The M-MACBETH Decision Support System

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Co-author of the MACBETH Approach

BANA Consulting

The MACBETH Approach: Method, Applications and Software

- **Purpose:**
  To help people make better decisions
- **Broad methodological framework:**
  Decision Analysis and Decision Conference
- **Specific type of modeling:**
  Multi-criteria value measurement
- **Selected application:**
  Bid evaluation, namely in public call for tenders
- **Software:**
  The M-MACBETH decision support system

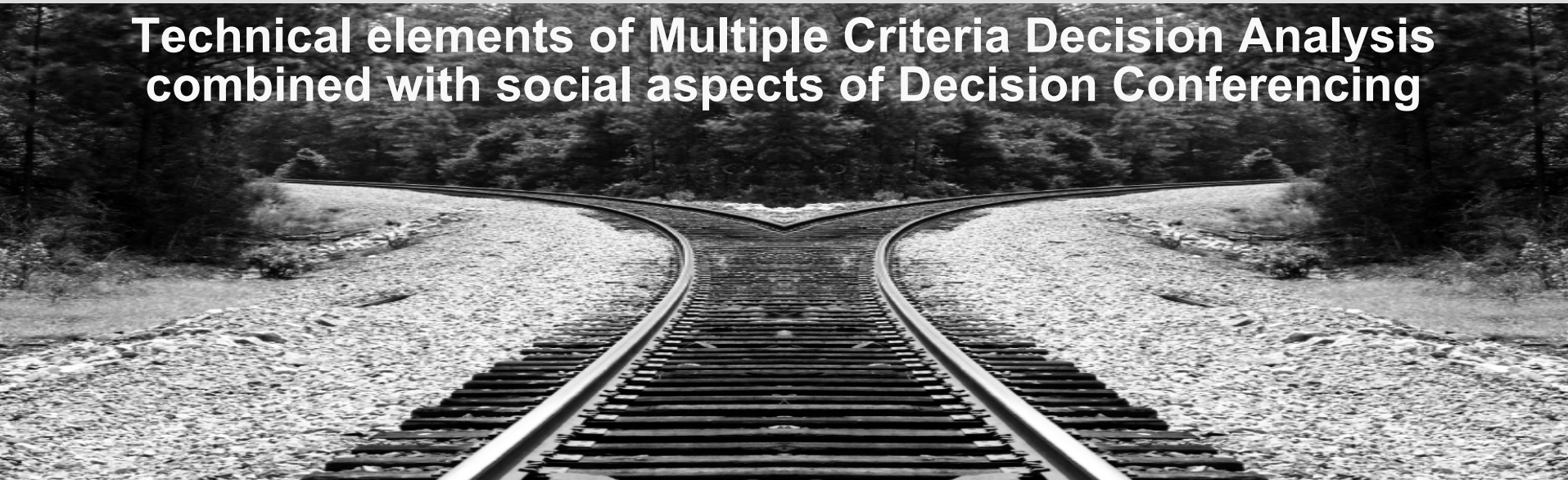
What kind of decision support?

Normative — Prescriptive — Constructive

Participation

→ a sociotechnical approach

Soft? Hard? Both: Smart



The MACBETH Approach: Method, Applications and Software

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DECISION ANALYSIS

Development and use of logical methods
for the improvement of decision-making
in public and private enterprise.

Such methods include:

- models for decision-making under conditions of uncertainty or multiple objectives
- techniques of risk analysis and risk assessment;
- experimental and descriptive studies of decision-making behavior
- economic analysis of competitive and strategic decisions
- techniques for facilitating decision-making by groups
- computer modeling software and expert systems for decision support

http://decision-analysis.society.informs.org/

Decision Analysis Society

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The Decision Analysis Society is a subdivision of INFORMS, the Institute for Operations Research and the Management Sciences. INFORMS is the world's largest organization of operations researchers and management scientists, with over 12,000 members. The Decision Analysis Society is now the second largest scoiety within INFORMS, with over 940 members and 170 international members.

INFORMS was created in 1995 by the merger of the Operations Research Society of America (ORSA, founded in 1952) and The Institute for Management Sciences (TIMS, founded in 1953). The Decision Analysis Society was founded in 1980 as the ORSA Special Interest Group on Decision Analysis, becoming the INFORMS Section on Decision Analysis upon the merger of ORSA with TIMS. In February 1996, the Section on Decision Analysis became the Decision Analysis Society of INFORMS, reflecting the increasing scope of our activities.

NEWS & ANNOUNCEMENTS

- Decision Analysis Society Flyer NEW
- Decision Analysis Journal Flyer NEW
- Decision Analysis Journal
- INFORMS Practice Conf. 2007
- INFORMS International 2007
- INFORMS Seattle 2007

A Taxonomy of Decision Models

Problem dominated by

Uncertainty — Multiple Objectives

EXTEND conversation

- Event tree
- Fault tree
- Influence diagram

REVISE opinion

- Bayesian nets
- Bayesian statistics

SEPARATE into components

- Credence decomposition
- Risk analysis

CHOOSE option

- Payoff matrix
- Decision tree

EVALUATE options

- Multi-criteria decision analysis

ALLOCATE resources

- Multi-criteria commons dilemma

NEGOTIATE

- Multi-criteria bargaining analysis

Reference: L.D.Phillips, Decision Analysis in 2005

MULTI-CRITERIA VALUE MEASUREMENT

- Measuring the relative value of options in each criterion:

  Numerical (e.g. direct rating) and

  Non-numerical approaches (e.g. MACBETH)

- Criteria weighting procedures

  Numerical techniques (e.g. swing weighting)

  Non-numerical techniques (e.g. MACBETH)

MULTI-CRITERIA VALUE MEASUREMENT

Evaluation framework: Additive value model

$$V(a) = \sum_{j=1}^{n} k_j . v_j(a)$$

With:
$$\begin{cases} v_j(\text{upper anchor}_j) = 100, \forall j \\ v_j(\text{lower anchor}_j) = 0, \forall j \\ V(\text{all upper anchors}) = 100 \\ V(\text{all lower anchors}) = 0 \end{cases}$$

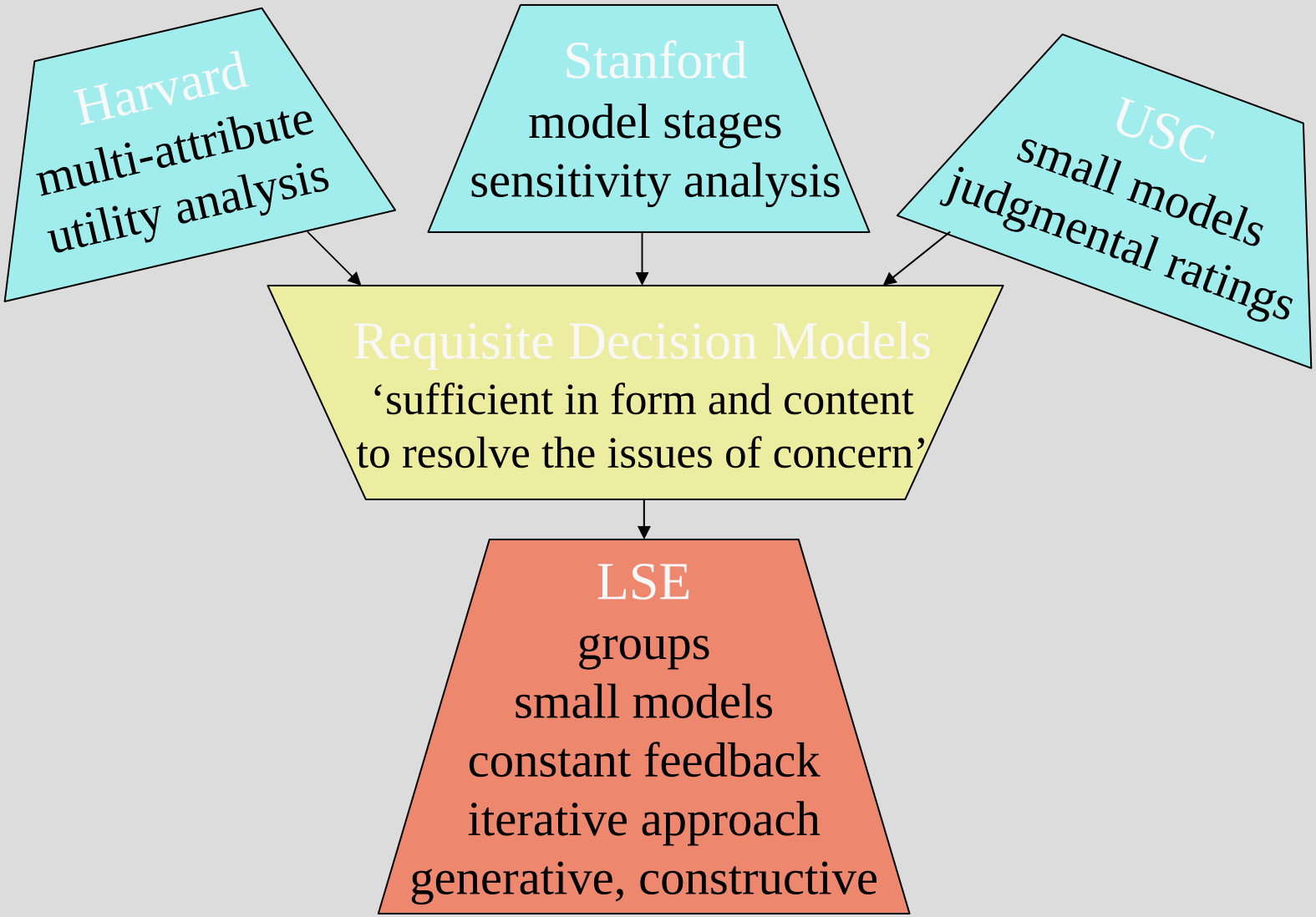
$V(a)$ overall value of option **a**

$v_j(a)$ local value (score) of option **a** against criterion j

k_j scaling constant (relative weight) of criterion j

$$\sum_{j=1}^{n} k_j = 1 \quad \textbf{and} \quad k_j > 0 \ (j = 1,\ldots,n)$$

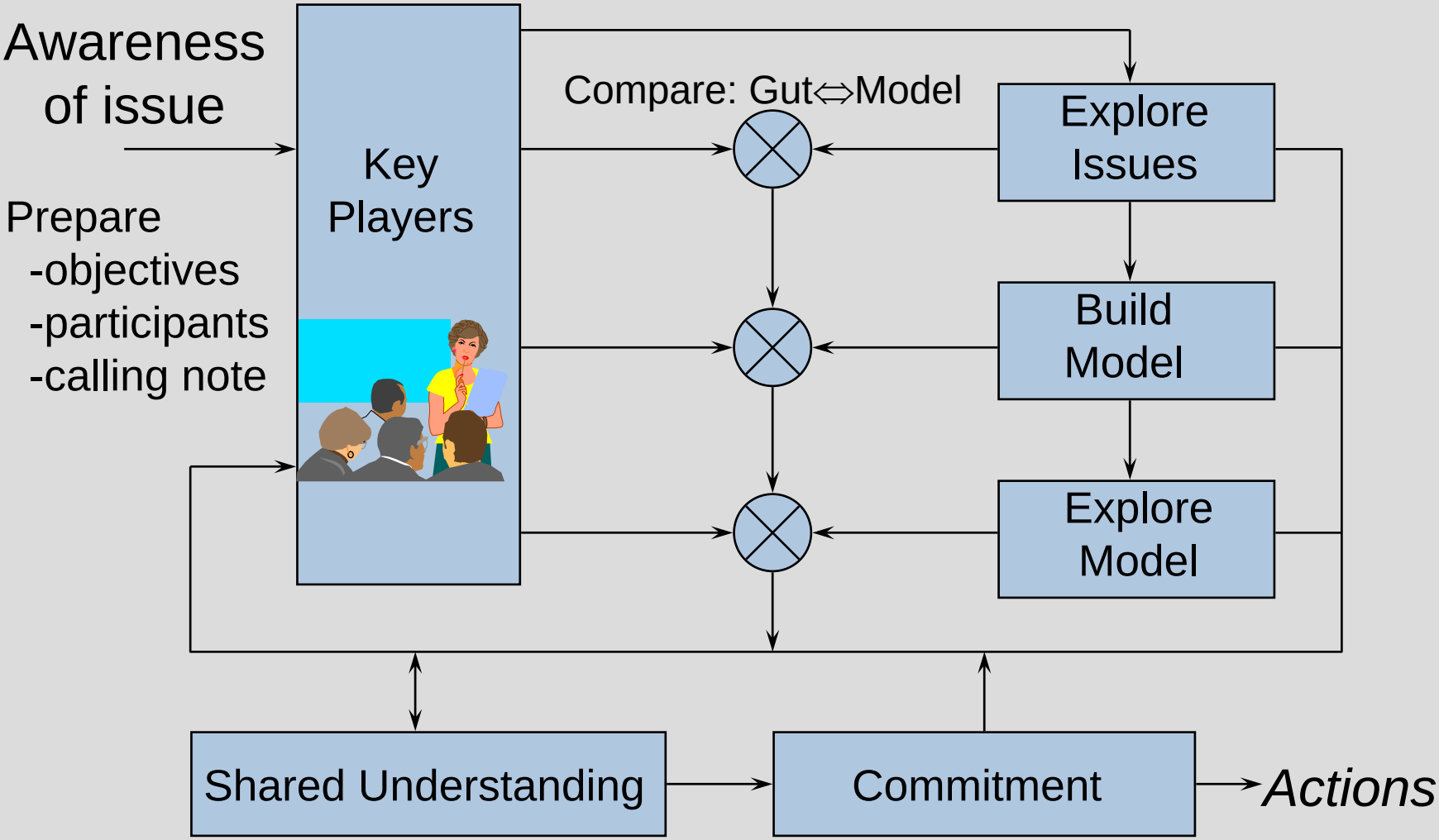
Schools of Decision Analysis



Requisite Decision Modelling

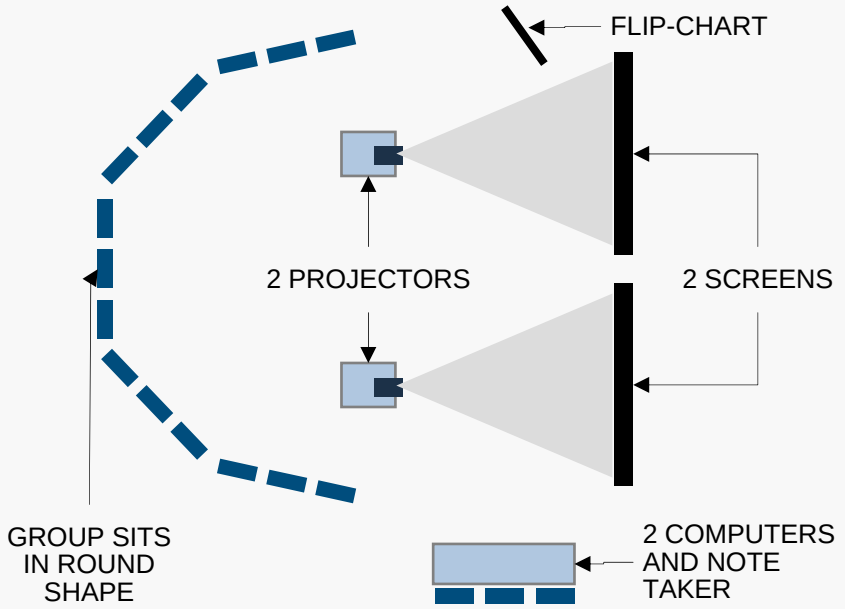
- **Definition**
  - Model is requisite when its form and content are sufficient to resolve the issues of concern.
- **Generation**
  - Through iterative and consultative interaction amongst specialists and key players, facilitated by an impartial decision analyst.

