The European Technology Assessment Conference:
"Technology Assessment and Policy Areas of Great Transitions"
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Tools for Technology Assessment (Multiple Criteria Decision Analysis)

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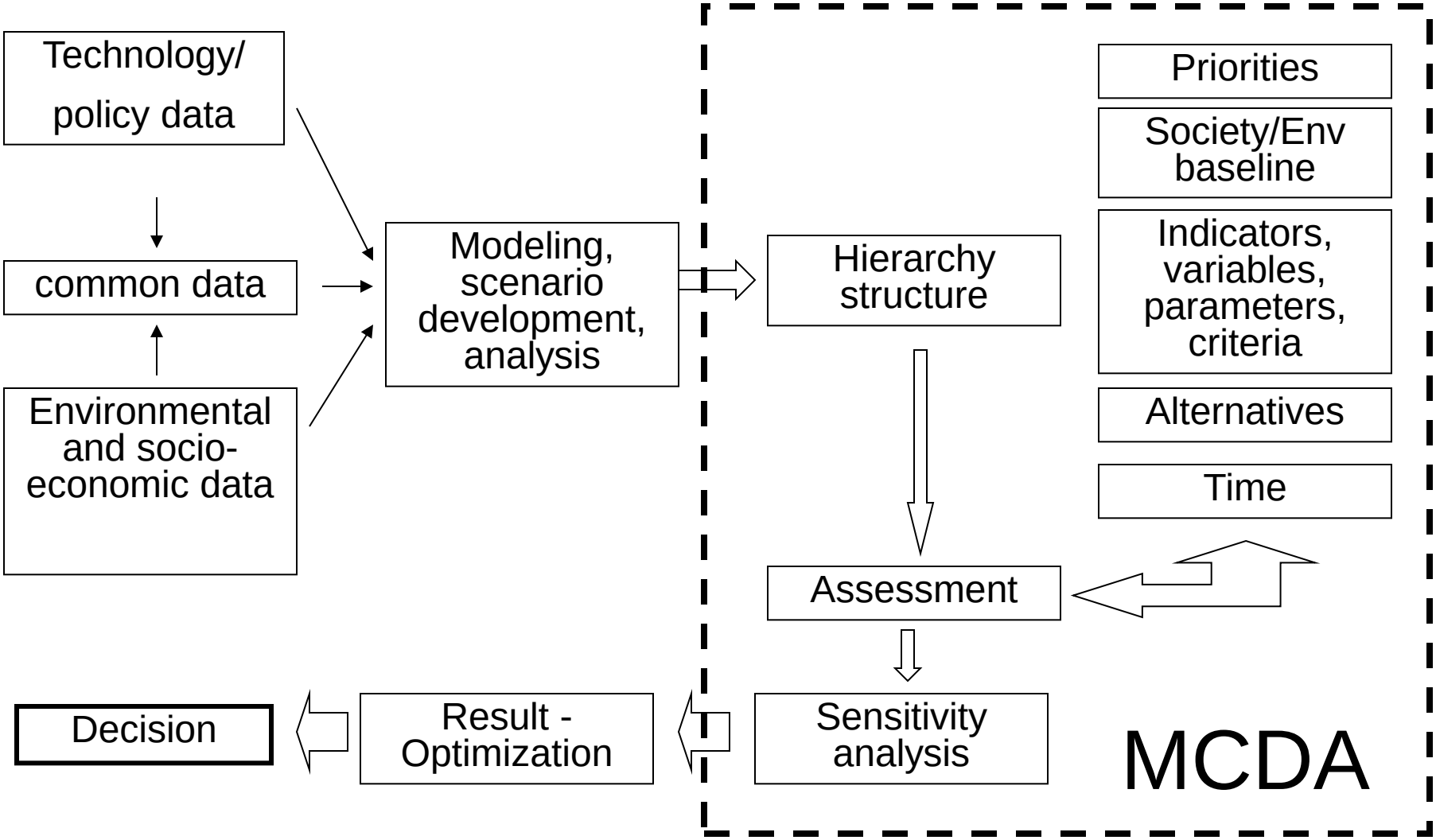
Technology Assessment (TA) is a practice intended to enhance societal understanding of the broad implications of science and technology.

Presentation outline:

- Multiple Criteria Decision Analysis (MCDA)
- Methodological approaches to tools Effectiveness analysis
- Application to Urban Underground Space (UUS)
- UUS – resource management (equality, public rights)
- UUS – high tech, innovation, side effects
- UUS – and urban sustainability – public involvement, futures research
- MCDA application (AHP – ANP) *top-down/bottom-up hierarchy, innerdependance, feedback, effectiveness, mcda follow up*
- Perspectives for TA and Futures research

MCDA Introduction

MCDA in TA A methodological flow-chart



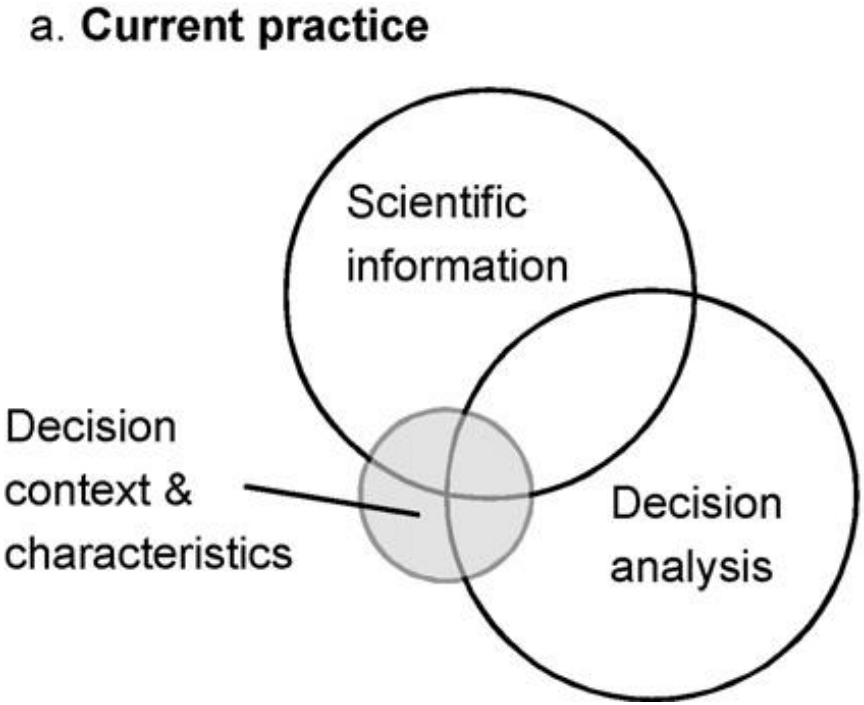
Effectiveness in MCDA

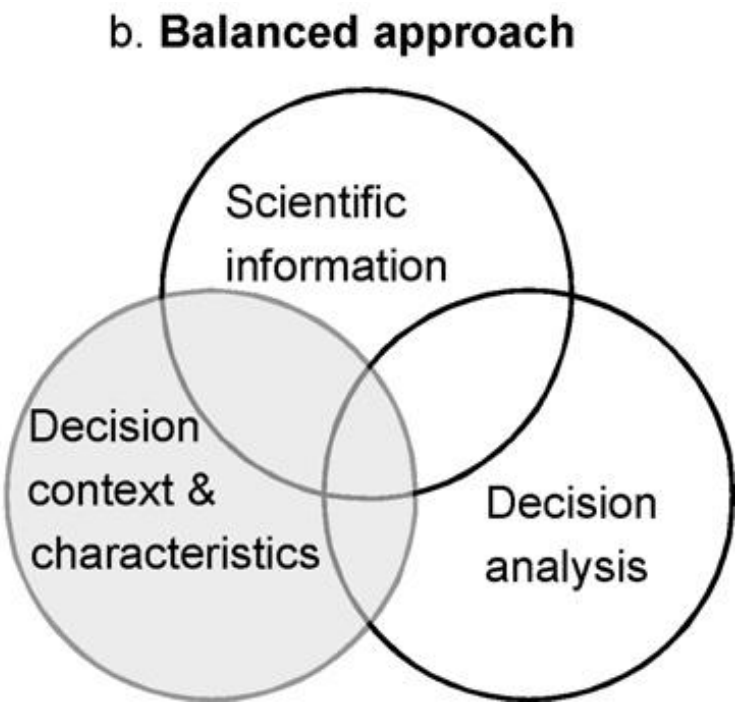
effective decision support tools:

- information needs, technology, human factors, and organizational routines (Wears and Berg, 2005)
- "sociotechnical" system approach (Randolph et al., 1999)

1. Credibility of a method itself
2. Abilities of individuals to use the method
3. Working environment (institutional, political, etc)

Effectiveness in MCDA





(from Pyke et al 2007)

Effectiveness of tools: borrowing an Environmental Assessment (EA) approach

Effectiveness in EA

a degree to which EA process works as intended and meets the purposes for which it is designed (Sadler, 1996)

Procedural

Substantive

Transactive

Effectiveness of tools: borrowing an Environmental Assessment (EA) approach

Criteria for EA effectiveness assessment: (based on review of suggested by Udo, 1992; McCartt and Rohrbaugh, 1989; Theophilou et al., 2010; Fischer and Gazzola, 2006; George, 1999; Noble, 2009; Retief et al., 2008)

Criteria	*Description*	*Desired value*
Timing of assessment	Timing of EA in relation to an initiative lifecycle. SEA usually considers that EA should start at the earliest possible stage of decision making	Just right
Resources required	A variety of resources: data, human, monetary, time	Just right (not minimum)
Data generation (internal learning effect)	EA process generates data, and/or additional significant knowledge, that could not be obtained otherwise (e.g. during design, modelling, surveys)	Maximise
Impact on an initiative	This is the central criteria to judge on effectiveness. The initiative should be improved as the result of an EA process	Maximise, concrete and solid
Wider influence (external learn. effect)	Influence that goes beyond considered initiative – impact on policies in the field	Maximise
Participation	All parties concerned and initiative stakeholders are willingly involved	Maximise willing, inclusive participation
Credibility	Opinion of professional communities on whether they trust EA results and believe that EA actually made an initiative better	Maximise

