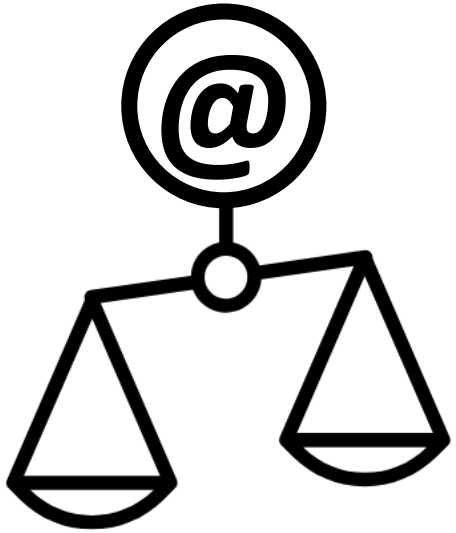
Life Sciences and Facility Management

Institute of Natural Resource Sciences

Participatory weighting and decision-making



Alice H. Aubert, Dr. (aube@zhaw.ch)

DF 88 – Frontiers in Life Cycle Sustainability Assessment – How can Life Cycle Thinking embrace the Triple Bottom Line?

Friday, 22 November 2024
ZHAW Wädenswil

Decisions for sustainability*

- Unavoidable trade-offs between multiple objectives covering the 3 dimensions of sustainability
- Multiple uncertainties

- Multiple affected actors, potentially
  - Conflicting opinions
  - No constructed opinions yet

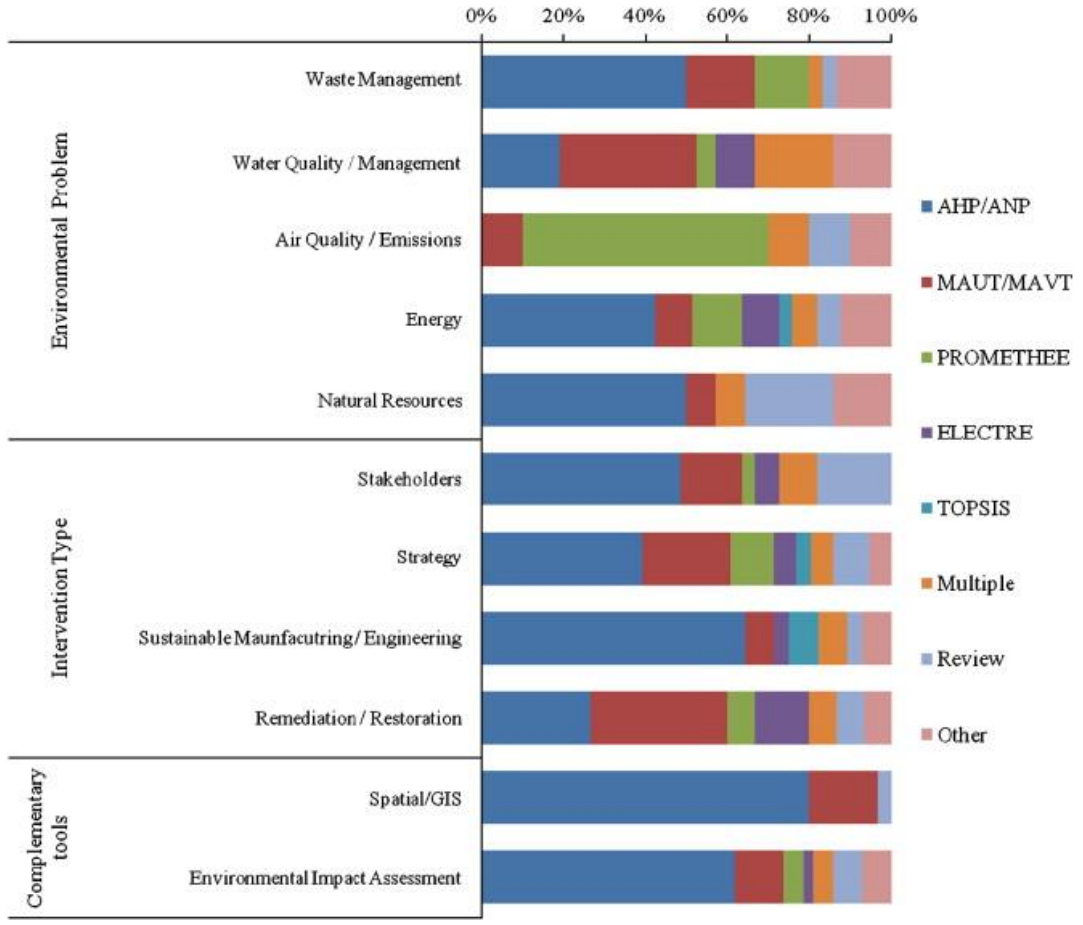
* Thomas Dietz (2023) «Decisions for sustainability: Facts and Values»

Multi-criteria Decision Analysis

- Disentangle facts from values
- *"... an **umbrella term** to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter. ..."*

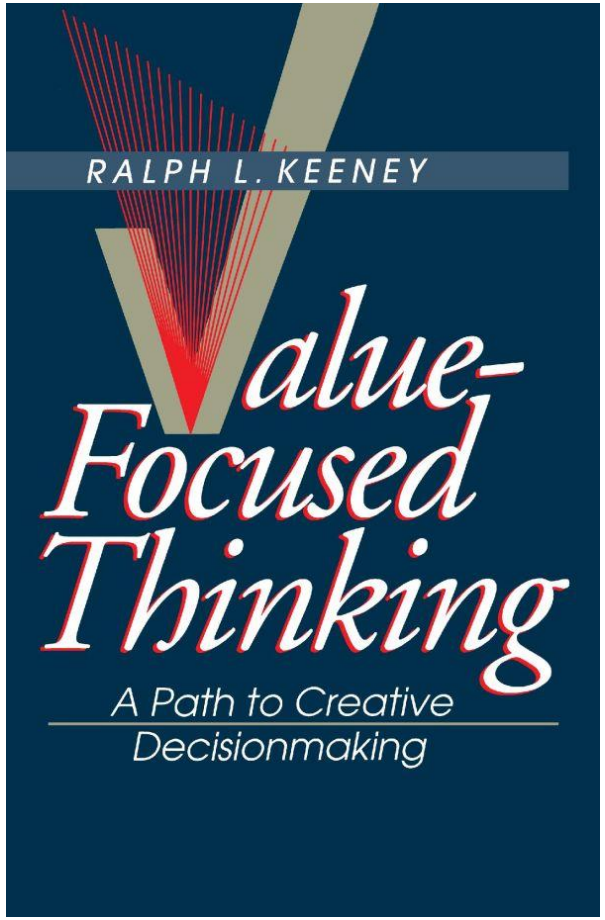
↑ Quote: Valerie Belton, Theodor J. Stewart (2003) "Multiple Criteria Decision Analysis" Kluwer Academic Publishers: p.2

