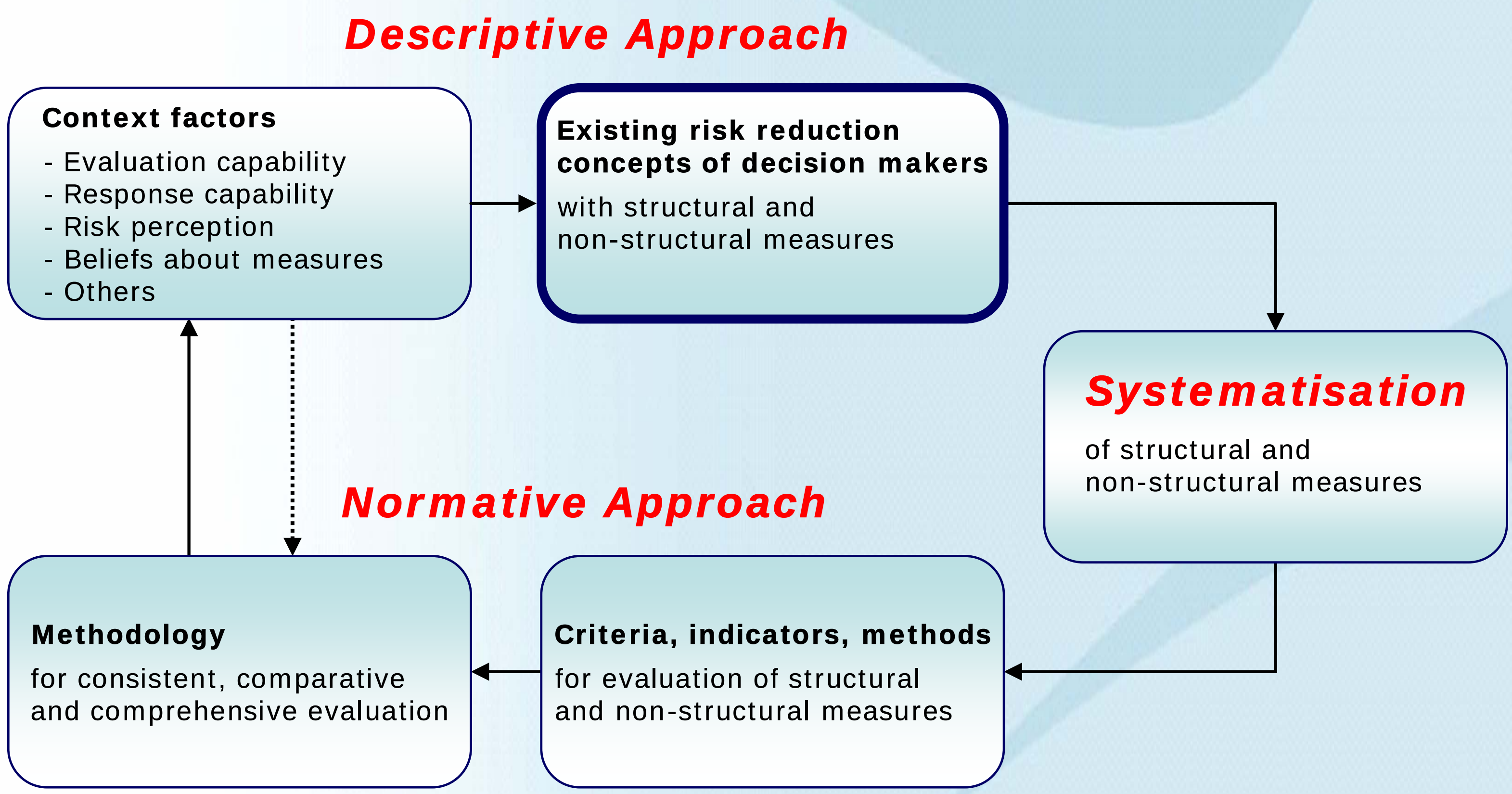
Major Objectives

1. To systemise structural (SM) and non-structural measures (NSM)
2. To develop a methodology for the evaluation of the effectiveness and efficiency of structural and especially non-structural measures
3. To analyse context conditions like risk perception of decision makers with a potential to influence the choice of structural and non-structural measures
4. To identify the site-specific effectiveness and efficiency of such measures and the influence of selected context conditions on their choice (EU case studies)
5. To derive recommendations for the improvement of flood risk management strategies

Approach

The scope of the objectives requires a combined research design integrating three principal approaches:



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Distinction of SM and NSM

Historical development

- Differentiation between structural (SM) and non-structural measures (NSM) occured in the 1940s - 1950s in the USA
- Background: Ecological philosophy emphasised the human adaptation capabilities and questioned the “dikes only” policy
- A number of systematisation concepts have been proposed (e.g. Penning-Rowsell & Peerbolte 1994, Marsalek 2000, Petry 2002, Parker 2002, 2007, Olfert & Schanze 2007)
- Not all of these concepts stick on the terms “structural measures” and “non-structural measure”

Understanding of SM and NSM

Proposed definition

- Structural measures (SM) are interventions in the flood risk system based on (structural) works of hydraulic engineering
- Non-structural measures (NSM) are all other interventions

Note

- The systematisation is recommended not to include the intended effects but functions and mechanisms.
- Rationale: It is scientifically not sound to use the effects for classification and then to comparatively investigate them.
- An additional reason is that risk reduction effects should be measured on the basis of the common currency "risk".

