# Messy Environmental Decisions
# A Summary of BOR Challenges

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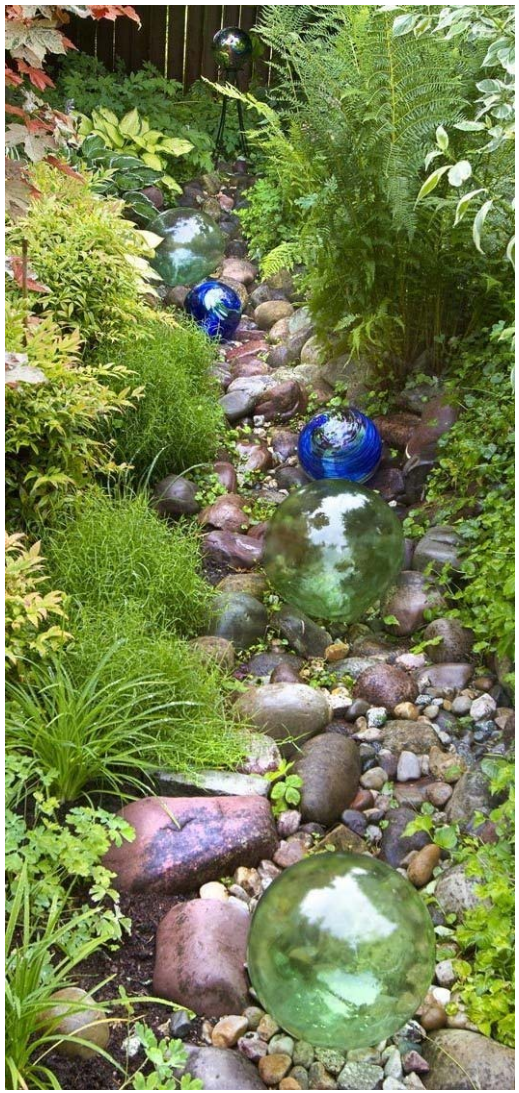
**Eawag: Swiss Federal Institute of Aquatic Science and Technology**

# Why are environmental decisions «messy»?

- Often unclear cause-effect relationships
  → difficult to structure
- Different stakeholders with different interests
  → trade-offs, conflicts
- Expert knowledge required
  → many «indicators» (objectives); redundancy
  → difficult to understand for lay people
- Publicly financed
  → constraints (time, $)
  → should satisfy many; generalization of results?
- Different types of uncertainty
  → future world, predictions, people's preferences?
- Often long-term effects; irreversible
  → interests of future generations?
  → stability of preferences over time?



# 1. Problem Structuring

**BOR challenges…**

…apply to any MCDA

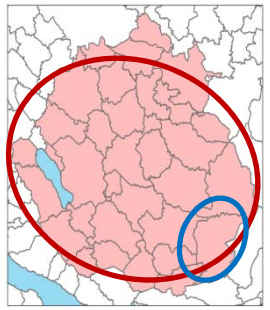
→ how problem is structured strongly affects outcome of MCDA, including behavioral issues

→ but starting point in MCDA is often well-structured decision problem

*Belton & Stewart (2010) in: Ehrgott, et al., Springer*

- Did we correctly characterize problem?
- Are system boundaries well-drawn?
- Whom to include or exclude? … etc.

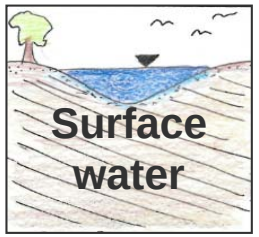
→ Recommendation: integrate PSM with MCDA to avoid later behavioral problems

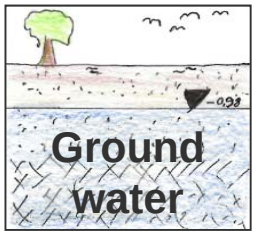


**Boundary:**

**Region**

**Community**




**Water for:**

**Drinking**

→ public health system

**Household**

→ end users

**Firefighting**

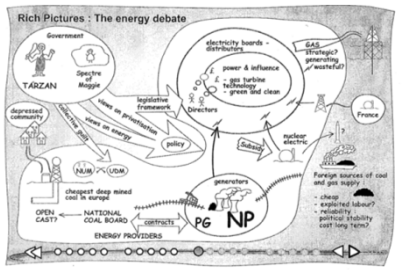
→ insurance

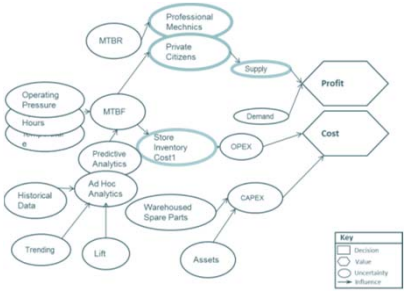
*Figure for water infrastructure system adapted from Lisa Scholten*