Using MCDA

MCDA Methods [that have been used by the authors]

American school:

Analytic Network Process

Analytic Hierarchy Process

by Thomas Saaty

http://www.superdecisions.com/

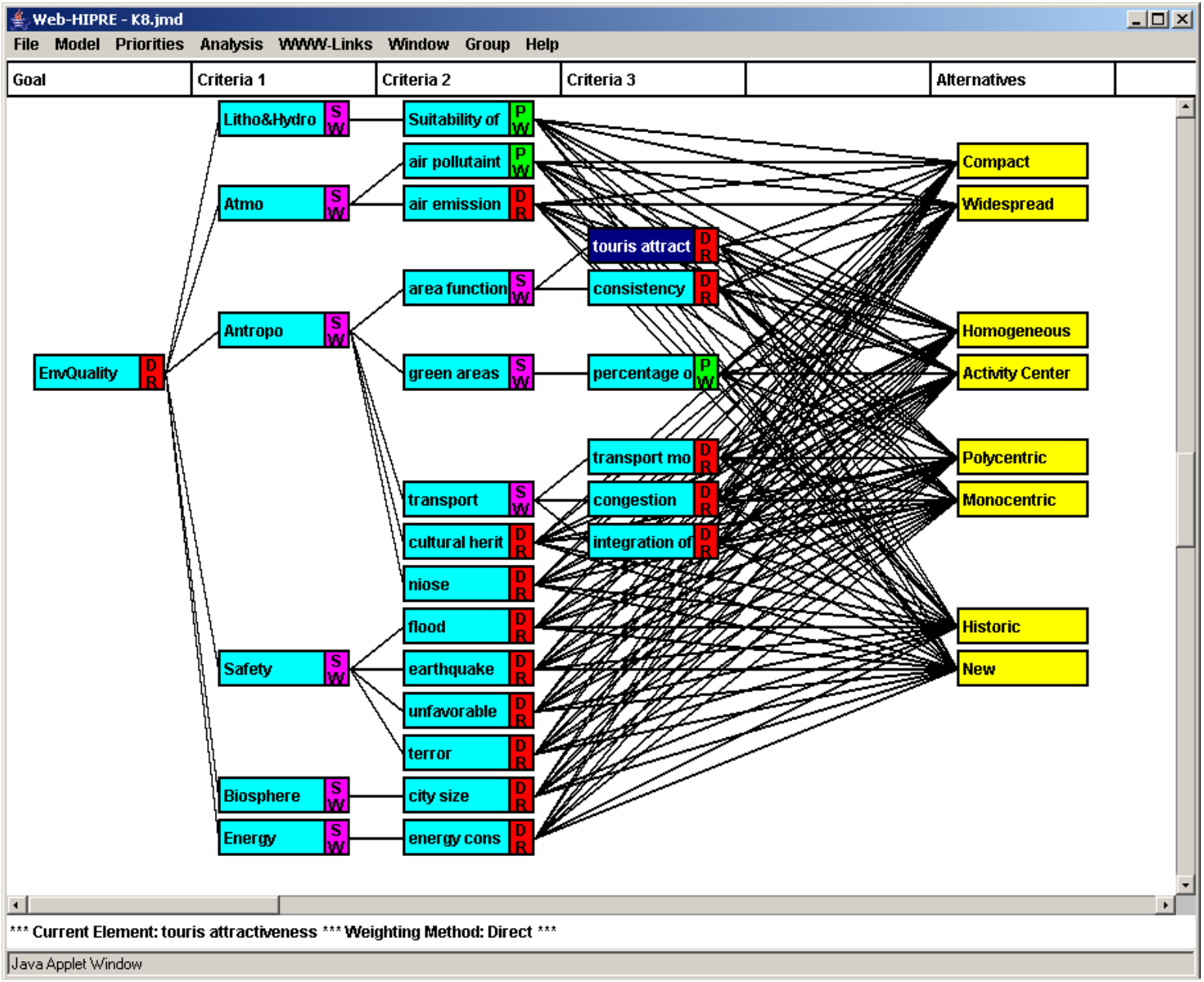
European school:

MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique)

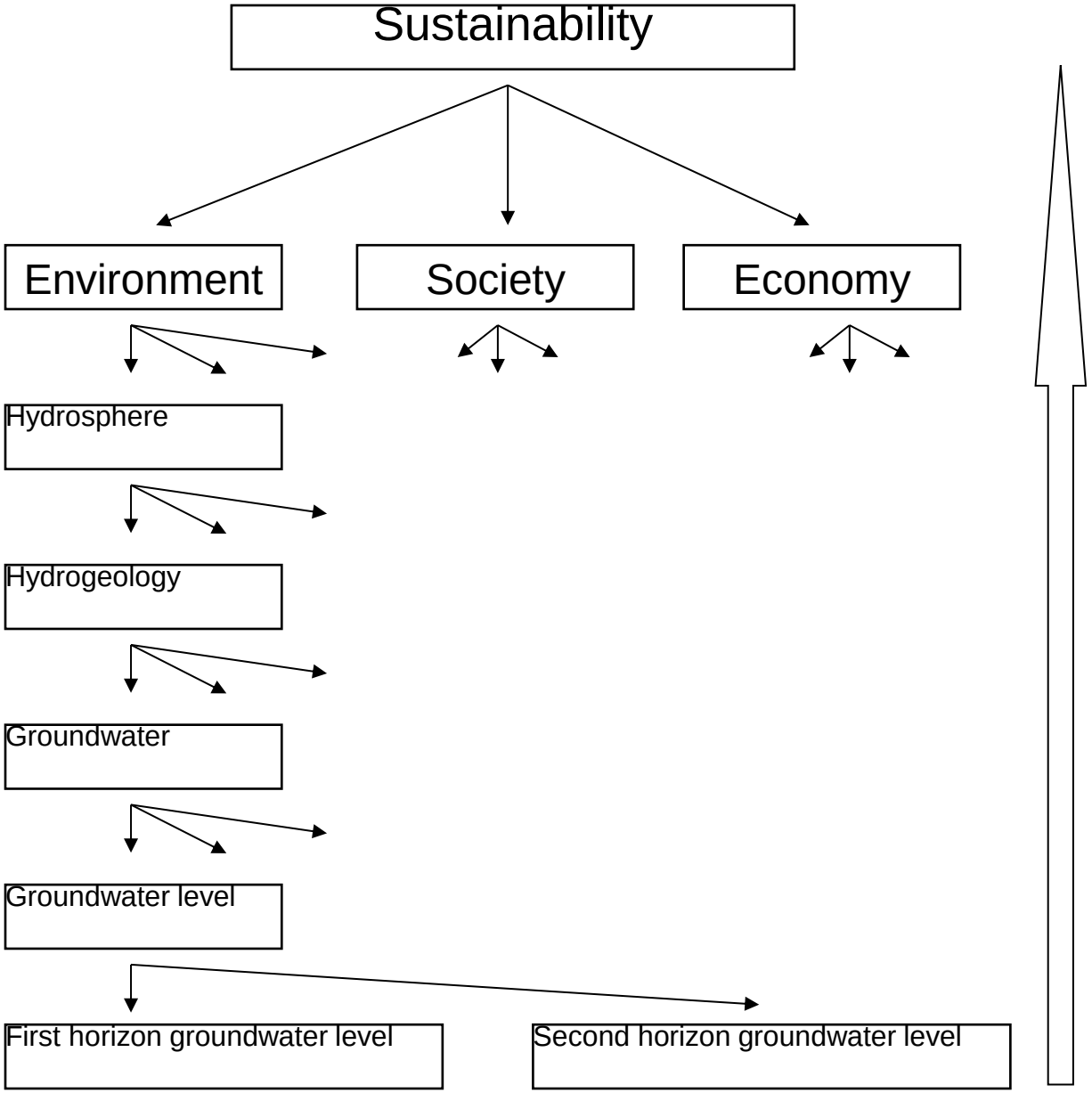
by Carlos Bana e Costa et.al.

http://www.m-macbeth.com/index.html

using MCDA


Web-HIPRE - K8.jmd
File Model Priorities Analysis WWW-Links Window Group Help
Goal
Criteria 1
Criteria 2
Criteria 3
Alternatives
EnvQuality DR
Litho&Hydro SW
Atmo SW
Antropo SW
Safety SW
Biosphere SW
Energy SW
Suitability of PW
air pollutaint PW
air emission DR
area function SW
green areas SW
transport SW
cultural herit DR
niose DR
flood DR
earthquake DR
unfavorable DR
terror DR
city size DR
energy cons DR
touris attract DR
consistency DR
percentage o PW
transport mo DR
congestion DR
integration of DR
Compact
Widespread
Homogeneous
Activity Center
Polycentric
Monocentric
Historic
New
*** Current Element: touris attractiveness *** Weighting Method: Direct ***
Java Applet Window

