# Preference stability over time using two weight elicitation methods for wastewater infrastructure planning

Judit Lienert, Mert Duygan, Jun Zheng

EURO – 27th European Conference on Operational Research
University of Strathclyde, 12. – 15. July 2015 Glasgow, Scotland

Eawag: Das Wasserforschungs-Institut des ETH-Bereichs

## Background

- MCDA relies on preference elicitation
- Weight elicitation:* prone to biases
  * depends on method
- Most reliable method? → Stability of preferences over time = reliability proxy (prop. rank reversals; sum of absolute differences weights, SAD)
- Limited experimental literature on preference stability (mostly economics)
- Environmental real-world decision making: additional challenges in preference elicitation – lack of guidance and sound best practices



## Background

Sustainable Water Infrastructure Planning (SWIP: www.eawag.ch/swip)
(National Research Programme NRP 61)

- Water supply & wastewater infrastructure is of core importance & expensive
- Infrastructure is aging
  (25% needs rehabilitation soon, …)
- Can infrastructure cope with new demands?
  (micropollutants, climate change, …)
- Existing planning tools are not planning into far future and are not participatory

*Provide framework and tools for long-term water infrastructure planning that includes uncertainty, non-technical objectives, and stakeholders*

## Background

Sustainable Water Infrastructure Planning (SWIP: www.eawag.ch/swip)

Future uncertainty (scenario planning)

Objectives & decision alternatives

Impacts of climate change on infrastructure


Max Maurer

Infrastructure, performance indicators, pipe decay models


Christ. Egger


Peter Reichert

MCDA assessment: predictions & actor preferences


Lisa Scholten


Judit Lienert

Ranking of alternatives


Jun Zheng

Lienert, Duygan, Zheng (2015) Preference stability sust. water infrastruct. (Eawag, Switzerland)

## Research objectives and hypotheses

Online experiment to compare two weight elicitation methods

- Difference betw. two elicitation methods? SWING and SMART/SWING-variant…
  … perceived difficulty?
  … reliability of weight elicitation?
- Feasibility of online weight elicitation?
- Do weights affect case study outcome?

Hypotheses

- **H1: services of wastewater infrastructure are of similar importance to all people**
- H2: Respondents attach higher weights to their field of expertise
- H3: SWING is perceived as more difficult
- **H4: Preferences are more stable over time if elicited with SMART/SWING-variant**
- H5: Strong preferences are more stable

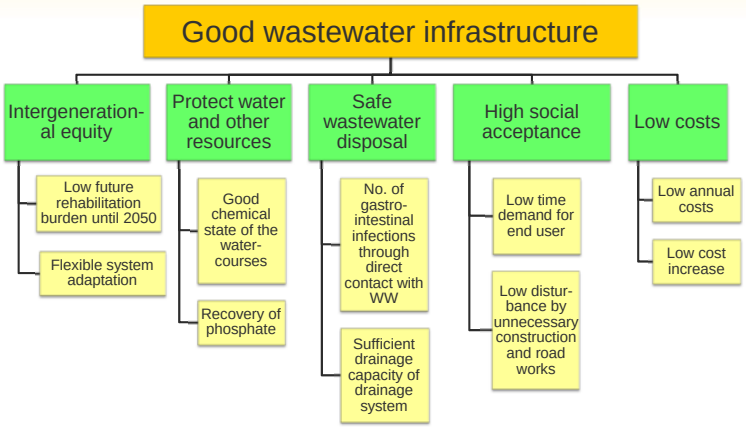
## Methods / Design

| July 2013 (N = 314) (Eawag / public) | | August 2013 (N = 200) | |
|---|---|---|---|
| SWING | N = 158 → | SWING | N = 94 |
| SMART/ SWING-var. | N = 156 → | SMART/ SWING-var. | N = 106 |

Explanation / description of objectives
A. Knowledge, experience
B. Elicitation:
compare 2 x 5 sub-objectives, then 5 main objectives (Status quo, worst/ best-possible case given)
1. ranking
2. rating (scoring)
C. Feedback (certainty, difficulty, reasons, consideration of range)
D. Explanatory variables (e.g. demo-graphic, environmentally friendly behavior, relation to water)

Explanation / description of objective
A. ---
B. Elicitation: as before, but randomized order of sub-objectives
…
1. ranking
2. rating (scoring)
C. ---
Any new knowledge/ experience? Did judgments change? Why?
D. ---

## Methods / Objectives hierarchy

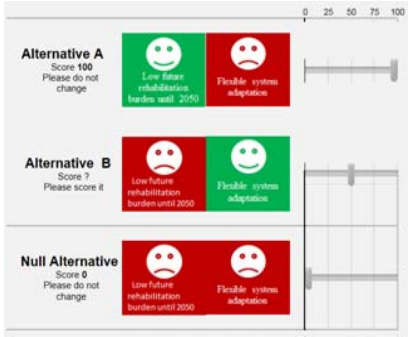



*Note: This is a simplified objectives hierarchy. Full hierarchy see Lienert et al. (2015) EURO J. Decis. Proc.)*

