Are objectives hierarchy related biases observed in practice?

A meta-analysis of environmental and energy applications of Multi-Criteria Decision Analysis

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Research on behavioural and procedural biases in MCDA

- Imbalance between the importance of the objectives hierarchy and the amount of research.
- Most studies carried out 15-30 years ago with students in hypothetical decision situations.
- Are findings of prior studies replicated in real-world applications?

Possible biases and factors affecting weights

- The splitting bias
- Range insensitivity bias
- Equalising bias

- Weighting method (e.g. swing, trade-off, AHP)
- Weighting technique (hierarchical or non-hierarchical)
- Location of the objective
- Number of objectives/sub-objectives
- Type of objective/attribute

Research questions

- RQ1: How do the size and structure of an objectives hierarchy affect the weights of objectives?
- RQ2: How are weights distributed across economic and environmental objectives?
- RQ3: Is there support for the equalising bias?

Meta-analysis & material

- Widely used in social and medical science, ecology and economics
- Efficient method to combine and analyse large amount of information

- Not used in MCDA to analyse weight distributions of objectives

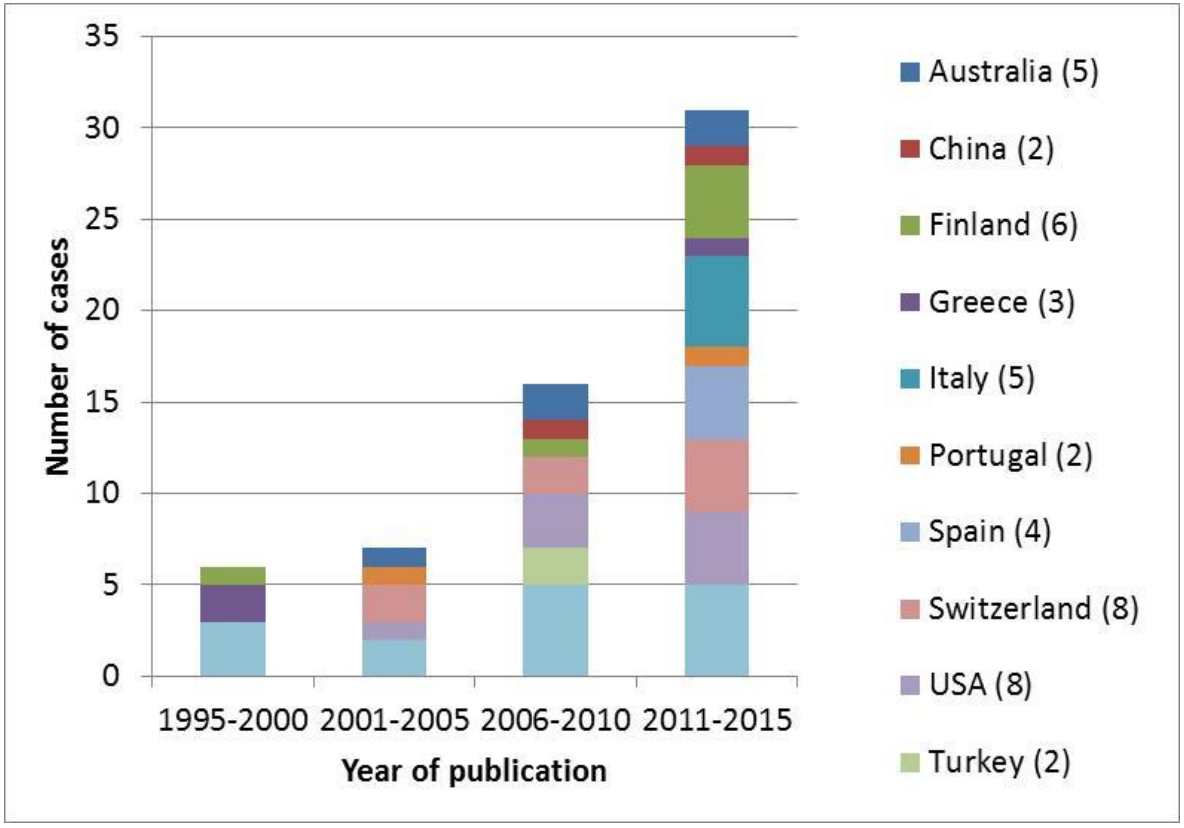
  => Methodological objective: examine benefits and limitations

- 61 environmental and energy MCDA cases
- 230 weight schemes
  - Weights assigned by a stakeholder or an average over stakeholders