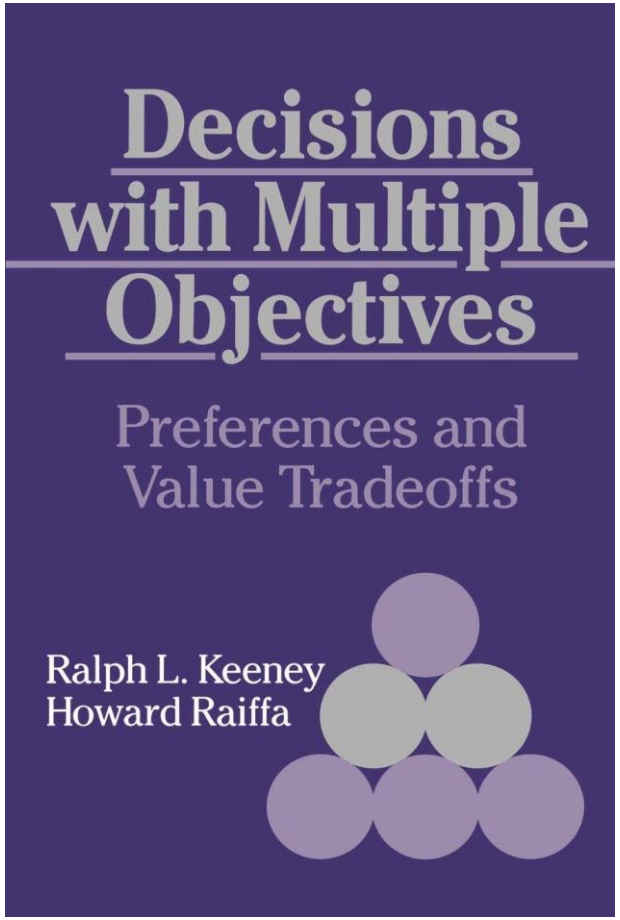
Graph: Huang, Keisler & Linkov (2011) *Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends.* Stoten (Figure 1) →



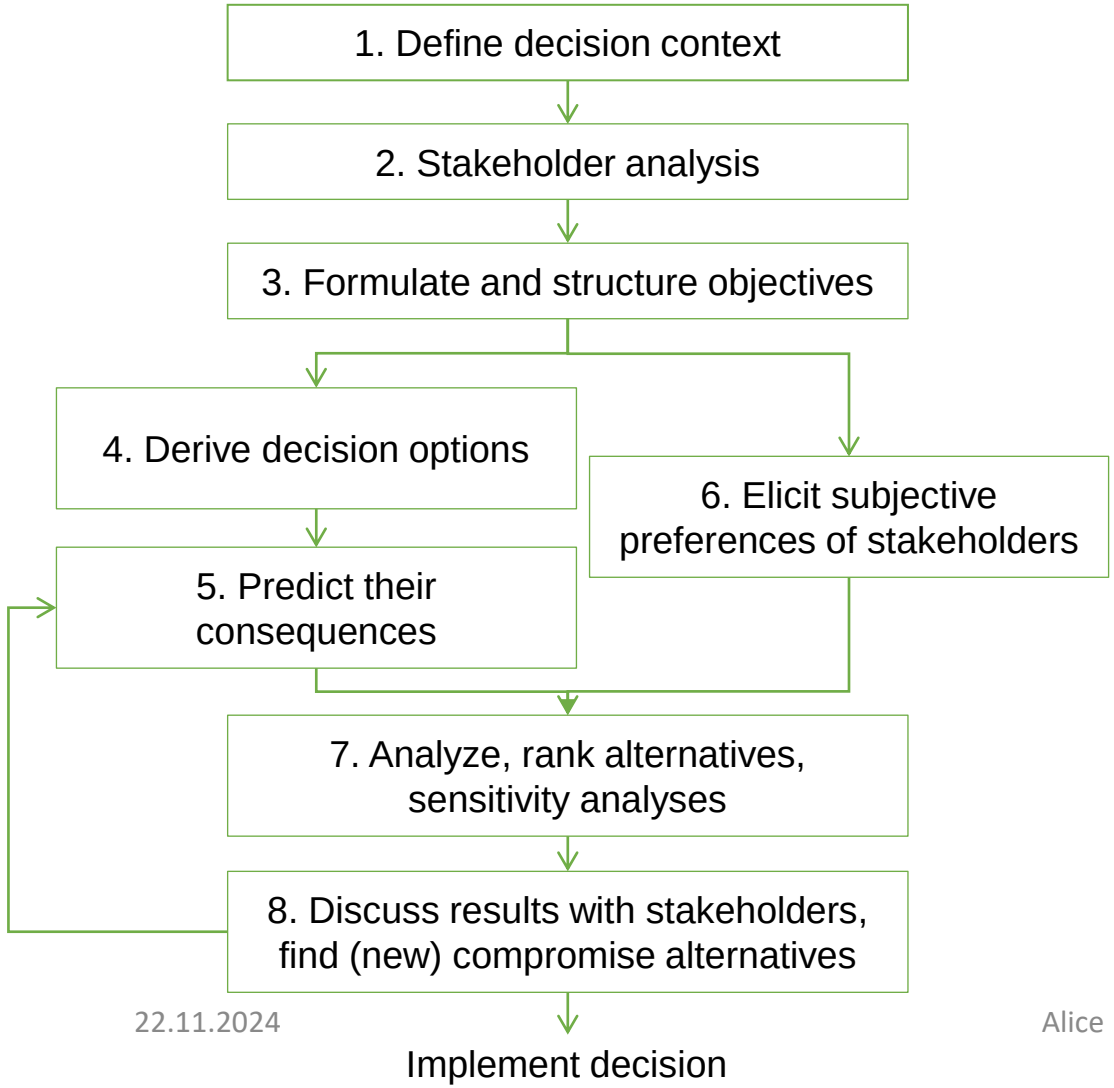
Percentage distribution of MCDA methods by application areas

Multi-Attribute Value/Utility Theory





MCDA process with MAVT



- **Structured** process to increase the **transparency**
- **Context-specific learning** process for all actors involved
  - Facts about the system or topic
  - Constructing own preferences
  - Understanding views of other stakeholders

Keeney, 1992 | Keeney & Raiffa, 1976 | Eisenführ et al., 2010

Multi-Attribute Value Theory

- Aggregate
  - system predictions (facts) and
  - subjective preferences (values)

➢ 3 preference parameters:
- Single attribute value functions
- Weights
- Aggregation model