Social component: The Decision Conferencing Process



LAYOUT OF THE DECISION CONFERENCE ROOM

ROOM LAYOUT



PROCESS CONSULTING TEAM

- 1 facilitator
- 1 analyst (computer operator for M-MACBETH)

Optional (depending on the context):

- 1 analyst/consultant (computer operator for background/support information)
- 1 note taker

GROUP OF PARTICIPANTS

- 5 to 15 people with a balanced perspective on the meeting's subject (experts, stakeholders, decision makers,…)


EXTREME
VERY STRONG
STRONG
MODERATE
WEAK
VERY WEAK
NEUTRAL


PRODUCTIVITY, COMPETITIVENESS AND CONNECTIVITY


BNDES

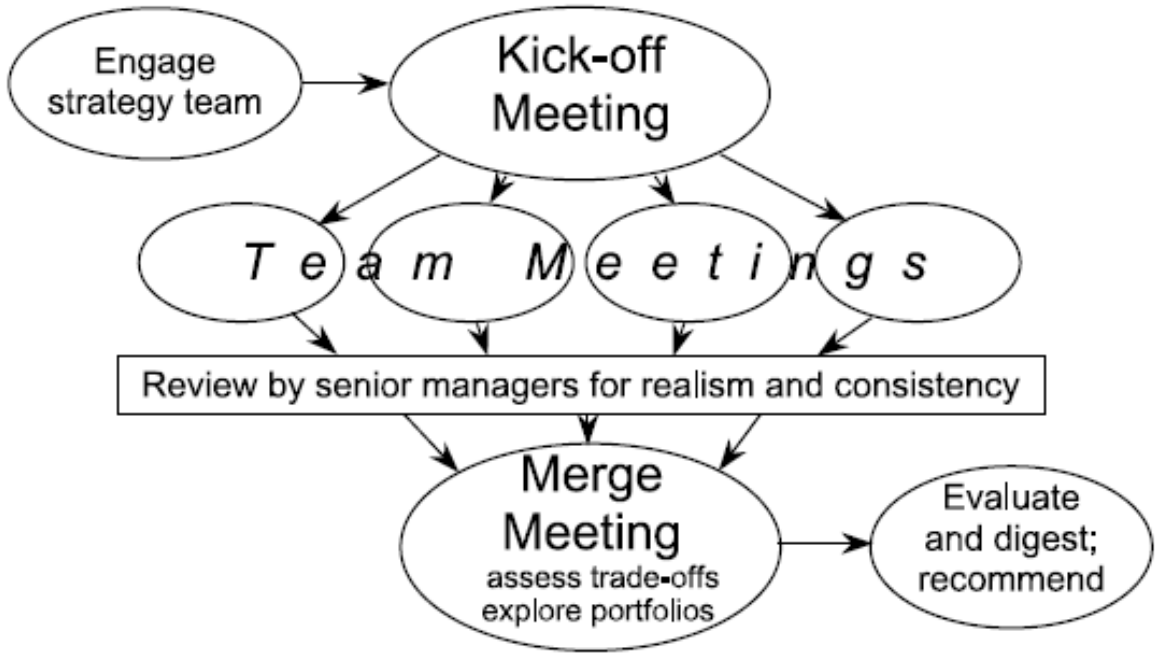
Design of the social process

Transparent prioritisation, budgeting and resource allocation with multi-criteria decision analysis and decision conferencing

Lawrence D. Phillips · Carlos A. Bana e Costa

Ann Oper Res (2007) 154: 51–68

Fig. 8 A social process for *decision conferencing*



PERGAMON

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Facilitating bid evaluation in public call for tenders: a socio-technical approach

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Abstract

A specific multicriteria socio-technical approach to facilitating bid evaluation processes is presented and several issues that warrant its use are discussed. Some real-world interventions in international public call for tenders illustrate practical aspects of structuring criteria and creating a computer-based additive value model in direct interaction with Evaluation Committees responsible for bid evaluation, supported by the MACBETH approach.

Keywords: Public call for tenders; Multicriteria bid evaluation; MACBETH; Real-world cases

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Development of Reusable Bid Evaluation Models for the Portuguese Electric Transmission Company

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Bid evaluation is the process of selecting a contractor from a number of bidders. The decision analysis models currently in use at the Portuguese Electric Transmission Company (REN) to evaluate bids were developed through a decision-conferencing process supported by the MACBETH multicriteria approach and software. This paper presents the various components of this interactive sociotechnical process. Given the number of contracts awarded by REN each year, it was crucial that the models be reusable in similar calls for tenders; this required substantial care in structuring the criteria, with a focus on constructed scales, and building value function models based on qualitative pairwise comparison judgments of difference in attractiveness. Also of particular interest is the approach for weighing benefits against costs.

Key words: bid evaluation; constructed scales; decision conferencing; MACBETH; model structuring; multicriteria weighting
History: Received on July 20, 2007. Accepted December 21, 2007, after 2 revisions.

Model-building tasks

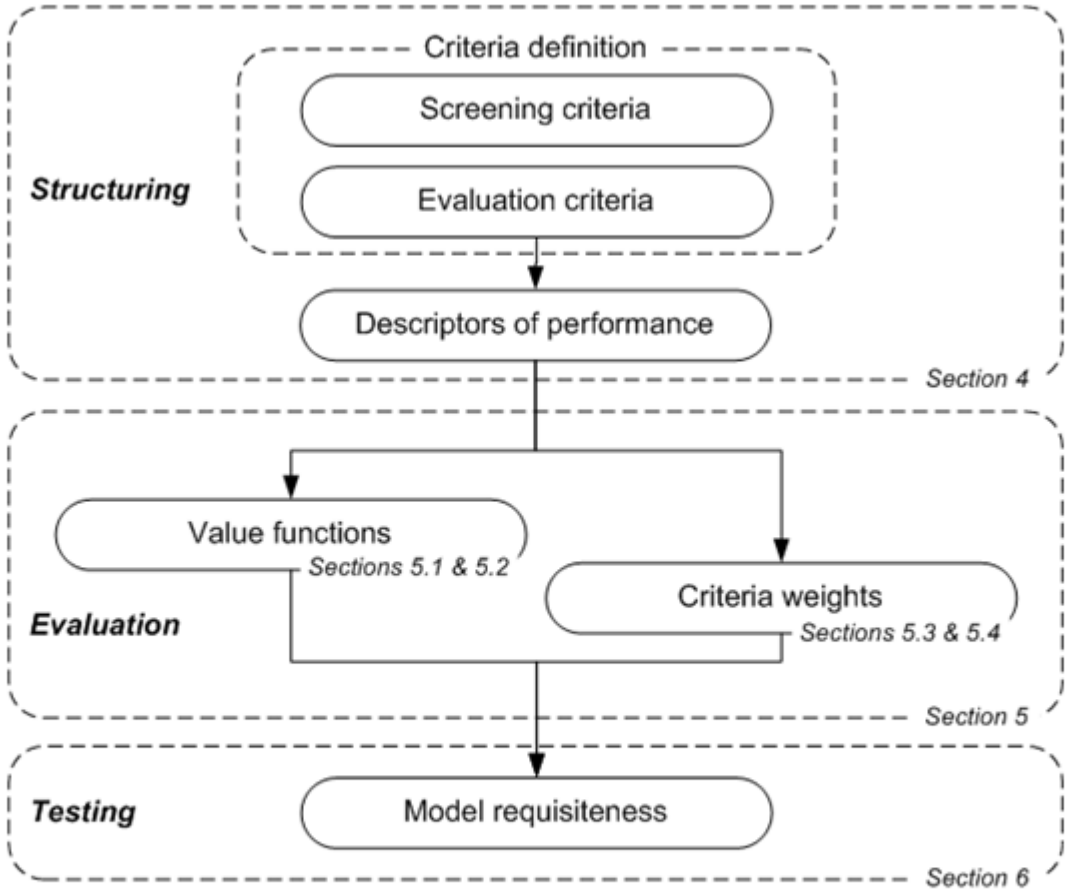
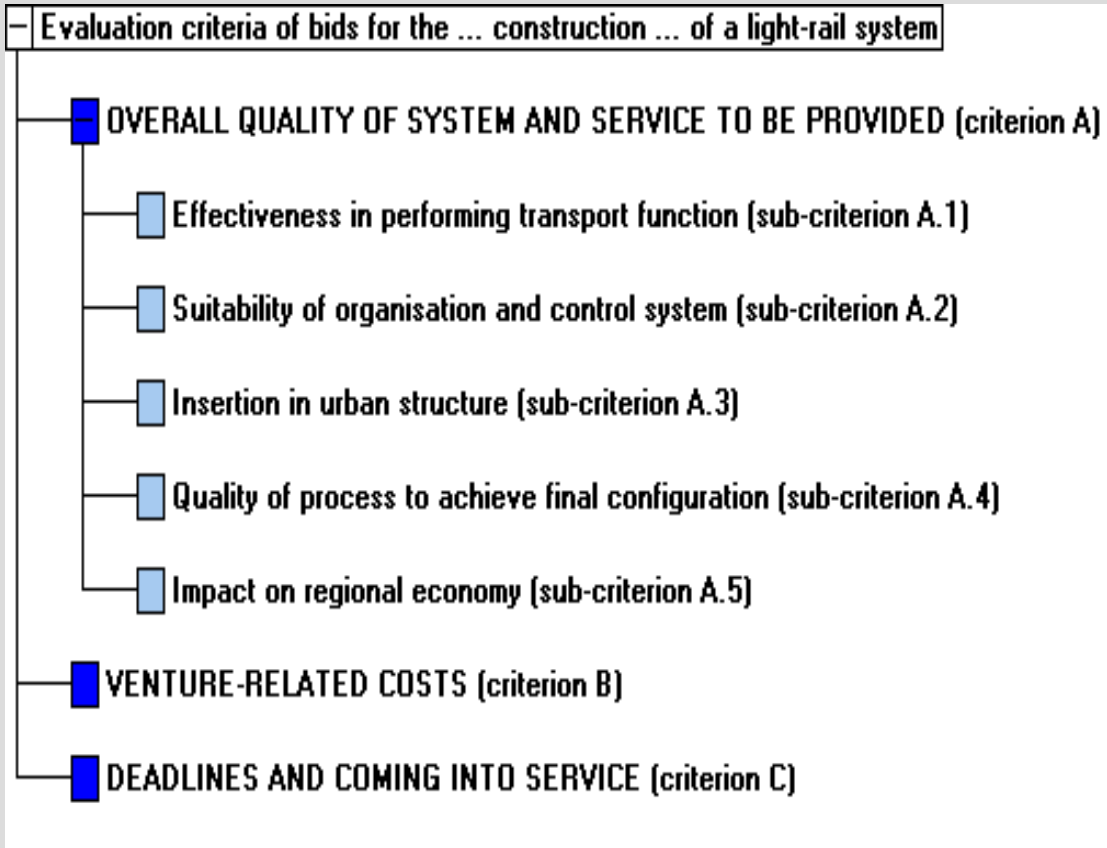


Figure 1. Model building tasks. The section where each task is presented in more detail is noted. Although the tasks shown are presented in a sequence it is possible to go back at any time to redefine or adjust what was previously done.

Structuring the evaluation criteria

The process of the "International Public Call for Tenders to award the design, construction, equipment, financing and short-term operation, of a light-rail system in the Metropolitan Area of Porto", issued by Metro do Porto, S.A. in 1996, took place in three stages: first stage—pre-qualification, second stage—selection and third stage—negotiation. We will now examine the second stage, in which the evaluation criteria were the ones displayed in Fig. 2a.

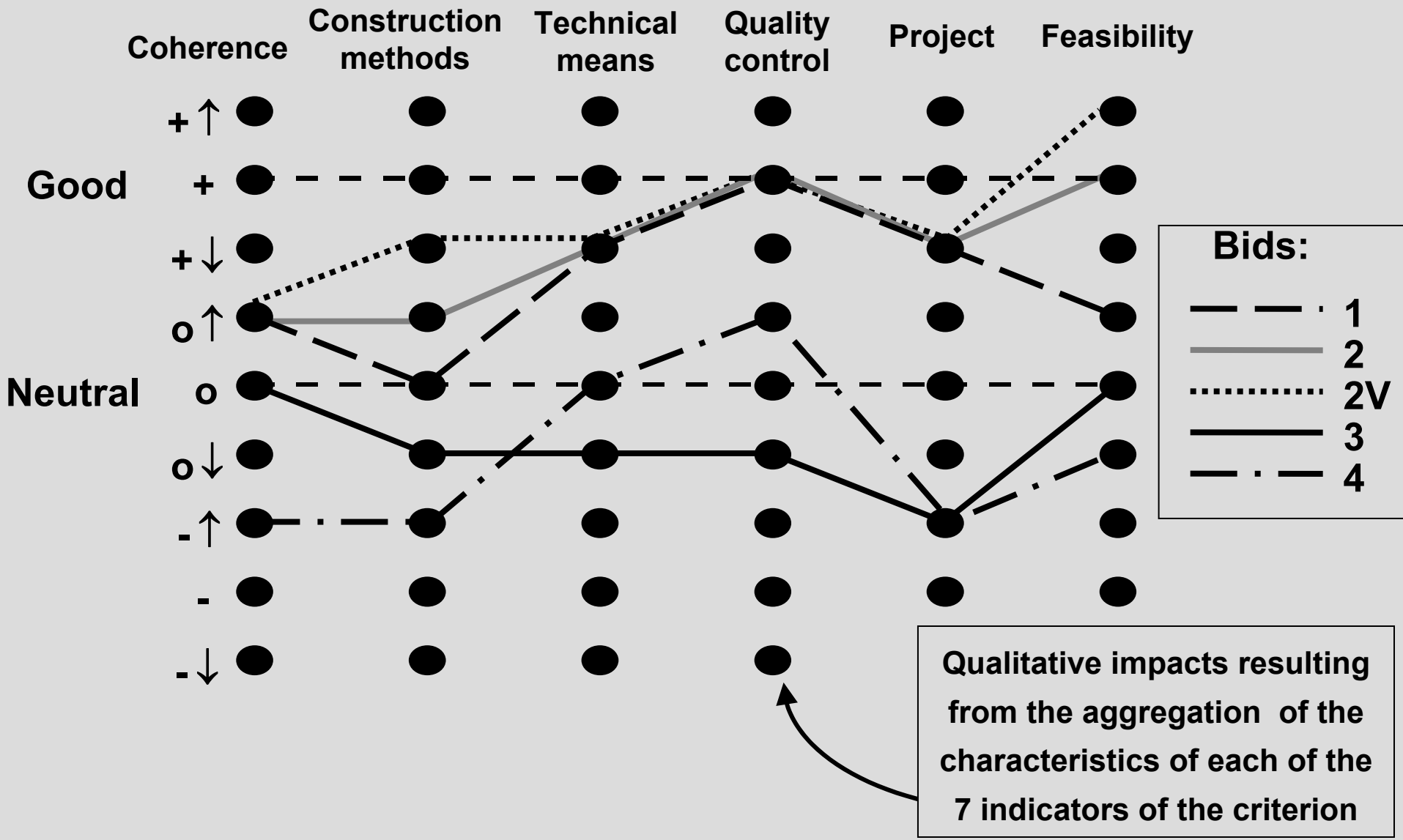


The task of the Evaluation Committee (composed of five engineers, one economist and one jurist) was to evaluate these bids and recommend which two bidders should be selected to move on to the third stage—negotiation.

Table 1
Example of a table of concerns (Metro do Porto S.A.)