Proposed systematisation of SM and NSM

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Criteria for evaluating SM and NSM

The following criteria with according methods have been indicated and described:

- **Effectiveness**
- **Efficiency**
- **Sustainability**
- **Reliability**
- **Robustness**
- **Flexibility**
- **Acceptability**

The presentation puts emphasis on effectiveness and efficiency.

Indicators of effects for SM and NSM

Indicators are the units of measuring effects obtained by SM and NSM. Thus they are the basis for evaluation.

Thematic groups for comprehensive evaluation:

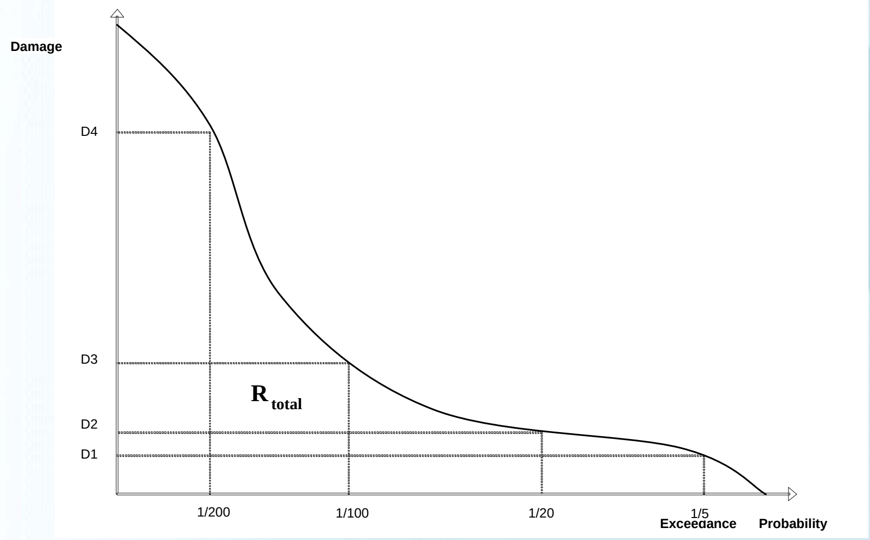
- **Hydrological / hydraulic indicators**
- **Socio-cultural indicators**
- **Economic indicators**
- **Ecological indicators**

With the exception of the first indicators group, a common currency for measuring effects of SM and NMS is needed.

Risk as common currency of SM and NSM

Functional group	Types of measure	Measures (Examples)	Targeted effects	Common currency
Structural Measures				
Flood control	Flood water storage	Flood polder	Reduction and retardation of peak	Reduction of flood risk
	River training	By-pass channel	Reduction of water	
	Flood protection	Dike	Limitation of inundation (water level)	
	Drainage and pumping	Urban drainage system		
Non-Structural Measures				
Flood control	Adapted land use in	Conservation tillage	Reduction of runoff	Reduction of flood risk
	River management	Dredging of sediments	Reduction of water level	
Use and retreat	Land-use of flood-prone area	Avoiding land use of flood-prone area	Reduction of elements at risk and their susceptibility	
	Flood proofing	Adapted construction		
	Evacuation	Evacuation of assets		
Regulation	Water management	Flood protection standards; restriction of land use	(indirect effects via measures)	(indirect effects via measures)
	Civil protection	Civil protection and disaster protection act		
	Spatial planning	Building ban		
Stimulations	Financial incentives	Investment Programme (e.g. for river works)		
	Financial disincentives	Insurance premiums according to flood zones		
Information	Communication/ Dissemination	Information events		
	Warning/Instruction	Hazard and risk map		
Compensation	Loss compensation	Public relief	Reduction of economic damage and market disturbance	

Measuring risk (in economic terms)



$$\overline{D} = \sum_{i=1}^{k} D[i] * \Delta P_i$$

$$D[i] = \frac{D(P_{i-1}) + D(P_i)}{2}$$

$D[i]$= mean damage of two known points of the curve

$$\Delta P = |P_i - P_{i-1}|$$

ΔP = probability of the interval between those points

Effectiveness

Effectiveness (ETS) describes the relation of the observed effects to the objectives. Objectives are case specific quantified expectations for certain effects described by indicators.

The criterion considers only intended effects, while unintended effects lacking.

Method: Effectiveness is determined by the degree of goal achievement (e.g. %).

$$ETS = \frac{E}{O} \cdot 100\%$$

Efficiency – Cost-effectiveness

Cost-effectiveness (CET) compares the relative expenditure (costs) and outcomes (effects) of actions. It is often used where full cost-benefit ratios cannot be derived.