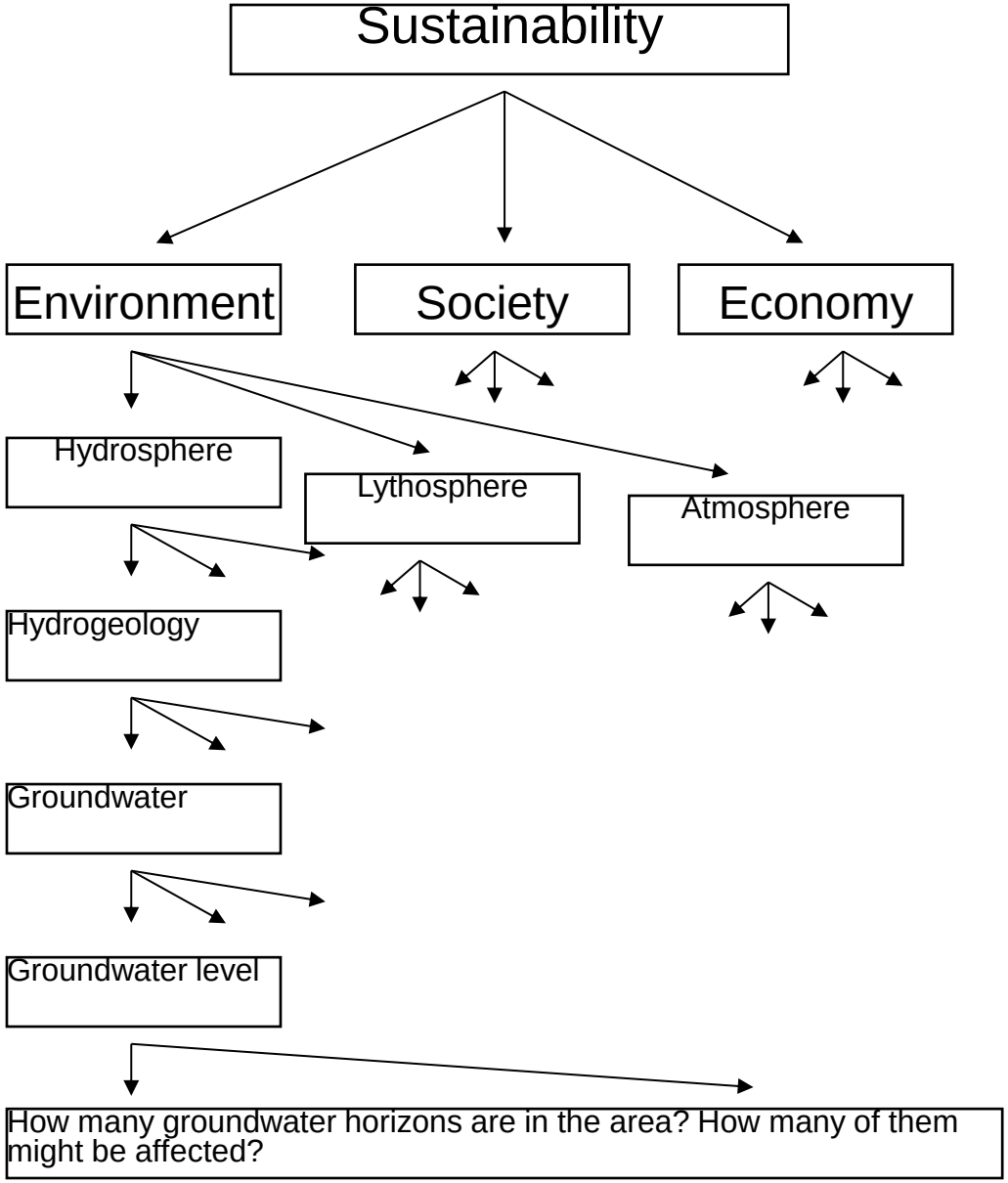
MCDA for TA: hierarchy elaboration techniques



Elaboration of hierarchy

bottom-up technique

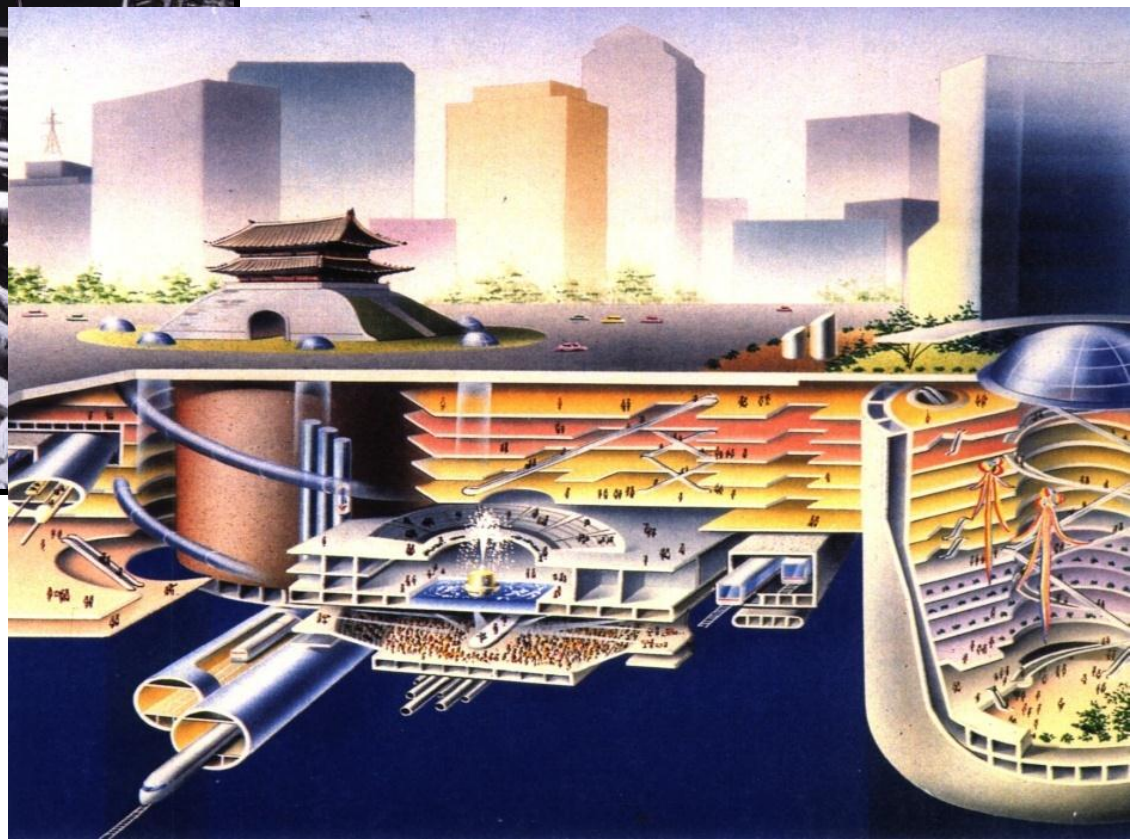
MCDA for TA: hierarchy elaboration techniques



Elaboration of hierarchy

top-down technique

TA application: Urban Underground Infrastructure (UUI) Challenges – upgrade, vision, planning, innovation



Application to Urban Underground Space (UUS)

Issues:

public acceptance of intensive UUS use;

need for a dense, compact cities (sustainable?)

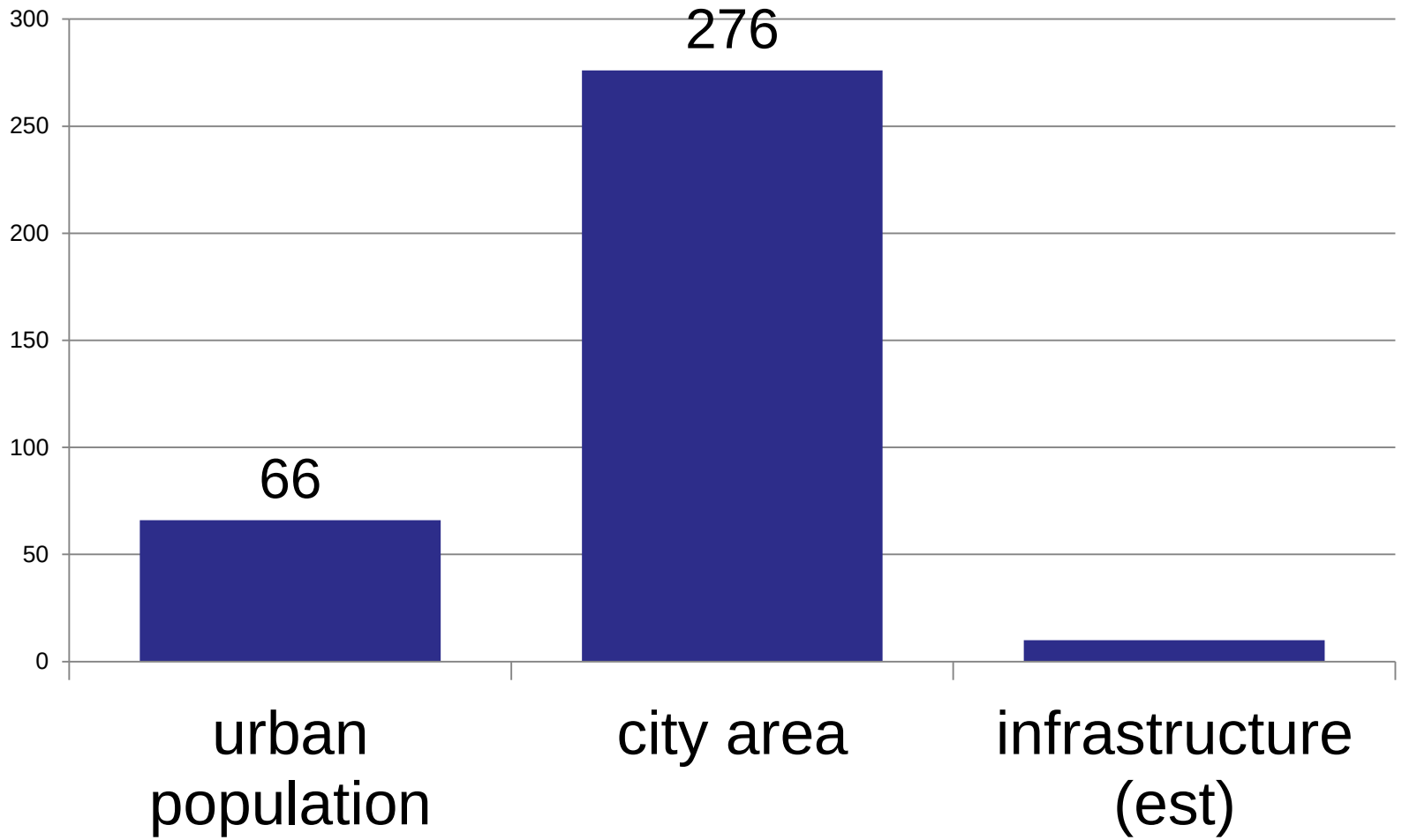
risks of UUS technologies (geothermal energy vs earthquakes) + other known risks + unknown risks;

public rights for equitable use of UUS resource

Society: knowledge, decision preferences (strategy of UUS use)

Global [Urban Physical] Infrastructure Challenges – not enough, not catching up with development