$$v(a) = \sum_{r=1}^{m} w_r v_r(a_r)$$

With $w_r > 0$

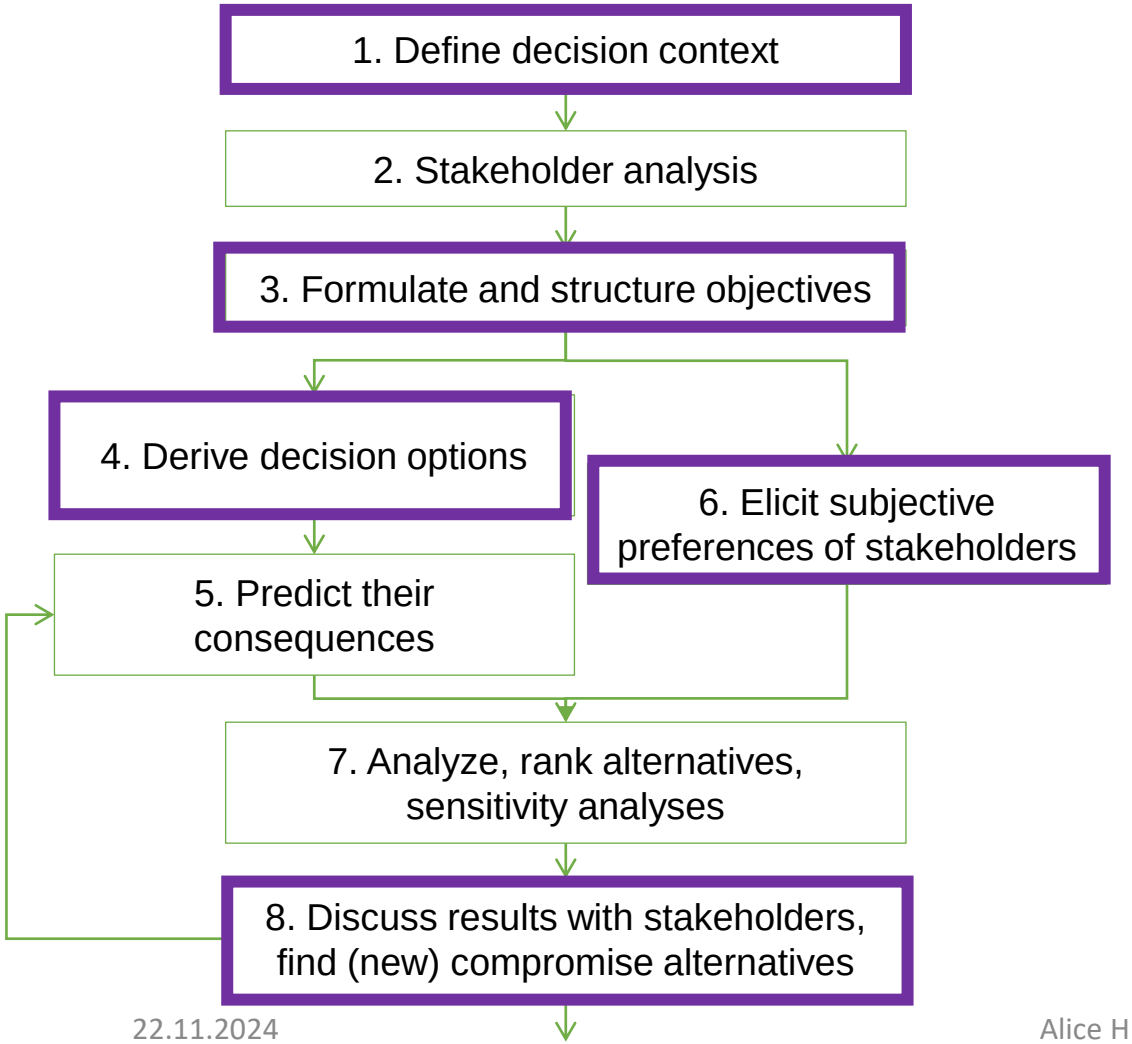
And $\sum_{r=1}^{m} w_r = 1$

Keeney, 1992 | Keeney & Raiffa, 1976 | Eisenführ et al., 2010

Eliciting preferences from stakeholders

©Eawag, Decision Analysis research group from J. Lienert

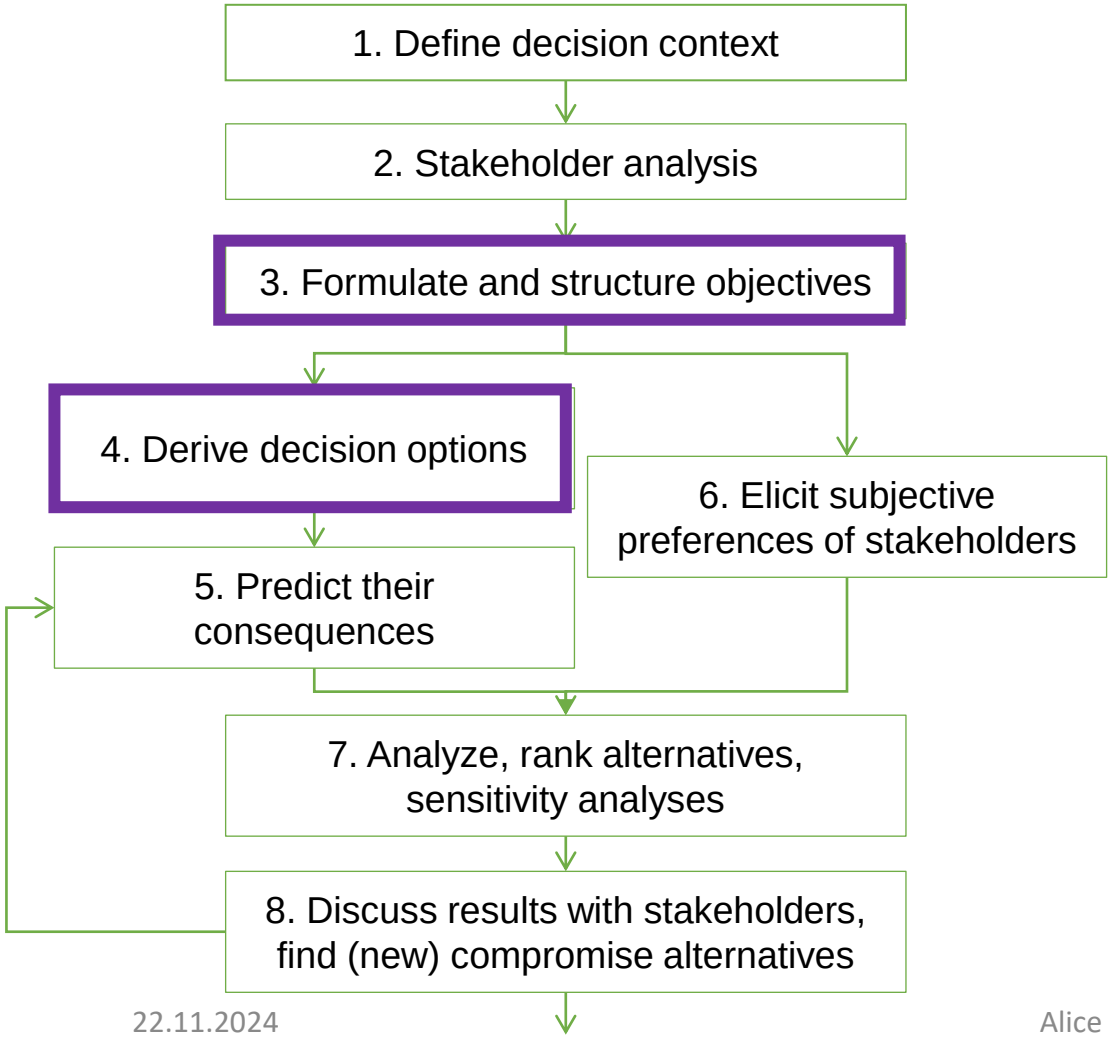
MCDA as participatory process

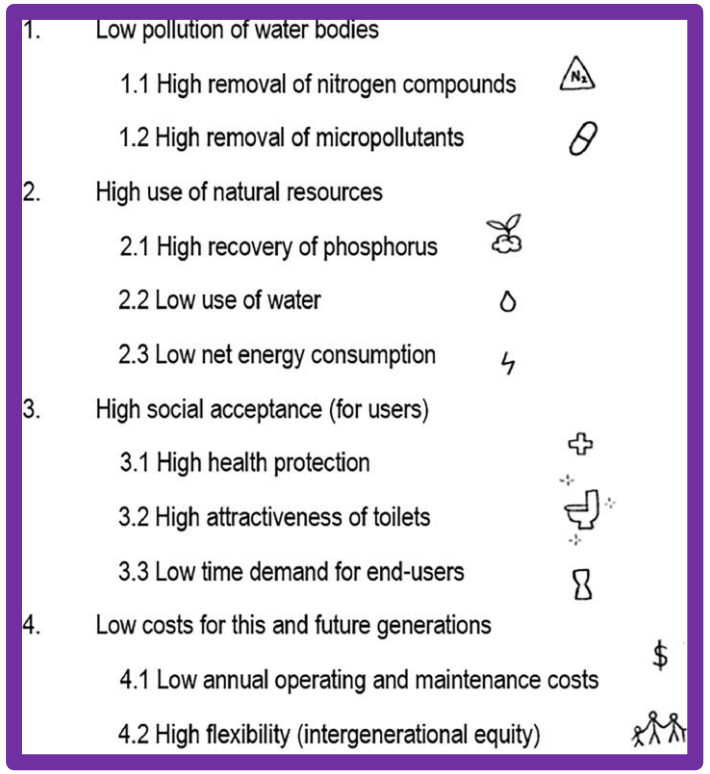


- **Participative** steps
- In the following: step-by-step participatory steps are discussed

PD Dr. Judit Lienert
Leader of the Group Decision Analysis