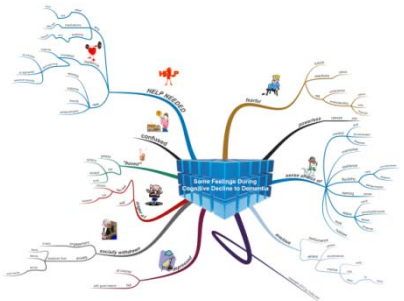
# 1. Combine MCDA w. Problem Structuring Methods

*M. Marttunen, V. Belton, J. Lienert (in prep.)*
*→ see talk by Valerie Belton*


- Problem Structuring Methods (PSM):
  aim to structure problem situation (not solve it)
  *Rosenhead & Mingers (2009) J. Wiley & Sons*
- Early efforts for integration, e.g.
  *Keeney (1992) Harvard Univ. Press; Belton et al. (1997) JMCDA: 6(3); Montibeller & Franco (2011) JORS: 62(5)*
- Recent trend to combine PSM & MCDA, e.g.
  * SWOT & AHP/ANP: 105 papers
  * DPSIR & AHP/ANP: 39 papers
  * TOPSIS & MAVT/MAUT: 21 papers …
  Review about pro's & con's of combinations:
  *M. Marttunen, J. Lienert, V. Belton (in prep.)*



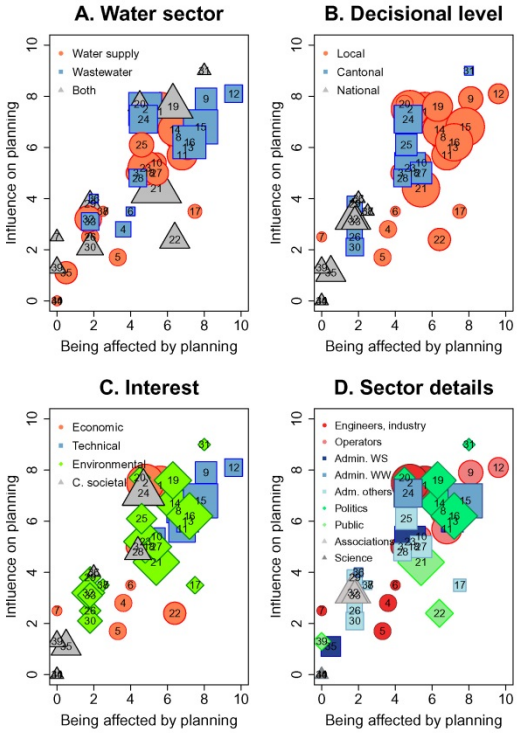



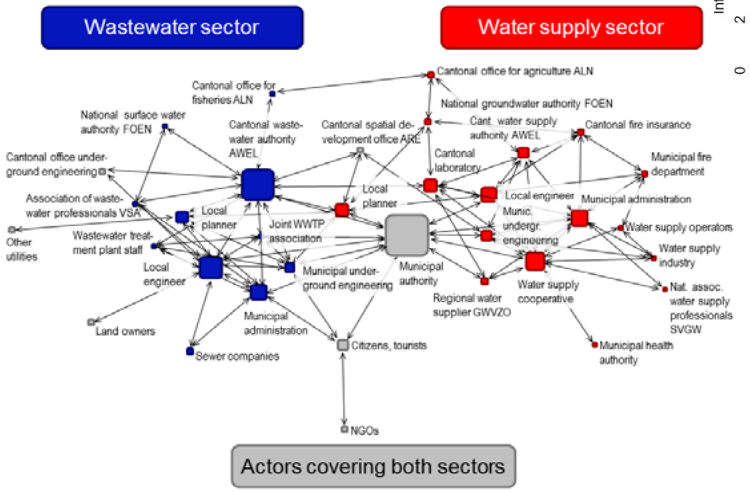



# 1. Combine MCDA w. Problem Structuring Methods

Example stakeholder analysis; *Lienert et al. (2013) JENVMAN: 125*

- 27 interviews: 66 actors play a role in water infrastructure management case
- How to select those to interview?
- Stakeholder analysis: who is important for / affected by decision?
- Snowball & Stratified sampling: all sectors / decisional levels / interests
- Social network analysis: e.g. centrality concept (who connects between actors?)