Methods: Cost-effectiveness analysis (CEA) in case of flood risk management states whether

- a given target of tolerable risk is achieved by minimal costs (cost minimisation) or
- risk reduction is maximised by a given costs (effect maximisation).

$$CET = \frac{C}{E_{given}} \rightarrow \min! \qquad CET = \frac{E}{C_{given}} \rightarrow \max!$$

Efficiency – Cost-benefit ratio

Cost-benefit ratio considers both cost and benefits in monetary terms. Overall goal is to select the solution with the highest cost-benefit ratio from a list of alternatives.

Methods: Cost-benefit analysis (CBA)

Benefit-cost ratio (BCR)

$$BCR = \frac{\sum_{t=0}^{n} B_t (1+i)^{-t}}{\sum_{t=0}^{n} C_t (1+i)^{-t}}$$

Net present value (NPV)

$$NPV = \sum_{t=0}^{n} B_t (1+i)^{-t} - \sum_{t=0}^{n} C_t (1+i)^{-t}$$

Case study Erlln at Mulde River (Germany)

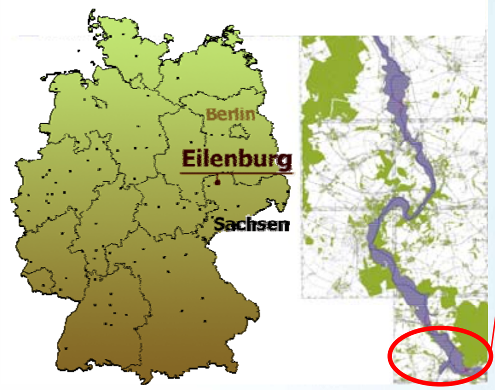
Comparison of SM and NSM

- SM: dike heightening, dike relocation
  (actual measure, already conducted)
- NSM: hypothetical resettlement of the village

Evaluation:

- Effectiveness
  - Target: no damages up to the 1:100 event
- Cost-effectiveness
- Benefit-cost ratio
  - Benefits: risk reduction (based on meso-scale risk maps)

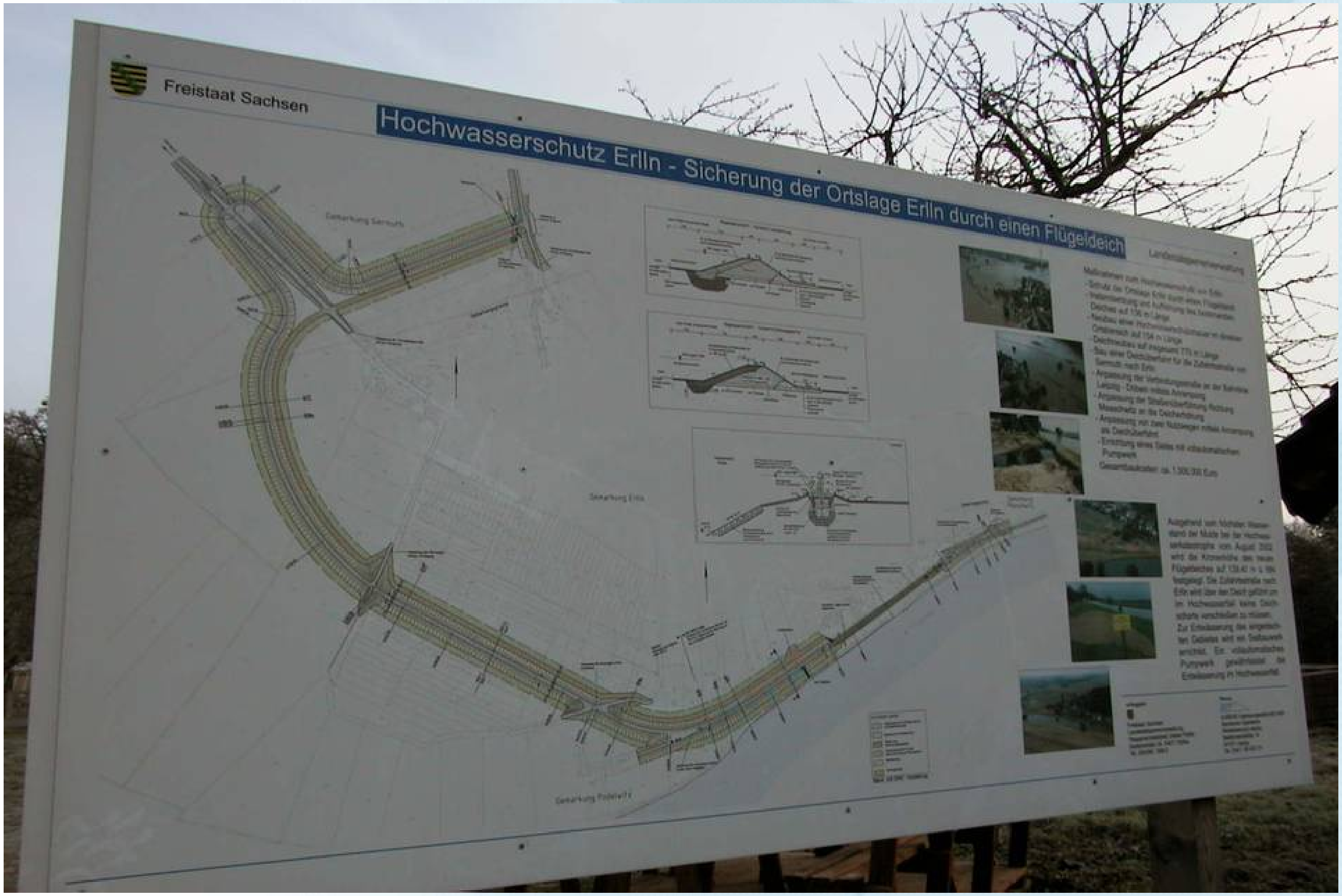
Case study Erlln at Mulde River (Germany)



