M-MACBETH:
A DECISION SUPPORT TOOL FOR MULTI-CRITERIA VALUE MEASUREMENT BASED ON QUALITATIVE VALUE JUDGEMENTS

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OUTLINE

- Overview of Multi-Criteria Value Measurement:
  - Measuring the relative value of options in each criterion:
    Numerical and
    non-numerical approaches (MACBETH)
  - Criteria weighting procedures

Slides available in: alfa.ist.utl.pt/~cbana/

- Demonstration of M-MACBETH

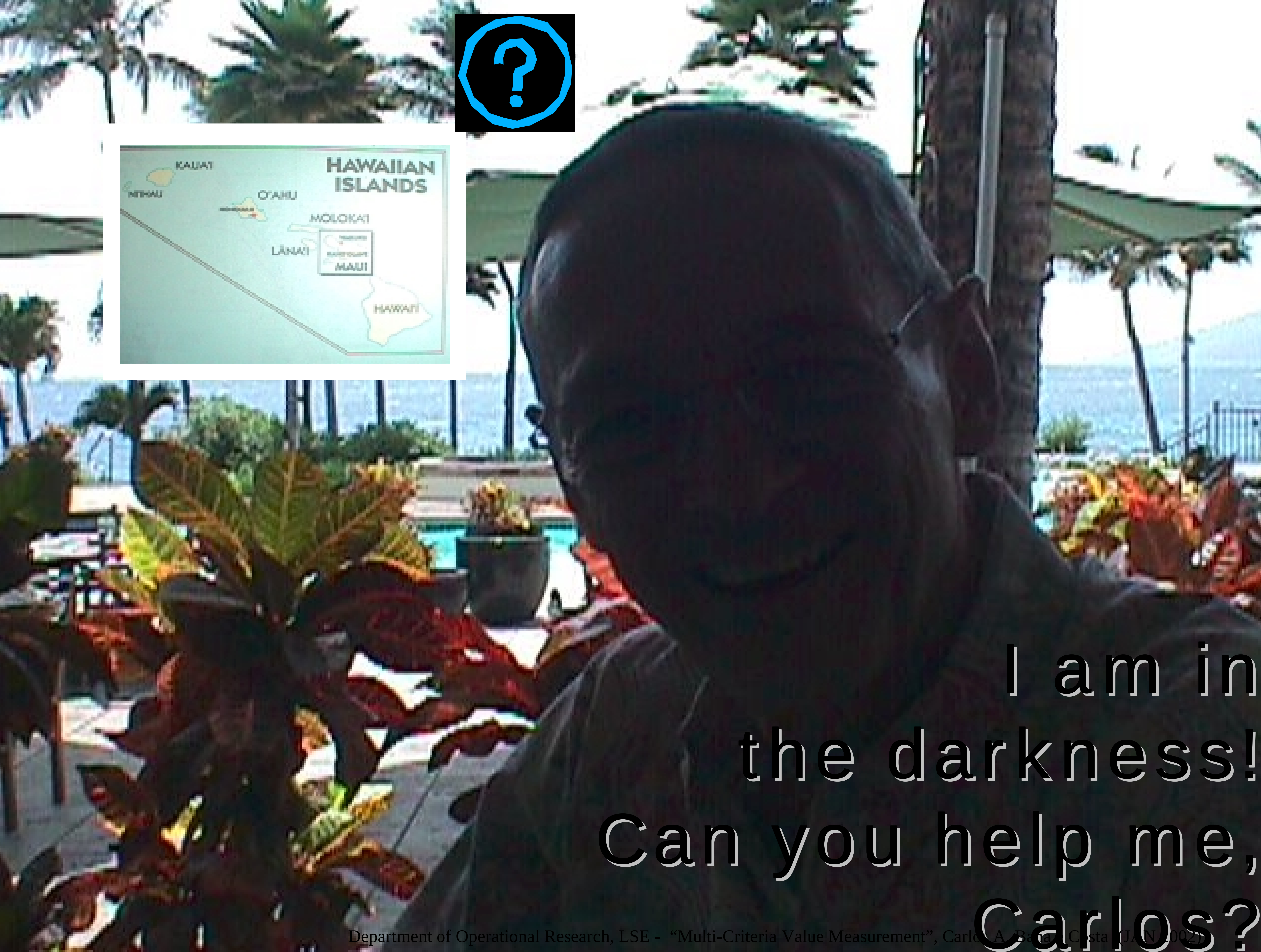
Download Trial version in: www.umh.ac.be/~smq/

Larry's Hawaiian problem:

He will stay 1 week at Hawaii after the conference

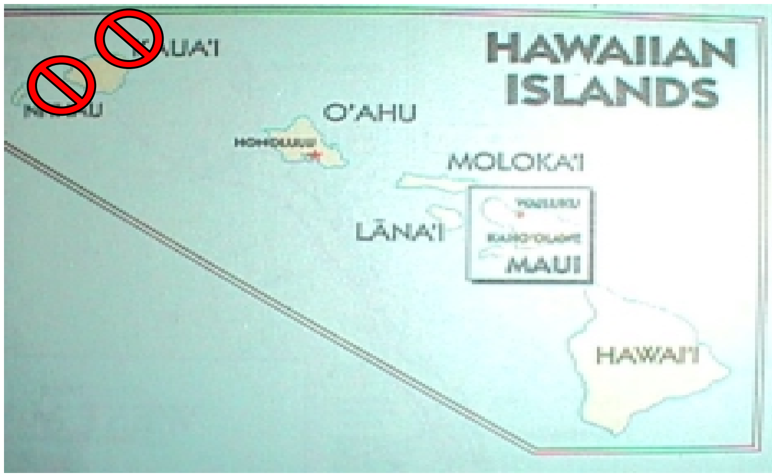
He wants to choose 1 island

Which one?


I am in
the darkness!
Can you help me,
Carlos?
HAWAIIAN ISLANDS
KAUA'I
NI'IHAU
O'AHU
MOLOKA'I
LĀNA'I
MAUI
HAWAI'I

Define options: Screening

Kauha'I & Ni'hau are too far away



New file

File name: Larry's Hawaiian island choice

Actions

	Names	Short
1	Oahu	Oahu
2	Molokai	Molo
3	Lanai	Lana
4	Maui	Maui
5	Hawaii (the big island)	Big

Define criteria

My key concerns are:

- Good snorkelling
- Spectacular scenery
- Remote beaches
- Fair flight price
- Short travel time

Value tree

- LARRY'S ISLAND CHOICE CONCERNS
  - BENEFIT CONCERNS
    - Good snorkelling
    - Spectacular scenery
    - Remote beaches
  - COST CONCERNS
    - Fair flight price
    - Short travel time

Evaluation framework: Additive value model

$$V(a) - V(b) = \sum_{j=1}^{n} k_j . \left[v_j(a) - v_j(b) \right]$$

With:

$$\begin{cases} v_j(best_j) = 100, \forall j \\ v_j(worst_j) = 0, \forall j \\ V(best\ allover) = 100 \\ V(worst\ \ allover) = 0 \end{cases}$$

$V(\bullet)$ overall value of option •

$v_j(\bullet)$ partial value (score) of option • in terms of criterion j

k_j scaling constant (relative weight) of criterion j

$\sum_{j=1}^{n} k_j = 1$ **and** k_j **> 0 (j = 1,…,n)**

Scoring the options against each criterion:

Techniques for cardinal (interval) value measurement

Numerical approaches

“**Direct rating**,

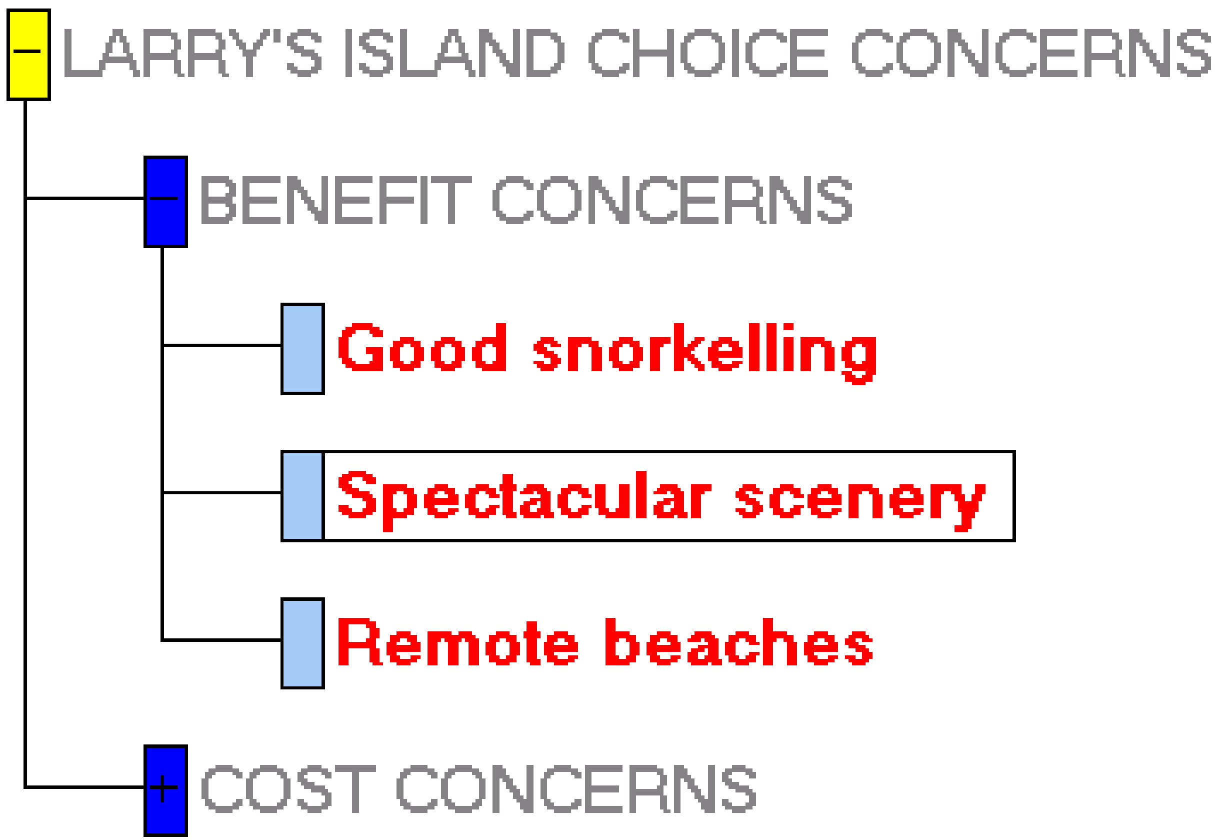
ratio estimation, category estimation, curve drawing

are versions of numerical estimation methods

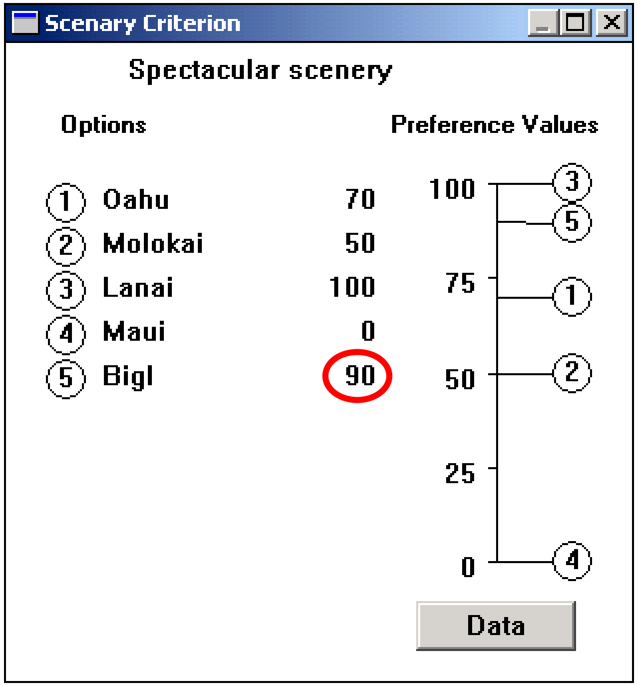
in which respondents are presented with some anchored scale and asked to rate or otherwise estimate numerically the attractiveness of the stimulus relative to the anchors.”

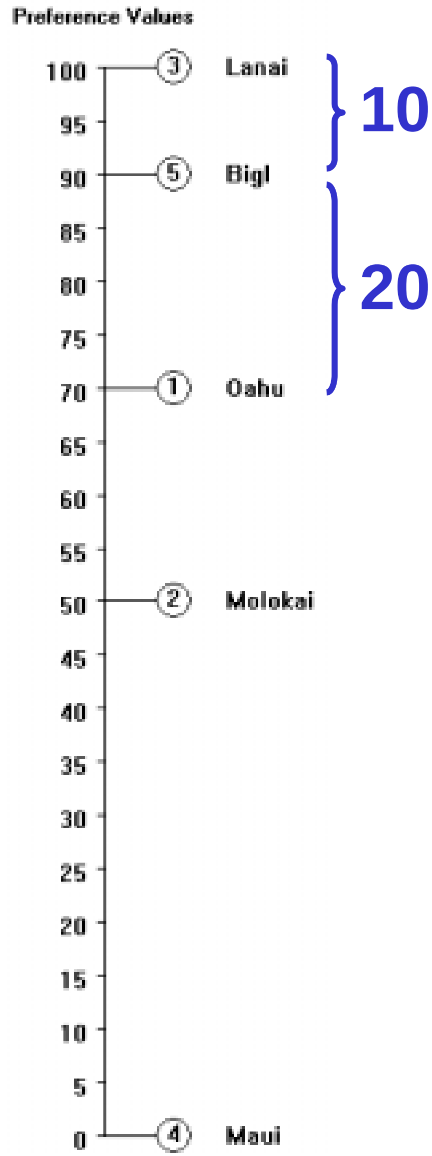
(von Winterfeldt & Edwards, 1986)

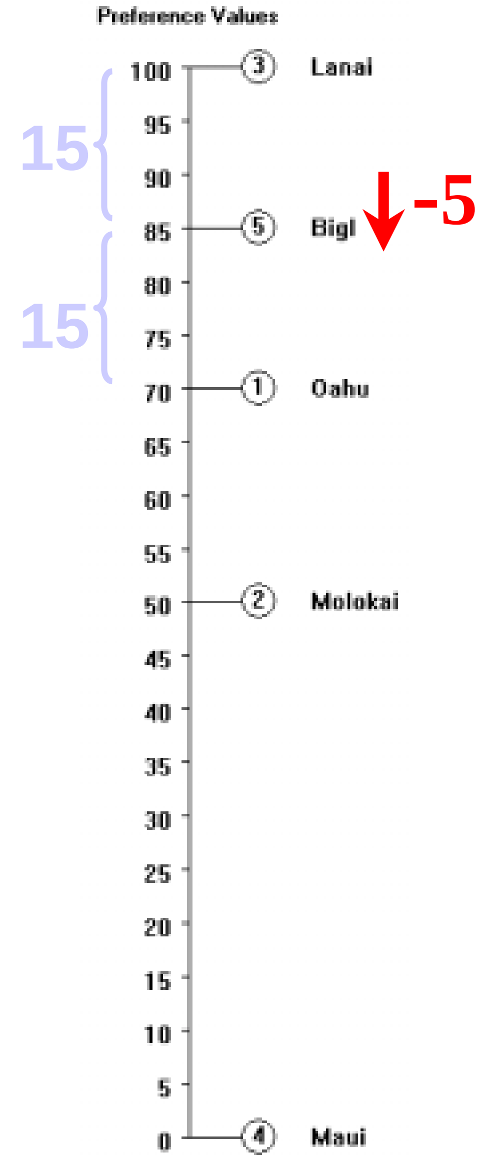
Example 1: Larry's "Spectacular scenery" concern