in Department Environmental Social Sciences
at Eawag (Switzerland)

Interaction 1: Identify objectives and create options

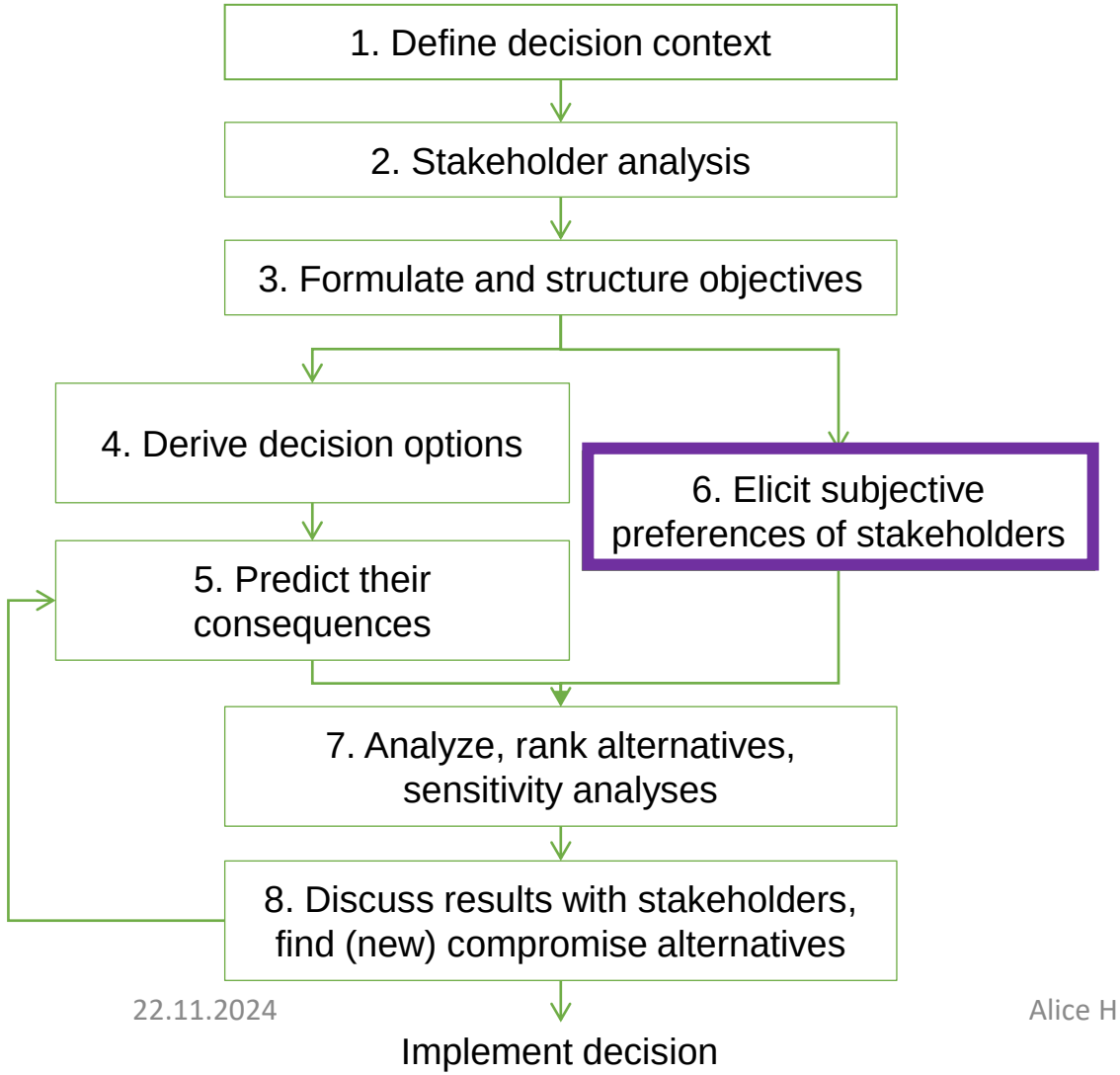




← Hierarchy of objectives

Figure 1 from Aubert, A. H., et al. (2024). EJOR https://doi.org/10.1016/j.ejor.2023.10.031
Marttunen et al. (2019) *Methods to inform the development of concise objectives hierarchies in multi-criteria decision analysis* EJOR, https://doi.org/10.1016/j.ejor.2019.02.039

Interaction 2: Elicit preferences



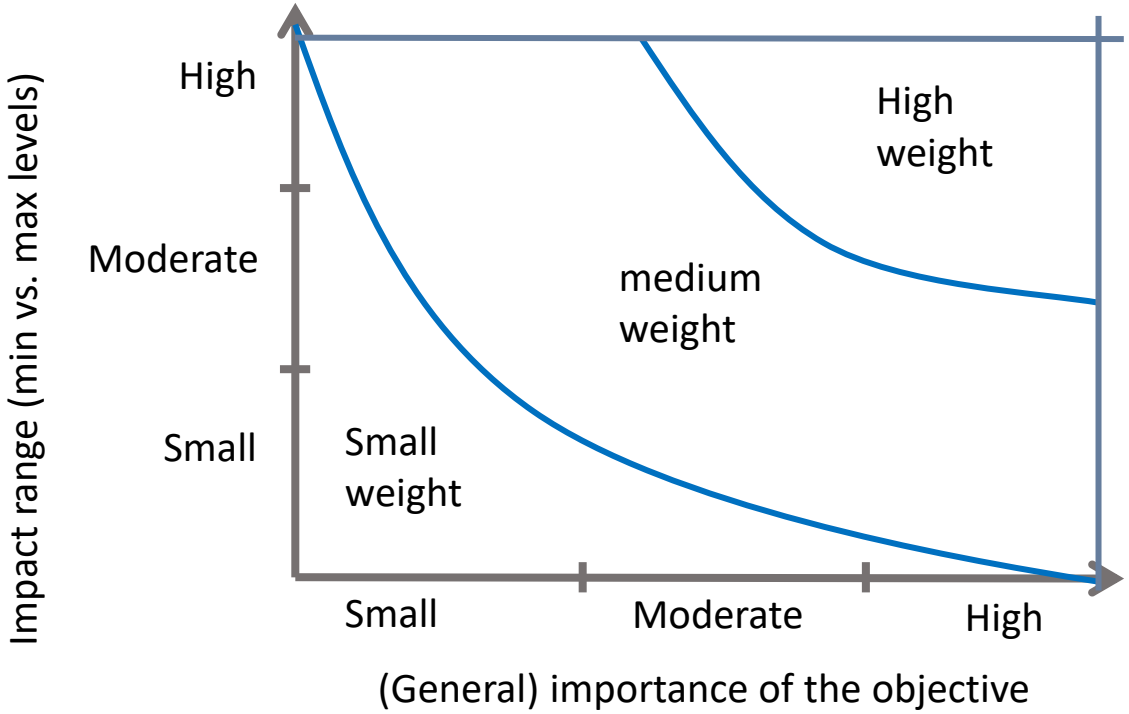
Simplified proposition:

- Focus on weights (how to handle trade-offs)
- Interview, group workshop or online survey
- Other preference parameters:
  - If need be, after sensitivity analysis

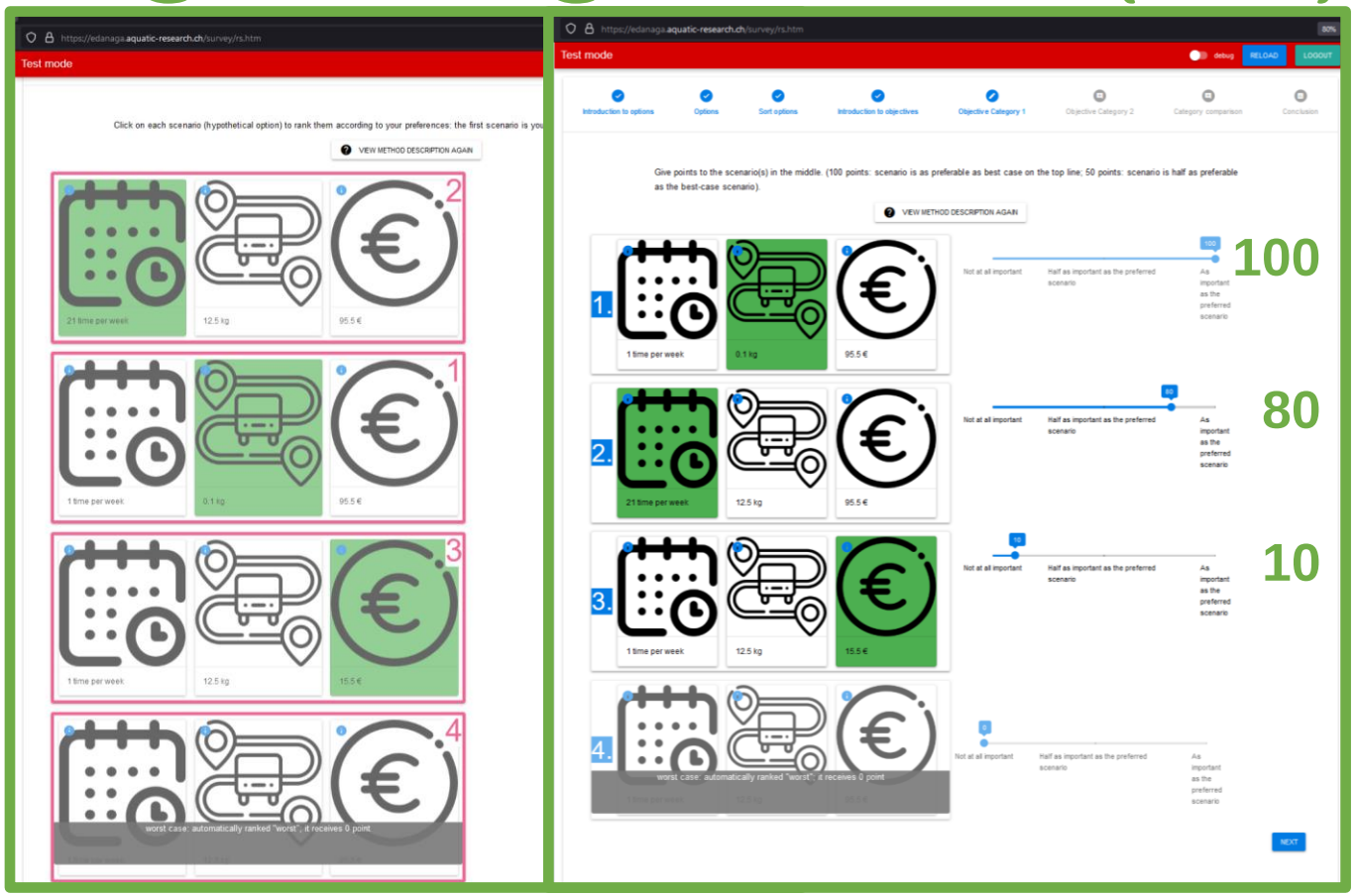
Weights in MAVT

- Scaling constants, relative importance of objectives
- Represent how stakeholder would prefer to address trade-offs
- Depend on
  - General importance
  - Impact range (!)
- Many methods, e.g.:
  - Swing
  - Pairwise trade-offs

(!) Required information:
Range best-worst levels for all objectives



Eliciting weights, e.g. Swing method (1/2)



1. Ranking of hypothetical alternatives
2. Scoring of rank-ordered hypothetical alternatives
3. Calculating weights

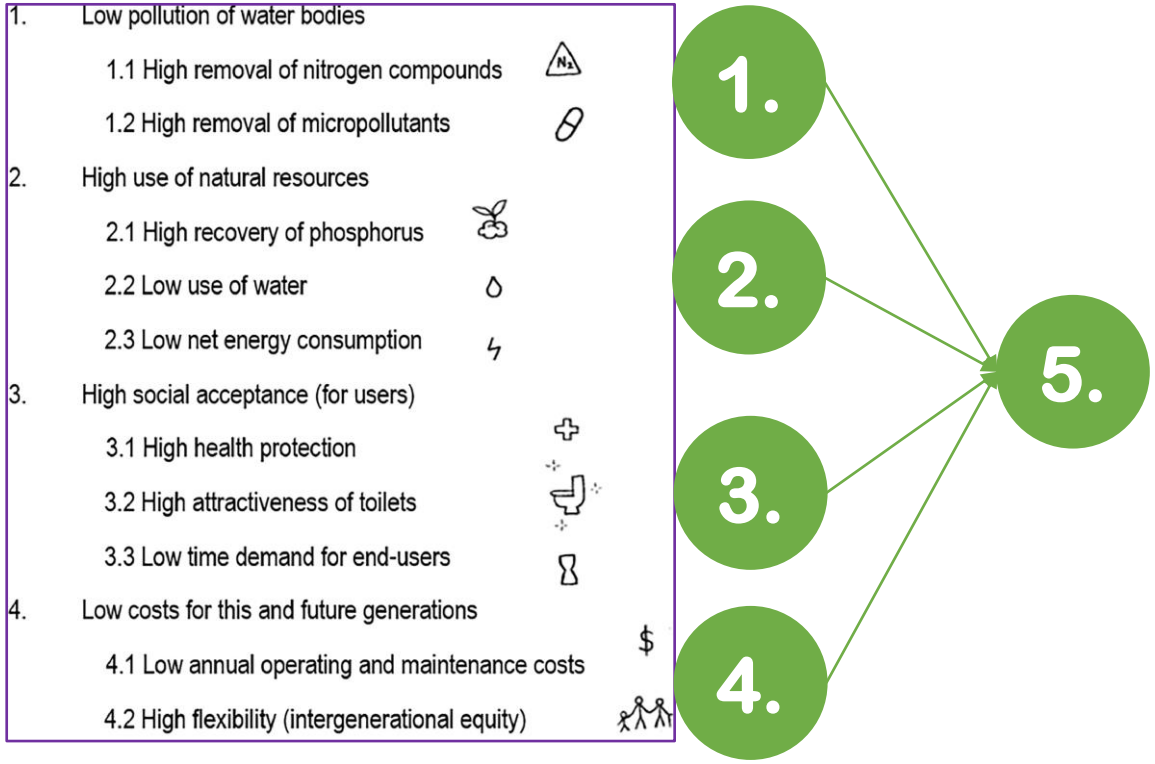
$$w_r = \frac{t_r}{\sum_{i=1}^{m} t_i}$$