Criteria	Sub-criteria	Indicators	Characteristics
Work methodology	Technical procedures	Project revision	Methodology
		Information management	System reliability
			Information back-up
			User friendship
			Root support for the MP document encryption scheme
			Location and access to archives
		Deadline management	Procedures for approval of work plans
			Databases
			Resource assignment control system
			Probability evaluation of deadline fulfilment
			Method followed in correcting deviations from plans
			Software used in deadline management
		Quality management	State of implementation of quality system in companies
			Appropriateness of proposed quality system
			Appropriateness of quality system implementation schedule
		Safety management	State of implementation of work safety system in firm
			Appropriateness of proposed work safety system
			Appropriateness of work safety system implementation schedule
		Costs control	Work costs database
			Cost prevision system
			Methodology to verify bills and quantities
			Methodology to establish new prices
			Price revision
			Cost-term interconnection
	Team organisation	Organisation chart	
		Team size	
		Diagram of personnel workload	
	Information flow	Process of information collection	
		Flowchart of information circuits	

Bids' profiles of impacts on the criterion "Bid's technical value and feasibility regarding the proposed constructive methods and the technical resources necessary to carry out the works"



Building the evaluation model

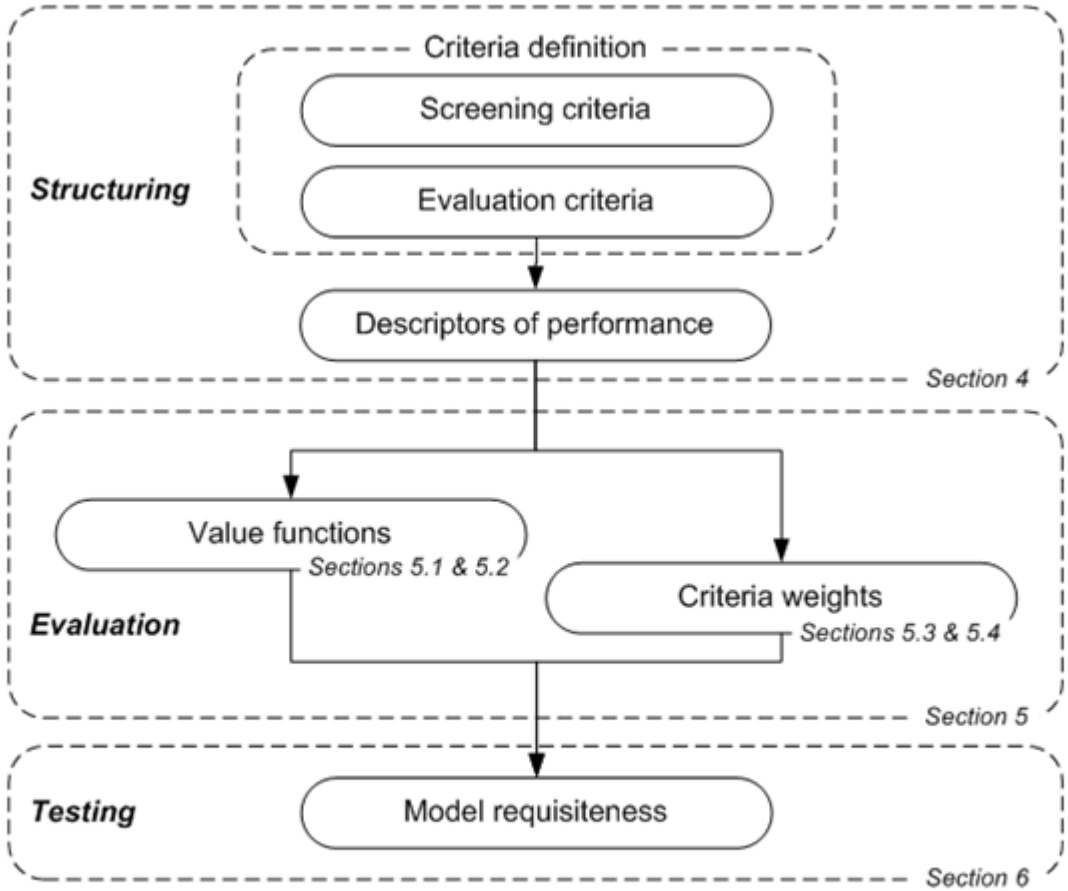


Figure 1. Model building tasks. The section where each task is presented in more detail is noted. Although the tasks shown are presented in a sequence it is possible to go back at any time to redefine or adjust what was previously done.

Non-numerical approach: MACBETH

Measuring **A**ttractiveness by a **C**ategorical **B**ased **E**valuation **T**ec**h**nique

An interactive pairwise comparison approach to guide the construction of a quantitative value model from qualitative value judgments

LATEST NEWS

- New training courses are now available (Belgium)

home

MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) is an interactive pairwise comparison approach to multiple criteria decision aid. It requires only qualitative judgements about differences in attractiveness to help an individual decision maker or a decision-advising group quantify the relative value of options. It employs an initial, interactive, questioning procedure that compares two elements at a time, requesting only a qualitative preference judgement.

As judgements are entered into the software, it automatically verifies their consistency. A numerical scale is generated that is entirely consistent with all the qualitative judgements. Through a similar process weights are generated for criteria.

The M-MACBETH software provides tools to facilitate:

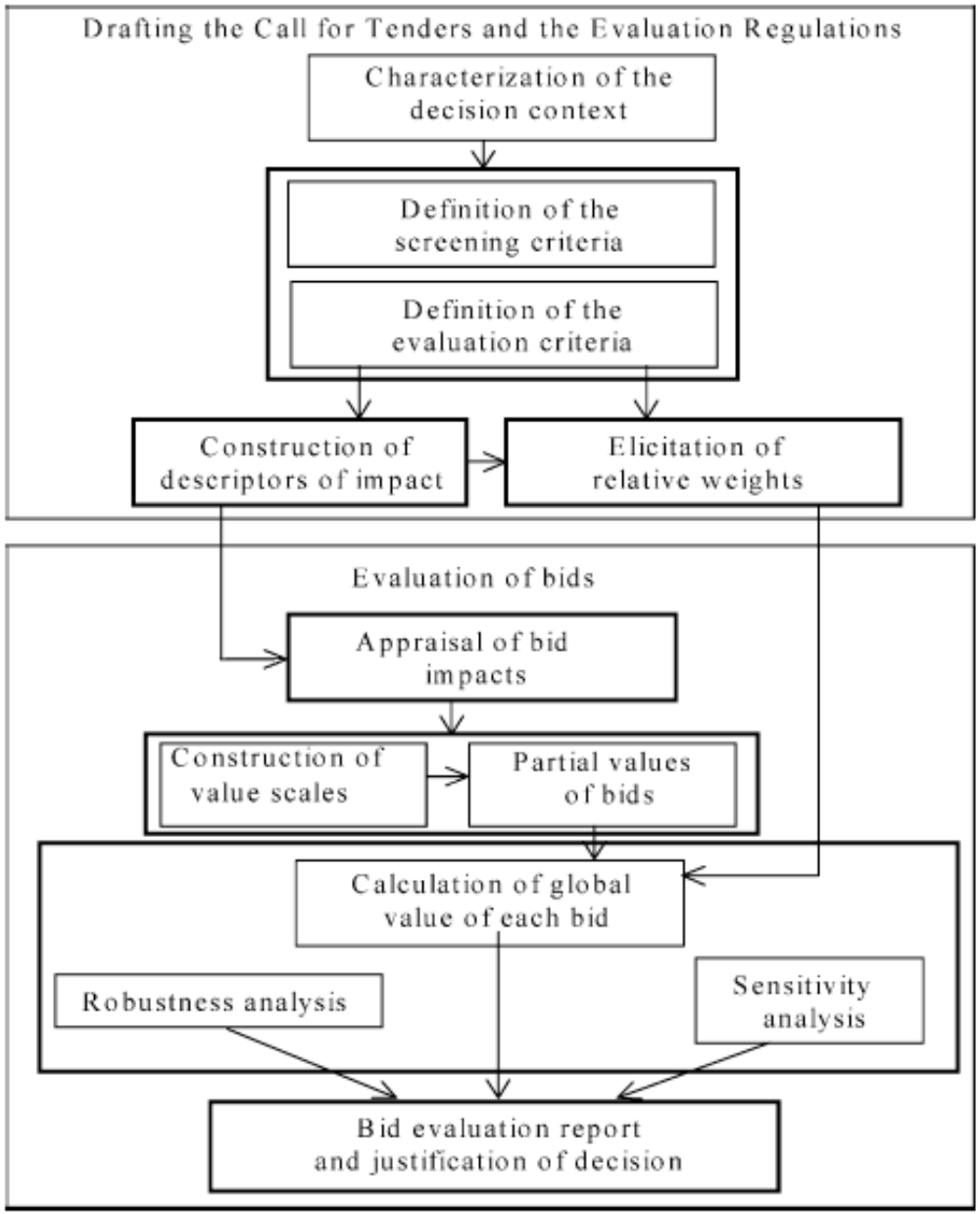
- Complete model structuring
- Management of complex problems involving qualitative value scores and weights
- Interactive sensitivity and robustness analyses

the designers of MACBETH are:

Carlos Bana e Costa	Jean Marie De Corte	Jean-Claude Vansnick
Technical University of Lisbon and London School of Economics	University of Mons-Hainaut Belgium	University of Mons-Hainaut Belgium

Applications

- Development of Strategic plans
- Allocation of resources
- Comparison of alternative locations for development of major infrastructures
- Participative evaluation of social, economic and environmental impacts of major infrastructures
- Resolution of horizontal and vertical conflict in when implementing public policy
- Analysis of cost, benefit and risk associated with projects and programs
- Evaluation of employee performance
- Evaluation of supplier performance
- Evaluation of bids in public calls for tenders
- Development of risk models and scenario analysis


Drafting the Call for Tenders and the Evaluation Regulations
Characterization of the decision context
Definition of the screening criteria
Definition of the evaluation criteria
Construction of descriptors of impact
Elicitation of relative weights
Evaluation of bids
Appraisal of bid impacts
Construction of value scales
Partial values of bids
Calculation of global value of each bid
Robustness analysis
Sensitivity analysis
Bid evaluation report and justification of decision

Example: Suppose there are three bids B1, B2 and B3

- Bids should be ranked according to their relative attractiveness in each criterion

B2 preferred to B1 preferred to B3

- Is ranking by relative attractiveness enough to know if the most attractive bid is good or bad? For this purpose, references of intrinsic value can be defined

B2 → Good → B1 → B3 → Neutral

- In each criterion, one wants to know not only if one bid is more attractive than another but also by how much

How does it work?

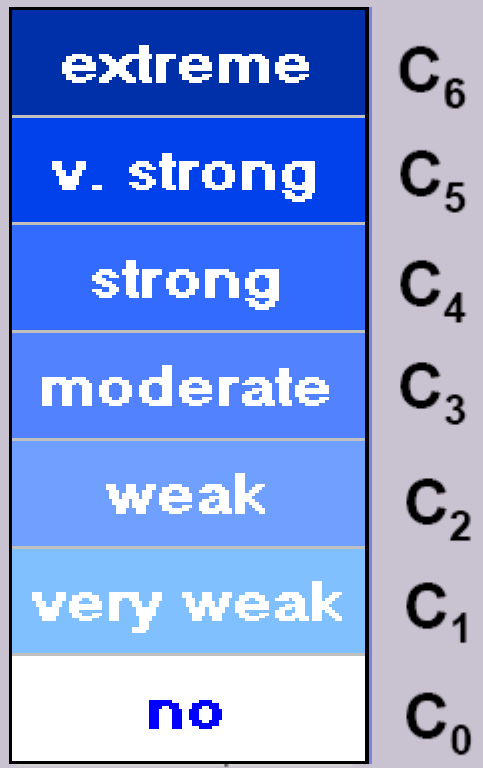
MACBETH uses a simple question-answer protocol

that involves only two options in each question:

Ask the evaluator to pairwise compare options
by given a *qualitative* judgement
of the difference in attractiveness
between each two options

For x and y such that
x is preferred to y,
the difference in attractiveness
between x and y is:

MACBETH semantic categories of difference of attractiveness:



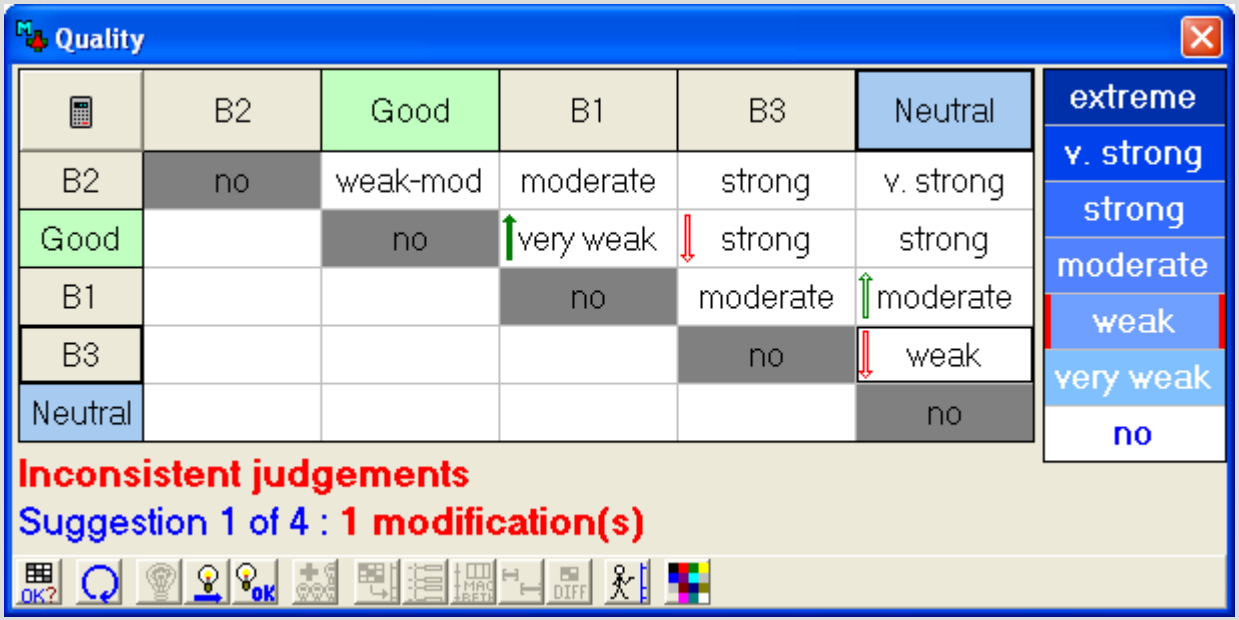
Note: the 'weak', 'strong' and 'extreme' were initially called the fundamental categories, but the M-MACBETH software that implements the MACBETH approach does not make this distinction and even allows for group judgments that do not distinguish between several consecutive categories, such as 'strong or very strong'.

How many judgements?

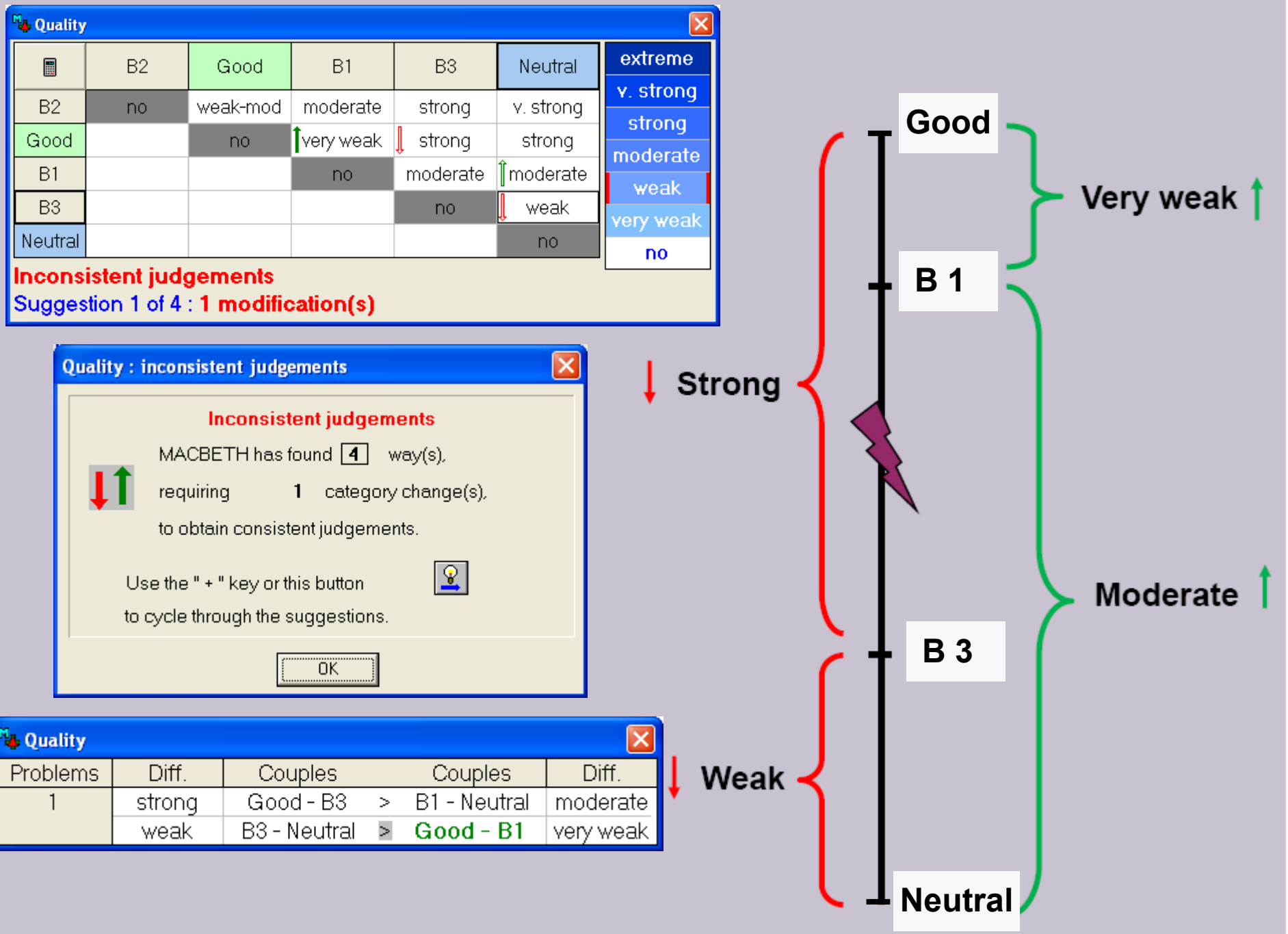
For a set X of m options, the number of pairwise comparisons can vary from a maximum of m(m-1)/2 judgments, when all pairwise comparisons are made, to a minimum acceptable number of m–1 judgments, as when comparing only each two consecutive options in the ranking or one option with all of the other m–1 (however, it is recommended to ask for some additional judgments to perform several consistency checks).