Direct Rating







[v(Bi) - v(Oa)] = 2.[v(La) - v(Bi)]   (90-70) = 2.(100-90)

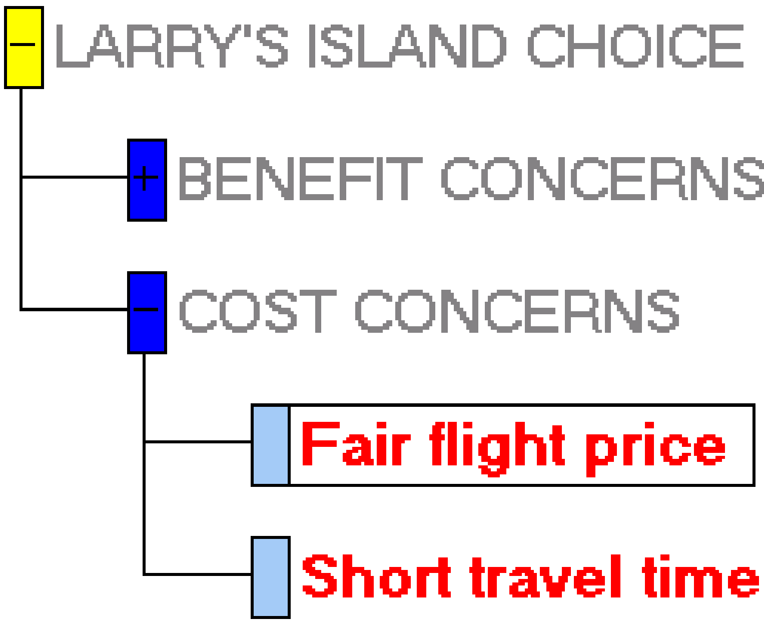
[v(Bi) - v(Oa)] = [v(La) - v(Bi)]   (85-70) = (100-85)

!!!

Building (interval) value functions

a value function enables to transform impacts into scores

Example 2: Larry’s “Fair flight price” concern

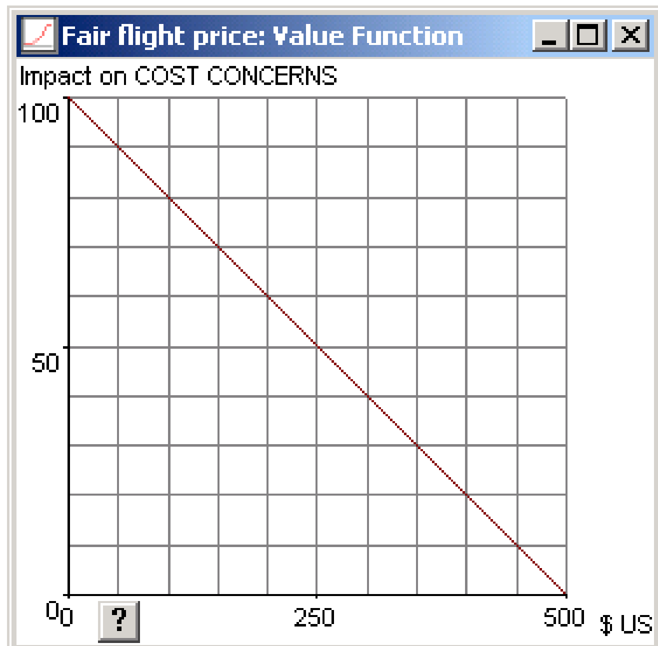


Operationalization:

Natural descriptor of impacts:
“Price of return ticket in $ US”
(a quantitative attribute)

Linear value function: Proportional scores

Common when the concern has a natural numerical descriptor



$$v_{\$}(?) = \frac{? \quad - \quad \text{least attractive cost}}{\text{most attractive cost} - \text{least attractive cost}} \times 100$$

Building (interval) value functions: “Bisection” or “mid-point splitting” approach

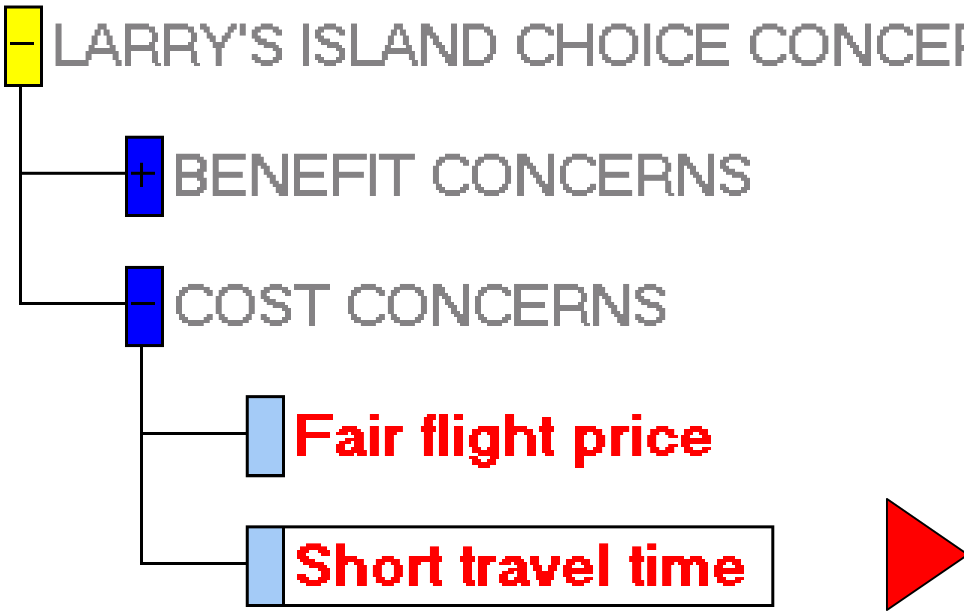
“In

bisection techniques

a most preferred stimulus and a least preferred stimulus are identified, and subsequently a midpoint stimulus is found that is equidistant from both extremes.”

(von Winterfeldt & Edwards, 1986)

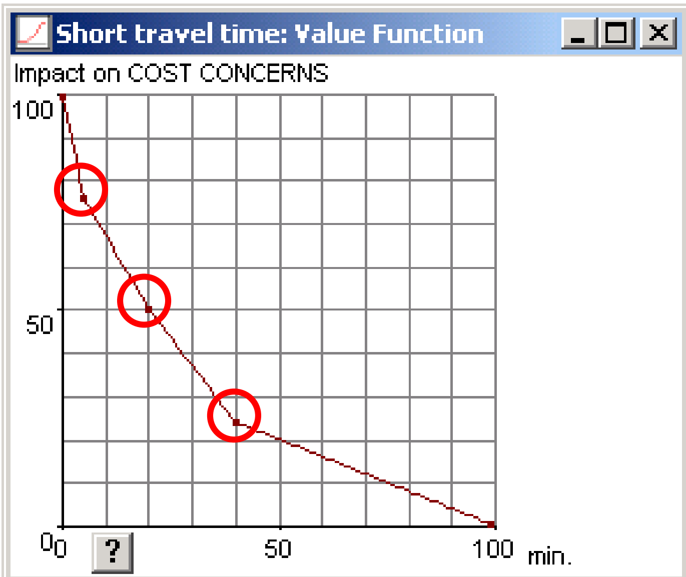
Example 3: Larry's "Short travel time" concern



Operationalization:

Indirect descriptor of impacts:
"Travel time in minutes"
(a quantitative attribute)

Non-linear value function: Bisection technique



Find '? min.' so that
the difference in attractiveness between
'0 min.' and '? min.'
is equal to
the difference in attractiveness between
'? min.' and '100 min.'

v(0 min.) - v(? min.) = v(? min.) - v(100 min.)