$W_{Transp.}$ = 100 / [100 + 80 + 10] = 0.53
$W_{Nütz.}$ = 80 / [100 + 80 + 10] = 0.42
W_{Preis} = 10 / [100 + 80 + 10] = 0.05

ValuePreferences.ch, Aubert & Masson (2021) https://doi.org/10.25678/00056J

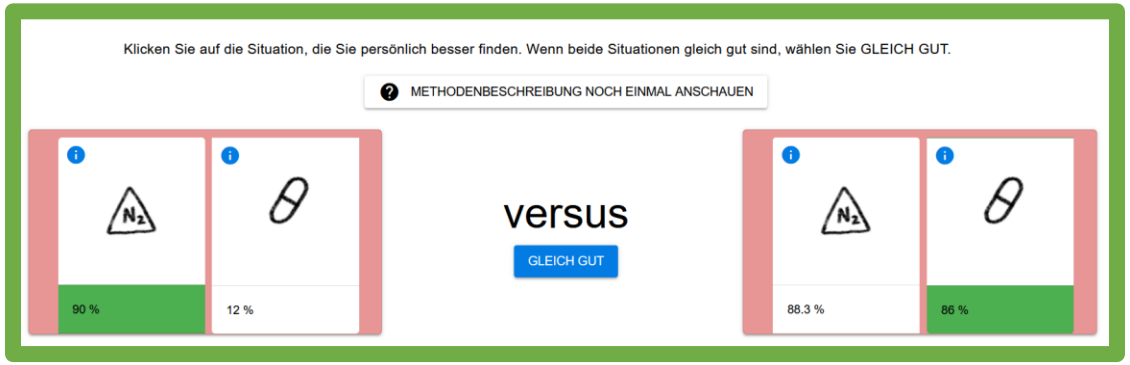
Eliciting weights, e.g. Swing method (2/2)

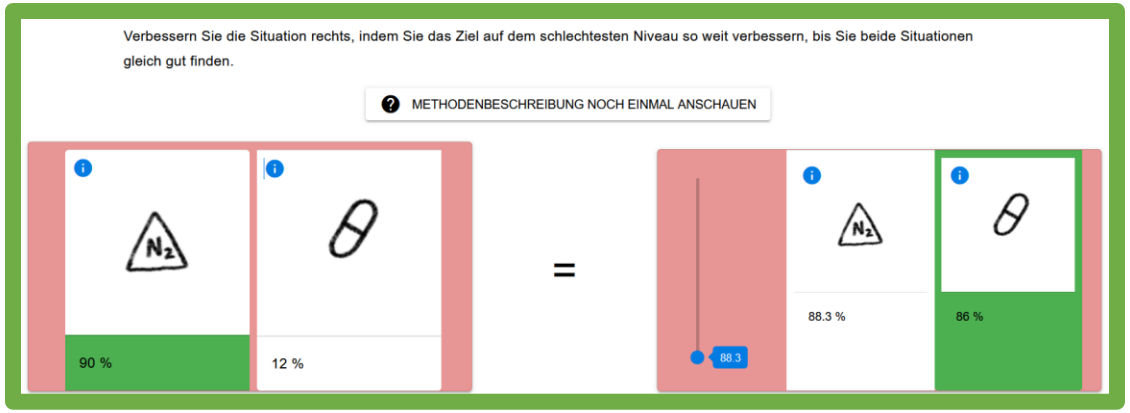
- Repeat within each branch
- Repeat between the most prefered objectives of each branch (bottom-up)
- Normalise in the lower level of the hierarchy of objectives



Riabacke, Danielson, Ekenberg (2012) State-of-the-art prescriptive criteria weight elicitation
Advances in Decision Sciences, 2012, 1-24, Article 276584, 10.1155/2012/276584

Eliciting weights, e.g. pairwise trade-offs





1. Comparing two hypothetical options that differ only in two objectives
2. Improving (stepwise) the least preferred to attain indifference
3. Repeat N-1 times ($\sum_{weights}=1$)
4. Resolve equation system

$$\begin{pmatrix} A_1 & A_2 & 0 & 0 & \cdots & 0 \\ 0 & B_2 & B_3 & 0 & \cdots & 0 \\ 0 & 0 & C_3 & C_4 & \cdots & 0 \\ \vdots & \vdots & \vdots & \cdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & Z_{N_{objectives}-1} & Z_{N_{objectives}} \\ 1 & 1 & 1 & \cdots & 1 & 1 \end{pmatrix} \times \begin{pmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \vdots \\ \omega_{N_{objectives}-1} \\ \omega_{N_{objectives}} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ \vdots \\ 0 \\ 1 \end{pmatrix}$$