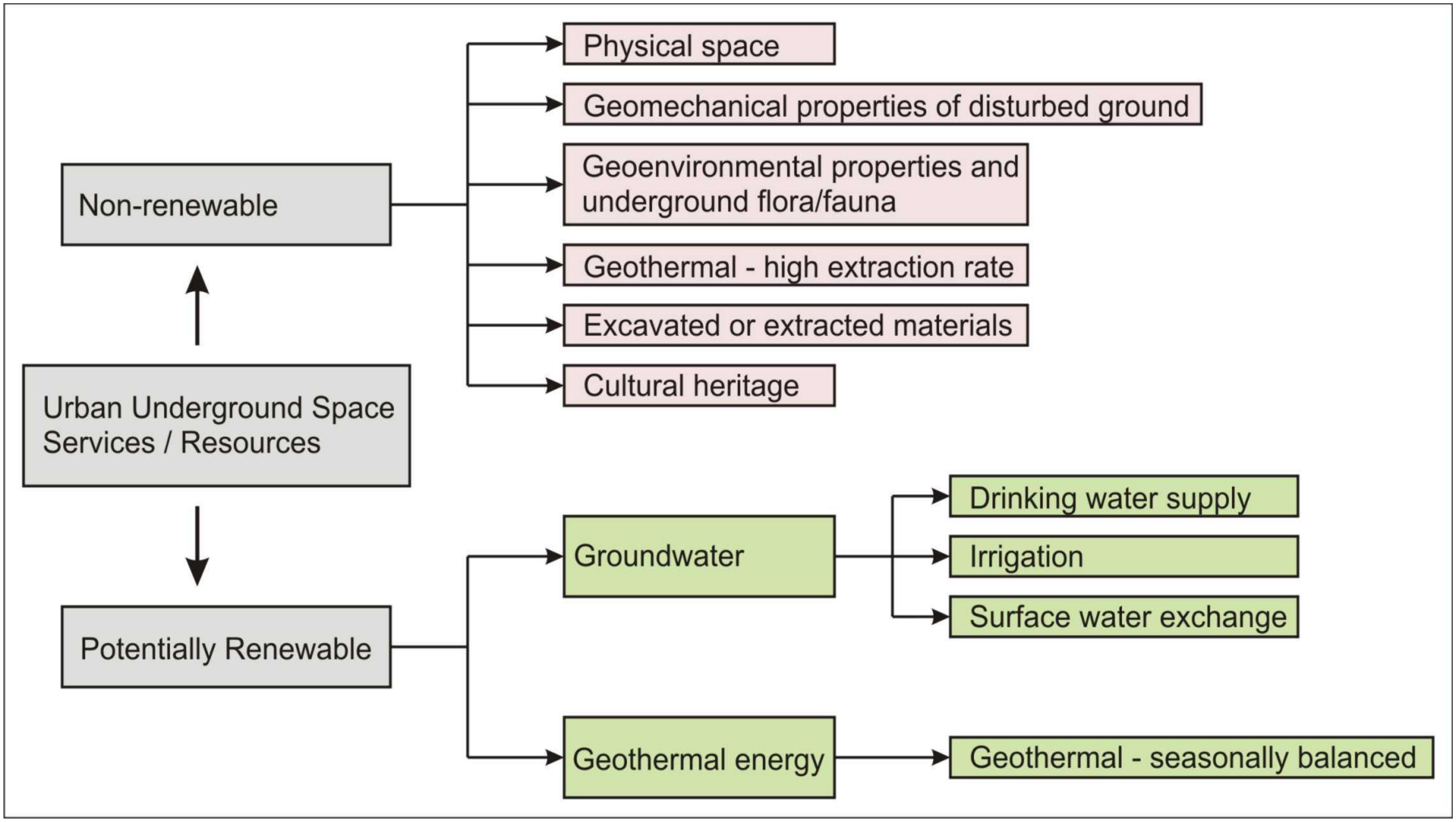
Global growth by 2030, %
data sources: population (UN, 2007); area (Angel et al, 2005); infrastructure (OECD, 2006)



Urban Underground Space resource management

UUS resources (after Parriaux, Bobylev, Sterling)

Sustainability Issues for Underground Space in Urban Areas (2012) Sterling, R., Admiraal, H., Bobylev, N., Parker, H., Godard, J.P., Vähäaho, I., Rogers, C.D.F., Shi, X., Hanamura T. *Proceedings of the ICE - Urban Design and Planning*



Urban Underground Space resource management/ innovation / highttech

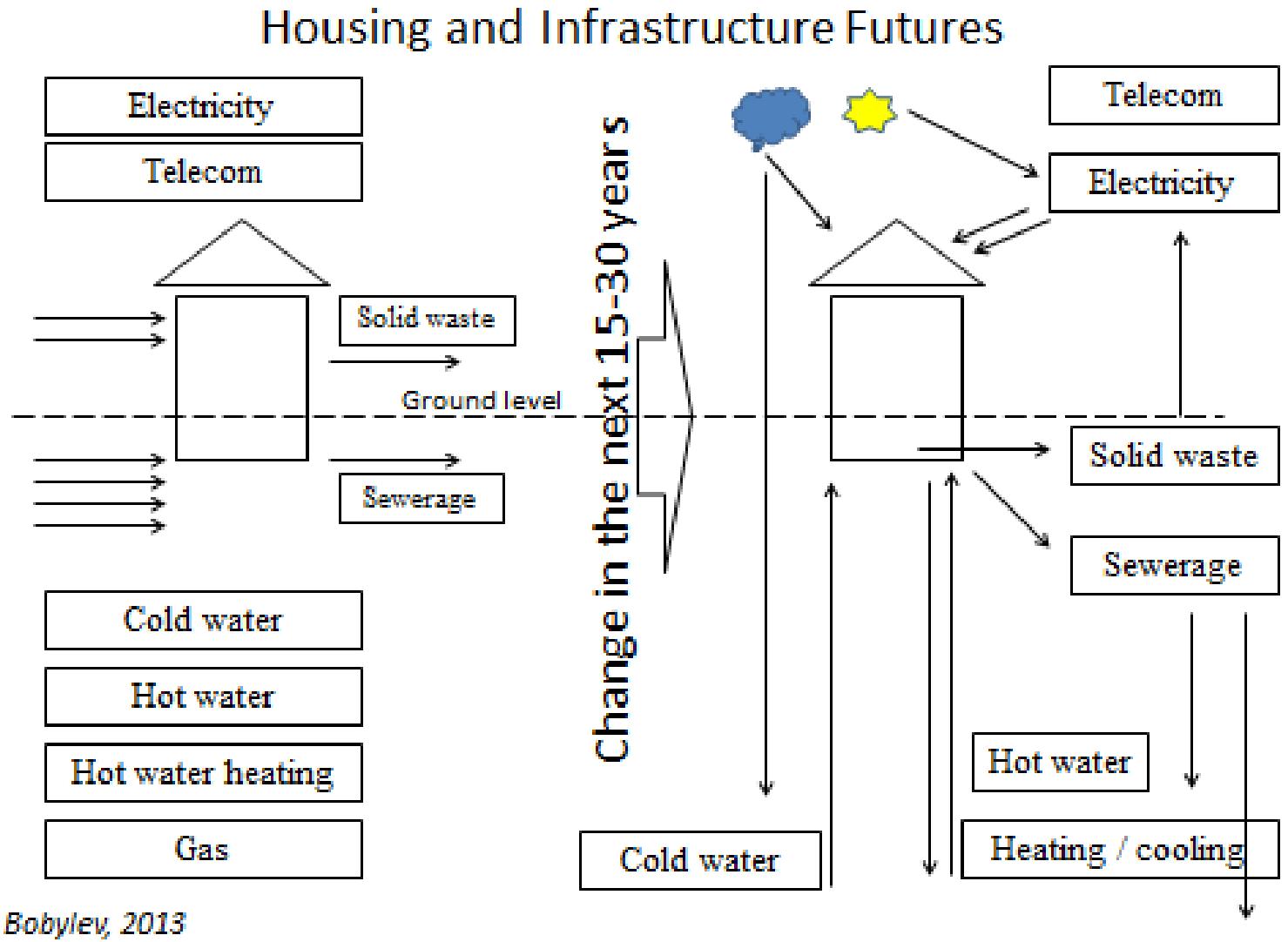
UUS technologies/ practices impacts:

local (e.g. microtunnelling)

regional (e.g. local earthquakes (e.g. Basel, Switzerland, 2006-2007)

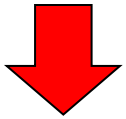
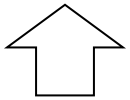
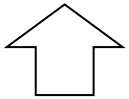
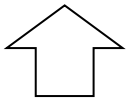
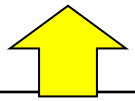
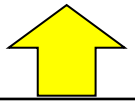
global (the broader discussion on urbanization and climate change)

Urban Underground Space Futures and lay public participation



Urban Infrastructure Futures, Bobylev, 2013

Assessment approaches, big issues, public/policy involvement

UPI characteristic	*Evolution associated with* ***urbanization***	*Evolution a w* ***adaptation to climate change***	*Opportunities for* ***climate change mitigation***
Interdependence			-
Convergence			Can save resources like energy
Critical facilities	-		None
Vulnerability			-
Sustainability			Sustainable, well planned infrastructure can help to mitigate climate change

Outlook: UPI characteristics and factors of global change

Assessment experiment:

The problem: 3 underground construction technologies (UCT):

- Open cut
- Conventional tunneling
- TM (microtunneling, pipe jacking)

The method: Analytic Network Process by Thomas Saaty

Bobylev, Nikolai (2011) Comparative analysis of environmental impacts of selected underground construction technologies using analytic network process. *Automation in Construction*, Elsevier. Volume 20, Issue 8, December 2011, Pages 1030-1040. doi:10.1016/j.autcon.2011.04.004