100 - v(20 min.) = v(20 min.) - 0
v(20 min.) = 50

Similar questions to find
the midpoints 25 and 75

Piecewise linear value function or curve fitting

Non-numerical approaches: MACBETH

What to do when evaluators
do not feel comfortable
in directly scoring the options?

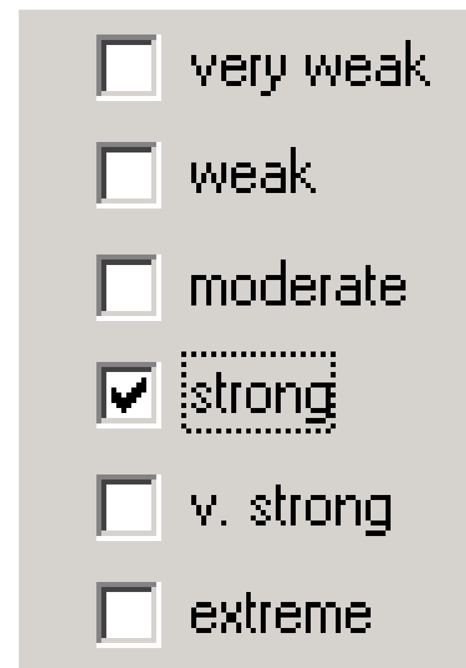
Use **MACBETH**
(**M**easuring **A**ttractiveness by a
Categorical **B**ased
Evaluation **T**ec**h**nique)

An interactive approach to guide the construction of an interval value scale, based on qualitative value judgments

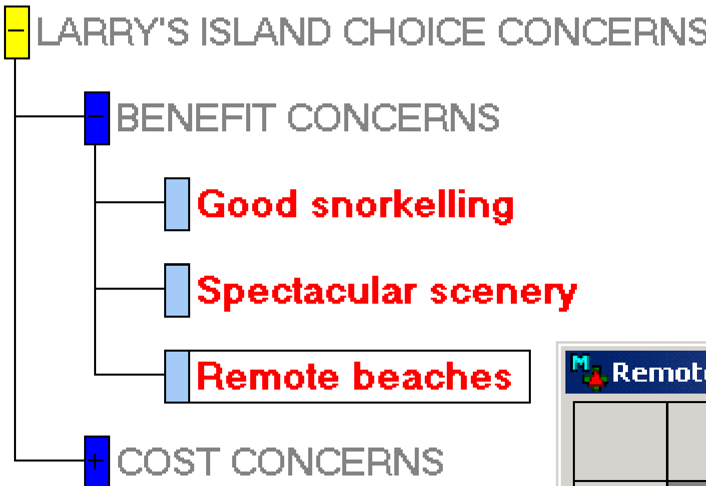
How does it work?

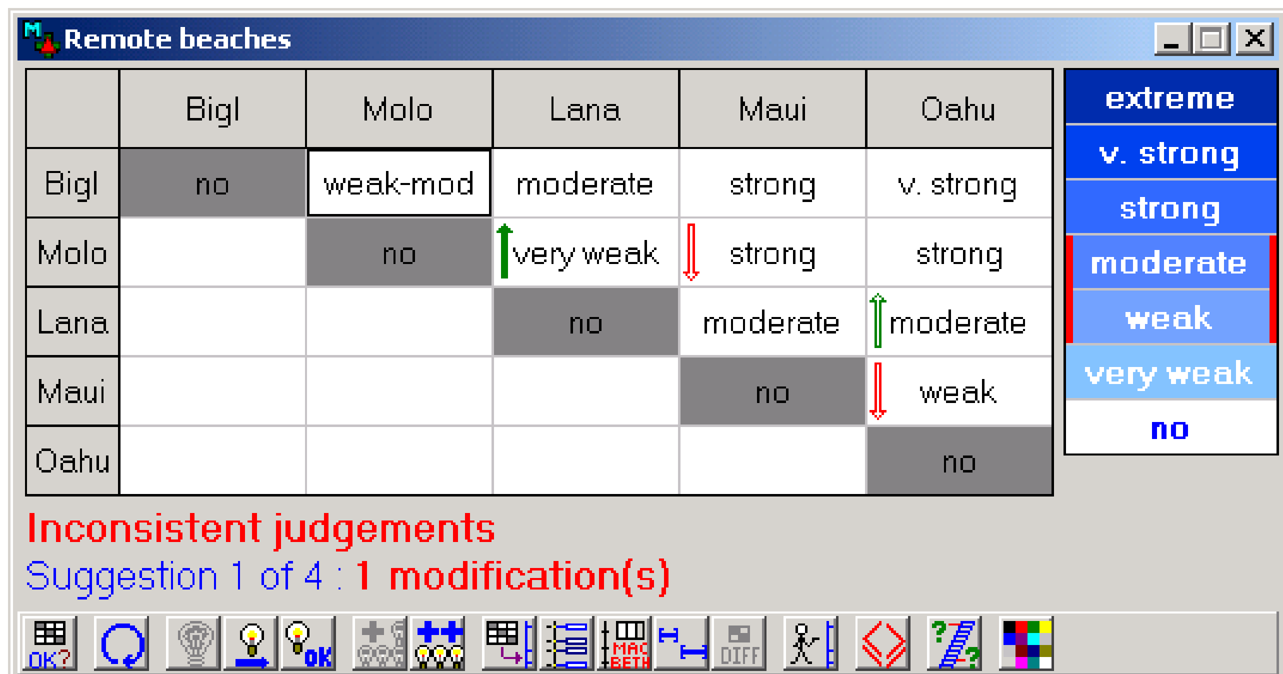
MACBETH uses a simple question-answer protocol which involves only two options in each question:
Ask the evaluator to pair-wise compare options by given a *qualitative* judgement of the difference in attractiveness between each two options

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



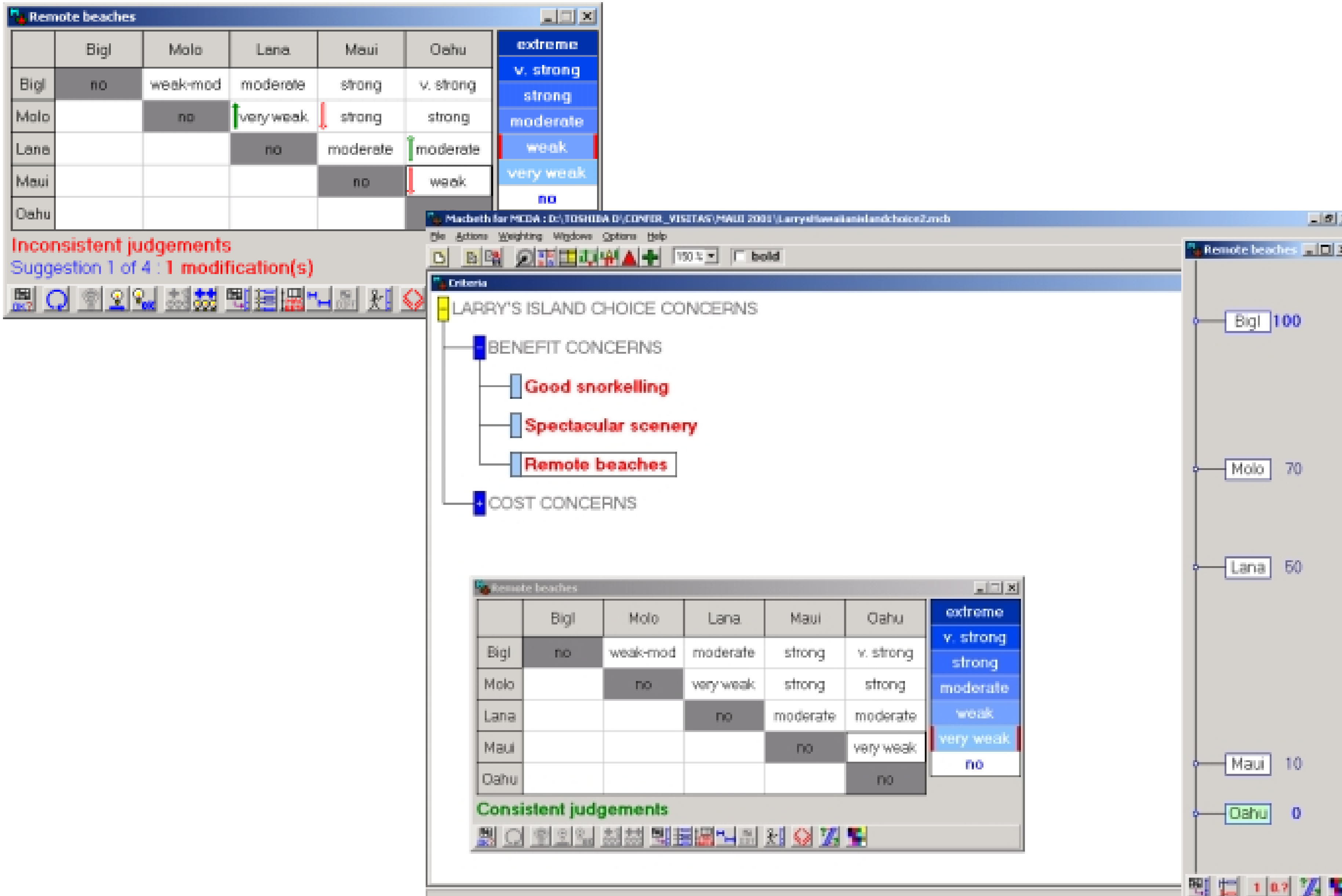
Example 4: Larry's "Remote beaches" concern





