On Multi-Criteria Decision Analysis in Water Infrastructure:

Experiences of Stakeholder Participation in TWIST++ project

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TWIST++ project in a nutshell

- Development of new and sustainable urban water infrastructure concepts with relevant technical components
- Development of a
  - Planning support system,
  - Data system and
  - A serious game
Model areas

Lünen: (85,000 inhabitants) Shrinking city close to the Ruhr-district

Wohlsborn-Rohrbach: Villages in the north of Weimar

Gelsenkirchen/Herten: Former brownfield in the middle of an urban area
What has to be analyzed?

- MCDA tool was developed for
  - Assessment and comparison of urban water systems (UWS) in the planning stage
  - Application in 3 different spatial settings
  - Supporting decision makers in identifying appropriate UWS
  - Evaluating the actions of the serious game

- Mono-criterial or bi-criterial methods inappropriate
Why stakeholder participation?

Reliability

Non-Redundancy

Independency

Non-Competing

Completeness

Measurability

Minimum size

Value relevance

Operability in various settings
Why stakeholder participation?

Further envisaged benefits:

- Incorporating knowledge, preferences and values of various stakeholders
- Learning amongst stakeholders in the development and assessment process
- Increasing transparency
- Basis for future communication, dialogue and negotiation
## Approach in TWIST++

### Detailed MCDA process

<table>
<thead>
<tr>
<th>Step</th>
<th>Activity</th>
<th>Methods</th>
<th>Stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Determining the assessment goal</td>
<td>• Brainstorming</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Determining the system boundaries and time horizon</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Identification of set of objectives with</td>
<td>• Literature research</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Panel of experts</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mindmapping</td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>Collection of objectives and criteria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>Structuring and objectives’ relations analysis</td>
<td>• Literature research</td>
<td>x</td>
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<td></td>
<td></td>
<td>• Panel of experts</td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>Classification of objectives</td>
<td>• ABC analysis (Questionnaire and workshops)</td>
<td>x</td>
</tr>
<tr>
<td>4</td>
<td>Data collection</td>
<td>• Interviews</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Aggregation of performance of each option across all criteria</td>
<td>• Literature research</td>
<td></td>
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<td></td>
<td></td>
<td>• Field Research</td>
<td>x</td>
</tr>
<tr>
<td>6</td>
<td>Weighting of objectives</td>
<td>• AHP (Questionnaire and workshop)</td>
<td>x</td>
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<tr>
<td>7</td>
<td>Sensitivity analysis</td>
<td></td>
<td></td>
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<tr>
<td>8</td>
<td>Consolidation and discussion of results</td>
<td>• Stakeholder workshops</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Panel of experts</td>
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Step 1 – Determining the assessment goal

- DWA-A 272 as foundation for further assessment
- During first experts’ meeting one main goal and six sub-objectives were identified with brainstorming technique

<table>
<thead>
<tr>
<th>Performance of water infrastructure system</th>
<th>Main goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-objectives 1st order</td>
<td></td>
</tr>
<tr>
<td>Ecological objectives</td>
<td>Security-related objectives</td>
</tr>
<tr>
<td>Economic objectives</td>
<td>Social objectives</td>
</tr>
<tr>
<td>Technical objectives</td>
<td>Spatial objectives</td>
</tr>
</tbody>
</table>

- Main goal: Performance of water infrastructure system
- Sub-objectives 1st order: Ecological objectives, Security-related objectives, Economic objectives, Social objectives, Technical objectives, Spatial objectives
Step 3a – Collection of sub-objectives and criteria

- Identification of sub-objectives based on literature research and feedback of experts‘ panel and project team
- Replenishment of set of objectives (SOO) with subsequent mindmapping
  - Revealed relations and dependencies of SOO elements
- Result:

<table>
<thead>
<tr>
<th>Main assessment goal</th>
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</thead>
<tbody>
<tr>
<td>6 sub-objectives (1st order)</td>
</tr>
<tr>
<td>75 criteria</td>
</tr>
<tr>
<td>190 indicators</td>
</tr>
</tbody>
</table>
Step 3b – Structuring SOO and relations analysis

- Examination of independency, indifference and congruency with pairwise comparison based on experts’ discussion
- Identification of comparable substructures of SOO to TWIST++ project based on literature research
- Main change: sub-objective „spatial planning“ was removed due to thematic overlaps and its criteria were assigned to other sub-objectives