Assessing MACBETH intracriterion preference information

As each judgement is entered in the matrix, its consistency with the judgments already inserted is checked and possible inconsistencies are detected.



if an inconsistency is detected, suggestions to overcome it are presented. Technically, this is done by a mathematical programming algorithm (see Bana e Costa et al. 2005 for details).


Quality
B2
Good
B1
B3
Neutral
B2 no weak-mod moderate strong v. strong
Good no very weak strong strong
B1 no moderate moderate
B3 no weak
Neutral no
extreme
v. strong
strong
moderate
weak
very weak
no
Inconsistent judgements
Suggestion 1 of 4 : 1 modification(s)
Quality : inconsistent judgements
Inconsistent judgements
MACBETH has found 4 way(s),
requiring 1 category change(s),
to obtain consistent judgements.
Use the " + " key or this button
to cycle through the suggestions.
OK
Quality
Problems
Diff.
Couples
Couples
Diff.
1
strong Good - B3 > B1 - Neutral moderate
weak B3 - Neutral > Good - B1 very weak
Strong
Weak
Good
B 1
B 3
Neutral
Very weak
Moderate
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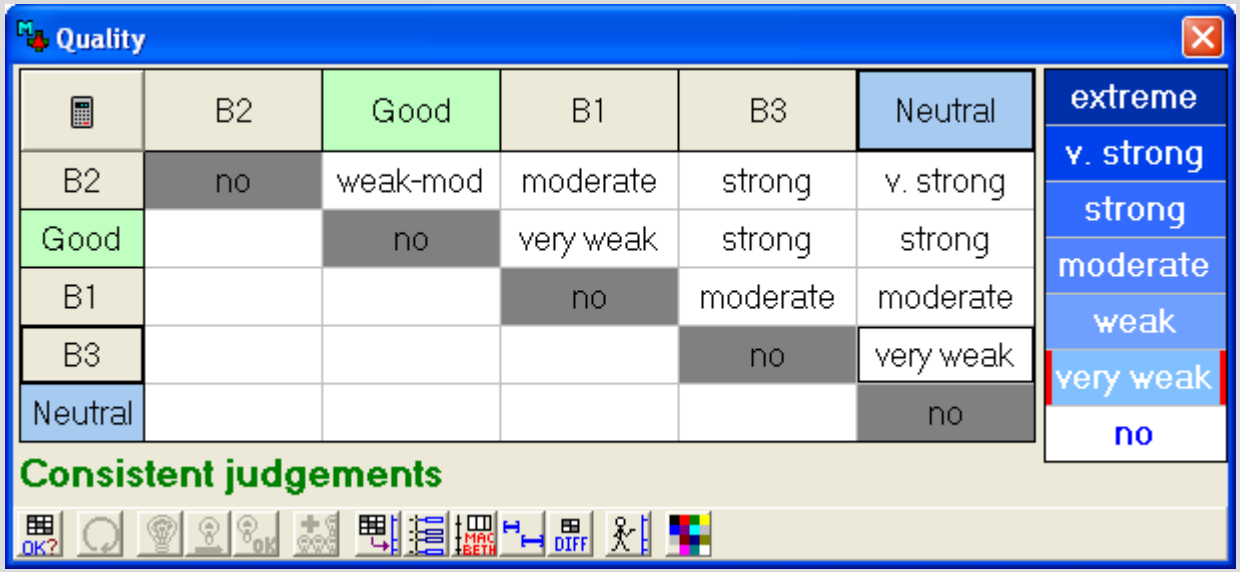
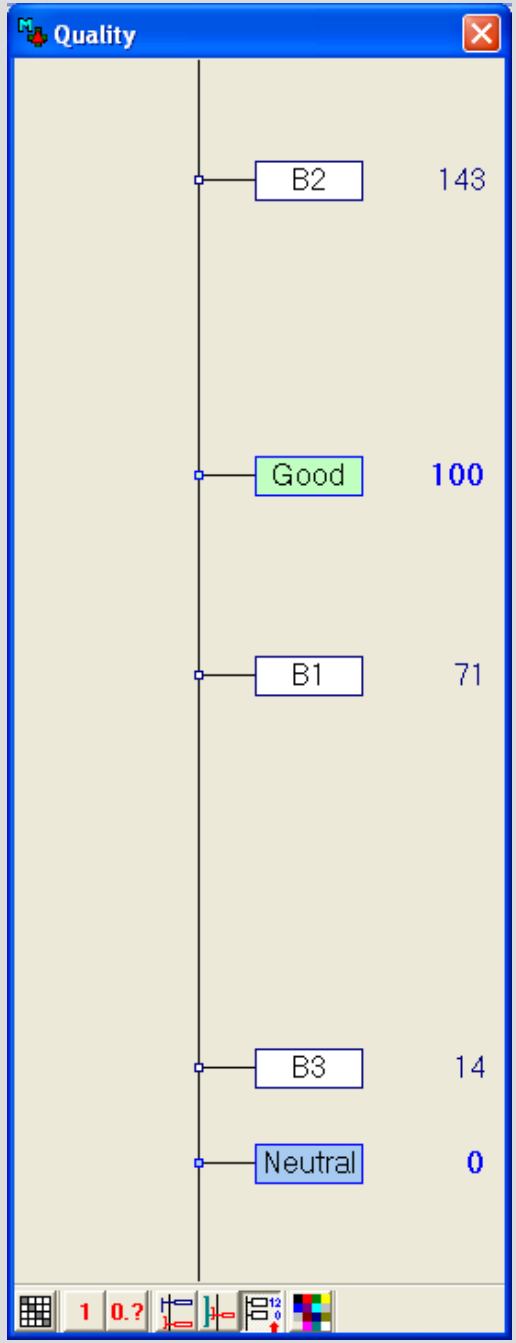




For a set of consistent judgements, MACBETH suggests a <u>numerical scale</u> v on X that satisfies the following measurement rules:

<u>Rule 1</u>

$\forall\ x, y \in X : v(x) = v(y)$ *iff* x and y are equally attractive

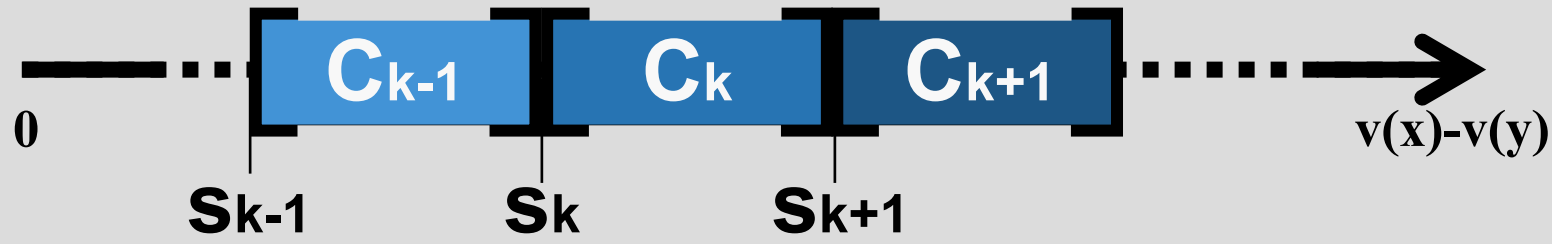
$\forall\ x, y \in X : v(x) > v(y)$ *iff* x is more attractive than y;

<u>Rule 2</u>

$\forall\ k, k' \in \{1, 2, 3, 4, 5, 6\}, \forall\ x, y, w, z \in X,$

with $(x, y) \in C_k$ and $(w, z) \in C_{k'}$:

$$k \geq k' + 1 \Rightarrow v(x) - v(y) > v(w) - v(z)$$



If x and y are indifference ("no" difference) :

$$v(x) - v(y) = 0$$

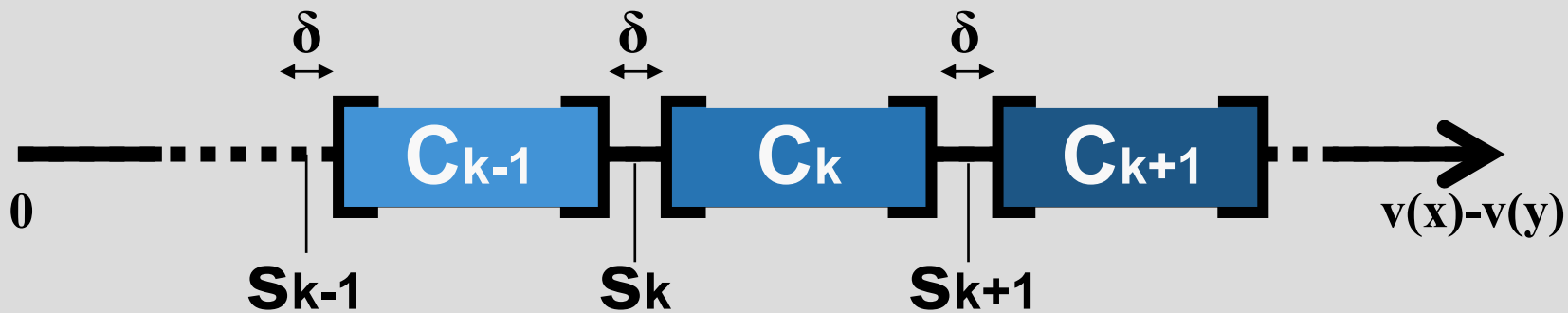
If $(x, y) \in C_k$ **and** $(w, z) \in C_{k'}$ $(k > k')$ **:**

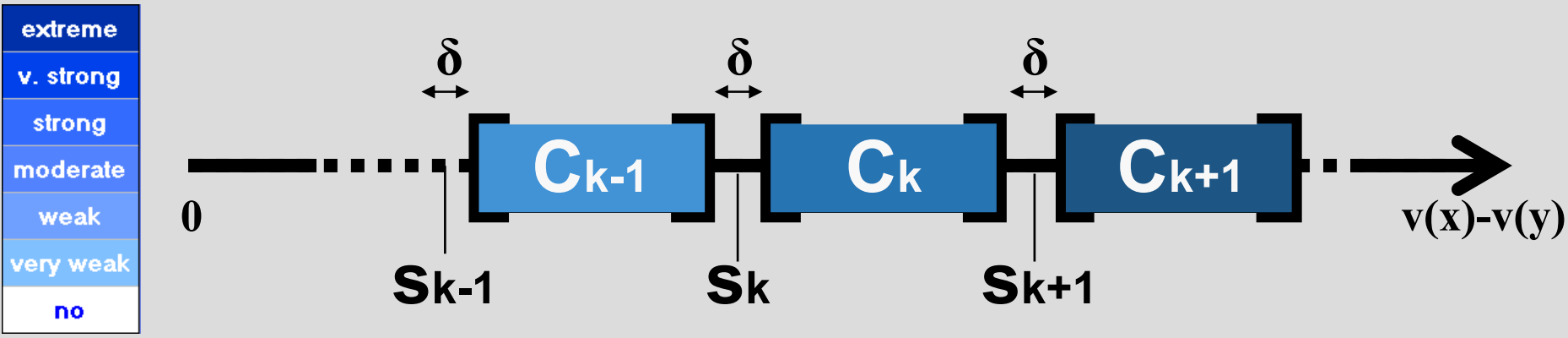
$$[v(x) - v(y)] > [v(w) - v(z)]$$

that is $[v(x) - v(y)] - [v(w) - v(z)] > 0$

or $[v(x) - v(y)] - [v(w) - v(z)] \geq \delta \quad (\delta > 0)$

Thus, δ is the minimal difference between two categories



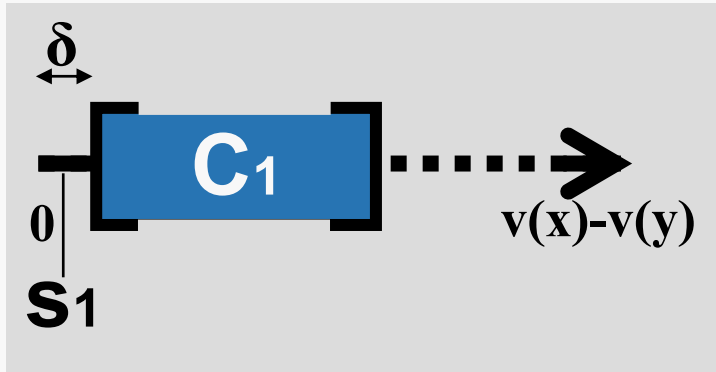


$(x, y) \in C_k$ $(k = 1$ to $5)$:

$$[v(x) - v(y)] \geq S_k + \delta/2$$

and $[v(x) - v(y)] \leq S_{k+1} - \delta/2$

$(x, y) \in C_6$: $[v(x) - v(y)] \geq S_6 + \delta/2$



Moreover $S_1 = \delta/2$ because:

For $(x, y) \in C_1$:

$[v(x) - v(y)] \geq S_1 + \delta/2$ and $v(x) - v(y) \geq \delta$ implies $S_1 = \delta/2$

Quality

	B2	Good	B1	B3	Neutral
B2	no	weak-mod	moderate	strong	v. strong
Good		no	very weak	strong	strong
B1			no	moderate	moderate
B3				no	very weak
Neutral					no

Consistent judgements

We also want to make the judgments of the same category as close as possible to each other, therefore one should minimize the sum of all the differences of value, that is, to minimize the maximal difference of value, that is, to minimize the score of the best option.

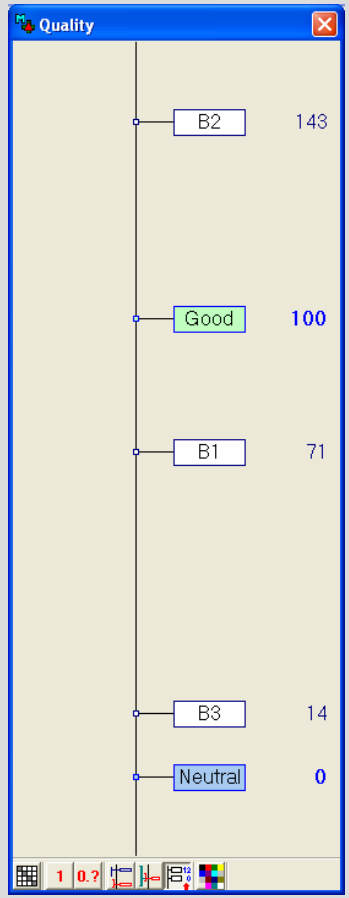
For a set of consistent judgements the MACBETH scale is obtained by linear program that minimizes the score of the best option subject to the above constraints (with δ = 1).