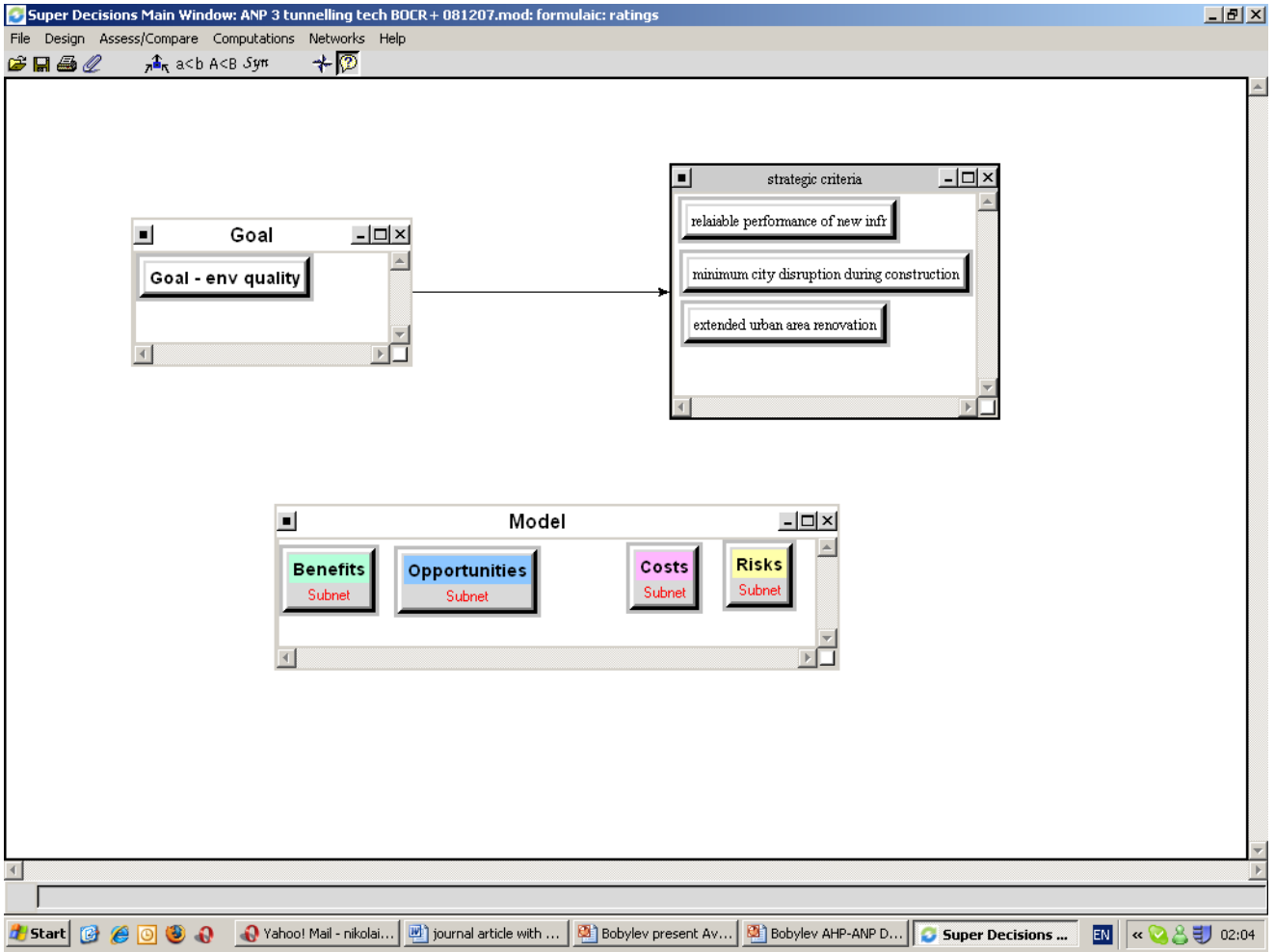
By Creative Decisions Foundation
4922 Ellsworth Avenue
Pittsburgh, PA 15213
Phone: 412-621-6546
Fax: 412-681-4510

Concepts in the ANP:

- Benefits, Opportunities, Costs and Risks
- Hierarchies and Networks
- Pairwise comparisons and ratings
- Dependence and Feedback
- Inner and outer Dependence
- Nodes and Cluster comparisons
- Control Criteria
- Strategic Criteria

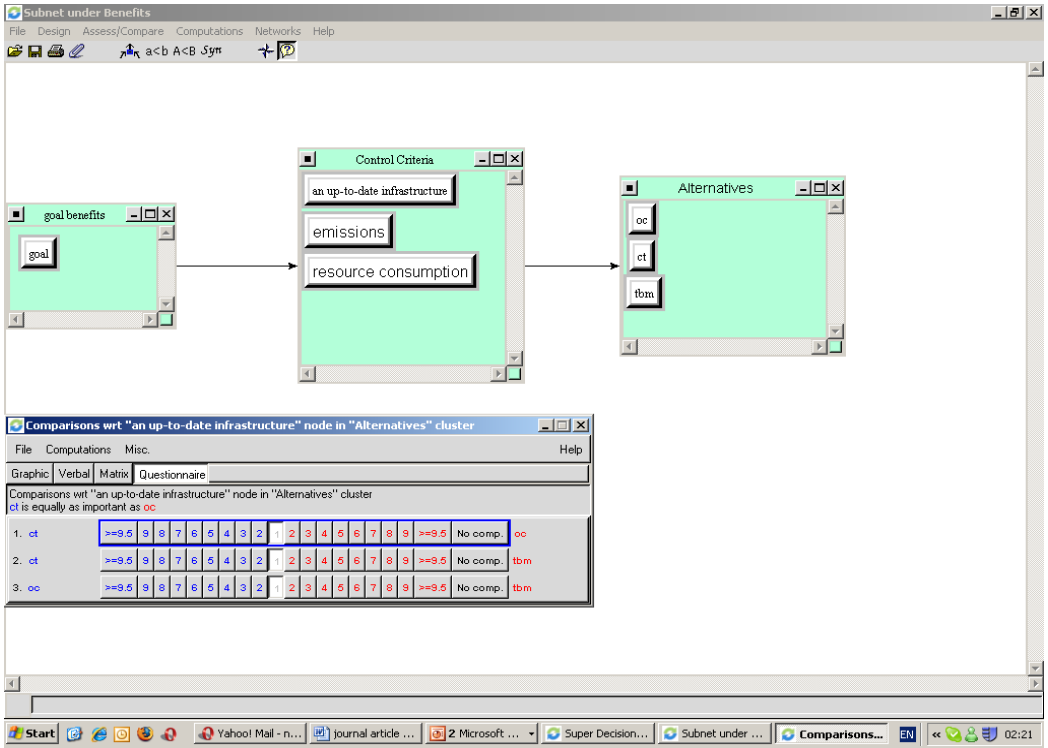
Assessment goal:

Determine which initiative is the best for the environment



Benefits (direct of UCT):

- Up-to-date infrastructure (which UCT creates a more up-to-date infrastructure?)
- Low emissions (which UCT provides less emissions? e.g. better for the environment?)
- Less consumption of resources



Benefits (direct of UCT) (AHP model):

Number of comparison sets:

•1 – compare control criteria (3) with respect to the goal (benefits for the environment)

Sample pairwise comparison question: what is more important for the benefits of the project: "Low emissions" or "Less consumption of resources"?

•3 – compare alternatives (3) with respect to each control criterion (3)

e.g. which UCT creates more up-to-date infrastructure?

Opportunities (potential benefits):

Criteria here:

- represent complex concepts,
- are difficult to measure,
- are subjective,
- are difficult to prioritize with respect to an assessment goal.

These criteria are best evaluated by measuring in the context of the alternatives themselves (feedback)

These criteria may also be interdependent, and this is measured by innerdependent comparisons

Opportunities (potential benefits) (ANP model):

Number of comparison sets:

- 6 –alternatives (3) with respect to each control criteria (6)

e.g. which UCT would provide more opportunities for the underground structure integration with existing structures?

- 3 – the control criterion (6) with respect to the alternatives (3)

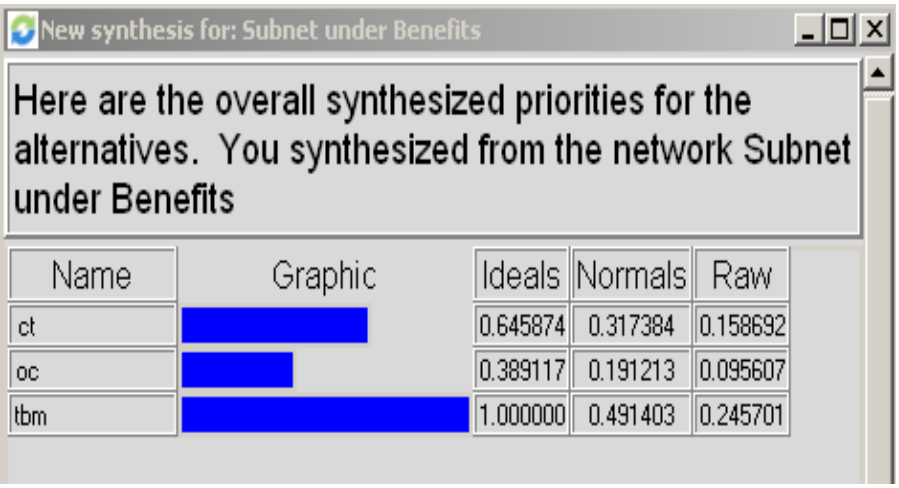
e.g. what would be the main benefit of UCT TM? flexibility, rationality, etc? (feedback)

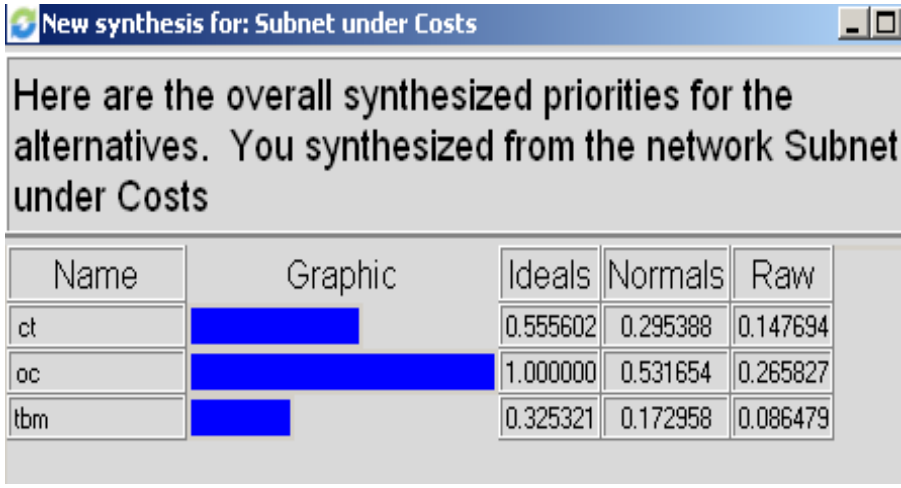
- 6 – all the control criteria in the cluster but one (6-1=5) with respect to this control criterion (6)