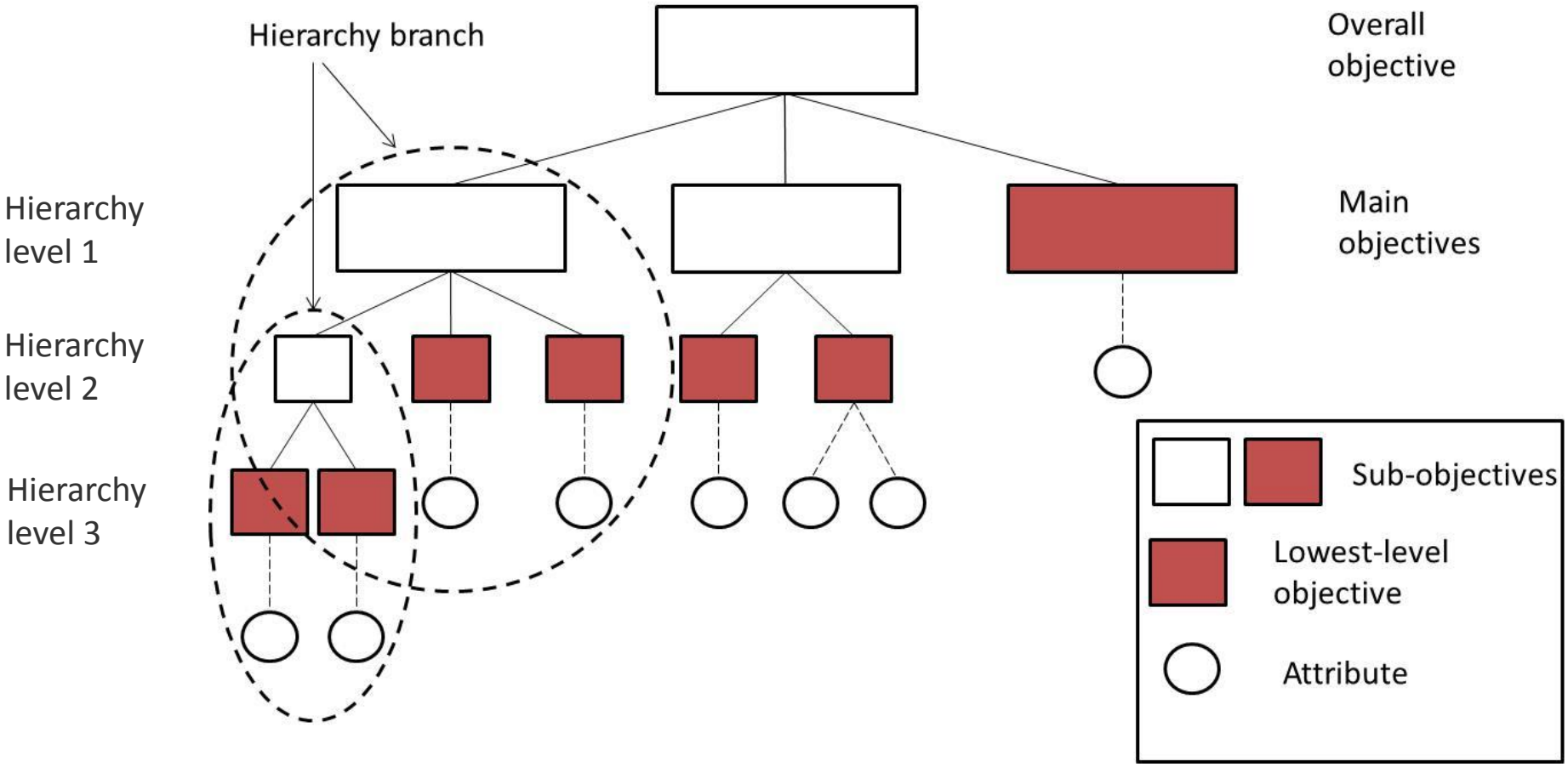
Large variety in the cases

- 25 countries
  - Switzerland, USA and Finland
- Application areas
  - Water resources (22 cases)
  - Energy planning (15)
  - Forestry (4)
- Methods to gather preferences
  - Interviews (26)
  - Questionnaires (17)
  - Workshops (16)
- MCDA methods
  - MAVT (24)
  - AHP (20)
  - PROMETHEE (6)

- Who gave weights?
  - Stakeholders (33)
  - Experts (17)
  - Policy makers or decision makers (3)