ValuePreferences.ch, Aubert & Masson (2021)
https://doi.org/10.25678/00056J

Eliciting weights, in any case

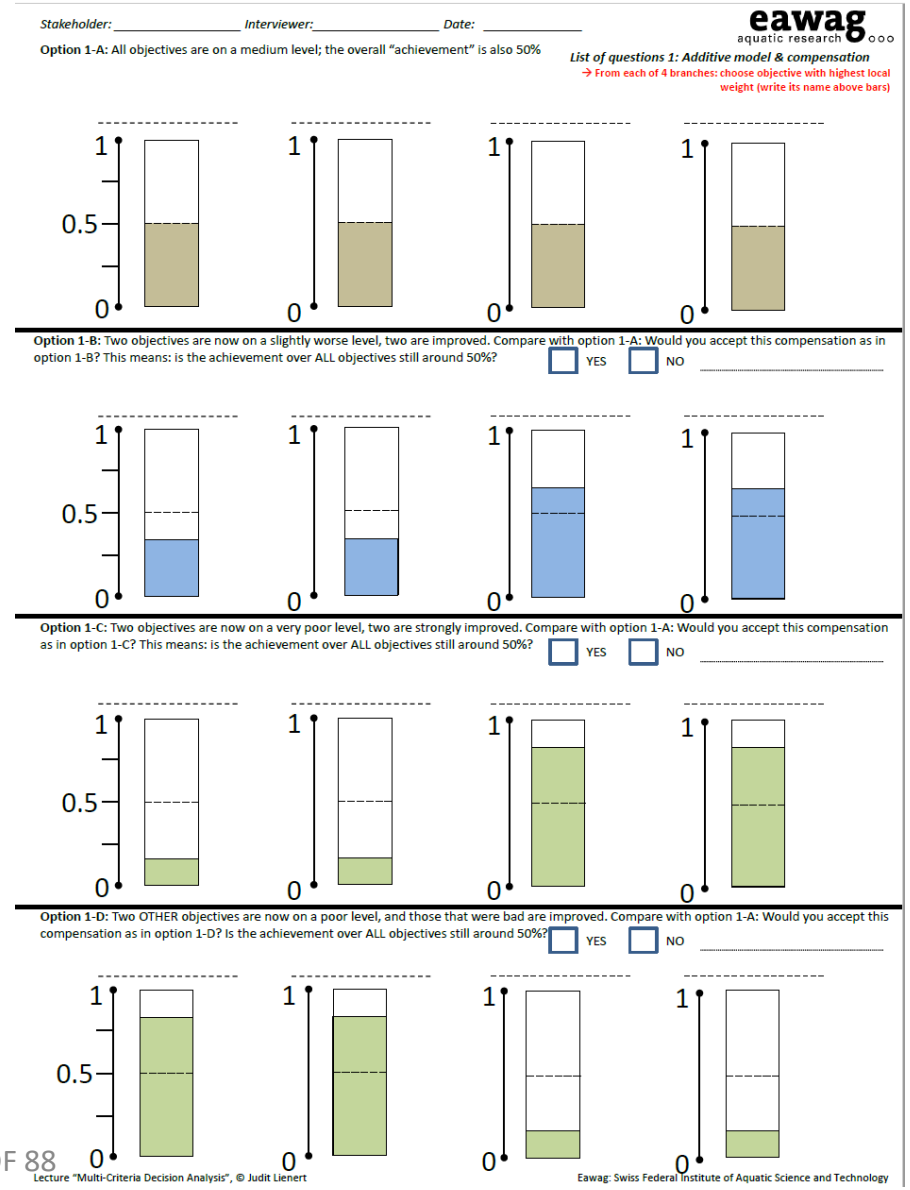
- Consistency check questions!
- Heuristics can bias the answers

Checking assumptions for additive aggregation model

Assumptions:

- Simple preferential independence
- Mutual preferential independence
- Difference independence

Additive aggregation model
→ allows for compensation between objectives



Beutler, …, Lienert (2024) A participatory MCDA framework reveals transition potential towards non-grid wastewater management, J. Env. Man., 367, Article 121962

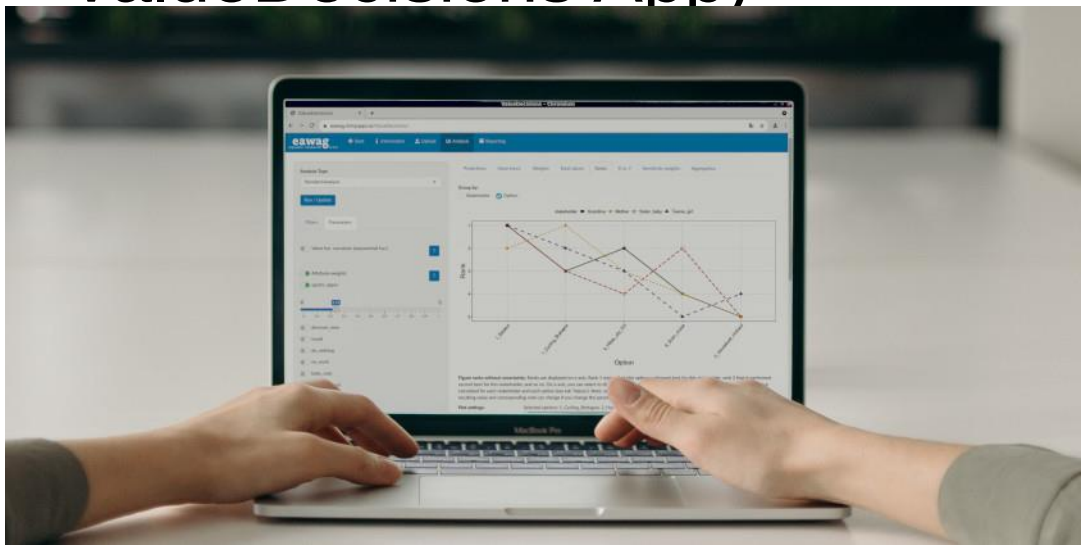
Checking assumptions for additive aggregation model

Assumptions:

- Simple preferential independence
- Mutual preferential independence
- Difference independence

Additive aggregation model → allows for compensation between objectives

- Interviews
- Sensitivity analysis (e.g. with ValueDecisions App)



Haag, Aubert, Lienert (2022) ValueDecisions, a web app to support decisions with conflicting objectives, multiple stakeholders, and uncertainty, Environ. Model. Softw., 150, Article 105361

If needed, elicit single attribute value functions

- Default assumption: linear
- If elicitation: focus on most important objectives, use Bisection Method in interview
- Transform levels of attributes (with unit) into 0-1 (unitless) scale
- Can have any shape
- Allow aggregation of different dimensions!