# 2. Large objectives hierarchies

Environmental decisions are typically characterized by large hierarchies

→ *See talk by Mika Marttunen*

Meta-analysis of 61 environmental /energy cases:
15 objectives on average (range 3–51)

*M. Marttunen, V. Belton, J. Lienert (subm.)*

Why so many?

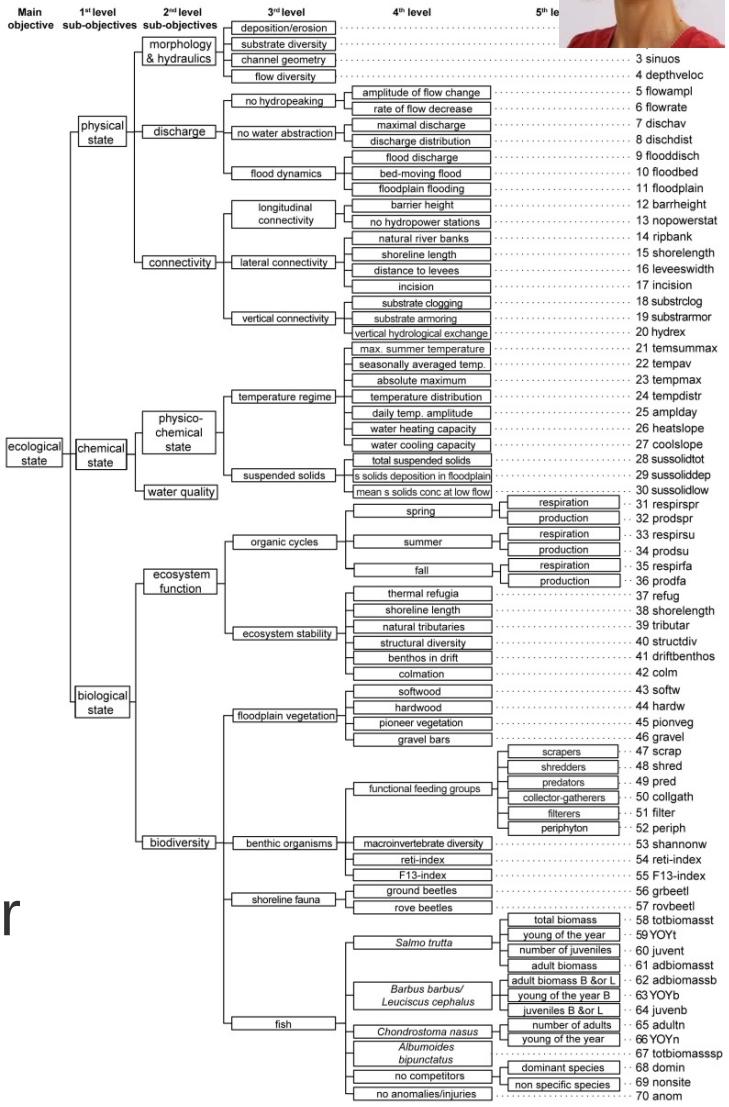
Various objectives in each pillar:

- Environment: Experts require specific indicators to measure e.g. “good ecological state”
- Socio-economic: Many actors with various / conflicting interests
- Equity: Interests of future generations?

# 2. Large objectives hierarchies

Example river rehabilitation

*Langhans & Lienert (2016) PLoS ONE: 11(3)*




- Interviews with 6 ecology experts
- 54–93 “essential” objectives
- No consensus; e.g. biology expert: “only” 54 biological objectives

Conclusions:

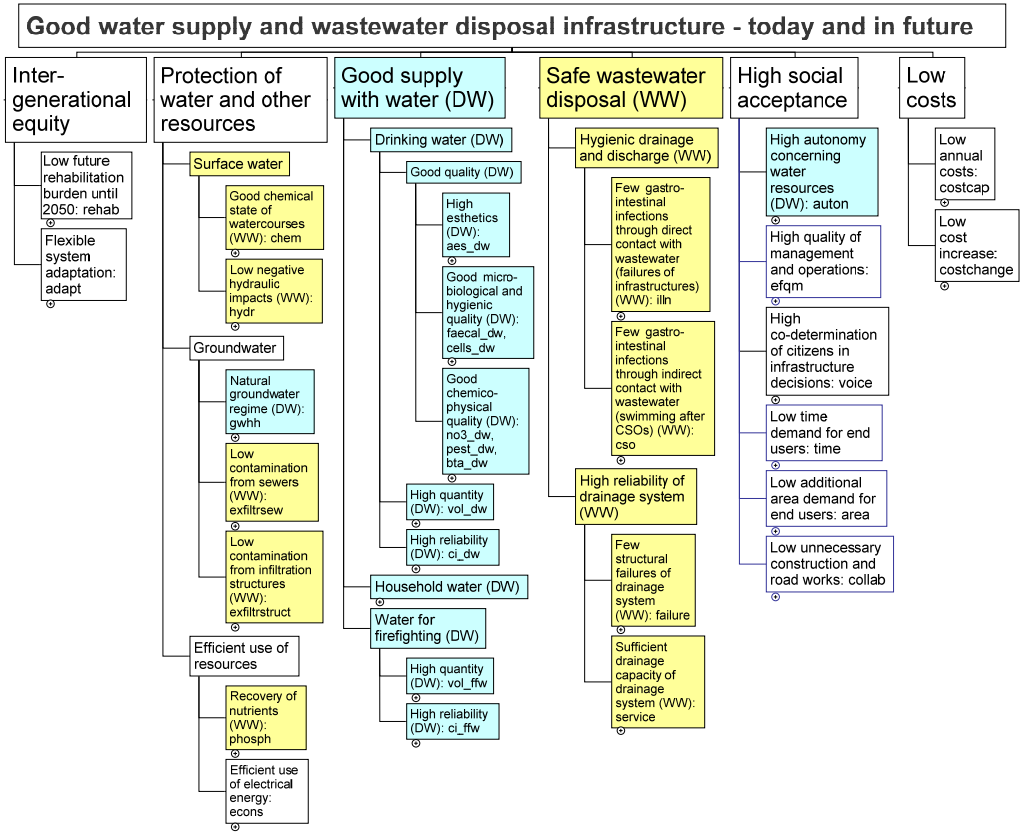
- To assess success of restoration, large hierarchy = advantage?
  * Redundant attributes increase statistical power
  * Flexibility: choose favorite indicator
  * Allows to identify cause-effects
- Else: reduce objectives

# 2. Large objectives hierarchies

Example Sustainable Water Infrastructure Management (SWIP)

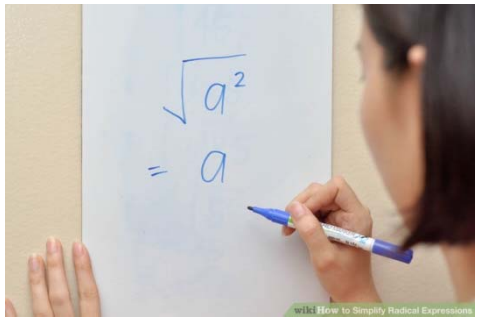
*Lienert et al. (2015) EJDP: 3(1–2); Scholten et al. (2016) EJOR: 242(1); Zheng et al. (accepted) JENVMAN*

- Based on expert knowledge, document analysis, 27 interviews, workshop
- 33 objectives
- Preference elicitation interviews required shortcuts (e.g. rough shape of marginal value function)



# 2. Reduce large objectives hierarchies

## BOR challenges




Benefits of more concise hierarchy:

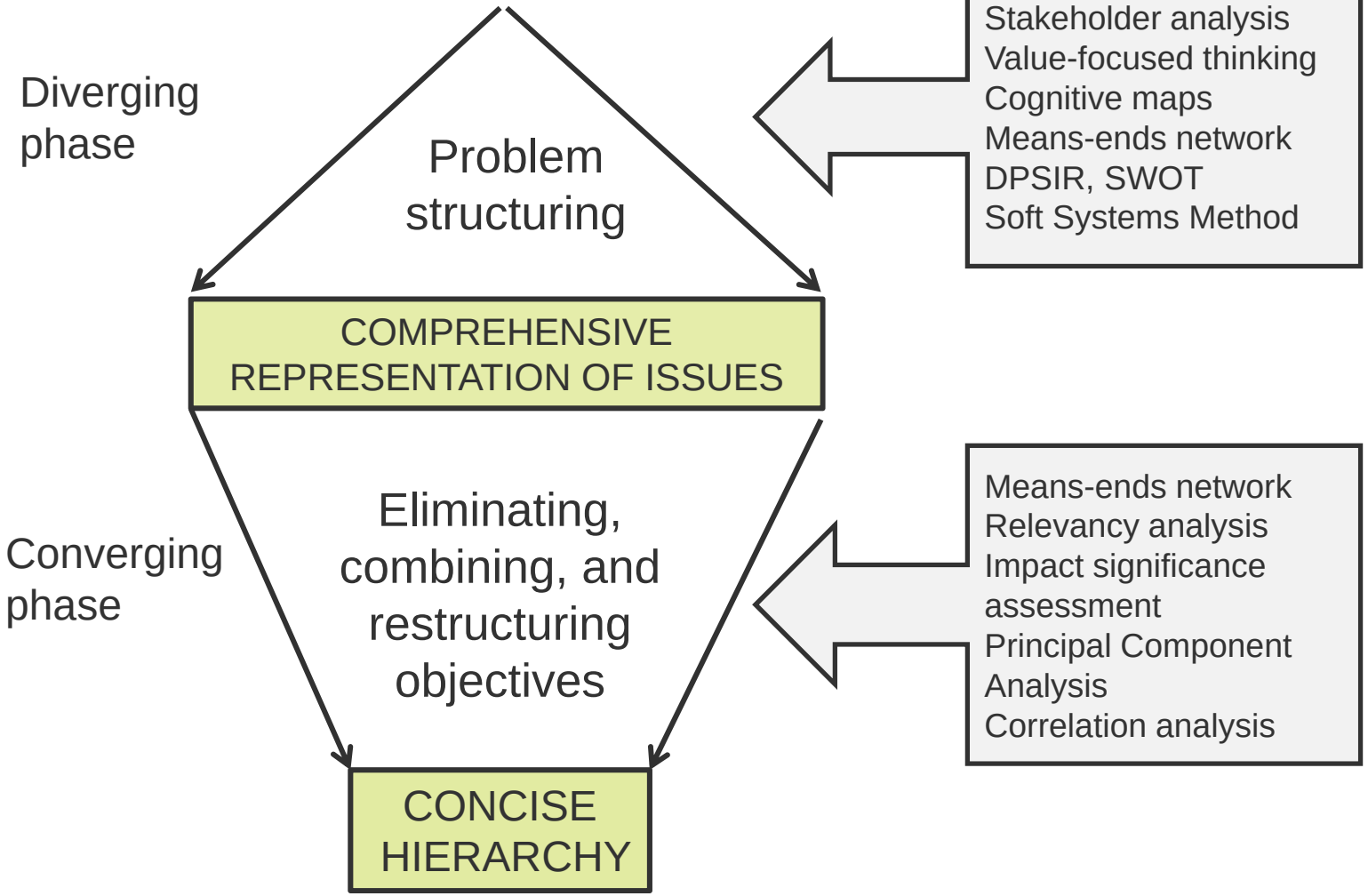
- Lower risk of bias in weight elicitation
  - Important objectives are overridden; “nothing matters”-effect
  - Preference elicitation becomes less demanding (tiresome, loss of focus)
- Easier to process information
  - Hierarchy is easier to understand, decrease of cognitive load
- Facilitate interaction & communication
  - Visibility of key issues & main trade-offs