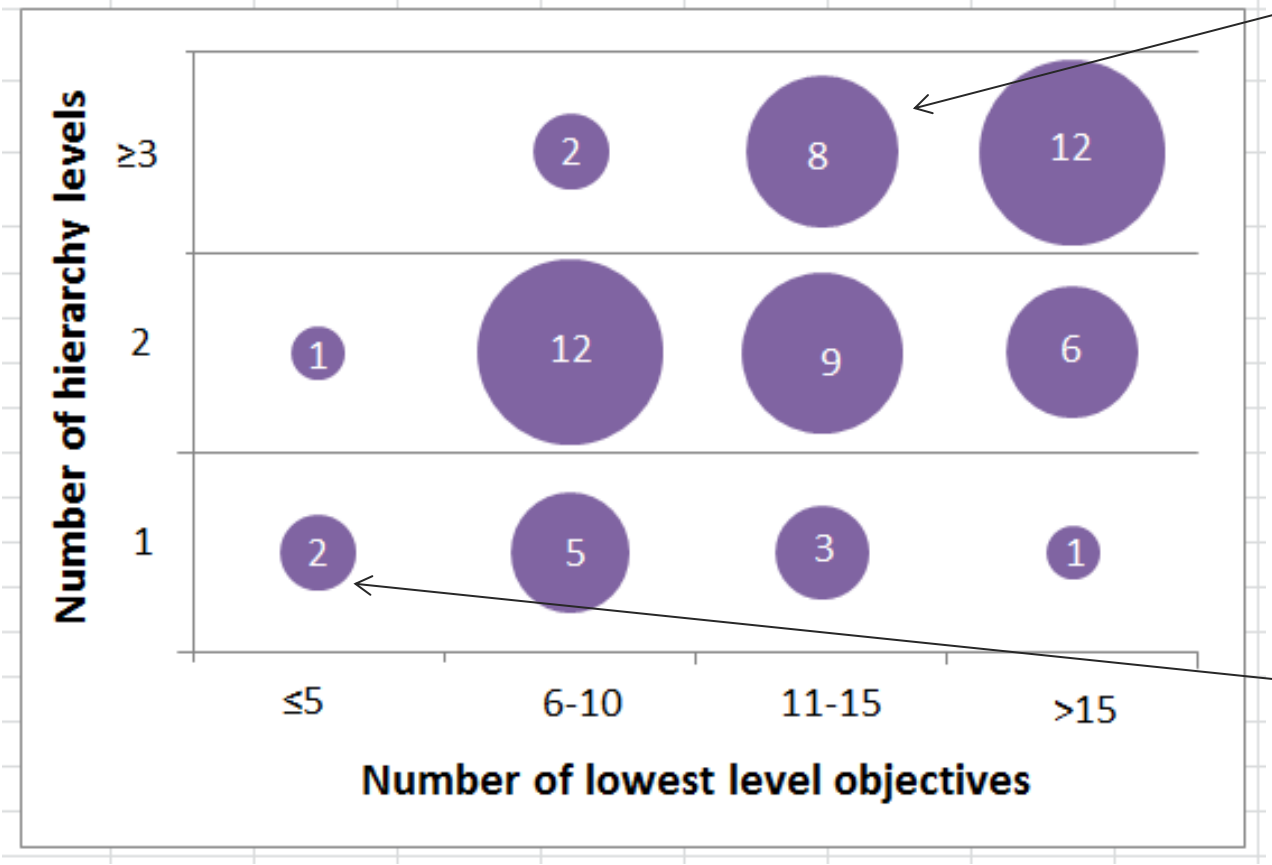
Hierarchy terminology

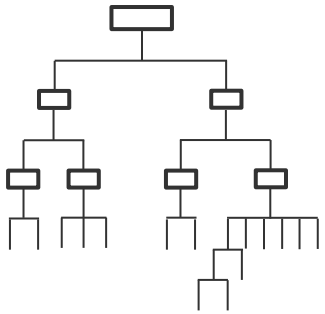


Global weight: the local weight of the objective is multiplied with the local weights of its parental objectives.

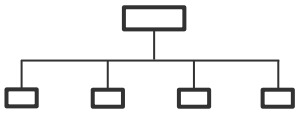
Great diversity in the objectives hierarchies

- Number of lowest-level objectives (LLOs)
  - Minimum 3, maximum 51
- Number of hierarchy levels
  - Minimum 1, maximum 5