Result

<table>
<thead>
<tr>
<th>Main assessment goal</th>
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<tbody>
<tr>
<td>5 sub-objectives (1\textsuperscript{st} order)</td>
</tr>
<tr>
<td>13 sub-objectives (2\textsuperscript{nd} order)</td>
</tr>
<tr>
<td>24 criteria</td>
</tr>
<tr>
<td>190 indicators</td>
</tr>
</tbody>
</table>
Step 3c – Classification of objectives

- ABC-analysis executed by each experts' panel member and the utility service partners of the three model areas, discussed in a panel meeting
  - Congruent evaluations with low relevancy (marked C) → criterion/indicator was eliminated from SOO
  - Divergent evaluations and/or medium relevancy (marked B) → discussion with panel, panel was voting on the inclusion of criterion/indicator

- Result:

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<tr>
<td>5 sub-objectives (1st order)</td>
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<tr>
<td>13 sub-objectives (2nd order)</td>
</tr>
<tr>
<td>21 criteria</td>
</tr>
<tr>
<td>33 indicators</td>
</tr>
</tbody>
</table>
**Result of step 3**

**Performance of water infrastructure system**

<table>
<thead>
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<th>Main goal</th>
<th>Sub-objectives 1st order</th>
<th>Sub-objectives 2nd order</th>
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<tr>
<td><strong>Ecological objectives</strong></td>
<td>[ ]</td>
<td>o Water pollution abatement</td>
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<tr>
<td></td>
<td>[ ]</td>
<td>o Soil protection</td>
</tr>
<tr>
<td></td>
<td>[ ]</td>
<td>o Climatic protection</td>
</tr>
<tr>
<td></td>
<td>[ ]</td>
<td>o Resource efficiency</td>
</tr>
<tr>
<td></td>
<td>[ ]</td>
<td>o Reduction of land consumption</td>
</tr>
<tr>
<td><strong>Security-related objectives</strong></td>
<td>[ ]</td>
<td>o Hygienic safety</td>
</tr>
<tr>
<td><strong>Economic objectives</strong></td>
<td>[ ]</td>
<td>o Economic efficiency</td>
</tr>
<tr>
<td></td>
<td>[ ]</td>
<td>o Systems flexibility</td>
</tr>
<tr>
<td><strong>Social objectives</strong></td>
<td>[ ]</td>
<td>o Acceptance</td>
</tr>
<tr>
<td></td>
<td>[ ]</td>
<td>o Avoidance of externalities</td>
</tr>
<tr>
<td><strong>Technical objectives</strong></td>
<td>[ ]</td>
<td>o Robustness</td>
</tr>
<tr>
<td></td>
<td>[ ]</td>
<td>o Extensibility</td>
</tr>
<tr>
<td></td>
<td>[ ]</td>
<td>o Integration into existing infrastructures</td>
</tr>
</tbody>
</table>
Step 6 – Weighting of objectives

- Application of AHP for obtaining weights for sub-objectives
- All stakeholder groups answered questionnaire
- Assessment of stakeholder group specific preferences

<table>
<thead>
<tr>
<th>Objective 1</th>
<th>Objective 2</th>
<th>Objective 3</th>
<th>Objective 4</th>
<th>Objective 5</th>
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</thead>
<tbody>
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</tr>
</tbody>
</table>

In comparison to…
Result of weighting

Performance of water infrastructure system

Main goal

Sub-objectives 1st order

Ecological objectives
- 21 %
  - Water pollution abatement
  - Soil protection
  - Climatic protection
  - Resource efficiency
  - Reduction of land consumption

Security-related objectives
- 23 %
  - Hygienic safety

Economic objectives
- 19 %
  - Economic efficiency
  - Systems flexibility

Social objectives
- 18 %
  - Acceptance
  - Avoidance of externalities

Technical objectives
- 19 %
  - Robustness
  - Extensibility
  - Integration into existing infrastructures

Sub-objectives 2nd order

- 23%
- 13%
- 11%
- 13%
- 8%
- 3%
- 6%
- 7%
- 3%
- 5%
- 4%
- 1%
## Observations and feedback

| ...on participation methods | - Different SOO might have evolved by other methods  
|                            | - Identification of set of objectives time and resource consuming process (12 physical meetings in 20 months)  
|                            | - Weighting method (AHP) easily replicable for other settings  
|                            | - Feedback process should be structured  
|                            | - Higher participation of IG should be ensured  

| ...on developed MCDA tool | - Great acceptance amongst stakeholders  
|                          | - Proved applicability in different spatial settings and for different technical options  
|                          | - Very good base for performance assessment in other projects in the planning stage |
Thank you!

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