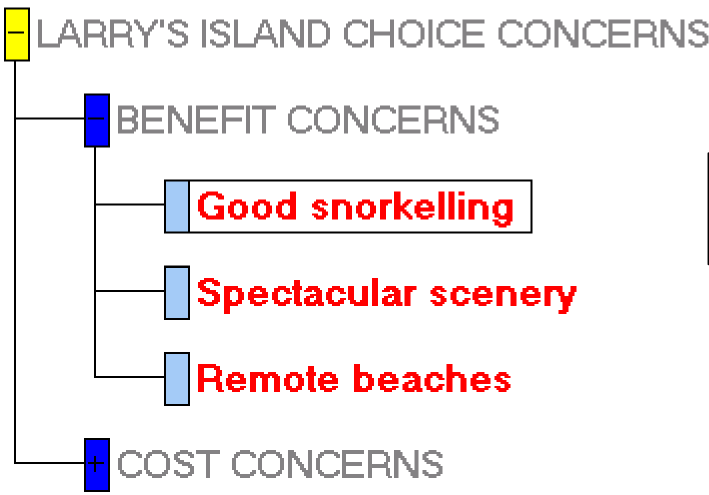
	Bigl	Molo	Lana	Maui	Oahu
Bigl	no	weak-mod	moderate	strong	v. strong
Molo		no	very weak	strong	strong
Lana			no	moderate	moderate
Maui				no	weak
Oahu					no

Interactive discussion of inconsistency



Qualitative descriptor

Example 5: Larry’s “Good snorkelling” concern



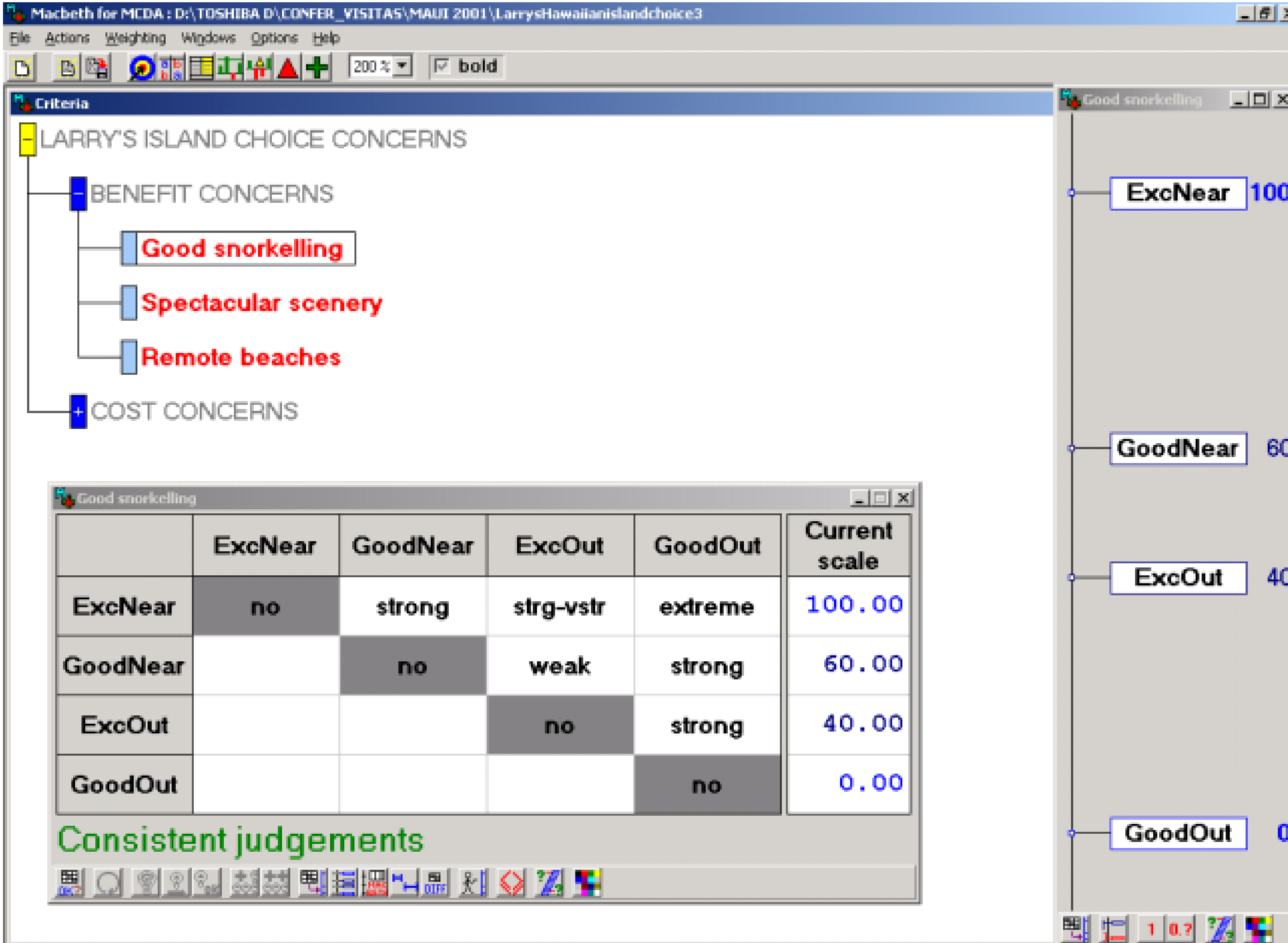
Operationalization:

Qualitative descriptor of impacts (constructed attribute):

Descriptor levels :

– +	Names	Short
1	Excellent snorkelling nearby hotel	ExcNear
2	Good snorkelling nearby hotel	GoodNear
3	Excellent snorkelling but out-of-the-way	ExcOut
4	Good snorkelling but out-of-the-way	GoodOut

Preference scale: MACBETH



	ExcNear	GoodNear	ExcOut	GoodOut	Current scale
ExcNear	no	strong	strg-vstr	extreme	100.00
GoodNear		no	weak	strong	60.00
ExcOut			no	strong	40.00
GoodOut				no	0.00

Weighting procedures:

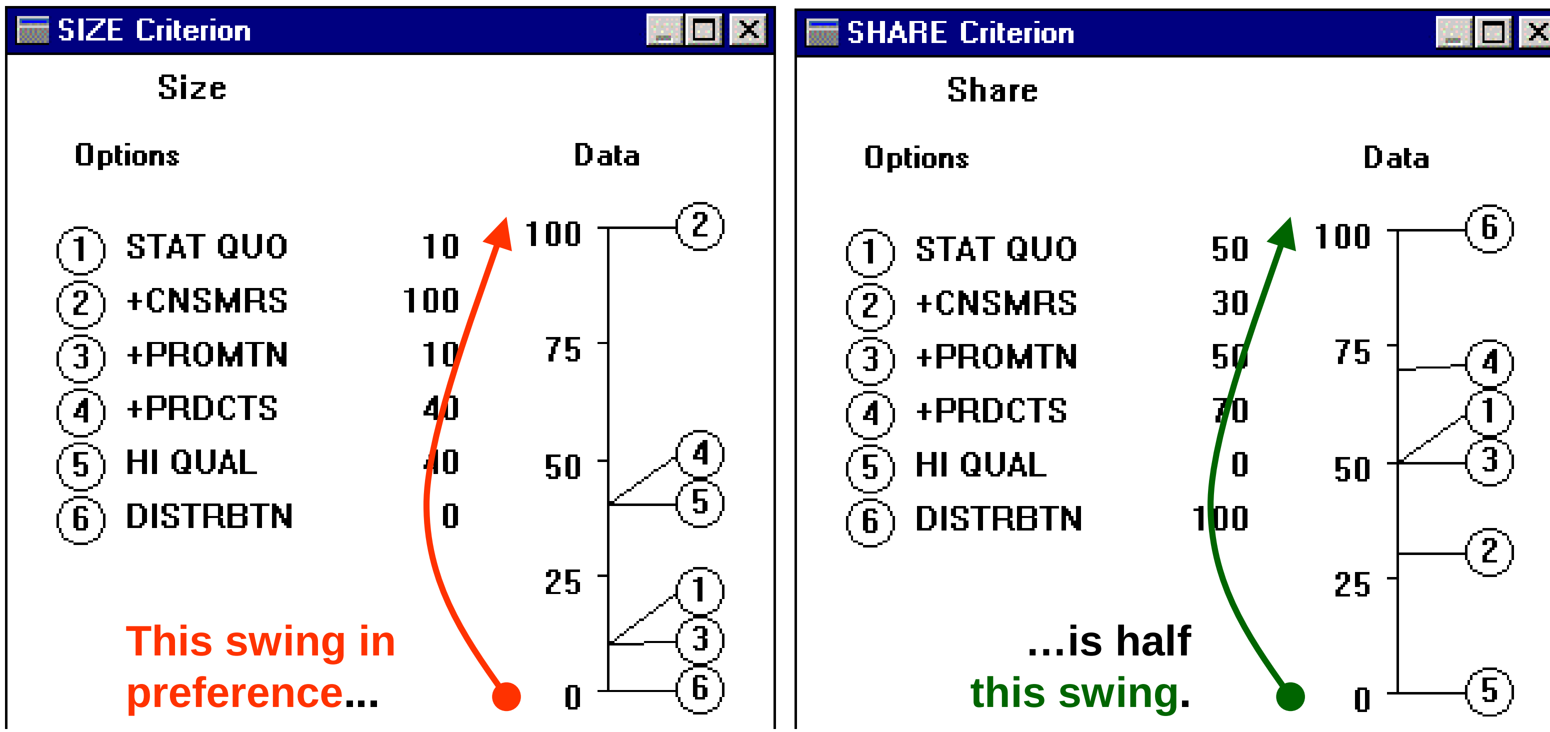
TRADEOFF PROCEDURE
(Keeney & Raiffa, 1976)

SWING WEIGHTING PROCEDURE
(von Winterfeldt & Edwards, 1986)

MACBETH
(Bana e Costa & Vansnick, 1997, 1999)

Adapted from Prof. Larry Phillips' week-2 lecture

Swing weighting procedure



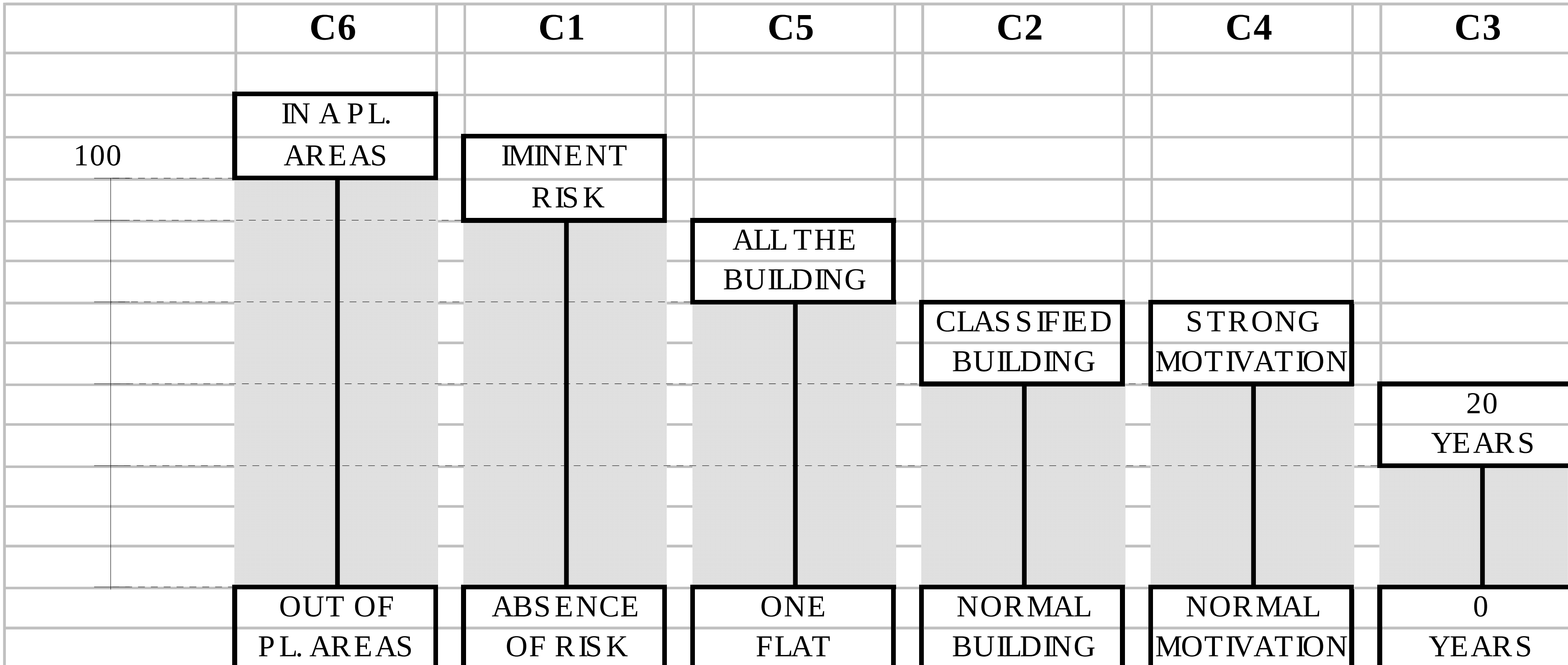
Swing weights: 50 100

"How big is the difference, and how much do you care about it?"