Very deep and broad
(Georgopoulou et al., 1997)
- 5 levels, 15 LLOs



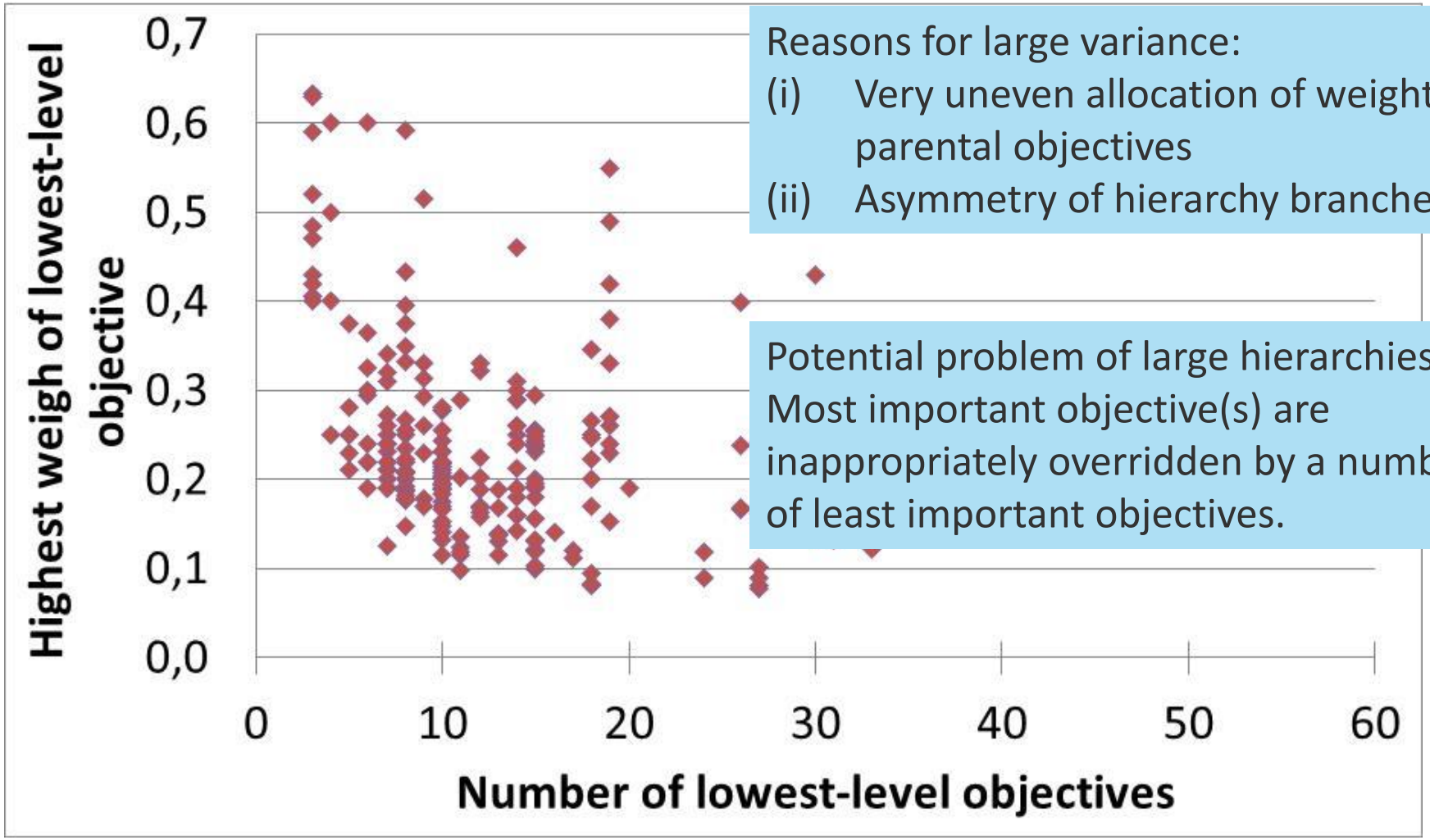
Flat and narrow
(Linkov et al., 2006)
- 1 level, 4 LLOs

RQ1: How does the size and structure of an objectives hierarchy affect the weights of objectives?

Three analyses:

1. Highest weights of the lowest-level objectives
2. Percentage of objectives getting very low weight
3. Effect of the asymmetry of the hierarchy

RQ1 (1/3): The number of lowest-level objectives vs. their highest global weights



Reasons for large variance:

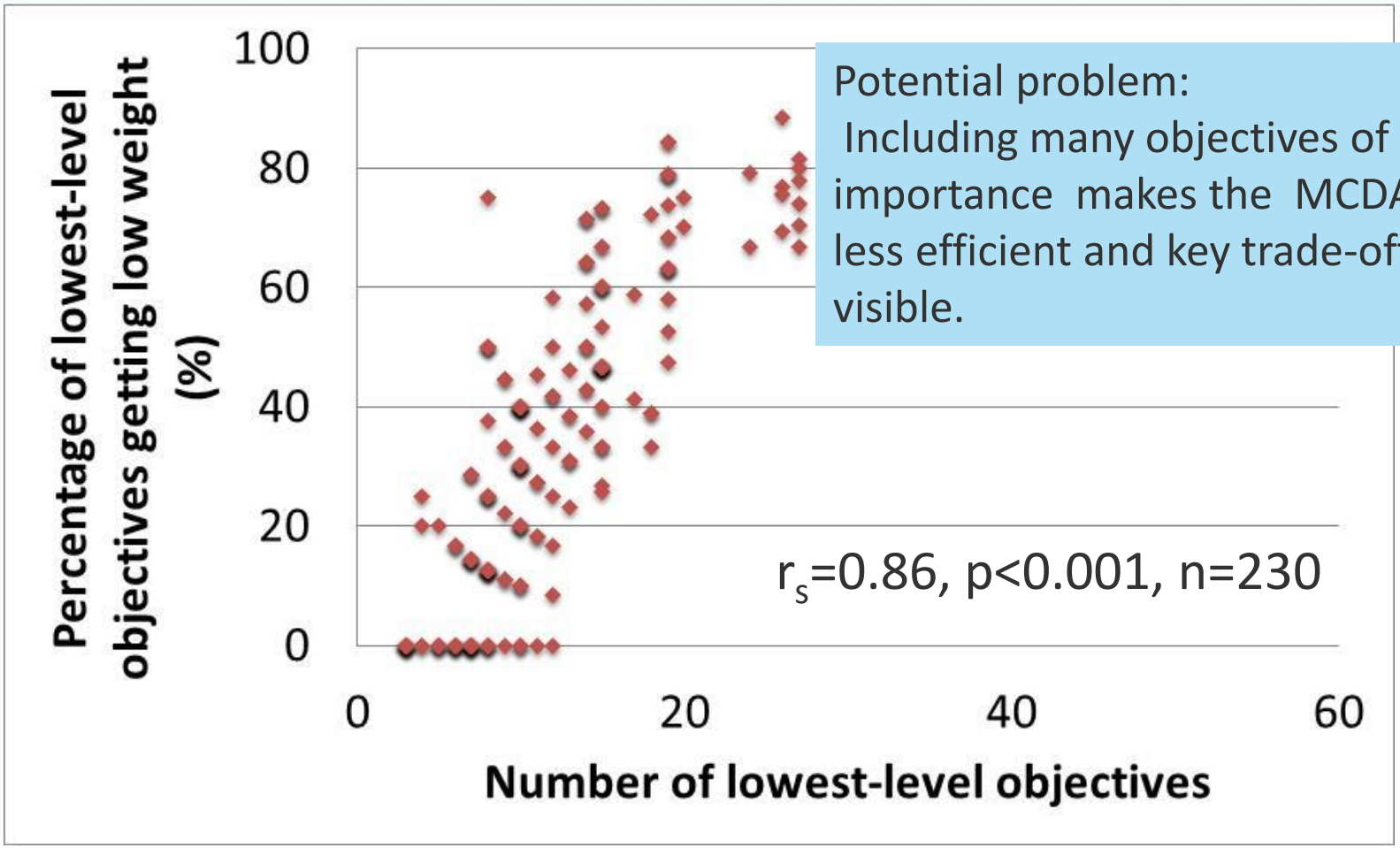
(i) Very uneven allocation of weights to parental objectives