But: Little guidance how to reduce objectives

# 2. Reduce large objectives hierarchies

Make hierarchies more concise in converging phase of building process

*M. Marttunen, F. Haag, V. Belton, J. Lienert (in prep.)*

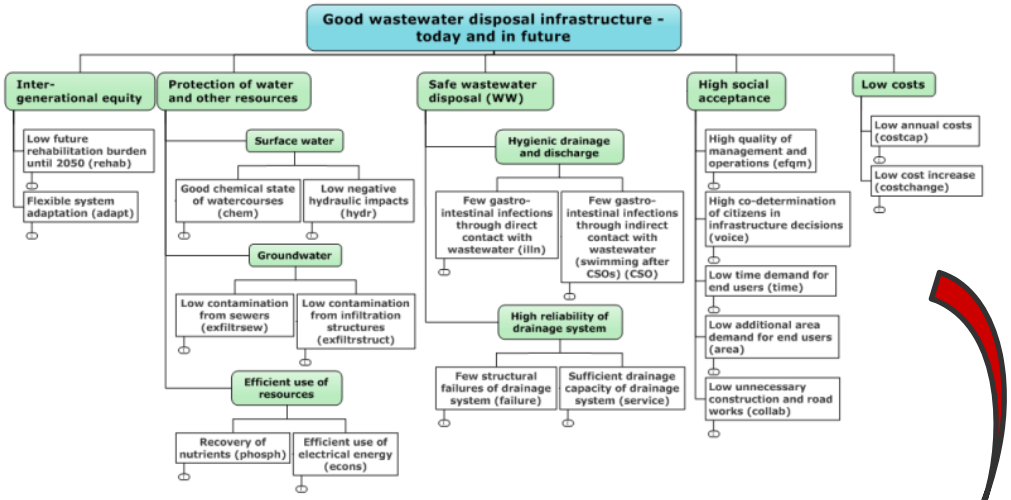


# 2. Reduce large objectives hierarchies

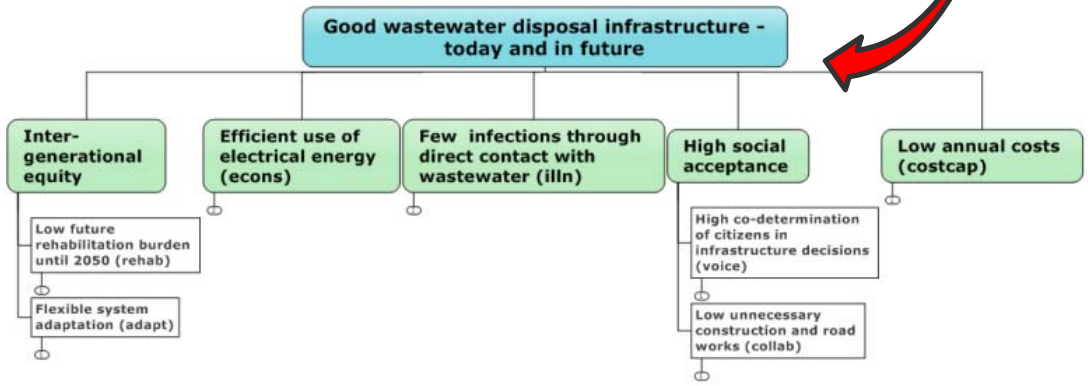
Promising methods to reduce hierarchies in size and complexity

*M. Marttunen, F. Haag, V. Belton, J. Lienert (in prep.)*

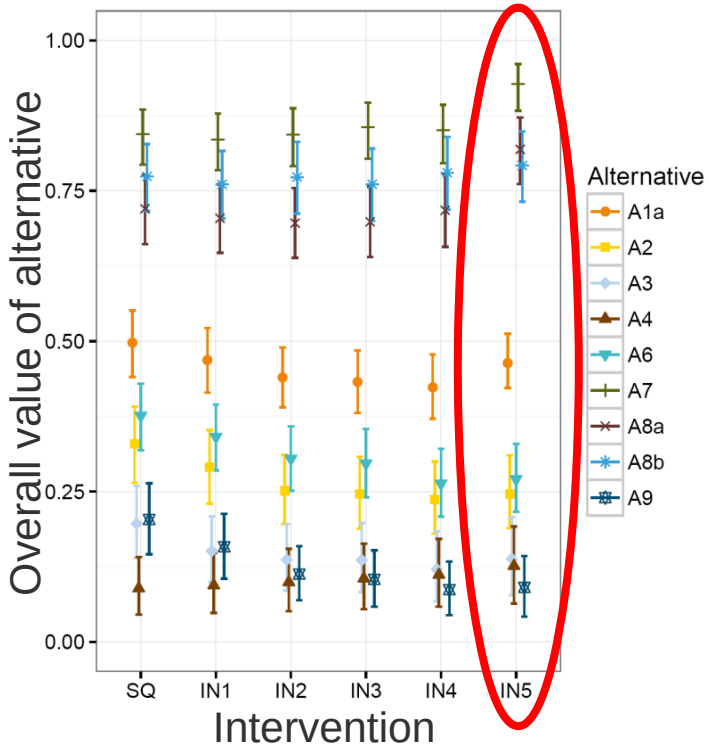
Original SWIP hierarchy (for wastewater): 18 objectives




Intervention #5: reduce to 7 objectives




Ranking of alternatives: relatively consistent



# 3. Problems of (expert) indicators

## BOR challenges

Ecological indicators (e.g. “good ecological state”): often proxy attributes & difficult to understand for lay people

*example: Langhans & Lienert (2016) PLoS ONE: 11(3)*

- (How) can we avoid using proxys?
- Decision maker: mental model / heuristics relating proxy to objectives of interest
- How does attribute choice (proxy / direct) influence stated preferences?
- *How do different representations of information influence stated preferences?*
- *Uncertainty of predictions?*
- *Often partially redundant attributes: Consider non-additive MCDA models. But how to elicit?*

# 3. Problems of (expert) indicators



Avoid proxys: Predict decision relevant impacts

*F. Haag, J. Lienert, M. Maurer, P. Reichert (in prep.)*

Instead of trying to…

… make predictions "understandable": try to directly predict impacts of interest

… find better proxy: try to quantitatively relate proxy to more direct attribute

Proportion of wastewater to river low flow [%]