Erlln
inhabitants 2003: ~ 100
- flood 2002 affected entire village
- heavy destruction

after 2002:
- full reconstruction of the village, new infrastructure
- dike heightening, dike relocation (HQ 100)
- deconstruction of the old dike at the Mulde (HQ 10)

Case study Erlln at Mulde River (Germany)



Costs and benefits of NSM compared to SM

Benefits (Erlln, Mulde River)

	Baseline option	**Dike HQ 100**			**Resettlement** (hypothetical)		
	AAD	AAD	AAD avoided	present value damage avoided	AAD	AAD avoided	present value damage avoided
min	30973	3024	-27948	598833	167	-30805	1056716
mean	**56334**	**5213**	**-51122**	**1,753,624**	**406**	**-55,928**	**1,918,493**
max	83058	8666	-74391	2551849	811	-82246	2821295

Costs (Erlln, Mulde River)

	Dike HQ 100			**Resettlement** (hypothetical)		
	investment costs	running costs	present value costs	compensation payments	running costs	present value costs
min				5550000		5550000
mean	**3,921,000**	**.**	**3,921,000**	**6,787,164**	**.**	**6,787,164**
max				7400000		7400000

Discount rate: 3%; project lifetime: 100 years

Efficiency of NSM compared to SM

Cost-effectiveness (Erlln, Mulde River)

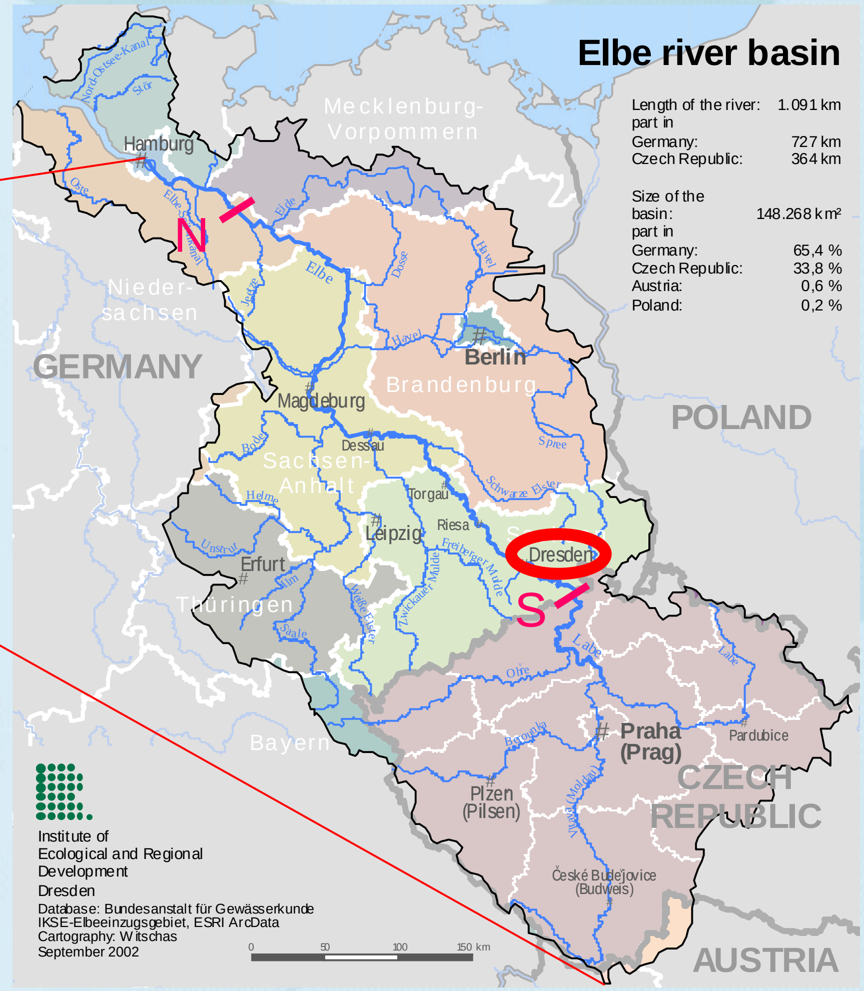
	Dike HQ 100			**Resettlement** (hypothetical)		
	effective (protection goal)	present value costs	cost per %	effective (protection goal)	present value costs	cost per %
min					5550000	
mean	**100%**	**3,921,000**	**39,210**	**100%**	**6,787,164**	**67,872**
max					7400000	