(ii) Asymmetry of hierarchy branches

Potential problem of large hierarchies: Most important objective(s) are inappropriately overridden by a number of least important objectives.

r_s=-0.512, $p<0.001$, n=230

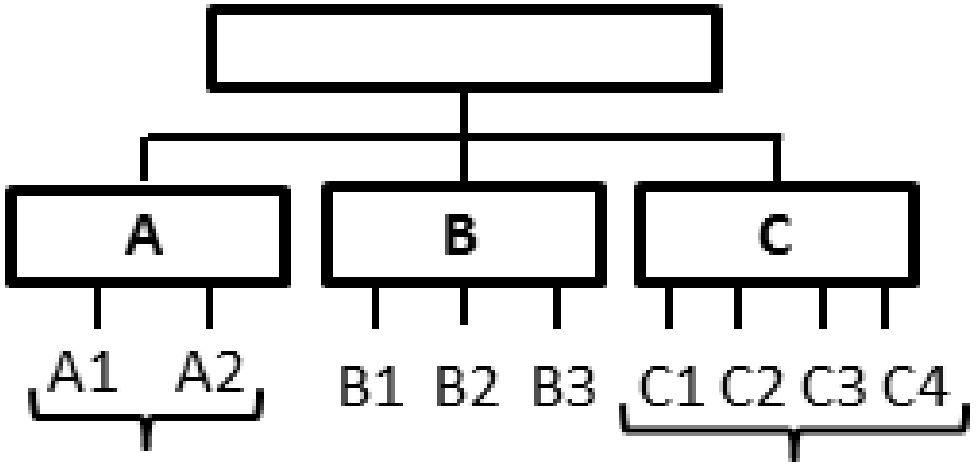
RQ1 (2/3): Percentage of the lowest level objectives getting very low global weight (≤ 0.05)



Potential problem:
Including many objectives of minor importance makes the MCDA process less efficient and key trade-offs less visible.

- > 15 lowest-level objectives 71% (n=51 weight schemes)

RQ1 (3/3): Effect of the asymmetry of the hierarchy: comparison of mean weights in the smallest and largest hierarchy branch