Proxy attribute

Landuse

Additional impact factors

Modeling (e.g., statistical model)

River characteristics

Prediction

Impacts on sensitive macro-invertebrate species (SPEAR index [%])

Attribute more directly describing the consequence of interest

# 4. Publicly financed; restrictions (time, money)

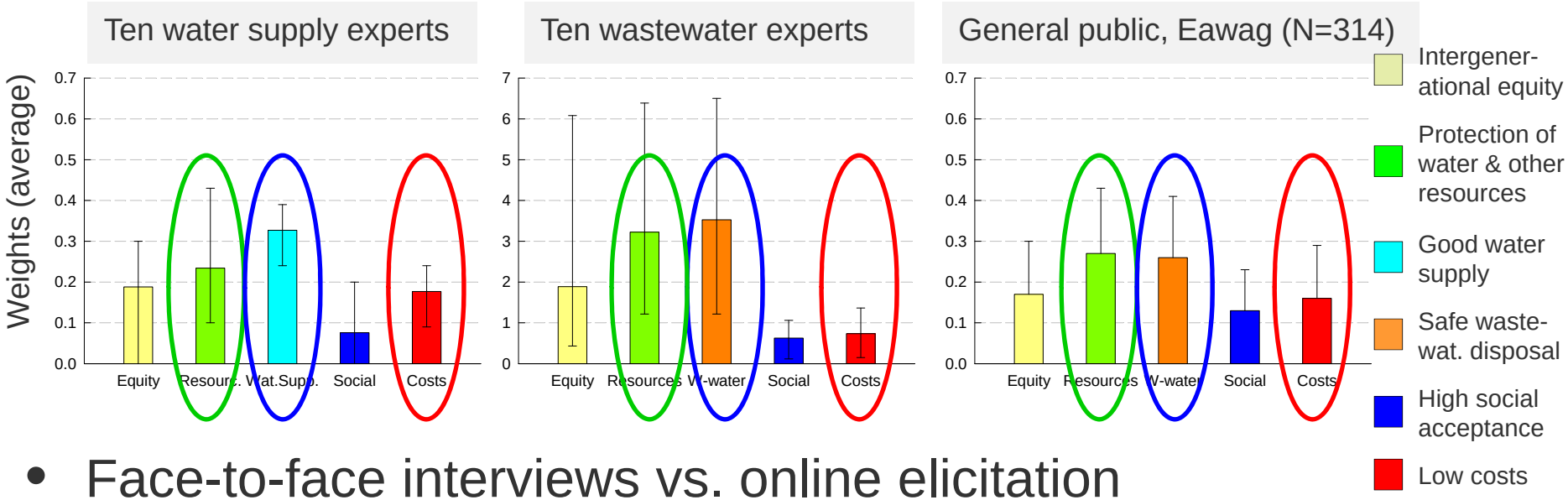
## BOR challenges

- Aim: include public preferences & wish that decision result satisfies many
- But restrictions: risk of over-simplification
- Online surveys to include public preferences?
  Criticized by *e.g. Marttunen & Hämäläinen (2008) Environm. Managem: 42*
- Serious games? → *see talk by Alice Aubert*


# 4. Publicly financed; restrictions


Example sustainable water infrastructure planning (SWIP)

*Lienert et al. (2016) EJOR: 253(3)*




- Face-to-face interviews vs. online elicitation (SWING / SMART/SWING-variant) → Same weight patterns
- But: SWING perceived as "easier"
- But: Statistically significantly different weights
  - SMART/SWING-variant: larger spread of weights … and
  - …less stable preferences after one month

# 4. Publicly financed; restrictions (time, money)

**BOR challenges**

- Compare preference elicitation methods (swing, trade-off, …) & elicitation procedures (interview, groups, games,…)
- Psychological mechanisms & other reasons for (systematic?) differences?
- Influence of decision context, information modes, knowledge, difficulty of task, learning processes,…?

How?

- Experiments (surveys, decision labs)
- Observational studies


# 5. Uncertainties

Environmental decisions are full of uncertainty!