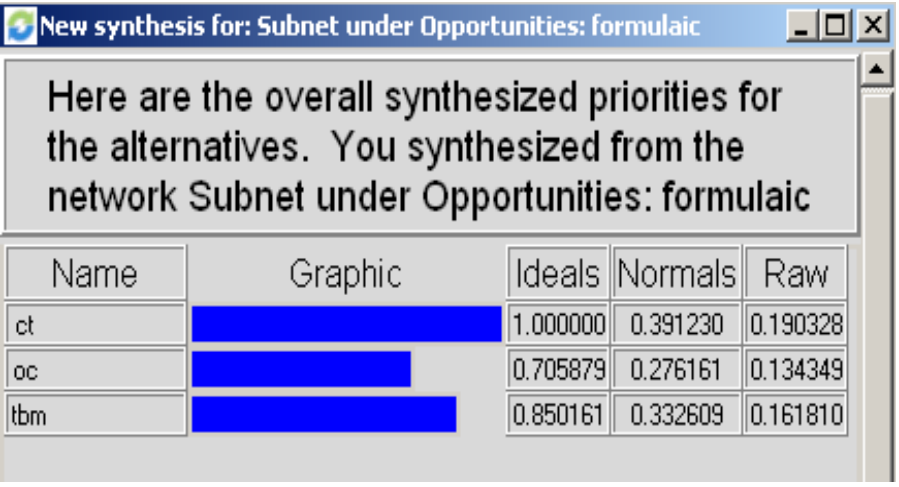
e.g. what is more important to ensure rationality: flexibility, integrality, etc.?

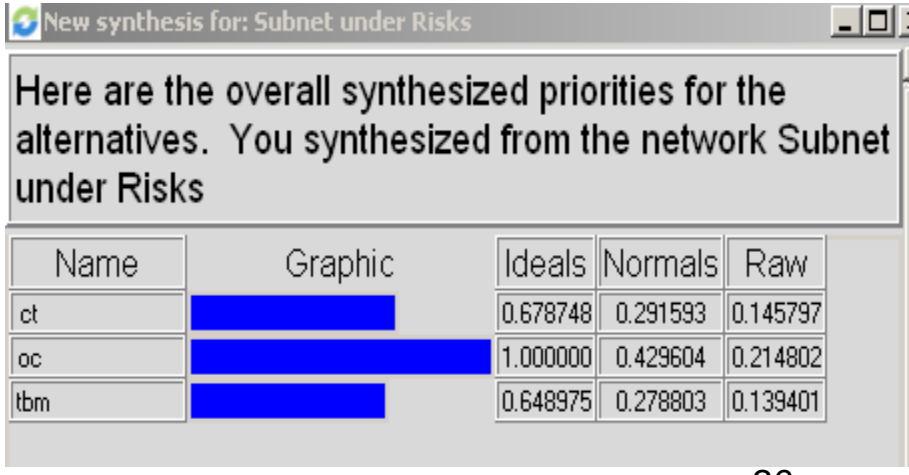
Intermediate results:

Benefits, Opportunities, Costs and Risks (BOCR):





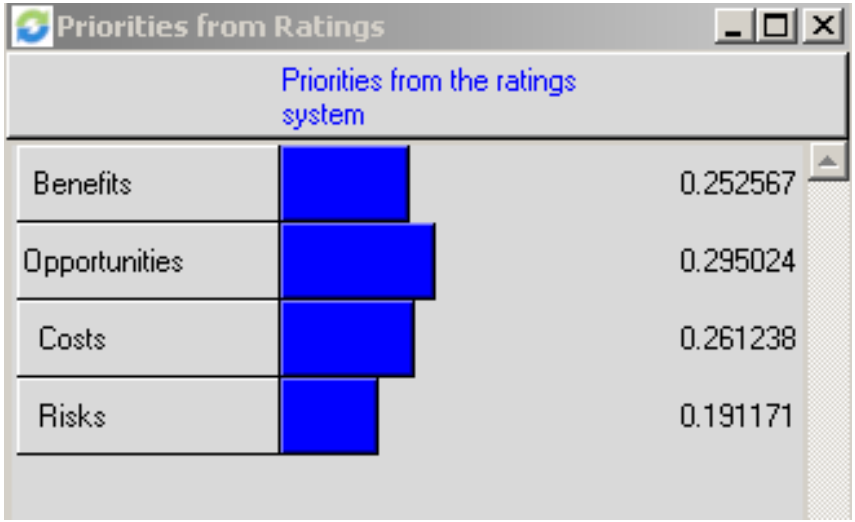




Rating BOCR using strategic criteria:

Strategic criteria:

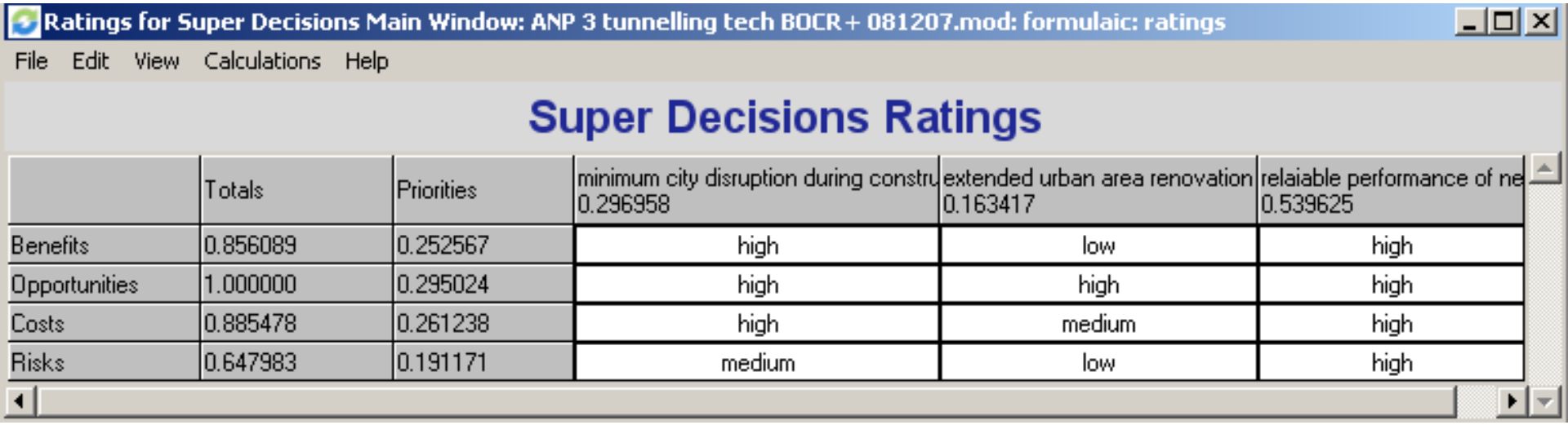
- Reliable performance of new infrastructure
- Minimum disruption of the city environment during construction
- Extended renovation of the urban area (opportunities for side projects)



Values of coefficients b,o,c,r in the Additive (negative) formula

Rating BOCR using strategic criteria:

•What is an importance (e.g. high, medium, low) of the best alternative under benefits (TM) for a strategic criteria e.g. “Reliable performance of new infrastructure”?


Ratings for Super Decisions Main Window: ANP 3 tunnelling tech BOCR + 081207.mod: formulaic: ratings

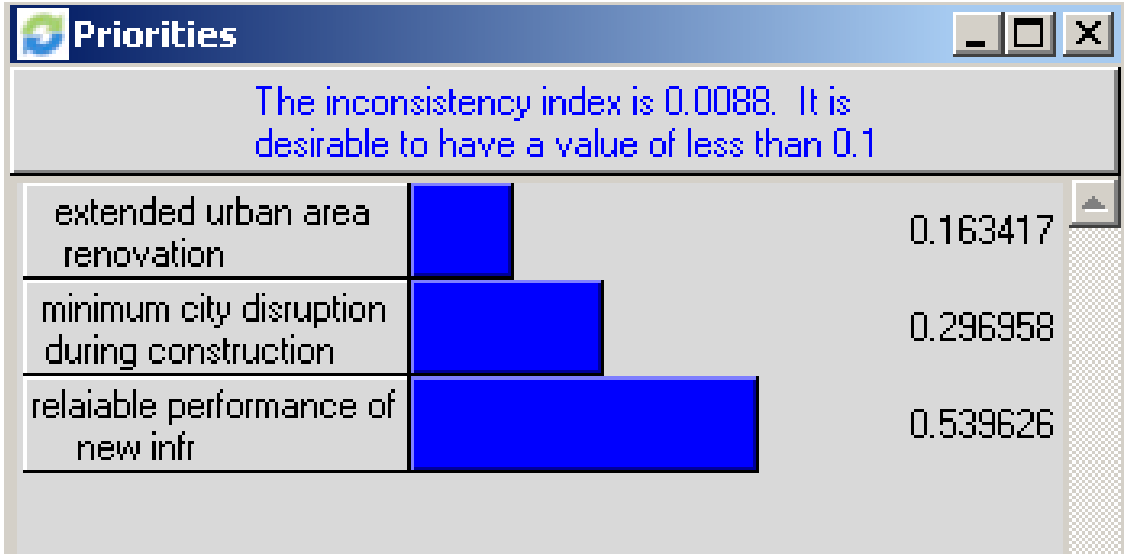
File Edit View Calculations Help

Super Decisions Ratings

	Totals	Priorities	minimum city disruption during constru 0.296958	extended urban area renovation 0.163417	relaiable performance of ne 0.539625
Benefits	0.856089	0.252567	high	low	high
Opportunities	1.000000	0.295024	high	high	high
Costs	0.885478	0.261238	high	medium	high
Risks	0.647983	0.191171	medium	low	high