## Methods / Visualization of weight elicitation

Example SWING

1. **Ranges:** description of best / worst case and status quo of objectives
2. **Ranking:** choose objective that is most important to improve
3. **Scoring** with slider (points between 100 – 0)

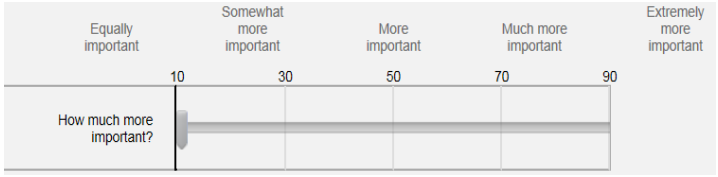



Lienert, Duygan, Zheng (2015) Preference stability sust. water infrastruct. (Eawag, Switzerland)

## Methods / Visualization of weight elicitation

Example SMART/SWING-variant (based on *Mustajoki et al. 2005, Decis. Sci.*)

1. **Ranges:** description of best / worst case and status quo of objectives
2. **Ranking:** choose objective that is most important to improve
3. **Scoring** with slider (points between 100 – 0) (inspired by AHP)



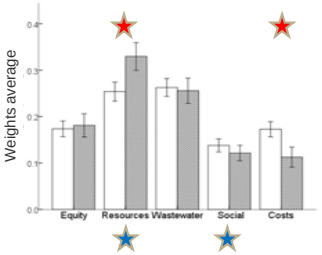

*Note: For main objectives, because there are more than two objectives, first a reference objective is selected with which all others are compared*
*(Mustajoki et al. 2005, Decis. Sci.)*

## Results / Preference patterns, H1 / H2

**H1: No differences between sample groups concerning weights**

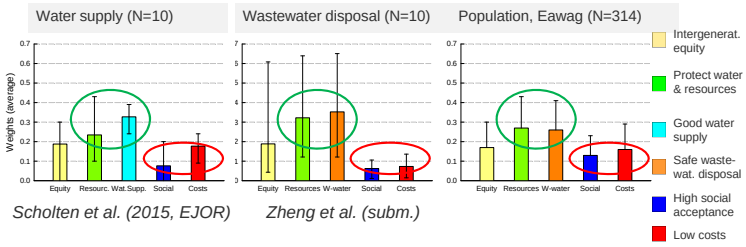
H2: Respondents attach higher weights to their field of knowledge/ expertise

- Most important objectives:
  *Protection of water and other resources*
  *Safe wastewater disposal*
- Public (N=249) and Eawag (N=65) gave similar weights, with two exceptions
  → Exceptions confirm H2
- SMART/SWING-var. more extreme than SWING SMART/SWING: higher weights to 'resources' / lower weights 'social'
- Few other differences (e.g. none for gender, age, …), most notably:
  Having children → higher weight 'equity'
  University→ higher weight 'resources'




## Discussion / Preference patterns, H1

H1: No differences between sample groups concerning weights



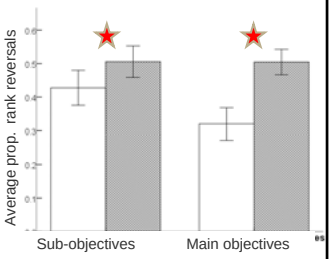

*Scholten et al. (2015, EJOR)* *Zheng et al. (subm.)*

- Weight distribution very similar to careful face-to-face expert elicitation in two separate studies *(Scholten et al., 2015, EJOR; Zheng et al., subm.)*
  → Strong evidence that 'low costs' is NOT most important objective
- H1 well supported, but surprising difference between SWING & SMART/SWING-variant → Does AHP rating scale cause larger spread of weights?
- Some support of follow-up hypothesis → SMART/SWING-variant seems to lead to more extreme weights (steeper slope of linear component of average weights)

## Results / Preference stability over time, H4, H5

**H4: Respondents using SMART/SWING-var. = more stable preferences**

- H4 clearly rejected!
- Proportion rank reversals, weights main objectiv. (N=200, p=.000, t-test)
  SWING: 0.32
  SMART/SWING-variant: 0.5
- Sum of absolute differences, weights main objectives (p=.000, t-test)
  SWING: 0.38
  SMART/SWING-variant: 0.77
- (similar results for sub-objectives)