SWING WEIGHTING PROCEDURE

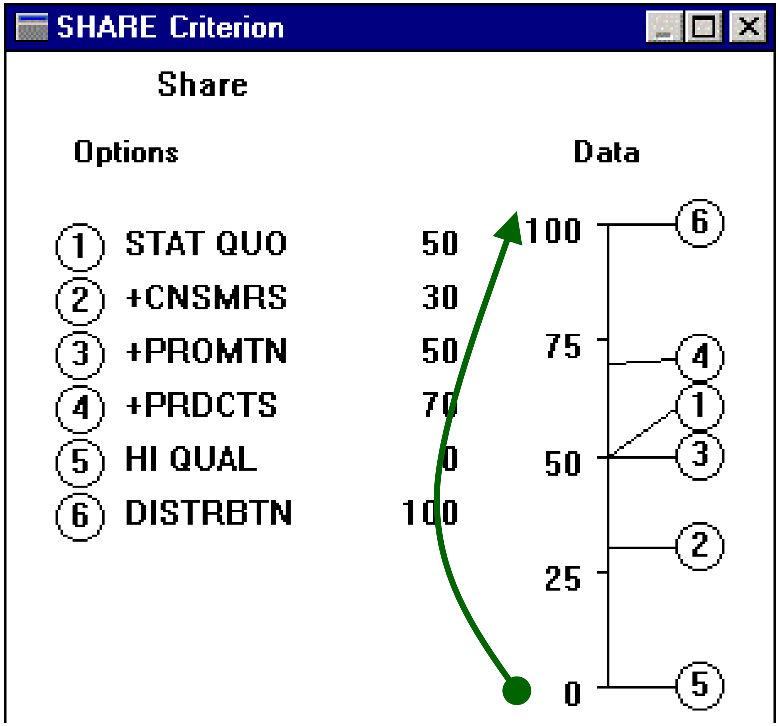
The swing procedure starts from an alternative with the worst impacts in all the criteria
The evaluator is allowed to change from worst impact to best in one PV.
He or she is asked which "swing" from worst to the best impact would result in the largest, second largest, etc., improvement of global attractiveness. The criterion with the most preferred swing is assigned 100 points.
The magnitudes of all other swings are expressed as percentages of the largest swing.
The derived percentages are the raw weights that are normalized to yield final weights.
(Adapted from Weber & Borcherding, 1993.)

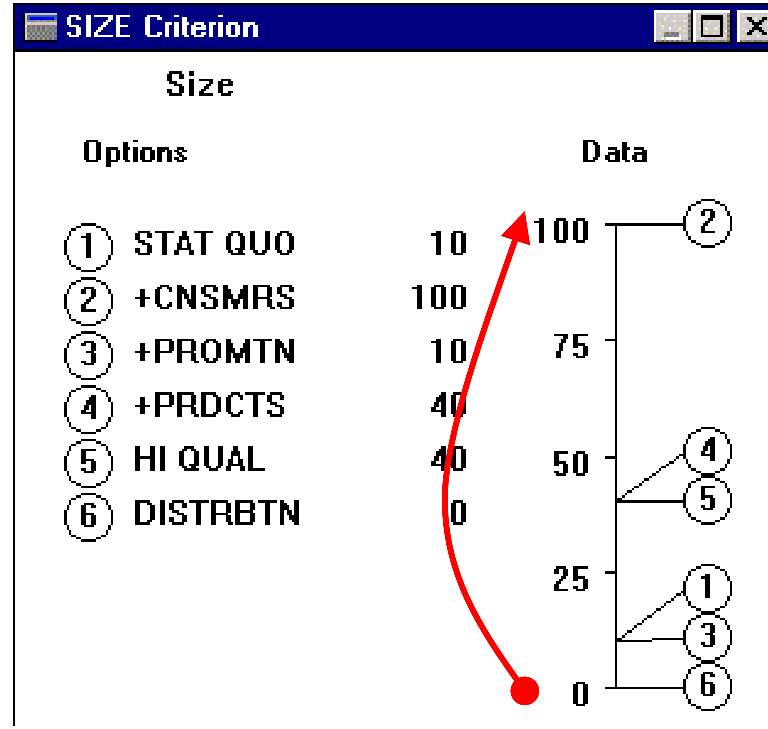
	C1 PHISICAL INJURIES	C2 CULTURAL VALUES	C3 DELAY IN ACTION	C4 TENANT MOTIVATION	C5 ACTION AREAS	C6 PL. ACTION AREAS
BEST PLAUSIBLE IMPACT	IMINENT RISK	CLASSIFIED BUILDING	20 YEARS	STRONG MOTIVATION	ALL THE BUILDING	IN A PL. AREA
WORST PLAUSIBLE IMPACT	ABSENCE OF RISK	NORMAL BUILDING	0 YEARS	NORMAL MOTIVATION	ONE FLAT	OUT OF PL. AREA



	C6	C1	C5	C2	C4	C3
%	**100**	**90**	**70**	**50**	**50**	**30**
Swing weights	**0,256**	**0,231**	**0,18**	**0,128**	**0,128**	**0,077**

MACBETH weighting procedure





The difference in attractiveness between this swing and...

...this swing, is:

Macbeth : C:\Macbeth\multi\Offi_dom.mcb

File Actions Points of vue Windows Options

125 % bold Evaluation copy

Points of vue

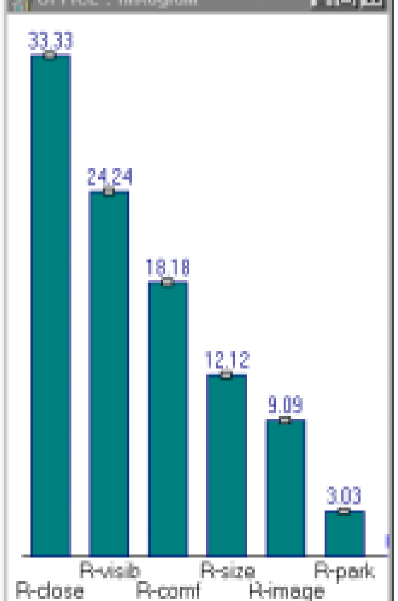
- OFFICE
  - Turnover
    - Closeness to clients
    - Visibility
    - Image
  - Working Conditions
    - Size
    - Comfort
    - Car parking

OFFICE : judgements

	R-close	R-visib	R-comf	R-size	R-image	R-park	Neutral	Current scale
R-close	no	weak	moderate	moderate	moderate	strong	positive	33.33
R-visib		no	weak	weak	moderate	moderate	positive	24.24
R-comf			no	weak	weak	moderate	positive	18.18
R-size				no	very weak	weak	positive	12.12
R-image					no	weak	positive	9.09
R-park						no	positive	3.03
Neutral							no	0.00

Consistent judgements

OFFICE : histogram



2) to compare the difference in overall attractiveness between any two swings with the first one is more attractive than the second one

The **tradeoff procedure** has the strongest theoretical foundation (Keeney and Raiffa, 1976). The key idea is to compare two options described on two criteria (for the remaining criteria both options have identical impacts). One option has the best impact on the first and the worst impact on the second criterion, the other has the worst on the first and the best on the second criterion. By choosing the preferred option out of the two the decision-maker decides on the "more important" criterion.

The critical step is the adjustment of the impact level in order to yield indifference between the two options. This is typically done by either worsening the chosen option in the best impact or improving the non-chosen option in the worst impact.