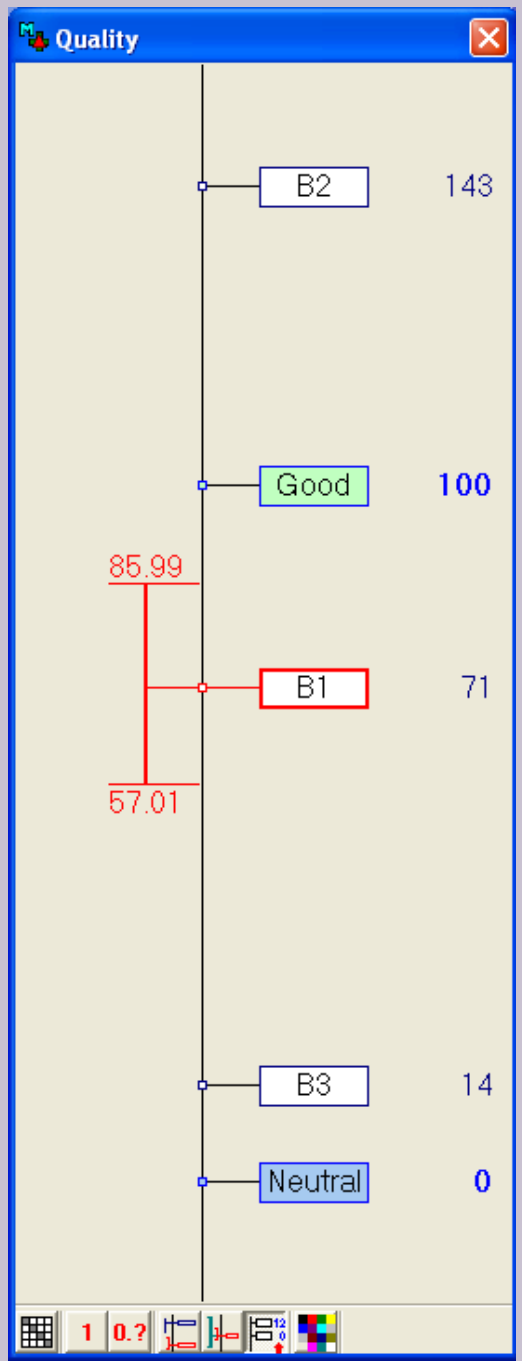
Quality

	Current scale	MACBETH anchored	MACBETH basic
B2	143	142.86	10.00
Good	100	100.00	7.00
B1	71	71.43	5.00
B3	14	14.29	1.00
Neutral	0	0.00	0.00

Quality

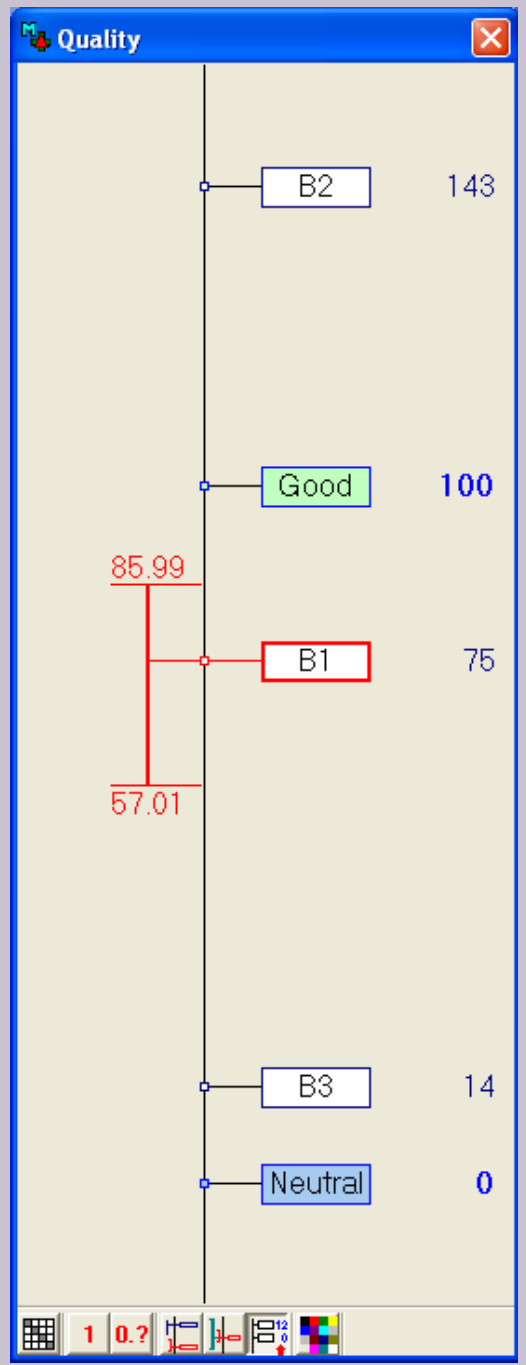
0	no	0 0
1	very weak	14.29 28.57
2	weak	
3	moderate	57.14 71.43
4	strong	85.71 128.57
5	v. strong	142.86 142.86





The software determines the interval within which each score of each option can vary when the other *m*-1 scores are fixed and still remain compatible with the matrix of judgments.

This allows the adjustment of the scale by comparing differences of scores, to arrive to a cardinal scale.



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A career choice problem: An example of how to use MACBETH to build a quantitative value model based on qualitative value judgments

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Abstract

MACBETH (measuring attractiveness by a categorical based evaluation technique) is an approach designed to build a quantitative model of values, developed in a way that enables facilitators to avoid forcing decision makers to produce direct numerical representations of their preferences. MACBETH employs a non-numerical interactive questioning procedure that compares two stimuli at a time, requesting only a qualitative judgment about their difference of attractiveness. As the answers are given, their consistency is verified, and a numerical scale that is representative of the decision maker's judgments is subsequently generated and discussed. This paper makes use of the MACBETH approach and software to help an individual select his future career from a number of self-imposed possibilities. A comparison is made with the direct numerical technique SMART, previously used with the same intent.

Keywords: MACBETH; Case-study; Multi-criteria decision analysis; Decision support system

"Behind" M-MACBETH

	A	B	C	D
A		Very Weak	Moderate	Very Strong
B			Moderate	Strong
C				Strong
D				

Extreme	6
Very Strong	5
Strong	4
Moderate	3
Weak	2
Very Weak	1

"Behind" M-MACBETH

	A	B	C	D
A		Very Weak 1	Moderate	Very Strong
B			Moderate 3	Strong
C				Strong 4
D				

Extreme	6
Very Strong	5
Strong	4
Moderate	3
Weak	2
Very Weak	1

"Behind" M-MACBETH

	A	B	C	D
A		Very Weak 1	Moderate 4	Very Strong
B			Moderate 3	Strong
C				Strong 4
D				

Extreme	6
Very Strong	5
Strong	4
Moderate	3
Weak	2
Very Weak	1

$$v(A)-v(C) = v(A)-v(B) + v(B)-v(C)$$

"Behind" M-MACBETH

	A	B	C	D
A		Very Weak 1	Moderate 4	Very Strong
B			Moderate 3	Strong
C				Strong 4
D				

Extreme	6
Very Strong	5
Strong	4
Moderate	3
Weak	2
Very Weak	1

$v(A)-v(C) < v(C)-v(D)$

"Behind" M-MACBETH

	A	B	C	D
A		Very Weak 1	Moderate 4	Very Strong
B			Moderate 3	Strong
C				Strong 5
D				

Extreme	7
Very Strong	6
Strong	5
Moderate	3-4
Weak	2
Very Weak	1

Increase v(C)-v(D) of 1

"Behind" M-MACBETH

	A	B	C	D
A		Very Weak 1	Moderate 4	Very Strong
B			Moderate 3	Strong 8
C				Strong 5
D				

Extreme	10
Very Strong	9
Strong	5-8
Moderate	3-4
Weak	2
Very Weak	1

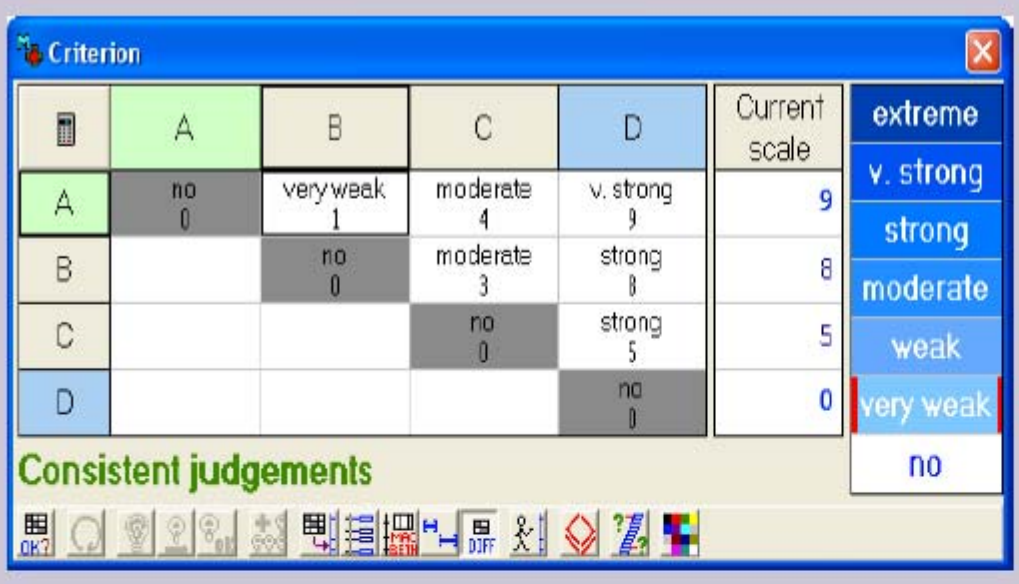
$$v(B)-v(D) = v(B)-v(C) + v(C)-v(D)$$

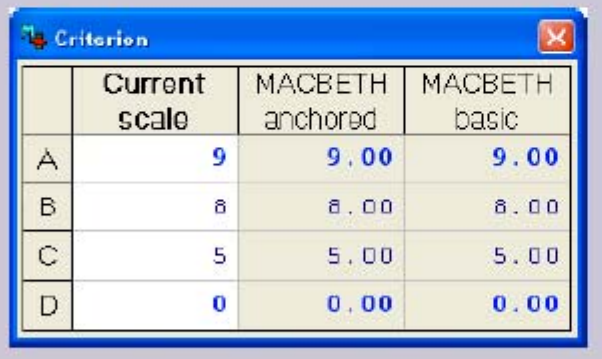
"Behind" M-MACBETH

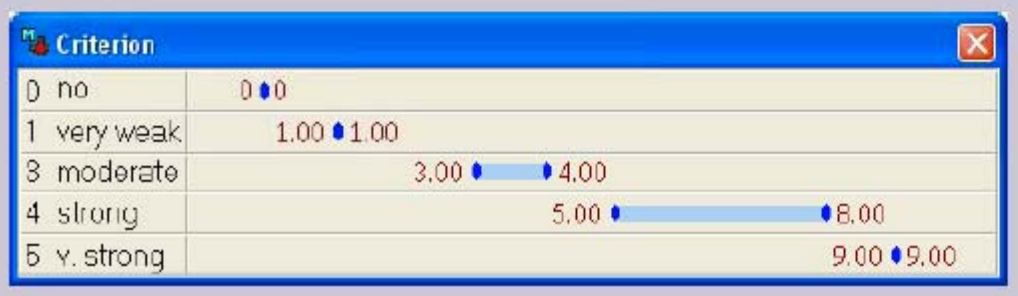
	A	B	C	D
A	no	Very Weak 1	Moderate 4	Very Strong 9
B		no	Moderate 3	Strong 8
C			no	Strong 5
D				no

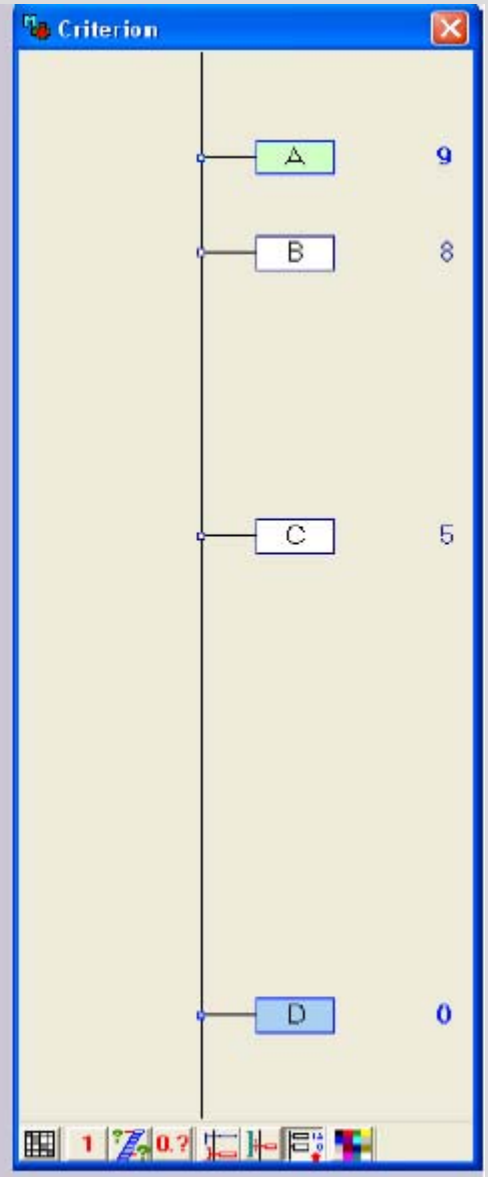
Extreme	10
Very Strong	9
Strong	5-8
Moderate	3-4
Weak	2
Very Weak	1

$$v(A)-v(D) = v(A)-v(B) + v(B)-v(C)+ + v(C)-v(D)$$









Use the hand-procedure to find the MACBETH scale for the 3 bids example (with B2 weakly preferred to Good)

Quality

	B2	Good	B1	B3	Neutral
B2	no	weak	moderate	strong	v. strong
Good		no	very weak	strong	strong
B1			no	moderate	moderate
B3				no	very weak
Neutral					no

Consistent judgements

Weighting the evaluation criteria:

There are some methodological and technical restrictions that must be taken into account in using MCDA in public call for tenders contexts.

One is that the awarding authority is legally obliged to publish, in the announcement of the call for tenders, the evaluation criteria and their respective weights.

Weighting must therefore take place before the bids are know.

Modelling question: How to ensure that the weighting procedure simultaneously respects the legal requirement and the theoretical conditions of the additive aggregation model?

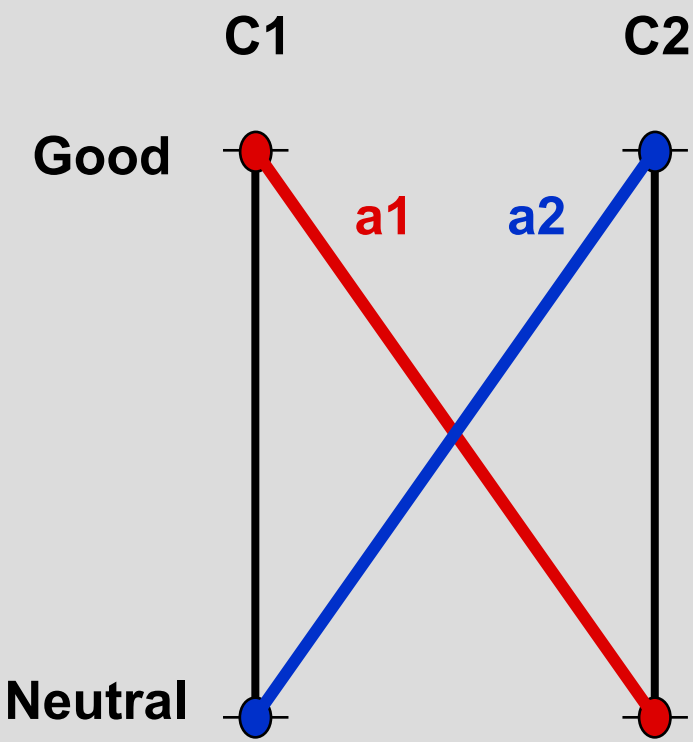
Answer: Define two references of intrinsic value in each one of the criteria, such as “good” and “neutral” levels of performance.

Good and neutral levels of performance:

Our experience has revealed that
expending the effort required to identify what is
a good (unquestionably attractive) performance
and
a neutral (neither attractive nor unattractive) performance
contributes significantly
to the intelligibility of the respective criterion.

And it allows the weighting of criteria in a theoretical sound way (particularly, the assessment of weights for bid evaluation before the bids are known) thus avoiding the ‘most common critical mistake’ (Keeney, 1992).