Cost-benefit analysis (Erlln, Mulde River)

Alternative	**Dike HQ 100**		**Resettlement** (hypothetical)	
	net present value (B-C)	benefit cost ratio (B/C)	net present value (B-C)	benefit cost ratio (B/C)
min	-3,322,167	0.15	-4,493,284	0.190
mean	**-2,167,376**	**0.45**	**-4,868,671**	**0.283**
max	-1,369,151	0.65	-4,578,705	0.381

Discount rate: 3%; project lifetime: 100 years

Case study Dresden at Elbe River (Germany)



Case study Dresden at Elbe River (Germany)

Comparison of SM and NSM

- Alternative 1: “Do nothing”
- Alternative 2: “Protection line as planned for the area” (SM)
- Alternative 3: “Portfolio of flood zone designation and small scale private measures (dry and wet proofing, evacuation)” (NSM)

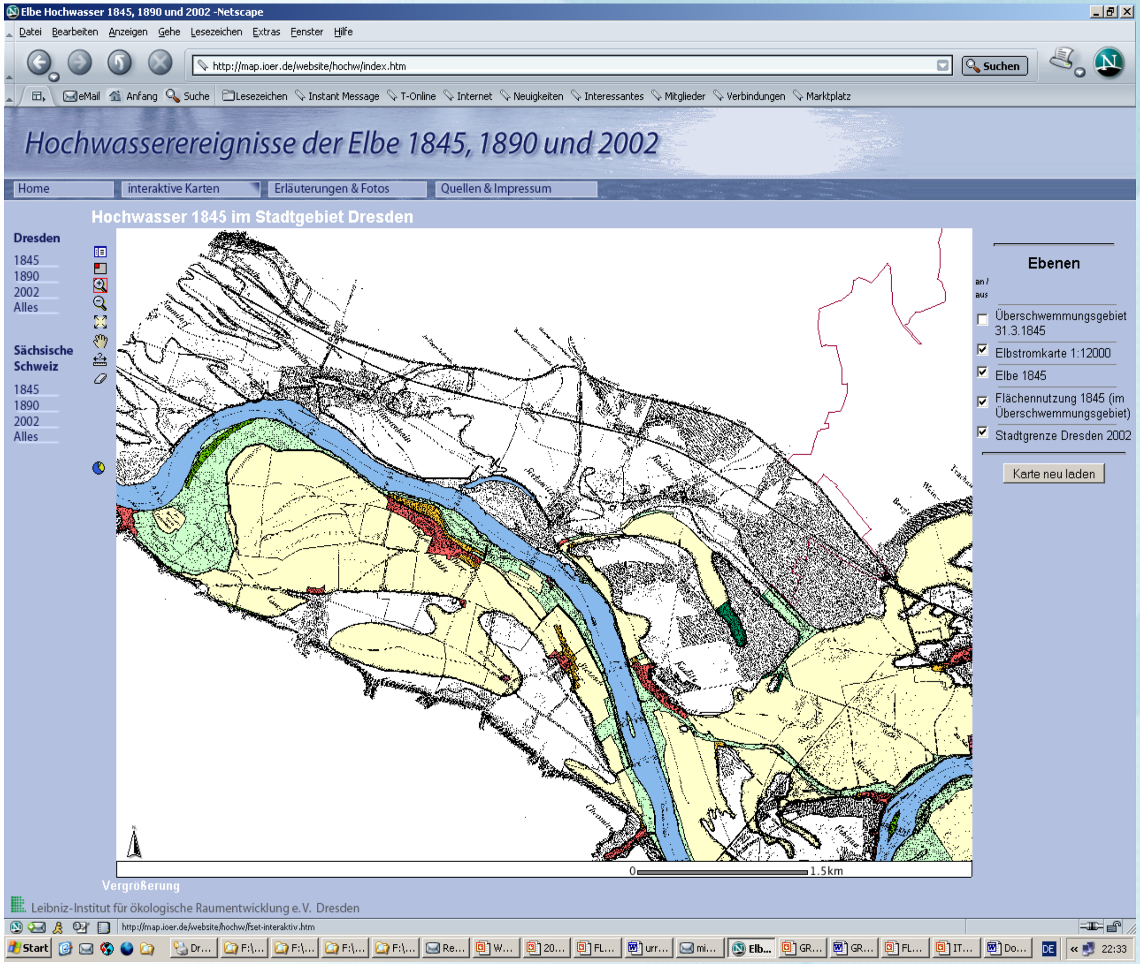
Evaluation:

- Effectiveness
  - Target: no damages up to the 1:100 event
- Benefit-cost ratio
  - Benefits: risk reduction (based on damage model)

Case study Dresden at Elbe River (Germany)