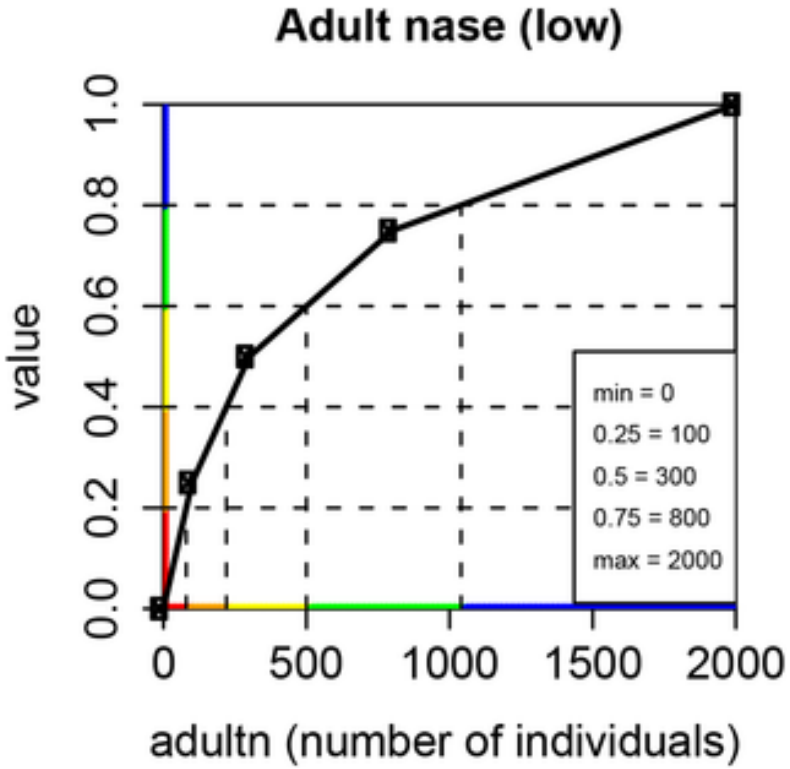
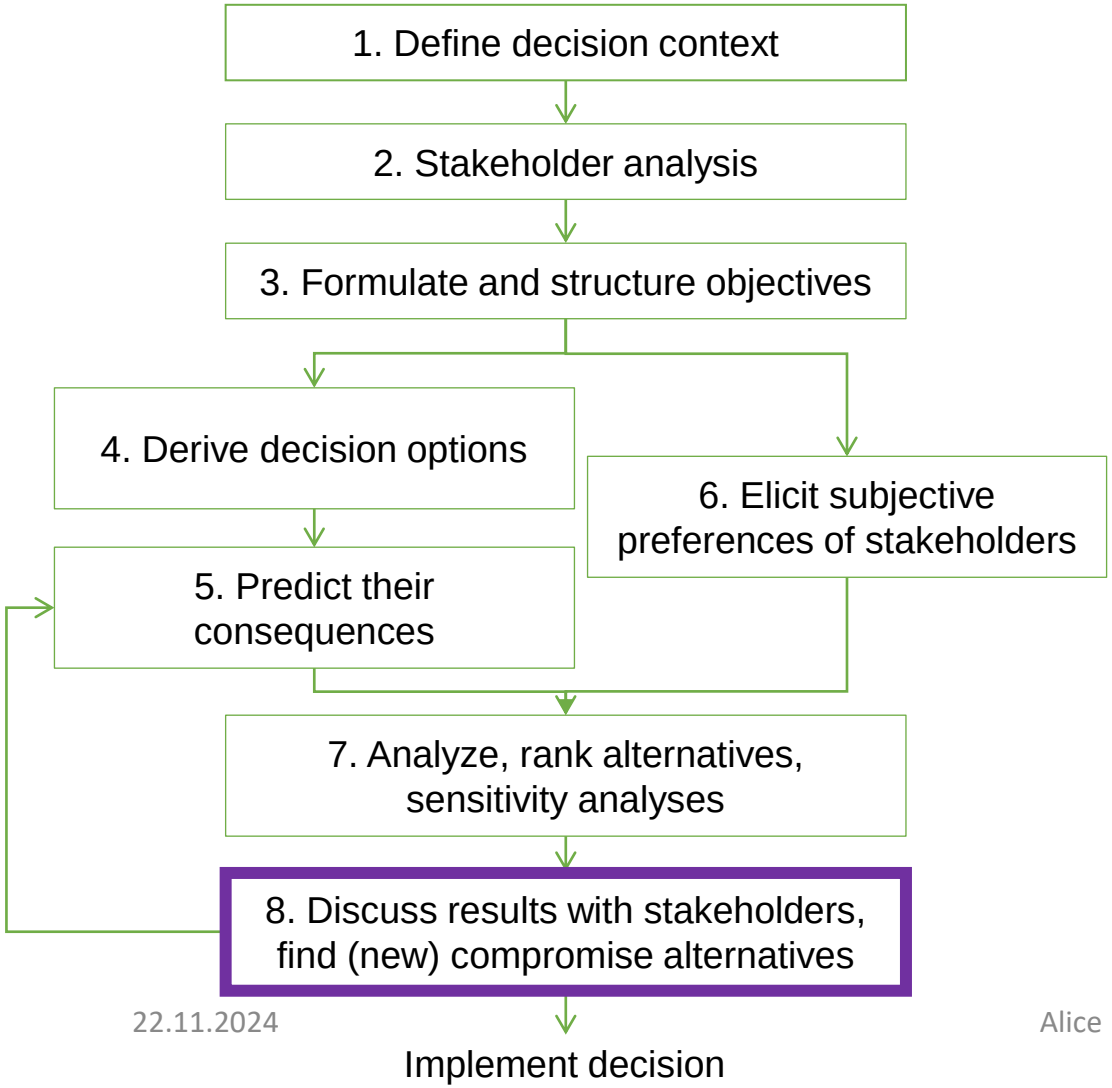


Figure 5 from Langhans & Lienert (2016) Four Common Simplifications of MCDA do not hold for River Rehabilitation, PlosOne, 11 (3), Article e0150695

Interaction 3: Discuss results



- Make conflicting preferences explicit
- Discuss
- Find new compromise alternatives
- If online survey with many participants, «explore» the collected weight data
- Visualisation tools help (e.g., ValueDecisions App)

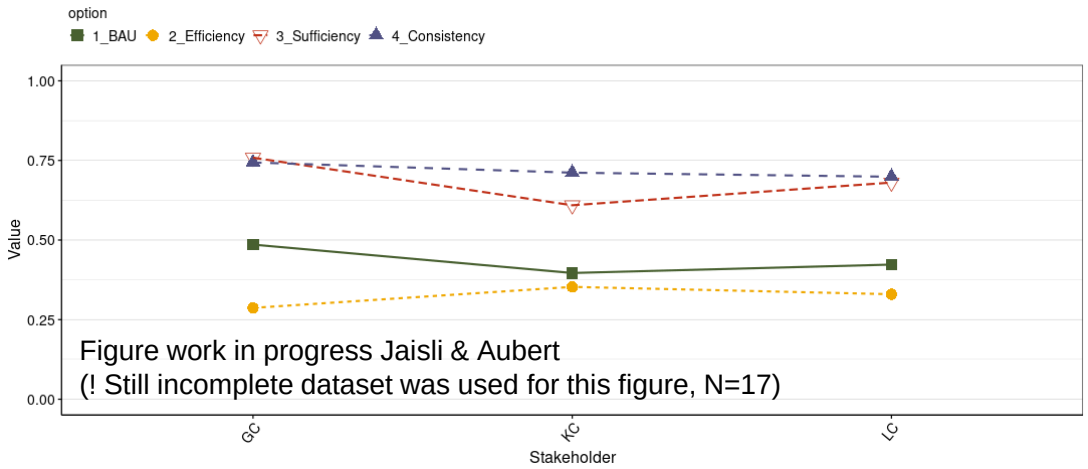


Figure work in progress Jaisli & Aubert
(! Still incomplete dataset was used for this figure, N=17)

Haag, Aubert, Lienert (2022) ValueDecisions, a web app to support decisions …, Environ. Model. Softw., 150, 105361

MCDA (MAVT), aggregating over different dimensions

Prescriptive decision support

How can we deal with conflicting opinions / interests?

- Make conflicting opinions explicit
- Collect (individual) preferences

How can we deal with these unavoidable trade-offs?

- Transform attributes using value functions
- Context specific (range of attributes)

Participatory weighting and decision-making

Life Sciences and Facility Management

Institute of Natural Resource Sciences

Prescriptive decision support:

- Make conflicting opinions explicit
- Requires (individual) preferences
- Context specific (range of attributes)
- Transformation using value functions

Questions?
Ideas for collaborations?
→ Alice Aubert aube@zhaw.ch

Many thanks to:

- Judit Lienert, Dr. PD (Eawag, CH)
- Mika Marttunen, Dr. (Syke, FI)
- Val Belton, Prof. Dr. (Uni. Strathclyde, UK)
- Fridolin Haag, Dr. (EWE TRADING GmbH, DE)
- Among other persons!