Rating BOCR using strategic criteria:

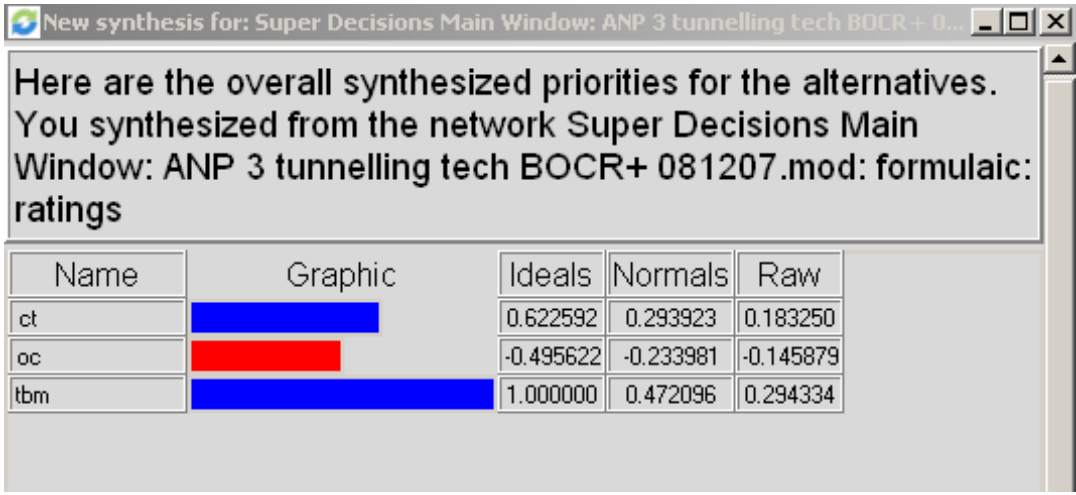
- Strategic criteria has their weight with respect to goal (one set of pairwise comparisons)



Final Assessment Step is to Combine the BOCR Using one of the Formulas:

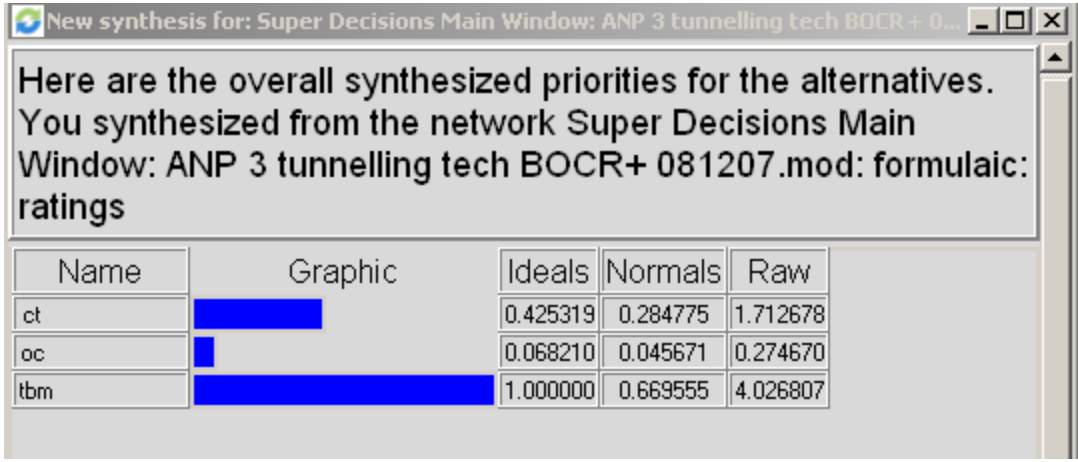
- Additive negative formula:

  bB+oO-cC-rR



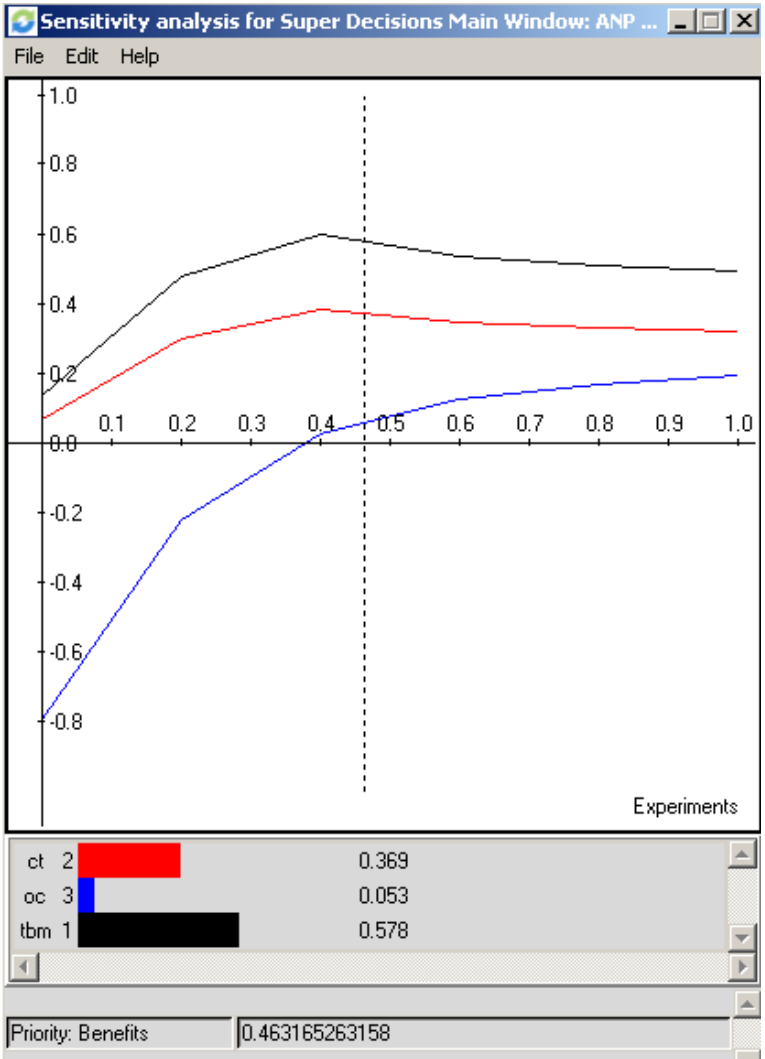
- Multiplicative formula:

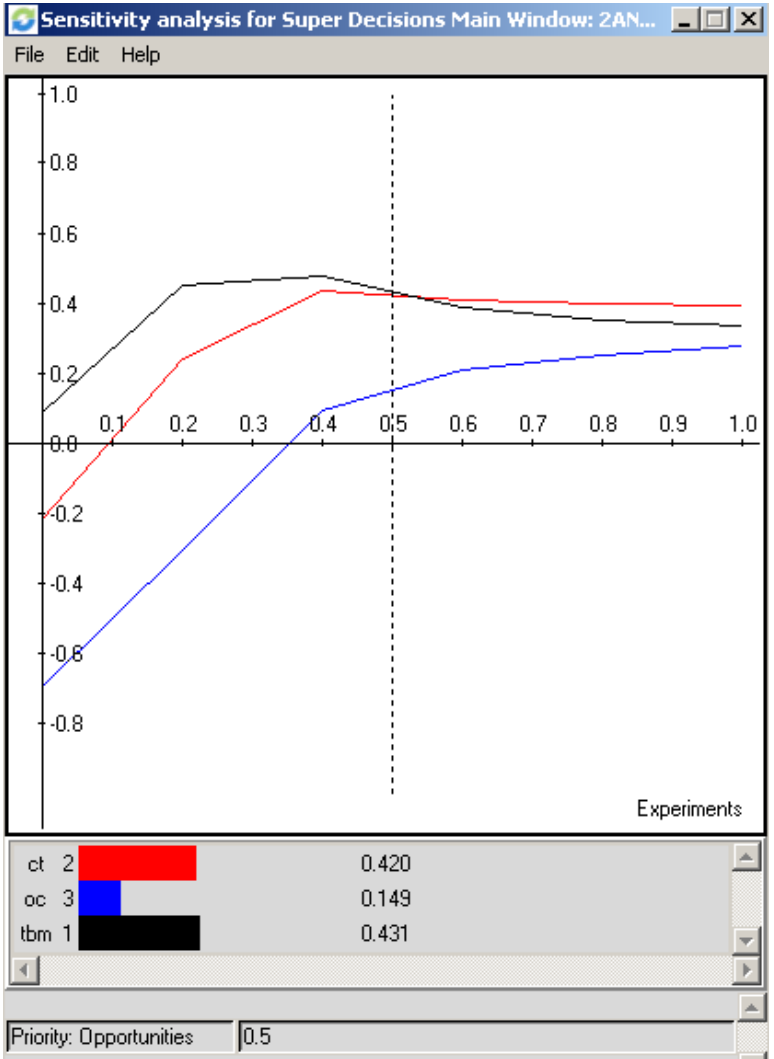
  BO/CR



Sensitivity Analysis:

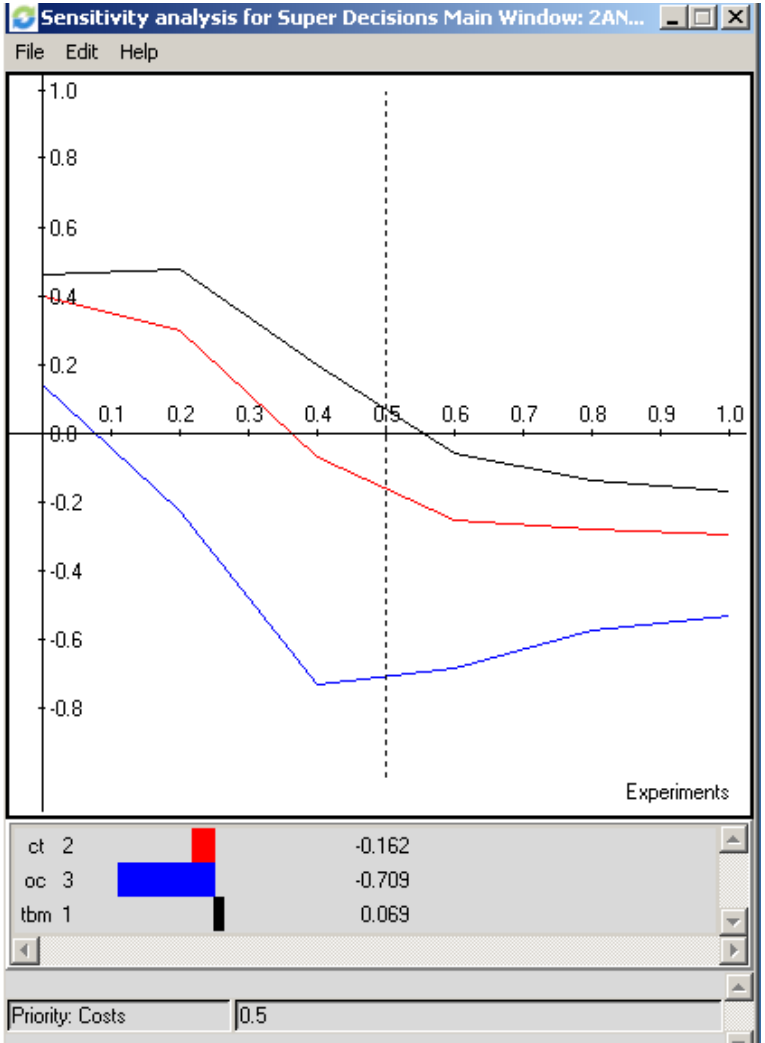
TM alternative is the best in the final result regardless coefficient b (which is weight of B)

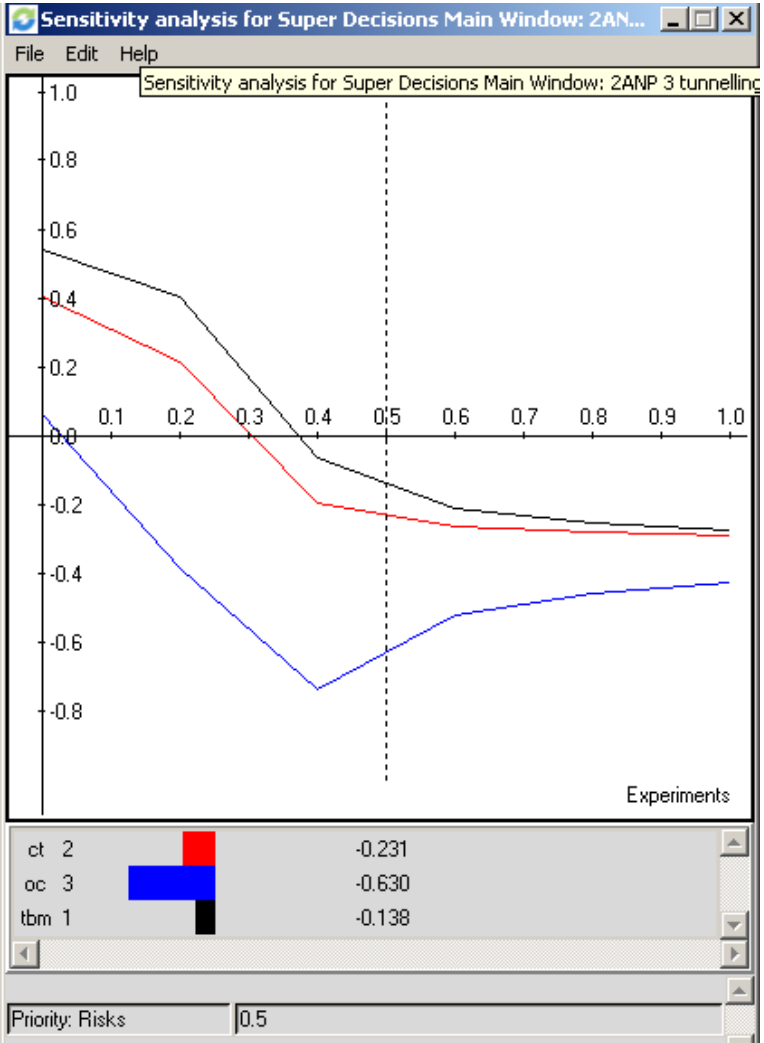




Sensitivity Analysis:

when costs or risks are dominant concerns (high coefficients c,r) all the alternatives are negative – it is not advisable to undertake the initiative





Findings/issues/research: using MCDA – What do we achieve?

Assessment results

- Alternatives rating (which is the best?)
- How close are alternatives to each other? (quite close – difficult decision, similar alternatives, high probability of mistake; too far – obvious decision, no need for assessment, incomparable alternatives),
- Sensitivity analysis: how given criterion values affect the overall ratings?
- Identify criterion or criteria groups which has the most (least) significant impact on the rating

MCDA tools follow-up

- Look at alternatives ratings: formulate alternatives again, minor changes in alternatives (technologies), suggest new alternatives, group alternatives, brake down alternatives
- Analyze criteria performance: too many (aggregate), too few (add sub-criteria), similar performance (eliminate), difficult/unclear to compare (re formulate)
- Analyze hierarchic structures: re arrange nodes, add/delete criteria
- Analyze the whole model: change formula, model, or method
- Conclude on important trade-offs to be made (which criteria contribute most to the final judgment)

Findings/issues/research: using MCDA –
Next steps in Decision Making – using MCDA results

Integral assessment function based on the values derived from MCDA

$$Q_j = \frac{\sum_{t=1}^{m} k_{jt} R_{jt} + \sum_{t=1}^{h} \bar{k}_{jt} (S_{jt} - N)}{N} \rightarrow \max \qquad k_t = \frac{t}{T}$$

Qj – integral assessment value for an *j* project alternative,
t – duration of a particular assessment period,
m – number of assessment periods within the operation period,
h – number of assessment periods within the construction period,
kt – time coefficients,
T – the whole period of project assessment

MCDA values:

N – without structure,
Sjt – construction period,
Rjt – operation period.

Source: Bobylev, 2003-2013

Teaching MCDA and student's works

- http://www.ii.spb.ru/2005/ins_inn_material/document_baza.php?id=94

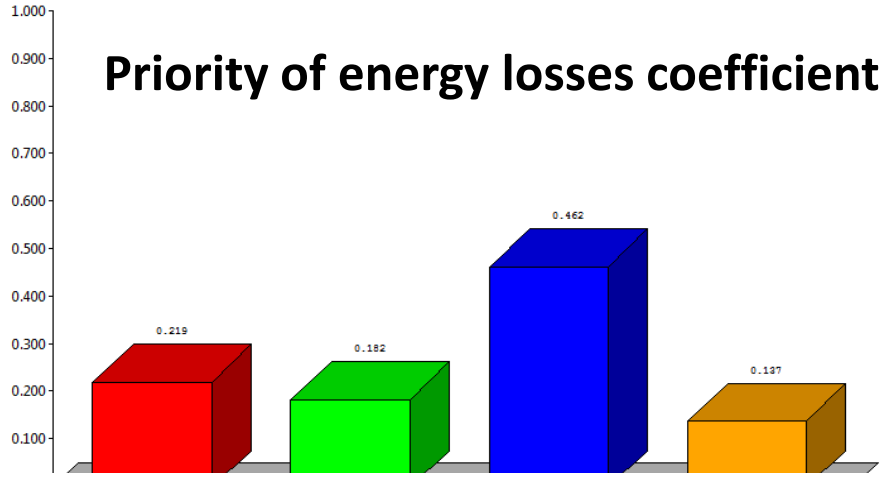
- St.Petersburg State University
- St.Petersburg State Polytechnical University

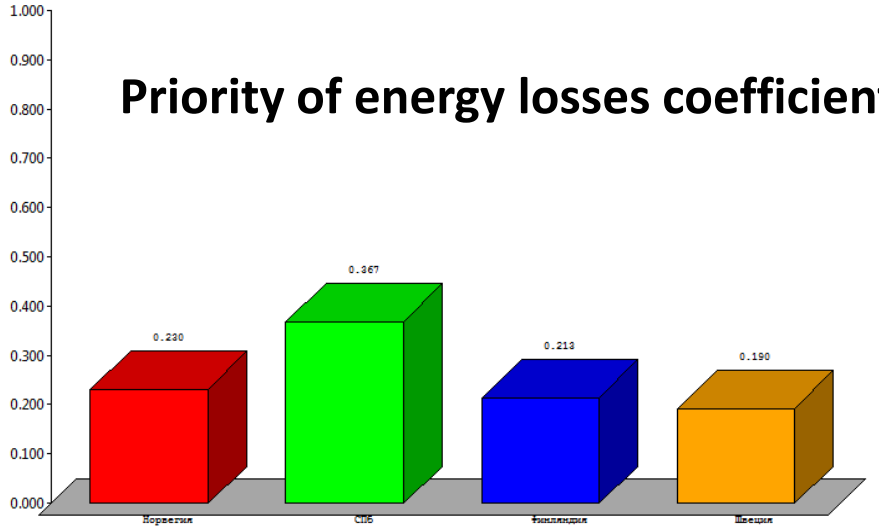
- ANP, MACBETH, other

- One semester teamwork MCDA project focused on student's degree major subject (innovations, business, environment, civil engineering)

- So far about 100 cases, about 20 of them presentable

Teaching MCDA: student's works – cases (autumn 2011)





Case: Choosing the best strategy for improving energy performance of a residential building (technology performance + public acceptance)

Norway
Saint Petersburg
Finland
Sweeden

Андреева Р.П., Богославец М.А., Захарян Г.А., Бобылев Н.Г. (2011) Выбор наилучшей стратегии улучшения энерго-эффективности жилого здания с использованием метода аналитических сетей. Тезисы недели науки СПбГПУ. Изд-во СПбГТУ, 2011. С 13-14.

Ongoing research and perspectives [Acknowledgement]

Sustainable Infrastructure for Resilient Urban Environments (SIRUE)

2012 - 2015

University of Birmingham, UK

St. Petersburg Research Centre for Ecological Safety of the Russian Academy of Sciences, Russia

PEOPLE

UNIVERSITY OF BIRMINGHAM

MARIE CURIE ACTIONS


Thank you for your attention!