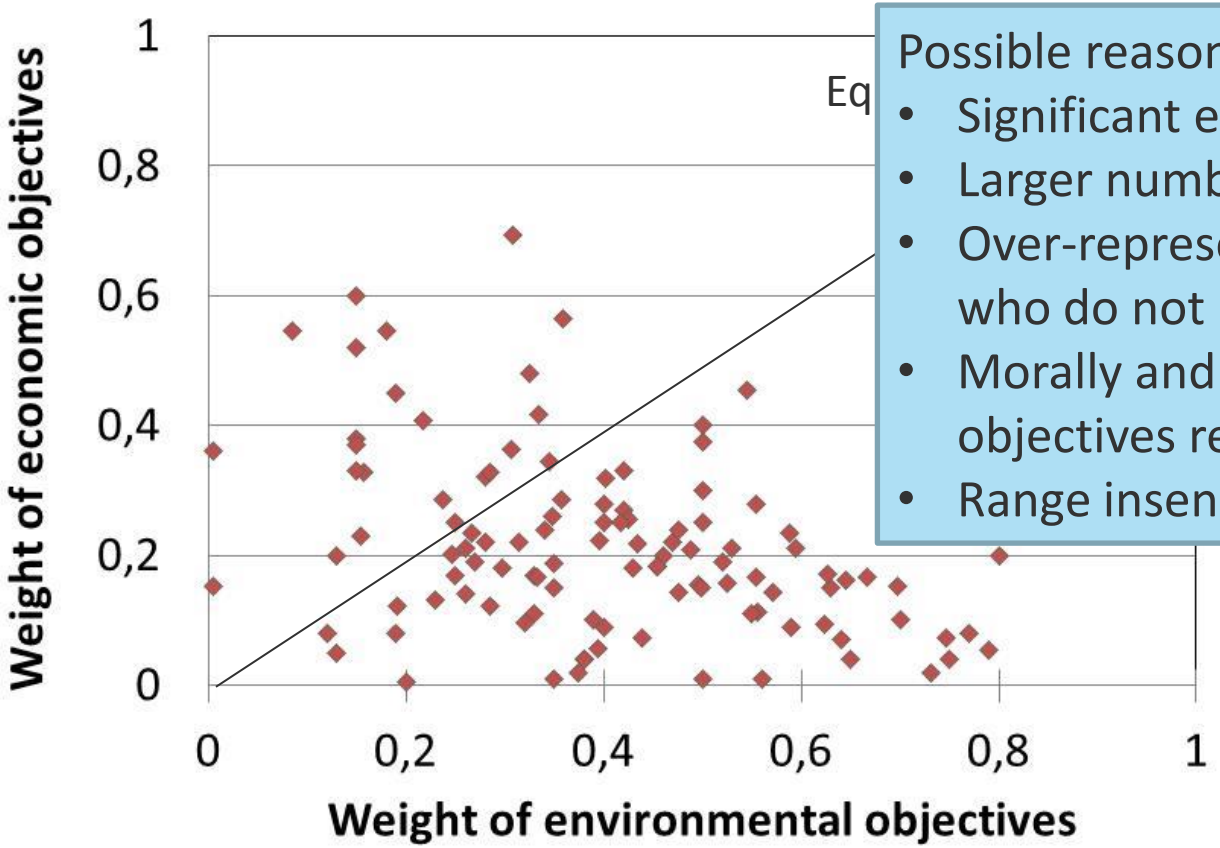


- The mean weight was higher in the smallest branch than in the largest branch, 71% weight schemes (n=103)

- In 85% of the weight schemes, the lowest-level objective receiving the highest global weight was in the smallest branch (n=65).

RQ2: How are weights distributed across economic and environmental objectives?

- In 77% of the incidents environmental objective had higher weight
- Environmental objectives: mean 0.38 (n=124)
- Economic objectives: mean 0.22

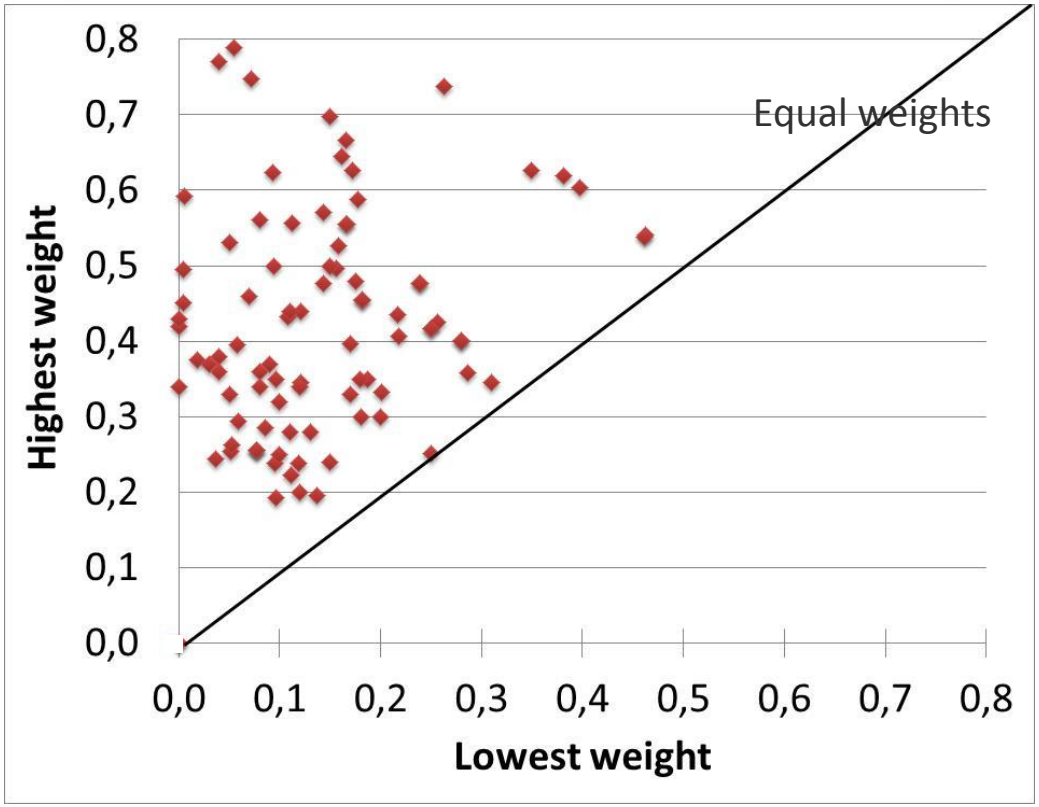


Possible reasons:

- Significant environmental impacts
- Larger number of envir. objectives
- Over-representation of stakeholders who do not have to carry the costs
- Morally and ethically important objectives receive more weight
- Range insensitivity bias

RQ3: Is there support for the equalising bias?
(e.g. Montibeller and von Winterfeldt 2015)

- The comparison of the highest and lowest weights of the main objectives
  - «Average weight cases» were excluded
  - The mean of the highest weights 0.43 (n=96)
  - The mean of the lowest weights 0.15



r_s=0.20, p<0.056, n=96

Conclusions

- Earlier findings supported
  - Hierarchy affects weights in many ways
- Asymmetry bias – a new bias in the MCDA field?
- Equalising bias not supported.

- No means to determine whether the given weights reflect participant's opinions.

- Recommendations regarding objectives hierarchy and weight elicitation.

- Meta-analysis
  - "Bird's-eye view"
  - Testing and formulating conjectures.
  - Heteregoneous cases.
  - MCDA applications provide good opportunities for further analyses.
  - Better documentation of weight elicitation procedures.

THANK YOU!

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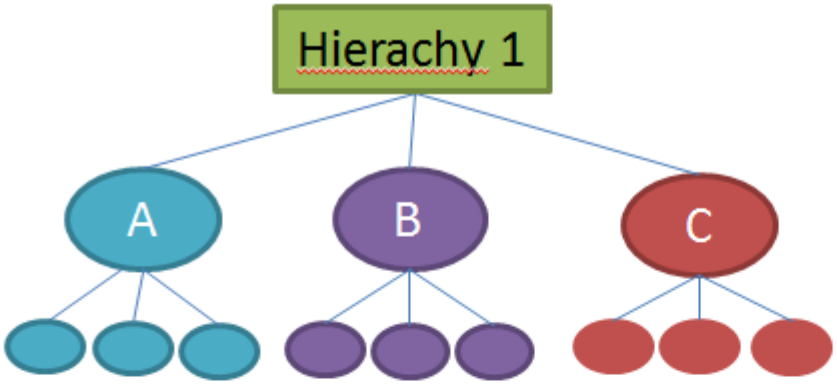
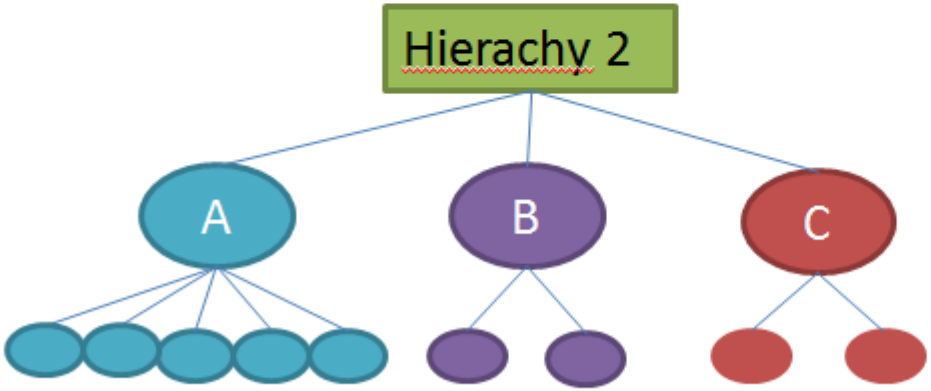
EXTRA SLIDES

Hypotheses





Lowest weight lower than in hierarchy 1

Highest weight higher than in hierarchy 1

Data collected from the selected articles

Type of information	Characteristics
General	Authors; Year; Country of application; Country of first author; Application area
Structure of the objectives hierarchy	Number of main objectives; Number of hierarchy levels; Number of hierarchy branches at the top level of the hierarchy; Number of lowest-level objectives
Number of objectives	Economic, Technical, Socio-economic, Social, Environmental, Risks, Other objectives
Costs in the hierarchy	Main objective (either divided or not divided into sub-objectives); Sub-objectives of the economic objective; Not included in the analysis
Weight elicitation method	Bottom-up; Top-down; Hierarchical weighting; Non-hierarchical weighting; Unclear
Source of preferences	Decision makers; Policy makers; Experts; Students; Hypothetical, Authors, Unclear
Method to collect prefences	Questionnaire or Survey; Workshop; Interviews, Literature, Unclear
Presentation of objectives' weights	Individually; Group mean; Mean across all participants; Number of weight profiles