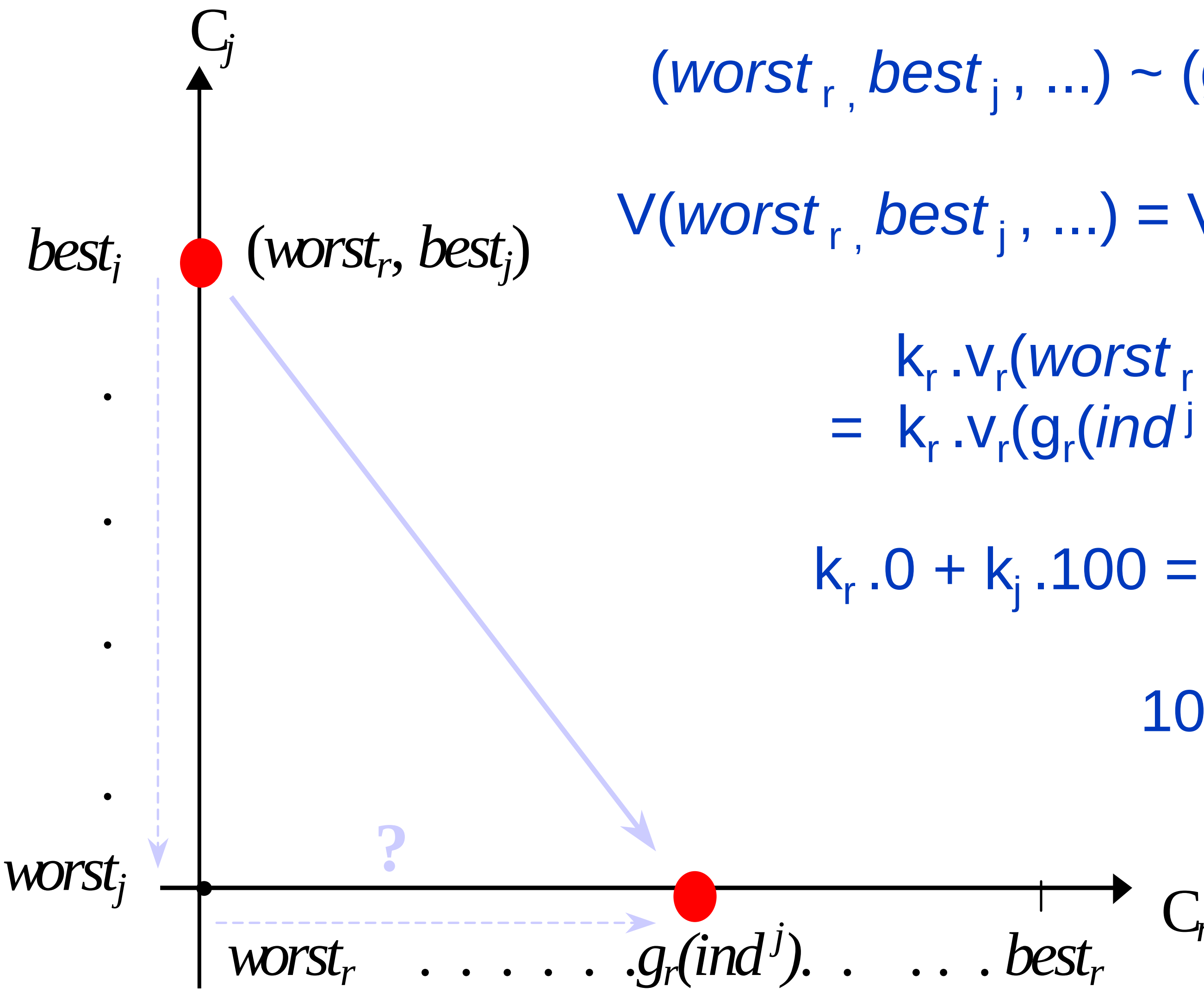
Such differences have to be elicited for the n - 1 meaningfully selected pairs of options. If the local value functions are known, numerical values for the scaling constants can be derived.

(Weber & Borcherding, 1993)

Tradeoff procedure

C_r - reference criterion

C_j - other criteria ($j \neq r$)



$(worst_r, best_j, \ldots) \sim (g_r(ind^j), worst_j, \ldots)$

$V(worst_r, best_j, \ldots) = V(g_r(ind^j), worst_j, \ldots)$

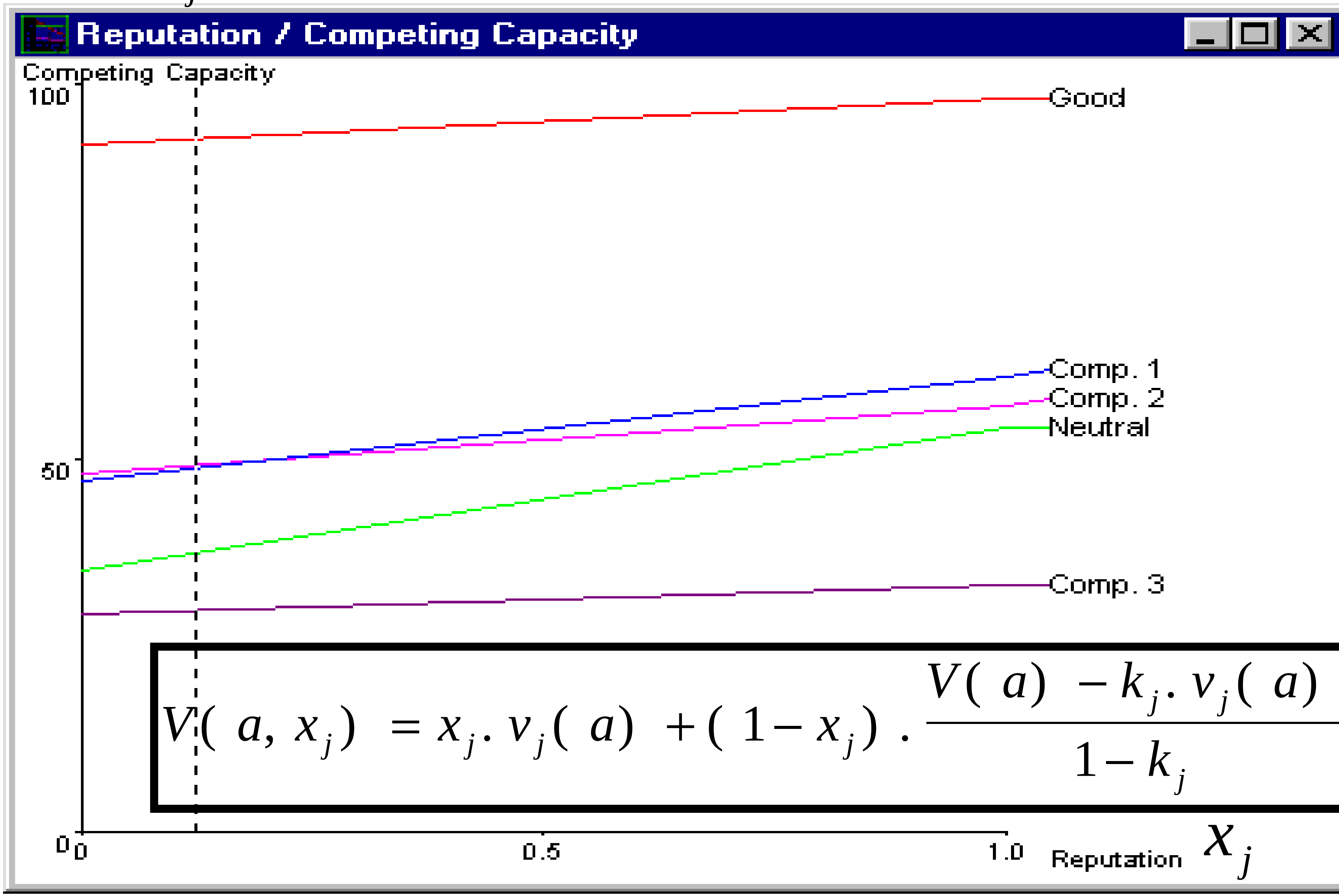
$k_r . v_r(worst_r) + k_j . v_j(best_j) + \ldots$
$= k_r . v_r(g_r(ind^j)) + k_j . v_j(worst_j) + \ldots$

$k_r . 0 + k_j . 100 = k_r . v_r(g_r(ind^j)) + k_j . 0$

$100\, k_j = k_r . v_r(g_r(ind^j))$

$$V(a, x_j)$$

SENSITIVITY ANALYSIS ON THE WEIGHTS



$$V(a, x_j) = x_j \cdot v_j(a) + (1 - x_j) \cdot \frac{V(a) - k_j \cdot v_j(a)}{1 - k_j}$$

x_j