Weighting judgment



Q. Is one of the reference options, read or blue, more attractive than the other?

A. Red is more attractive than blue.

Q. The difference of attractiveness between them is
very weak
weak
moderate
strong
very strong
extreme

A. Moderate

Example of weighting references for a cost criterion:

GOOD

A bid cost with a global present value equal to € 0.6X

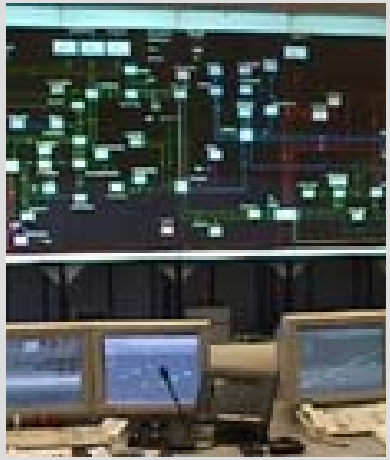
NEUTRAL

A bid cost with a global present value equal to € X

The client

Rede Eléctrica Nacional. S.A.

Portuguese Electric Transmission Company



The problem

Every week, REN launches several calls for tenders:

- Construction of:
  - New power lines
  - Up-rating of existing lines
  - Electrical facilities
- Supplying of:
  - Equipments
  - Systems of power substations
- Development of engineering projects

The problem

The REN board asked for the collaboration of a MACBETH Team (C.A. Bana e Costa, J. Lourenço, J. Costa) to revise the bids evaluation system that was in use at the company.

Diagnosis

Arbitrary hierarchical average sum of direct scores of bids, using an evaluation grid

- Scores taken as weights and weights taken as scores
- Weights of criteria based on direct judgements of relative importance:

"*The most common critical mistake*" *(Keeney, 1992)*

Therapy

Rebuild the evaluation system entirely!

Bana e Costa, C.A., Lourenço, J.C., Chagas, M.P., Bana e Costa, J.C. (2008), "Development of reusable bid evaluation models for the Portuguese Electric Transmission Company", *Decision Analysis*, 5, 1 (22-42).

Benefit criteria

Constructing descriptors

Define two levels of performance “good” and “neutral”

Name : Methodology and critical points for deployment

Short name : MCPD

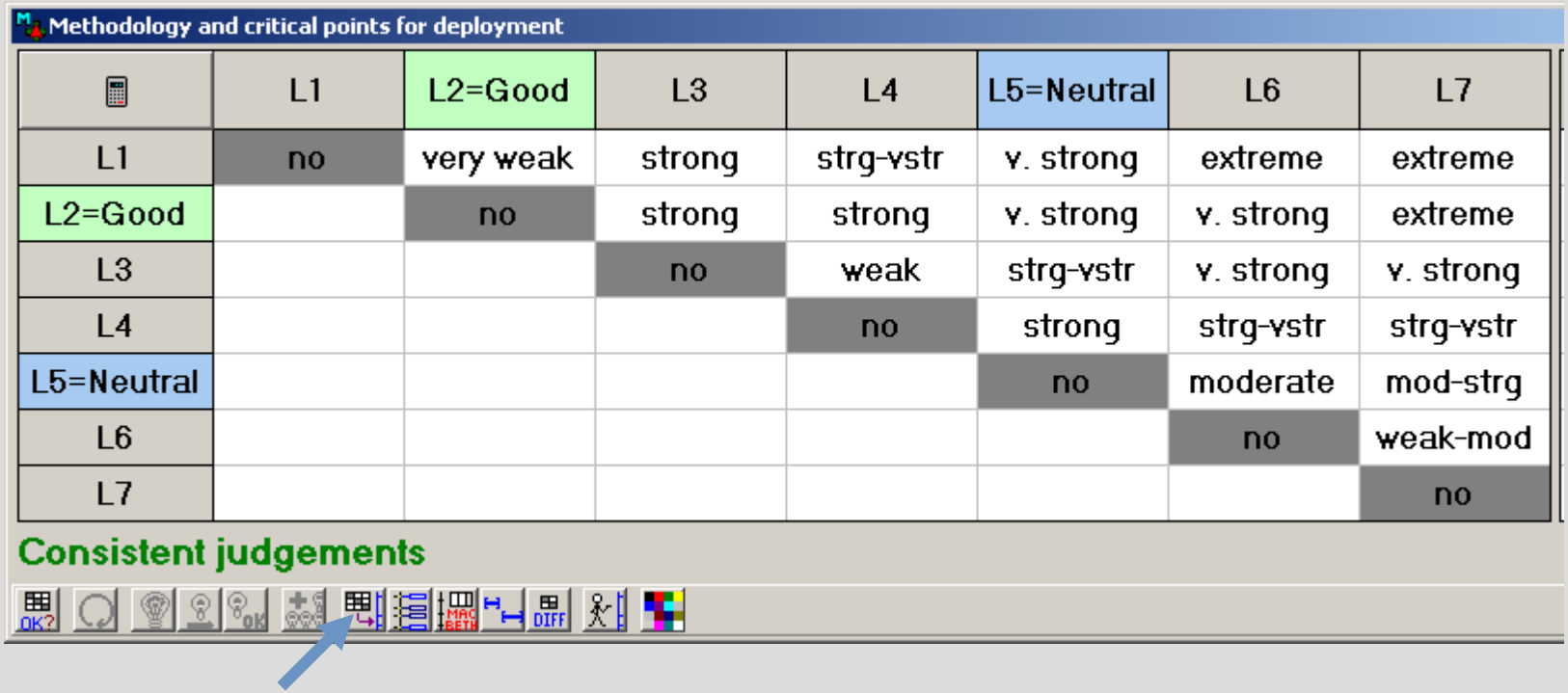
Generic methodology, identifies critical issues and proposes solutions	Good
Detailed methodology, does not identified critical issues	Neutral

Add more levels, covering the plausible range of performances.

Describe each performance level carefully, clearly and unambiguously

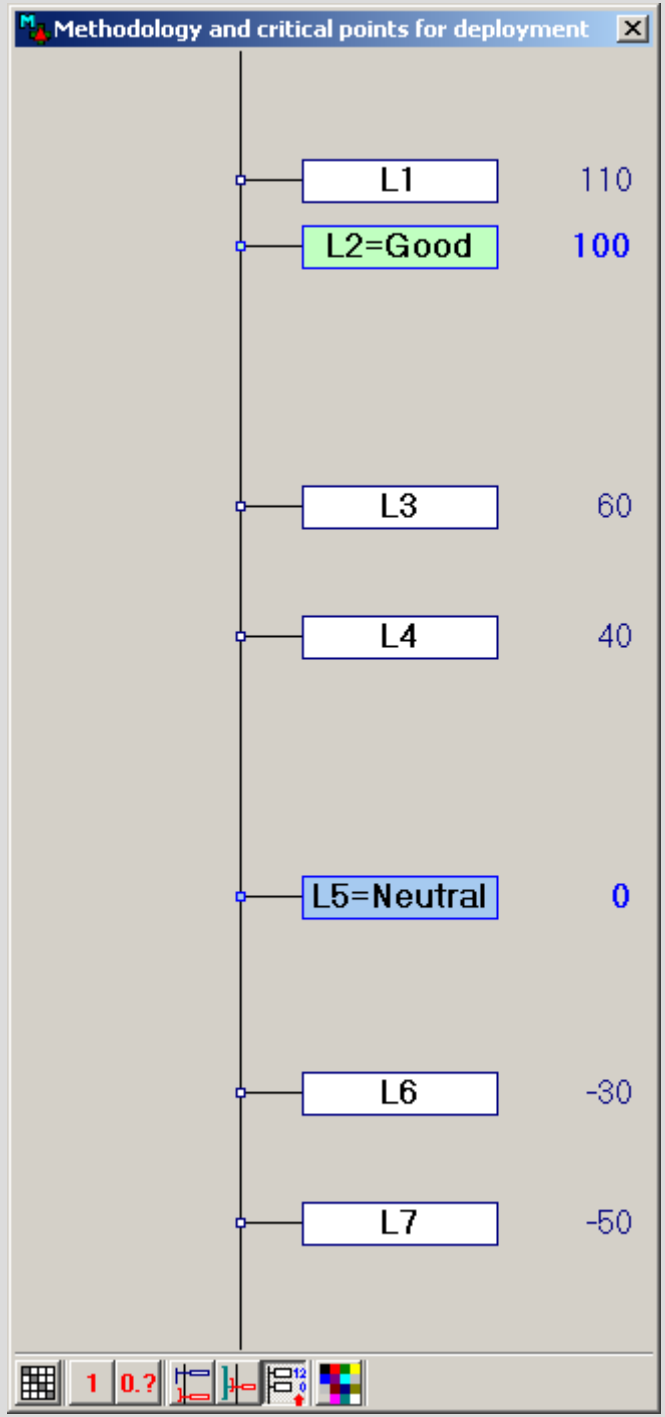
Detailed methodology: identifies critical issues and propose solutions	L1
Generic methodology: identifies critical issues and propose solutions	L2=Good
Detailed methodology: identifies critical issues but does not propose soluti	L3
Generic methodology: identifies critical issues but does not propose solutic	L4
Detailed methodology: does not identify critical issues	L5=Neutral
Generic methodology: does not identify critical issues	L6
The methodology is not explained	L7

Building a value function



	L1	L2=Good	L3	L4	L5=Neutral	L6	L7
L1	no	very weak	strong	strg-vstr	v. strong	extreme	extreme
L2=Good		no	strong	strong	v. strong	v. strong	extreme
L3			no	weak	strg-vstr	v. strong	v. strong
L4				no	strong	strg-vstr	strg-vstr
L5=Neutral					no	moderate	mod-strg
L6						no	weak-mod
L7							no

Building a value function



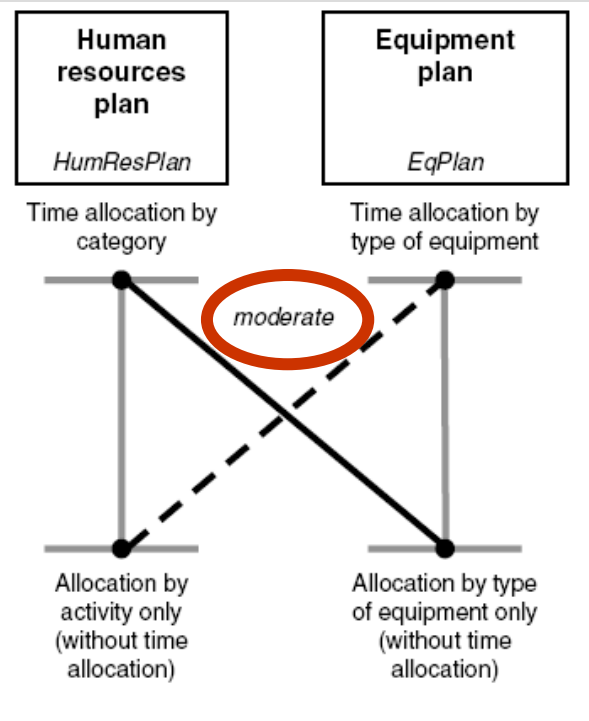
Weighting the benefit criteria

Rank and pairwise compare the fictitious options

Weighting references

Overall references
[ExecProg]
[MCPD]
[HumResPlan]
[EqPlan]
[SupplyConstr]
[ValueAdded]
Neutral all over

SupplyConstr	ValueAdded	EqPlan	MCPD	HumResPlan	ExecProg
L1=Good	L1	L1	L1	L1	L1=Good
L2=Neutral	L2=Good	L2++	L2=Good	L2=Good	L2
L3	L3	L2+	L3	L3	L3=Neutral
L4	L4=Neutral	L2=Good	L4	L4	L4
		L3	L5=Neutral	L5=Neutral	
		L4=Neutral	L6	L6	
		L4/L5	L7		
		L5			



Weighting (Overall)

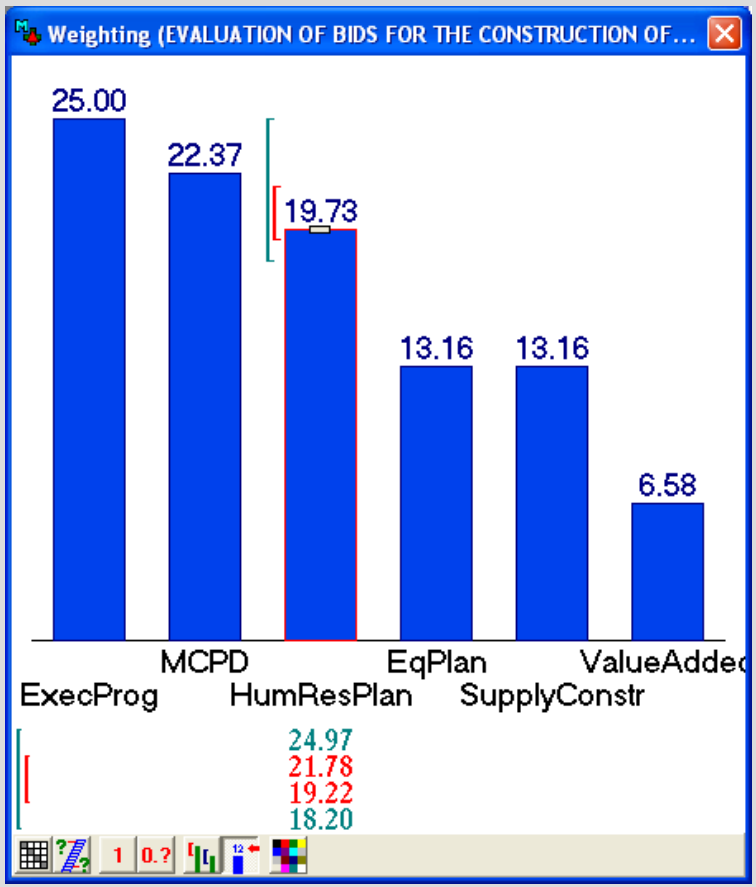
	[ExecProg]	[MCPD]	[HumResPlan]	[EqPlan]	[SupplyConstr]	[PlusValues]	Neutral allover
[ExecProg]	I	weak	weak	strong	strong	v. strong	vstrg-extr
[MCPD]		I	weak	P	P	P	v. strong
[HumResPlan]			I	moderate	P	P	v. strong
[EqPlan]				I	I	P	strong
[SupplyConstr]				I	I	moderate	strong
[PlusValues]						I	moderate
Neutral allover							I

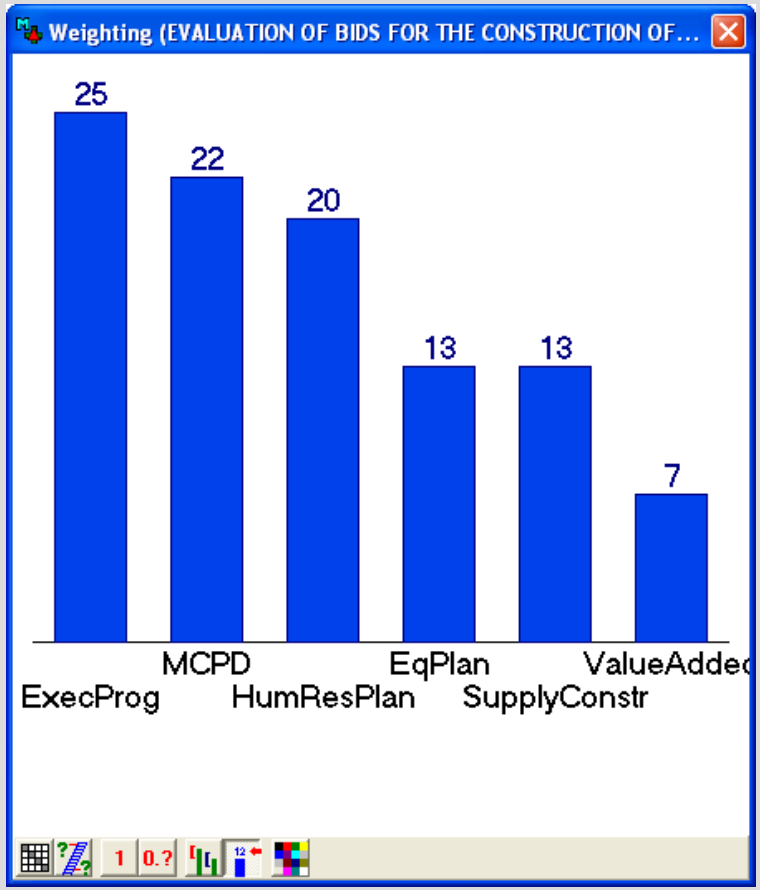
extreme
v. strong
strong
moderate
weak
very weak
no