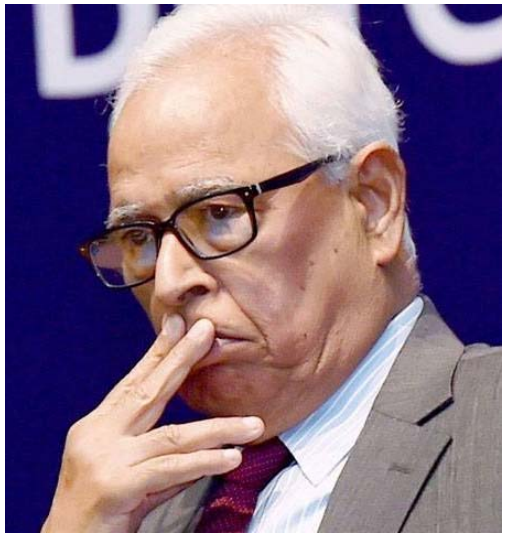
*Lienert et al. (2015) EJDP: 3(1–2); Reichert et al. (2015) JENVMAN: 154; Scholten et al. (2016) EJOR: 242(1); Zheng et al. (acc.) JENVMAN*

- Uncertain predictions
  → Monte Carlo simulation
  → Represent scientific knowledge with intersubjective (imprecise) probabilities
- Uncertain preferences (sure outcomes)
  → Allow for uncertainty during elicitation
- Preferences for uncertain outcomes
  → Elicit utility function
- Which uncertainties matter?
  → local/ global sensitivity analyses
- Uncertainty of future world
  → combine MCDA with scenario planning

# 5. Uncertainties

## BOR challenges

- How to reduce effort for preference elicitation in practice?
  → A priori sensitivity analysis?
  → Interactive elicitation; following idea of:
  *de Almeida et al. (2016) EJOR: 250*
- How to communicate uncertainties in such a way that they are understood by lay people? Mental models / heuristics?
- How to elicit utility functions (lotteries) in practice without distorting utility function? To date mostly “academic” examples
- Do preferences change across future scenarios? Elicit preferences for each?

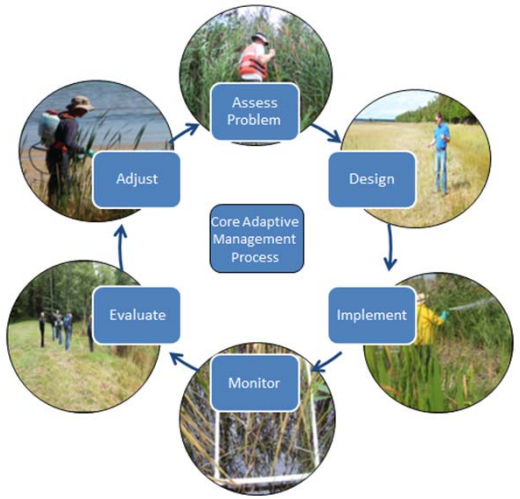


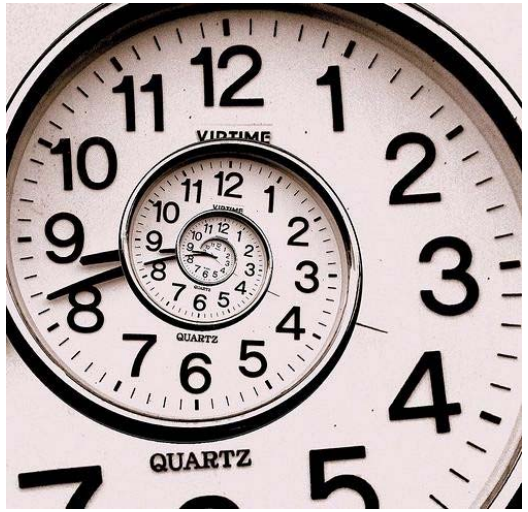
# 6. Timing aspects

## BOR challenges

- Desirable that environmental decisions are stable over time and persist beyond a single situation *Gregory et al. (2012) Structured decision making, Wiley-Blackwell, p. 210* (especially if they affect long time ranges)
- But: are preferences stable over time?
- What influences preferences stability over time? Differences between elicitation methods? *Lienert et al. (2016) EJOR: 253(3)*
- How are preferences formed over time?

→ BOR-aspects: of decision making over time, timing strategies, adaptive management... *new PhD Philipp Beutler*



# Conclusions: Environmental decisions & BOR

Perspective of decision analyst (to avoid or overcome behavioral problems):

- Integrating problem structuring & MCDA
- Systematic (sound) reduction of objectives
- Developing attributes “that matter”

Perspective of decision makers / lay people:

- Mental models, preference formation, heuristics, biases, … given highly complex / uncertain issue
- Procedures that best support unbiased, stable real-world decision-making?
- Including public preferences in policy decisions?

Work in progress exemplifies different types of behavioral issues → suitable research approaches need to be discussed!


*www.eawag.ch/en/department/ess/empirical-focus/decision-analysis-da/*