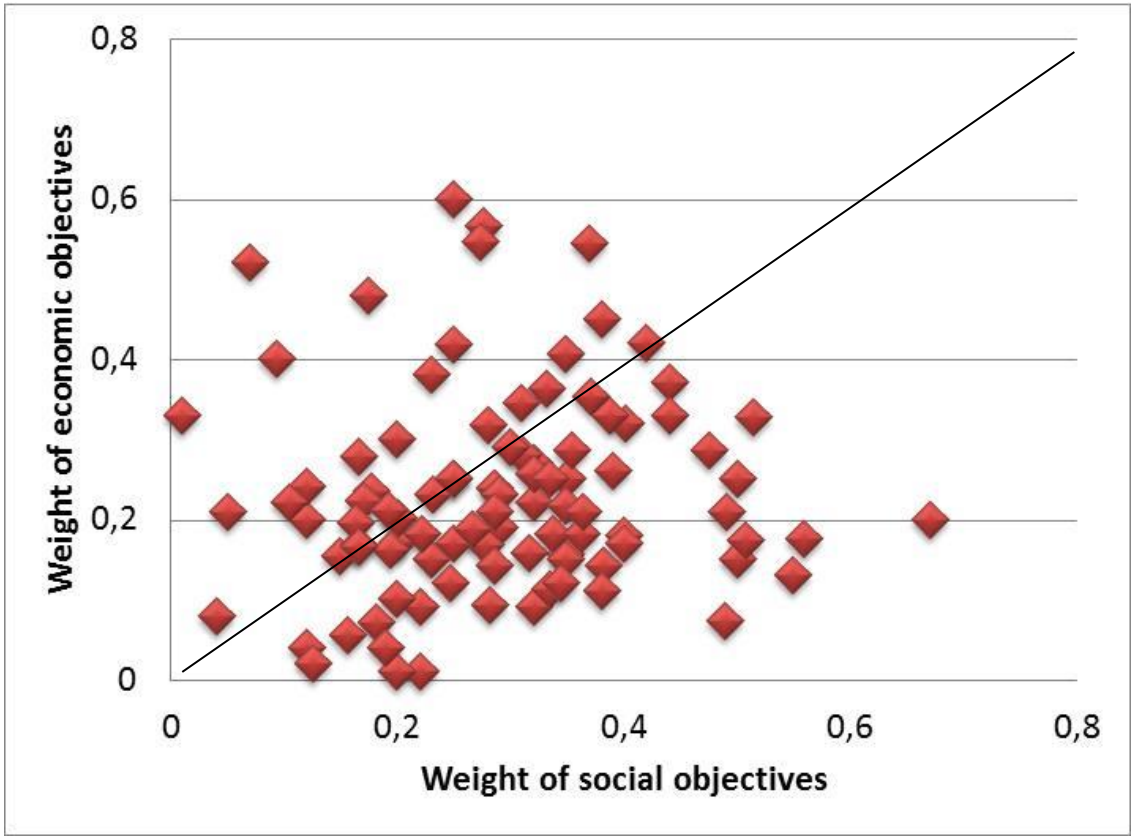
Characteristics of the objectives hierarchies (n=61)

	Mean	Standard deviation	Minimum	Maximum
Number of top level objectives	4.7	3.1	2	18
Number of lowest-level objectives	14.6	8.2	3	51
Total number of objectives	19.3	11.4	4	73
Number of hierarchy levels	2.3	0.9	1	5
Number of lowest-level economic objectives (n=51)	3.1	2.4	0	10
Number of lowest-level social objectives (n=39)	3.8	2.8	0	17
Number of lowest-level environmental objectives (n=56)	5.7	7.3	1	51

RQ2: How are weights distributed across economic, social and environmental objectives?

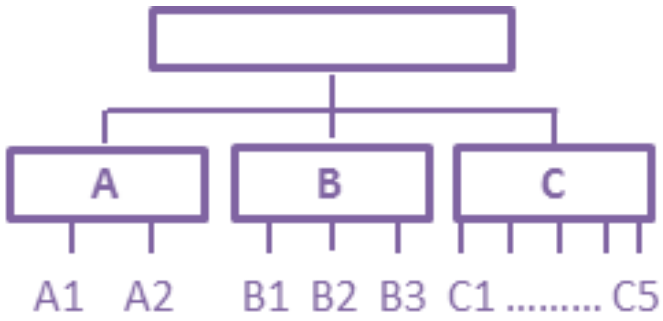
Analysis 2b: Comparison of weights of social and economic objectives (n=124)

The difference in the mean weights was statistically significant (Related-Samples Sign Test, Z=28, p<0.001, n=96).



”The asymmetry bias”

- Occurs in cases where a hierarchy consists of branches that have a different number of sub-objectives.
- Similarities with the splitting bias but is opposite and occurs only in the hierarchical weighting procedure.
- The phenomenon has received little attention in the MCDA literature.
- Assigning weights taking into account both the number of sub-objectives and their ranges is very demanding.



Example: Assume that all sub-objectives are globally of equal importance. They should thus each receive a global weight of 1/10 (0.1).

To give the intended global weights to the sub-objectives, the objective C should receive a 2.5 times higher weight than the objective A.