For five pairwise comparisons:
0 = no rank reversals
1 = 5 rank reversals

## Results / Preference stability over time, H4

Effect of explanatory variables on preference stability (regression analysis)

| Rank reversal of sub-objectives | β | Sig. |
|---|---|---|
| Method | .144 | **.034** |
| Knowledge | -.269 | **.000** |
| Experience | -.024 | ns |
| Age | .069 | ns |
| Education | -.127 | .071 |
| New experience | .150 | .052 |

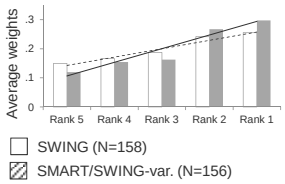
| Rank reversal of main objectives | β | Sig. |
|---|---|---|
| Method | .386 | **.000** |
| Knowledge | -.138 | **.038** |
| Experience | -.073 | ns |
| Age | .187 | **.005** |
| Education | -.024 | ns |
| New experience | .158 | **.032** |

| SAD of weights of sub-objectives | β | Sig. |
|---|---|---|
| Method | .482 | **.000** |
| Knowledge | -.132 | **.035** |
| Experience | .072 | ns |
| Age | .132 | **.034** |
| Education | -.097 | ns |
| New experience | .129 | .062 |

| SAD of weights of main objectives | β | Sig. |
|---|---|---|
| Method | .492 | **.000** |
| Knowledge | -.046 | ns |
| Experience | .030 | ns |
| Age | .186 | **.003** |
| Education | -.090 | ns |
| New experience | .138 | **.046** |

## Discussion / Preference stability over time, H4

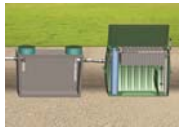
- SWING produced more stable preferences over 1 month than SMART/SWING-variant (strong for rank reversals; less for SAD)
  → Systematic difference between the two weight elicitation methods? Why?
- SAD: AHP-rating scale in SMART/SWING-var. → Larger spread of weights (?)
- Why more rank reversals? "More difficult" SWING → think harder → more stable preferences *(Hoeffler & Ariely 1999, J.Cons Psy)*?
  → Replication of results required
  → test for psychological mechanisms
- Explanatory variables: method most important → follow-up for age / new information




## Case study / Do weights affect outcome of decision?

Real Swiss case study from SWIP, rural region near Zürich

- Individual/ aver. group weights 1st vs. 2nd survey; additive MAVT-model; linear VF
- Difference in ranks of 6 wastewater alternatives? Current centralized to decentral system; year 2050; Kendall's Tau corr. c.
- Average group weights: although difference in weight patterns (SWING, SMART/SWING-variant):
  → no effect on MAVT-values 1./2. survey
  → Identical ranking 1./2. survey
  → Best rank: decentralized system(!)
- Individual weights: clear effect of method (N=200; t=4.3, p=.000)
  SWING: 52% same rank (K.Tau: 0.556)
  SMART/SWING-var.: 35% (K.Tau: 0.265)



## Discussion & Conclusion

- SWING produced stat. sign. more stable weights and MCDA-results than (new, "easier") SMART/SWING-variant
  → Designing and testing reliability of elicitation methods IS important!
- BUT effect cancels out if average group weights are used → aggregated population aver. = stable collective recommendation?
- Advantage of MCDA: can consolidate diverging preferences by searching for and constructing (new) consensus alternatives
  → verify in each (environmental) decision: is group average indeed wisest choice?
- Weights concur with individual interviews
  → online elicitation does seem feasible

Lienert, Duygan, Zheng (2015) Preference stability sust. water infrastruct. (Eawag, Switzerland)

eawag aquatic research

## Literature for this talk

- *Also see SWIP project homepage (incl. two videos): www.eawag.ch/swip*
- *judit.lienert@eawag.ch*


- *Hoeffler, S., & Ariely, D. (1999) Constructing stable preferences: A look into dimensions of experience and their impact on preference stability. Journal of consumer Psychology 8: 113-139.*
- *Lienert, J., L. Scholten, C. Egger, M. Maurer (2015) Structured decision-making for sustainable water infrastructure planning and four future scenarios. EURO Journal on Decision Processes (EJDP) 3(1-2): 107-140. (SI on Environmental Decision Making).*
- *Lienert, J., Duygan, M., Zheng, J. (subm.) Preference stability over time using two weight elicitation methods for wastewater infrastructure planning.*
- *Mustajoki, J., Hamalainen, R. P., Salo, A. (2005) Decision support by interval SMART/SWING-incorporating imprecision in the SMART and SWING methods. Decision Sciences 36: 317-339.*
- *Scholten, L., Schuwirth, N., Reichert, P., Lienert, J. (2015) Tackling uncertainty in multi-criteria decision analysis – An application to water supply infrastructure planning. European Journal of Operational Research 242(1): 243-260.*
- *Zheng, J., Egger, C., Lienert, J. (subm.) A scenario-based MCDA framework for wastewater infrastructure planning. .*