Land use

1945

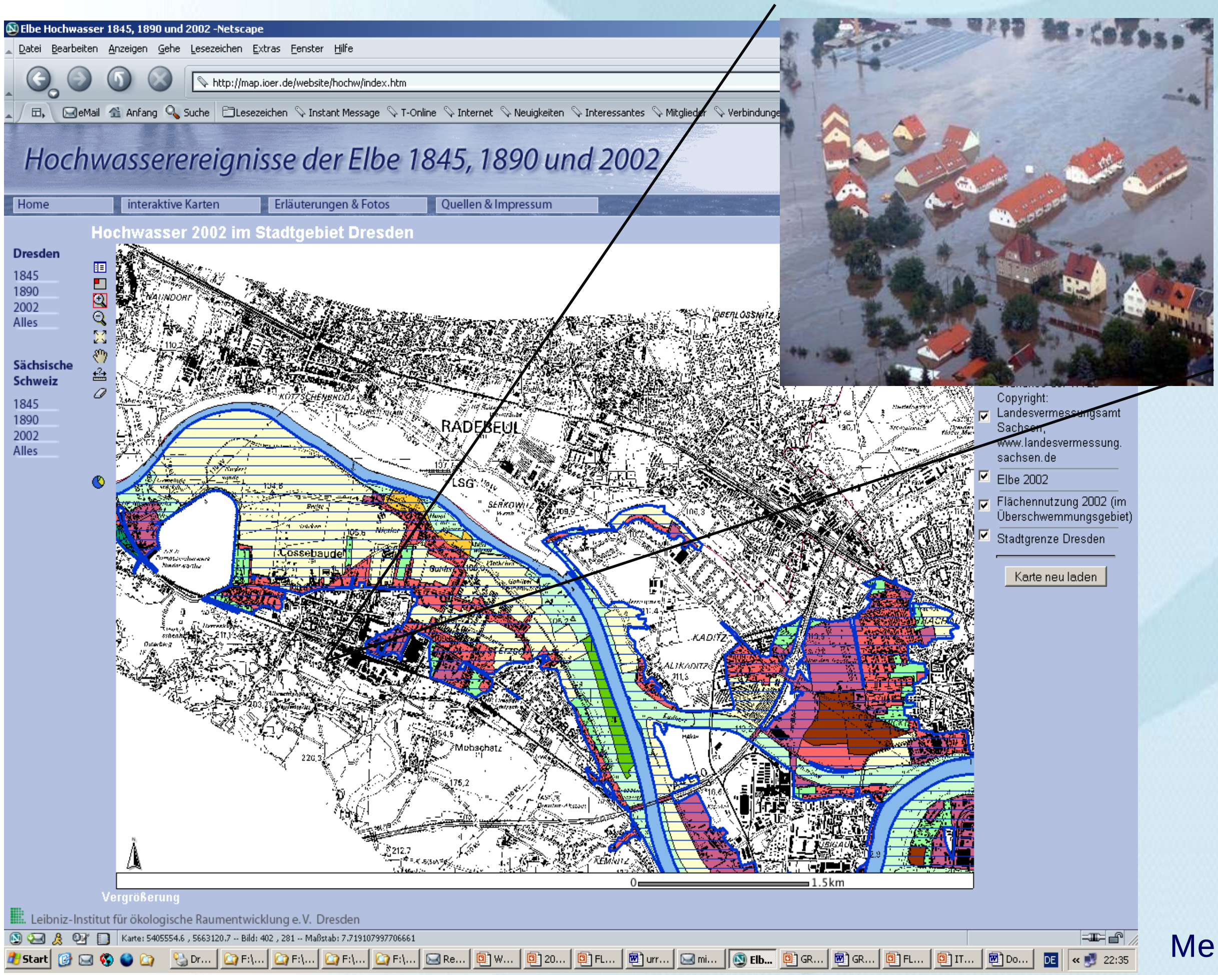


Meinel et al. (2004)

Case study Dresden at Elbe River (Germany)