Consistent judgements

Weighting the benefit criteria

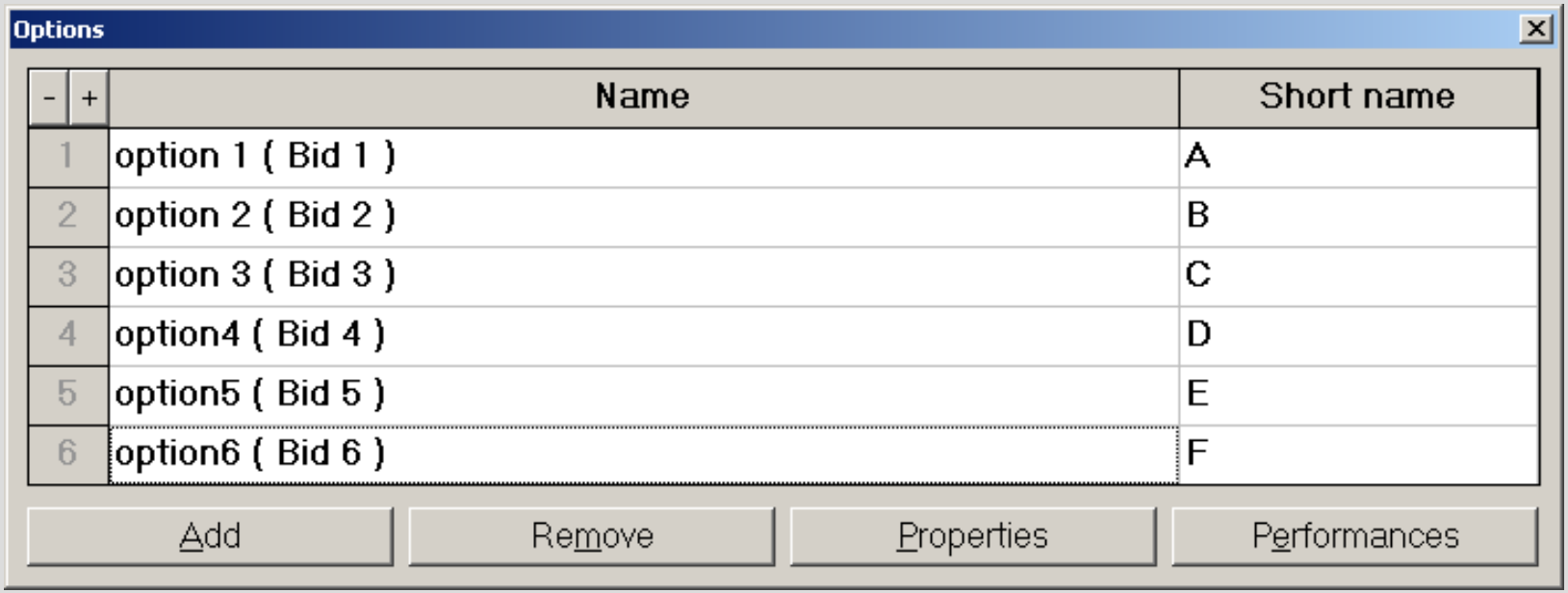
3. Discuss and adjust the MACBETH weights





Using the model

Enter the options (bids) in the MACBETH model



Using the model

For each criterion, enter option's performance into the model

Name : Methodology and critical points for deployment

Short name : MCPD

Detailed methodology; identifies critical issues and propose solutions	L1
Generic methodology; identifies critical issues and propose solutions	L2=Good
Detailed methodology; identifies critical issues but does not propose soluti	L3
Generic methodology; identifies critical issues but does not propose solutic	L4
Detailed methodology; does not identify critical issues	L5=Neutral
Generic methodology; does not identify critical issues	L6
The methodology is not explained	L7

Table of performances

Options	MCPD
A	L5=Neutral
B	L4
C	L2=Good
D	L6
E	L1
F	L3

Using the model

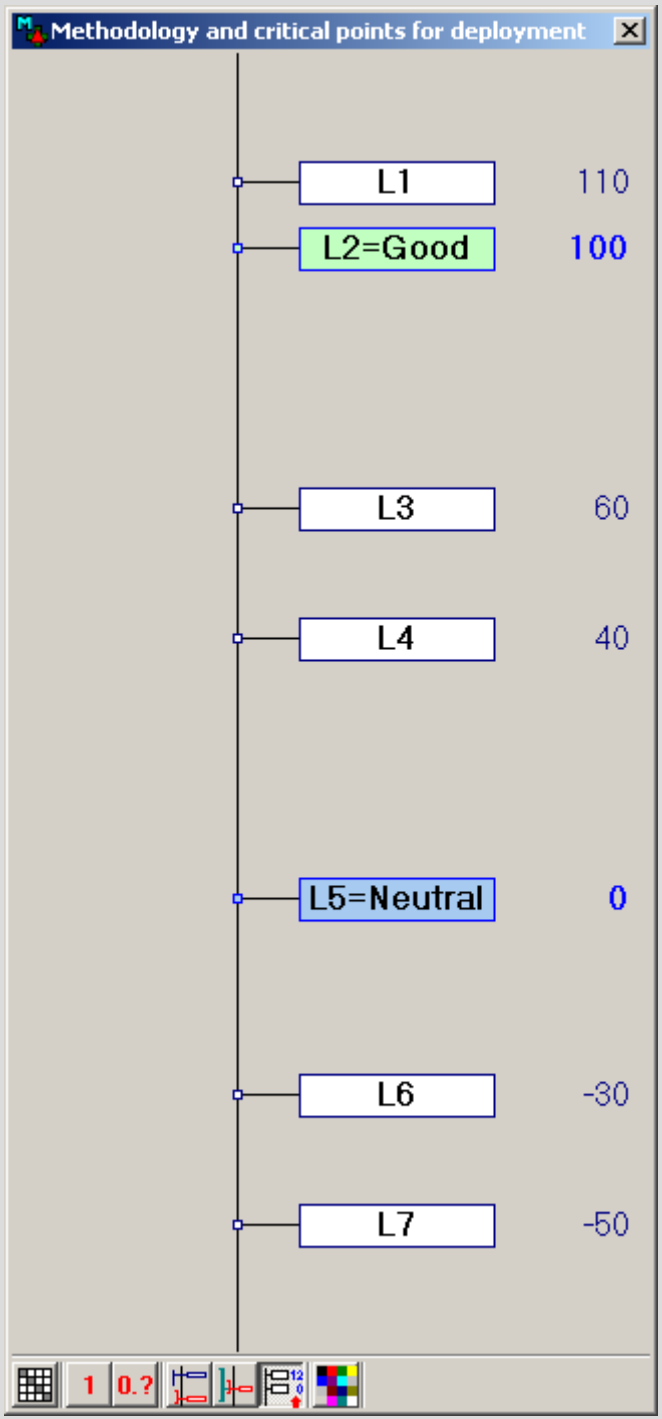


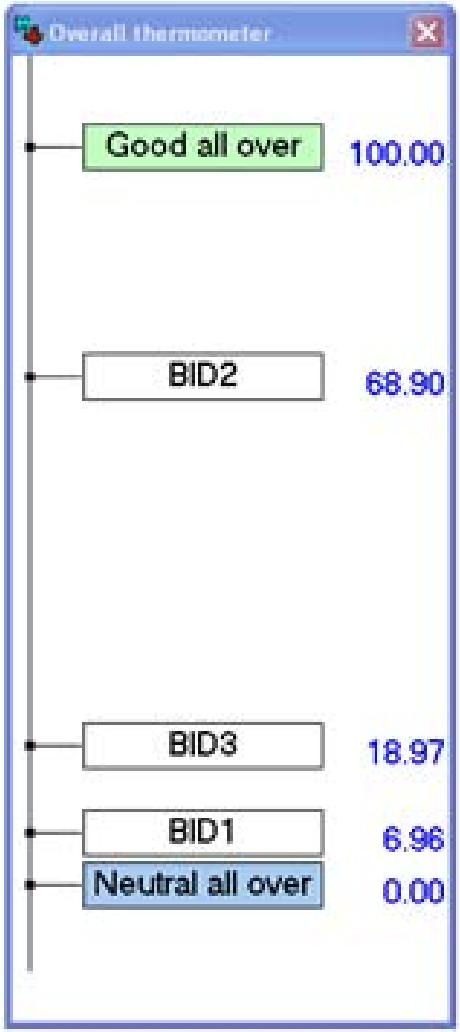
Table of performances

Options	MCPD
A	L5=Neutral
B	L4
C	L2=Good
D	L6
E	L1
F	L3

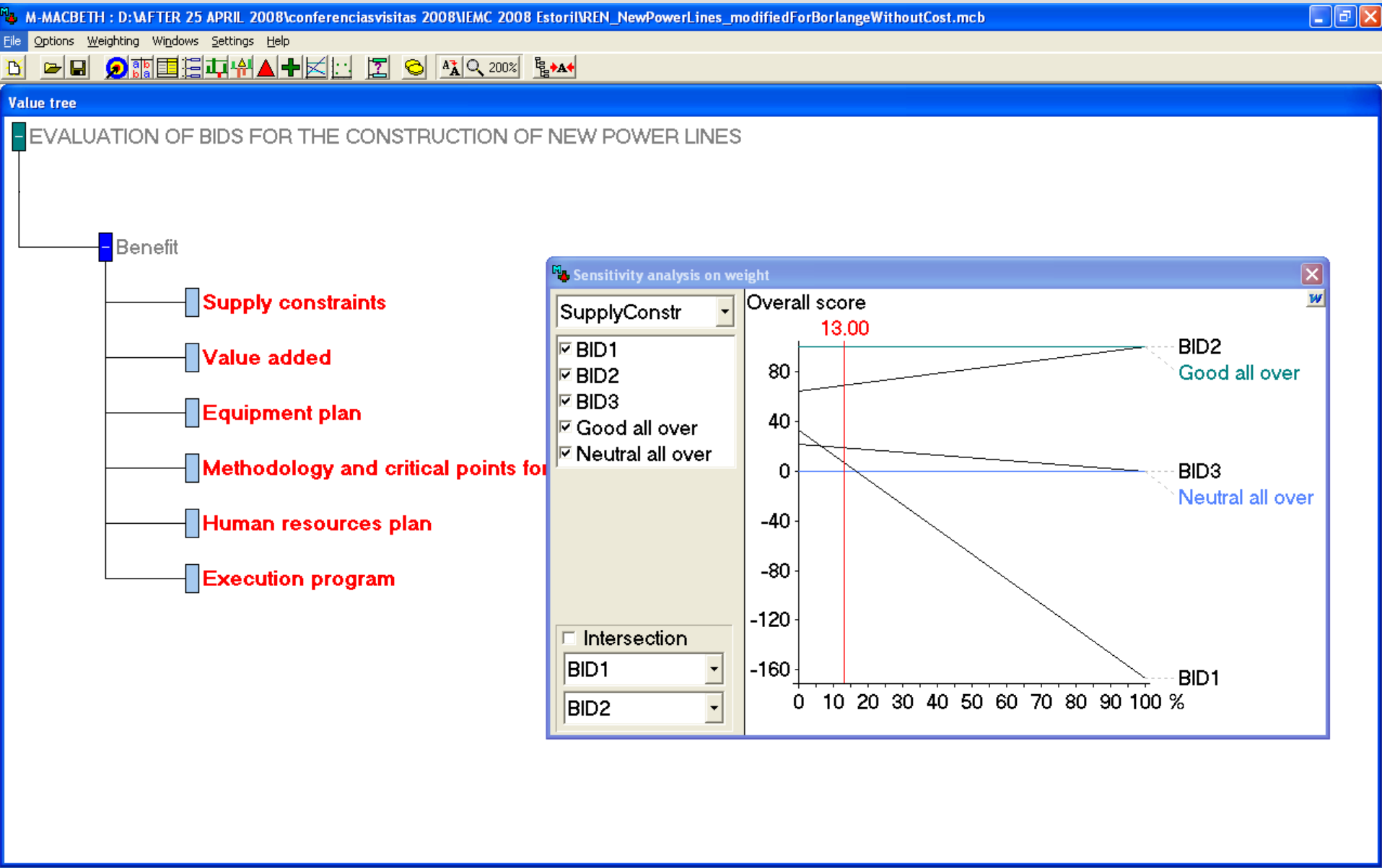
Options evaluation

A : 0
B : 40
C : 100
D : -30
E : 110
F : 60

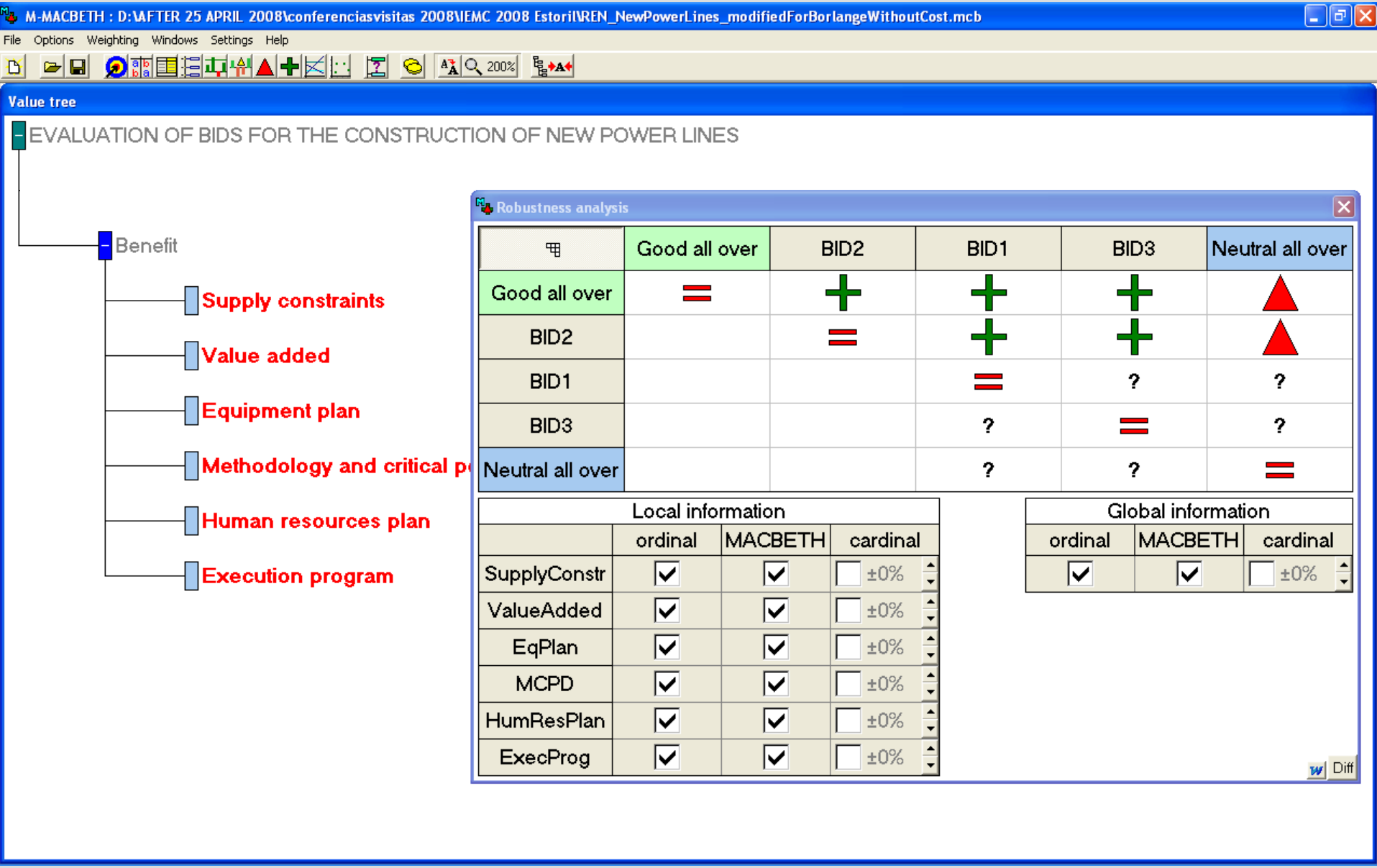
Analysing the model outputs: Comparing differences



Analysing the model outputs: Sensitivity on weighting



Analysing the model outputs: Robustness



OPORTO SUBWAY CASE

The process of the International Public Call for Tenders to award the design, construction, equipment, financing and short-term operation, of a light-rail system in the Metropolitan Area of Oporto, issued in 1995 by Metro do Porto, S.A., took place in three stages:
1st Stage– Pre-qualification,
2nd Stage – Selection
3rd Stage – Negotiation.

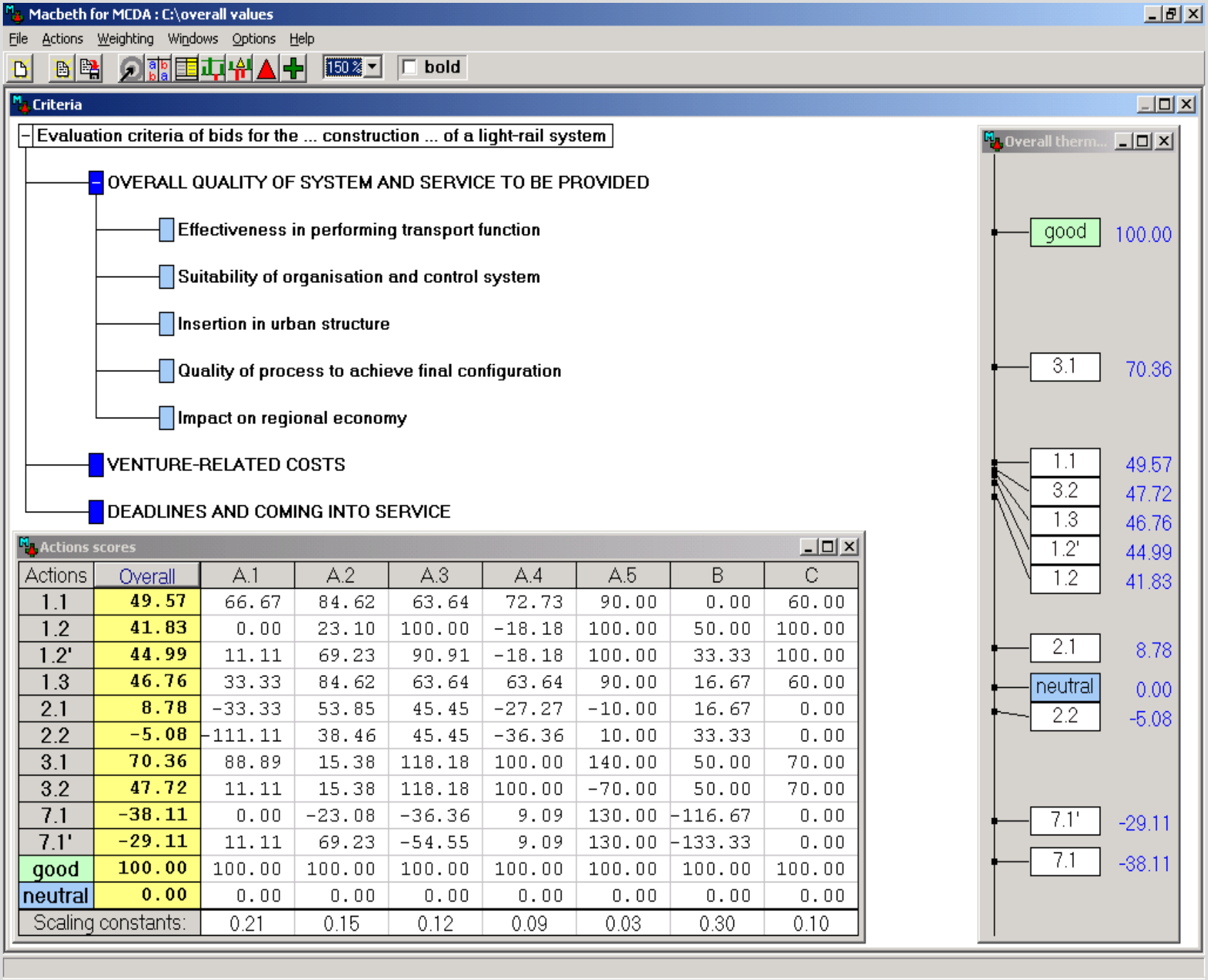
Four of the Groups that participated in the pre-qualification were selected: A1, A2, A3 and A7, presenting a total of eight bids (all accepted):
1.1, 1.2, 1.2’ and 1.3 from Group A1, 2.1 and 2.2 from Group A2,
3.1 and 3.2 from Group A3, 7.1 and 7.1’ from Group A7.

We will examine the 2nd stage, which objective was:
To select for negotiation two bidders (not bids)
from the four pre-qualified Groups.

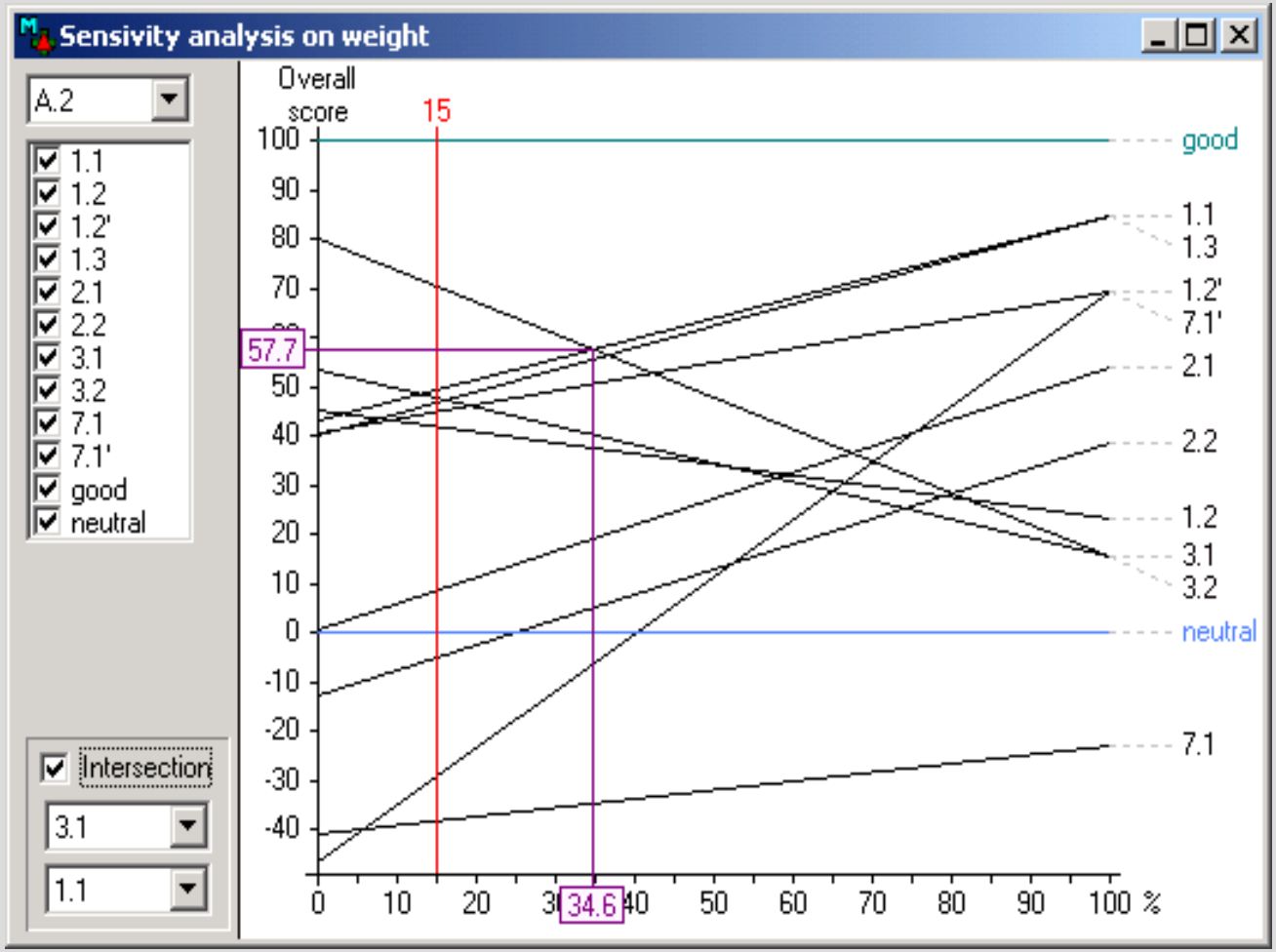
The Decision Conferencing Process: A socio-technical process composed of a decision conferences with the Evaluation Committee series of MCDA decision conferences intermediate with “off-line” data gathering and processing :

As stated in the Evaluation Report,
“{…} the Evaluation Committee started by adopting, as a key thread in its work methodology, an Evaluation Regulation for bid evaluation, that established the organic support and procedural and methodological framework to perform its functions. Obviously, this Regulation fully adopts the evaluation criteria established in the {…} Call for Tenders.”

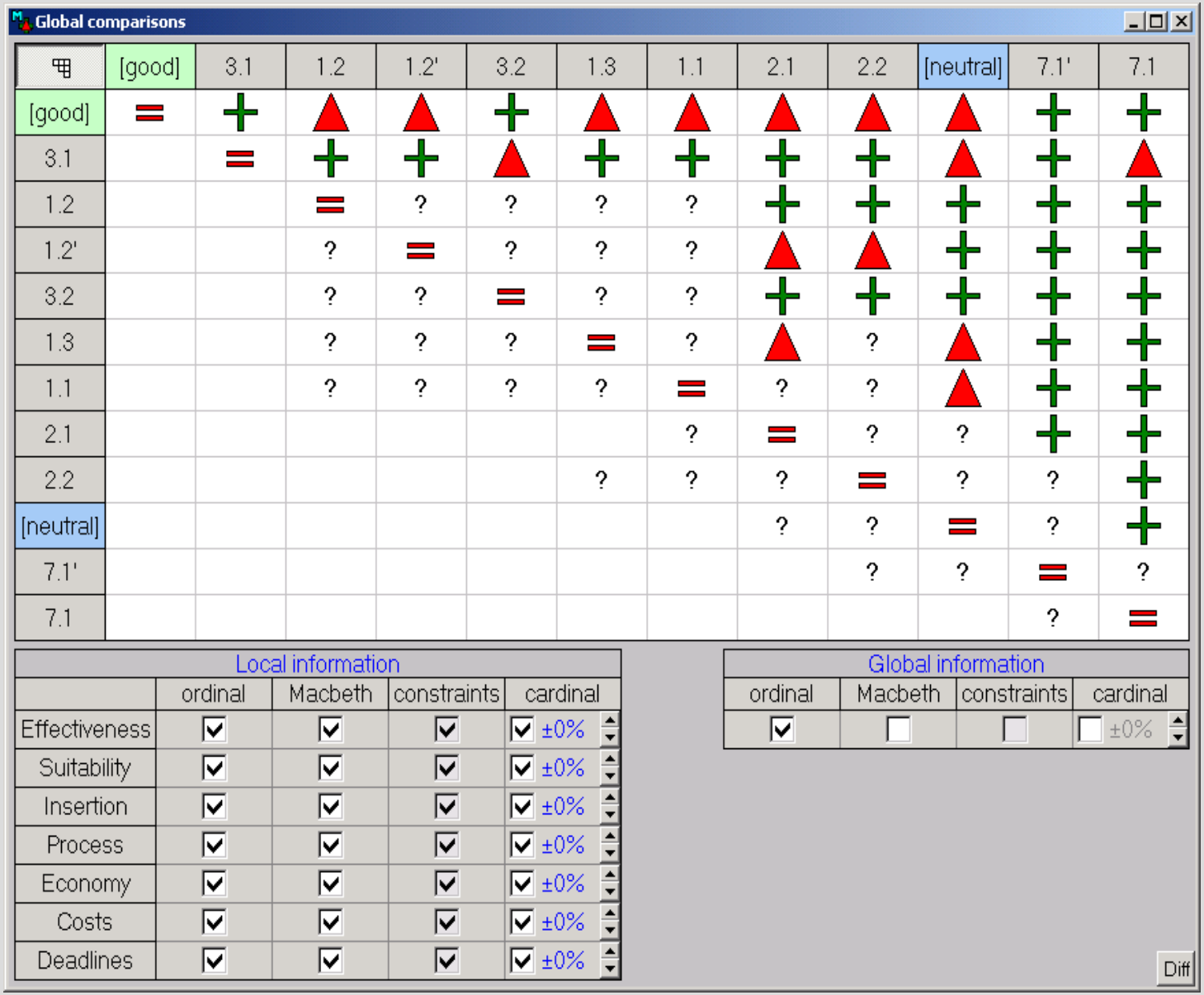
“In accordance with the {…} Evaluation Regulation, analysis of the bids was carried out by application of a Multicriteria Decision Aid Methodology” (MACBETH).”


Macbeth for MCDA : C:\overall values
File Actions Weighting Windows Options Help
150 %
bold
Criteria
Evaluation criteria of bids for the ... construction ... of a light-rail system
OVERALL QUALITY OF SYSTEM AND SERVICE TO BE PROVIDED
Effectiveness in performing transport function
Suitability of organisation and control system
Insertion in urban structure
Quality of process to achieve final configuration
Impact on regional economy
VENTURE-RELATED COSTS
DEADLINES AND COMING INTO SERVICE
Actions scores
Actions | Overall | A.1 | A.2 | A.3 | A.4 | A.5 | B | C
1.1 | 49.57 | 66.67 | 84.62 | 63.64 | 72.73 | 90.00 | 0.00 | 60.00
1.2 | 41.83 | 0.00 | 23.10 | 100.00 | -18.18 | 100.00 | 50.00 | 100.00
1.2' | 44.99 | 11.11 | 69.23 | 90.91 | -18.18 | 100.00 | 33.33 | 100.00
1.3 | 46.76 | 33.33 | 84.62 | 63.64 | 63.64 | 90.00 | 16.67 | 60.00
2.1 | 8.78 | -33.33 | 53.85 | 45.45 | -27.27 | -10.00 | 16.67 | 0.00
2.2 | -5.08 | -111.11 | 38.46 | 45.45 | -36.36 | 10.00 | 33.33 | 0.00
3.1 | 70.36 | 88.89 | 15.38 | 118.18 | 100.00 | 140.00 | 50.00 | 70.00
3.2 | 47.72 | 11.11 | 15.38 | 118.18 | 100.00 | -70.00 | 50.00 | 70.00
7.1 | -38.11 | 0.00 | -23.08 | -36.36 | 9.09 | 130.00 | -116.67 | 0.00
7.1' | -29.11 | 11.11 | 69.23 | -54.55 | 9.09 | 130.00 | -133.33 | 0.00
good | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00
neutral | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00
Scaling constants: | 0.21 | 0.15 | 0.12 | 0.09 | 0.03 | 0.30 | 0.10
Overall therm...
good 100.00
3.1 70.36
1.1 49.57
3.2 47.72
1.3 46.76
1.2' 44.99
1.2 41.83
2.1 8.78
neutral 0.00
2.2 -5.08
7.1' -29.11
7.1 -38.11

Sensitivity analysis on the weight of sub-criterion A.2 (the vertical line represents the current value of the weight; 34.6 is the value of the weight for which the two best bids would be indifferently the best ones)



Robustness analysis on the weights



REFERENCES

Bana e Costa, C.A., Vansnick, J.C., De Corte, J.M. (2003), MACBETH, *Working Paper LSEOR* 03.56, London School of Economics, London.

Bana e Costa C.A., M.P. Chagas. 2004. A career choice problem: an example of how to use MACBETH to build a quantitative value model based on qualitative value judgments. *European Journal of Operational Research* 153(2) 323-331.

Bana e Costa C.A., J.M. De Corte, J.C. Vansnick. 2005. On the mathematical foundations of MACBETH. J. Figueira, S. Greco, M. Ehrgott, eds. *Multiple Criteria Decision Analysis: State of the Art Surveys*. Springer, New York, 409-442.

Bana e Costa C.A., J.M. De Corte, J.C. Vansnick. 2005. M-MACBETH Version 1.1 User's Guide, http://www.m-macbeth.com/downloads.html#guide.

Bana e Costa J. 2007. Behind MACBETH. Presented at the Nato Advanced Research on Risk, Uncertainty and Decision Analysis for Environmental Security and Non-chemical Stressors, Lisbon, Portugal, http://www.m-macbeth.com/references.html#basic.

Bana e Costa, C.A., Lourenço, J.C., Chagas, M.P., Bana e Costa, J.C. (2008), "Development of reusable bid evaluation models for the Portuguese Electric Transmission Company", *Decision Analysis*, 5, 1 (22-42).