Land use

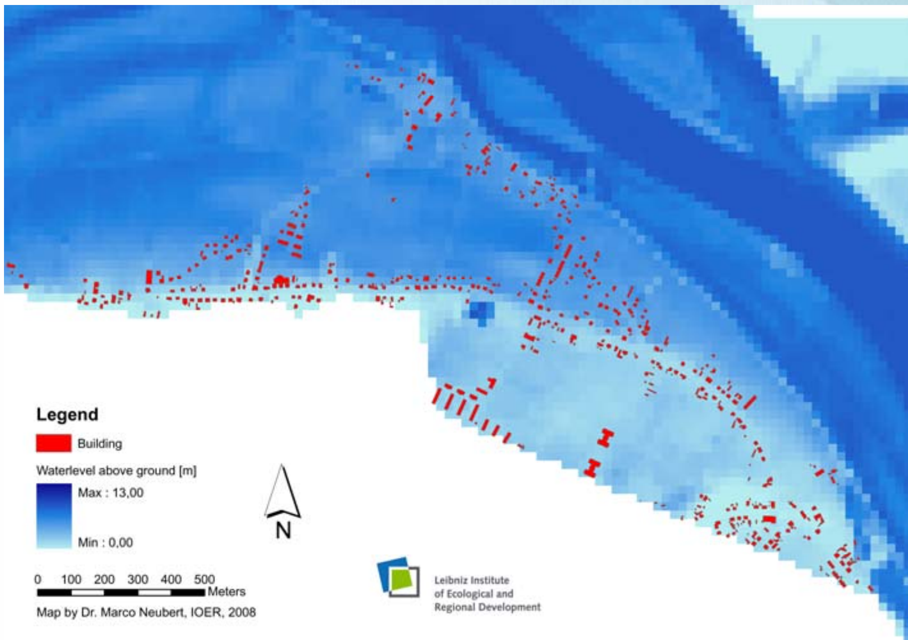
2002 Elbe River flood

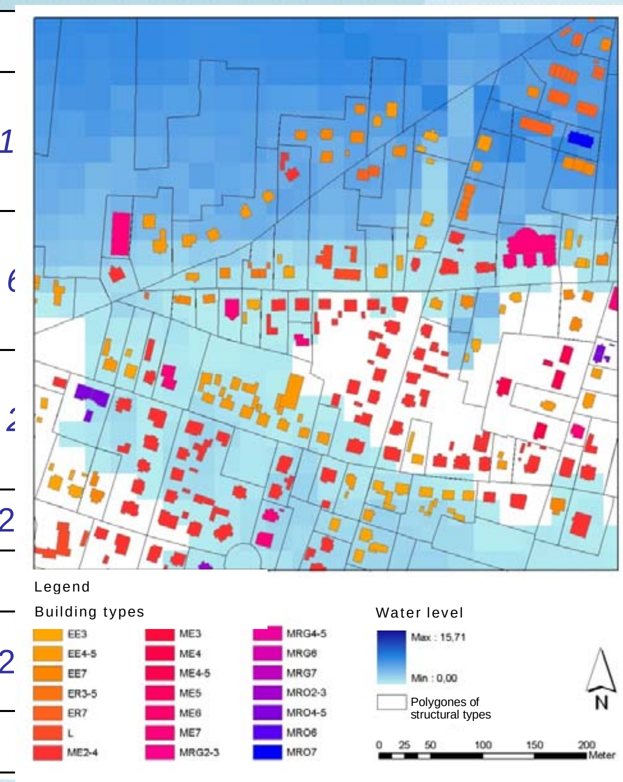


Meinel et al. (2004)

Case study Dresden at Elbe River (Germany)

Current risk



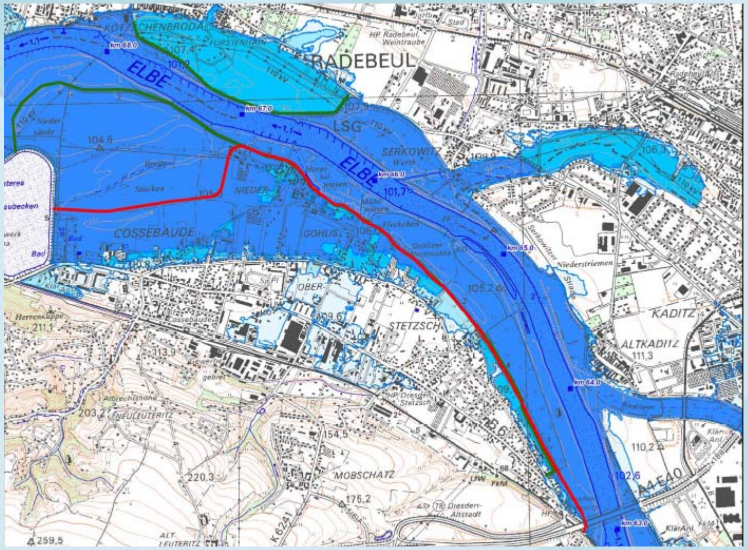


Maximum Loss Potential (MLP) for the 100 years period	88.045.490	68.289.253	2
Average Annual Damage (AAD)	**880.455**	**682.893**	2

Case study Dresden at Elbe River (Germany)

Alternative 2

"Protection line as planned for the area" (SM)



Alternative 3

"Portfolio of flood zone designation and small scale private measures" (NSM)

Case study Dresden at Elbe River (Germany)

Comparison of SM and NSM

Criterion / Alternative	"Do nothing"	"Protection line"	"Portfolio"	"Protection line with dike breach"	"Portfolio with reduced costs"
PV costs	0	13.102.506	5.542.122	13.102.506	1.847.374
PV damage	99.617.159	5.767.157	35.447.860	21.619.232	35.447.860
PV damage avoided (benefits		93.850.002	64.169.298	77.997.927	64.169.298
Effectiveness		**94%**	**64%**	**78%**	**64%**
NPV		80.747.497	58.627.177	64.895.422	62.321.925
BCR (average)		**7,2**	**11,6**	**6,0**	**34,7**

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Dimensions of strategy development

(Hutter & Schanze 2008)

Content

- General aims and specific targets
- Evaluation of measures
- Structural and non-structural measures
- System analysis: controllable, not controllable variables

Process

- Models of formulation and implementation: linear, adaptiv
- Strategic planning modes: programming, scenario-based planning, etc.
- Learning processes at different levels: individual, group, organisation, network

Societal context

External:

- Political
- Legal
- Social
- Economic

Internal:

- Politics
- Resources
- Responsibility
- Culture
- Capabilities

Context conditions for choosing SM and NSM

Selected context factors based on literature review

Internal context conditions	External context conditions
(1) Capability of decision makers to make consistent decisions (2) Response repertoire of decision makers (3) Risk perception (4) Beliefs about general properties of SM and NSM	(5) Legal and policy context (6) Indicators, methods and data to evaluate SM and NSM (7) Site-specific economic, social and ecological conditions

Context conditions influencing the choice of SM and NSM – a set of hypotheses

	Decision makers emphasize structural measures	Decision makers balance structural and non-structural measures	Decision makers emphasize non-structural measures
(1) Internal condition: Consistency	Decision makers have low capability due to difficulties in combining decision criteria and measures from different policy realms (e.g., spatial planning, water management).	Decision makers have high capability due to intensive communication, shared frameworks, and effective conflict management tools.	Decision makers have low capability, but forceful policy entrepreneurs in favour of non-structural measures.
(2) Internal condition: Response repertoire	Decision makers are interested in restoring order and a "control belief" quickly after a flood disaster.	Decision makers believe that a fundamentally new way of reducing flood risk through considering the full range of measures is necessary.	Decision makers believe that a fundamentally new way of reducing flood risk through "breaking from the past" is necessary (= overcoming traditional flood protection).
(3) Internal condition: Risk perception	Decision makers explain flood risk mainly through referring to the flood hazard. Consequently, they pay no or only very limited attention to non-structural measures (especially for reducing damage potentials in flood-prone areas).	Decision makers perceive flood risk as a function of probability and consequences which fosters a comprehensive understanding of flood risk and the full range of measures.	Decision makers perceive flood risk mainly as a man-made disaster caused through unwise use of flood plains for urban development
(4) Internal condition: Belief in measures	Decision makers believe in keeping structural and non-structural measures distinct to consider an established "division of labour" (e.g., sticking to specialization of knowledge, considering institutional constraints).	Decision makers believe in portfolios of structural and non-structural measures to develop effective and efficient programmes for pre-flood risk management.	Decision makers believe that portfolios of structural and non-structural measures increase difficulties in evaluating the specific net benefits of each. They believe in a clear non-structural approach to pre-flood risk management.
(5) External condition: Legal and political context at national level	There are no legal requirements that demand from decision makers to consider non-structural measures.	There are legal requirements that demand from decision makers to consider non-structural measures.	There are legal requirements that demand from decision makers to consider non-structural measures.
(6) External condition: Availability of criteria, indicators, and so forth	Valid indicators and "tried and true" methods for evaluating structural measures are available	Valid indicators and "tried and true" methods for evaluating and comparing structural as well as non-structural measures are available	Valid indicators and "tried and true" methods for evaluating non-structural measures are available
(7) External condition: Site-specific economic, social, and ecological conditions	Economic conditions (e.g., high development pressure on floodplains) and social conditions (citizens want to restore a "sense of safety") motivate decision makers to consider structural measures and to neglect non-structural measures.	Urban regime with a collective preference for a "smart growth" strategy that considers natural hazards as limiting (hazard-prone areas) and enabling factors (hazard-free areas as growth areas).	Economic conditions (e.g., high costs of additional structural measures) and social conditions (e.g., likely protest of residents) motivate decision makers to consider non-structural measures.

Empirical results on the influence of selected context factors on 'balancing SM and NSM'

Context factor	Conclusions regarding a change towards 'balancing SM and NSM'
Risk perception	It is unlikely that risk perception is a major limiting context factor.
Perception of responsibility	Change requires a broad understanding of responsibility among politicians and officials.
Beliefs about measures	Change needs unlearning that *only* "big solutions" with SM can solve "big problems".
Response repertoire	Enlargement will probably develop only over a considerable time span.
Leadership and networks	Change requires multi-level networks with relationships between different policy fields.
Availability of guidelines, indicators and methods	Change requires new guidelines, indicators, and methods to reduce uncertainty on evaluating NSM relative to SM.
Funding	Change requires new funding mechanisms that are more suitable for NSM.
Formal institutions	Decentralization within the public sector could facilitate change.
Informal institutions	Informal institutions (like e.g. culture) are difficult to change.

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Conclusions for FRM strategies

1. The potential scope of flood risk reduction options by far exceeds the traditional flood protection approaches. A common systematisation could facilitate communication.
2. New approaches allow for evaluating and comparing the effectiveness and efficiency of a number of NSM with SM using risk as a common currency.
3. 'Balancing SM and NSM' in decision making (DM) is not just a matter of evaluation capabilities.
4. Other important context factors are (i) a broad responsibility of DM, (ii) unlearning on the size of a solution, (iii) multi-level networks, (iv) new funding mechanisms and (v) decentralisation in the public sector.
5. Challenges arise from further measures and evaluation criteria (e.g. sustainability, robustness).

CRUE
FLOODING ERA-NET

SIXTH FRAMEWORK PROGRAMME

Leibniz Institute of Ecological and Regional Development

Institutions involved

Leibniz Institute of Ecological and Regional Development

fhrc
Flood Hazard Research Centre

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