“Social” Multicriteria Evaluation: An Introduction

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Structure of the talk

- What is multi-criteria evaluation
- Why Social Multi-criteria Evaluation (SMCE)?
- How such an approach should be developed?
- Conclusions

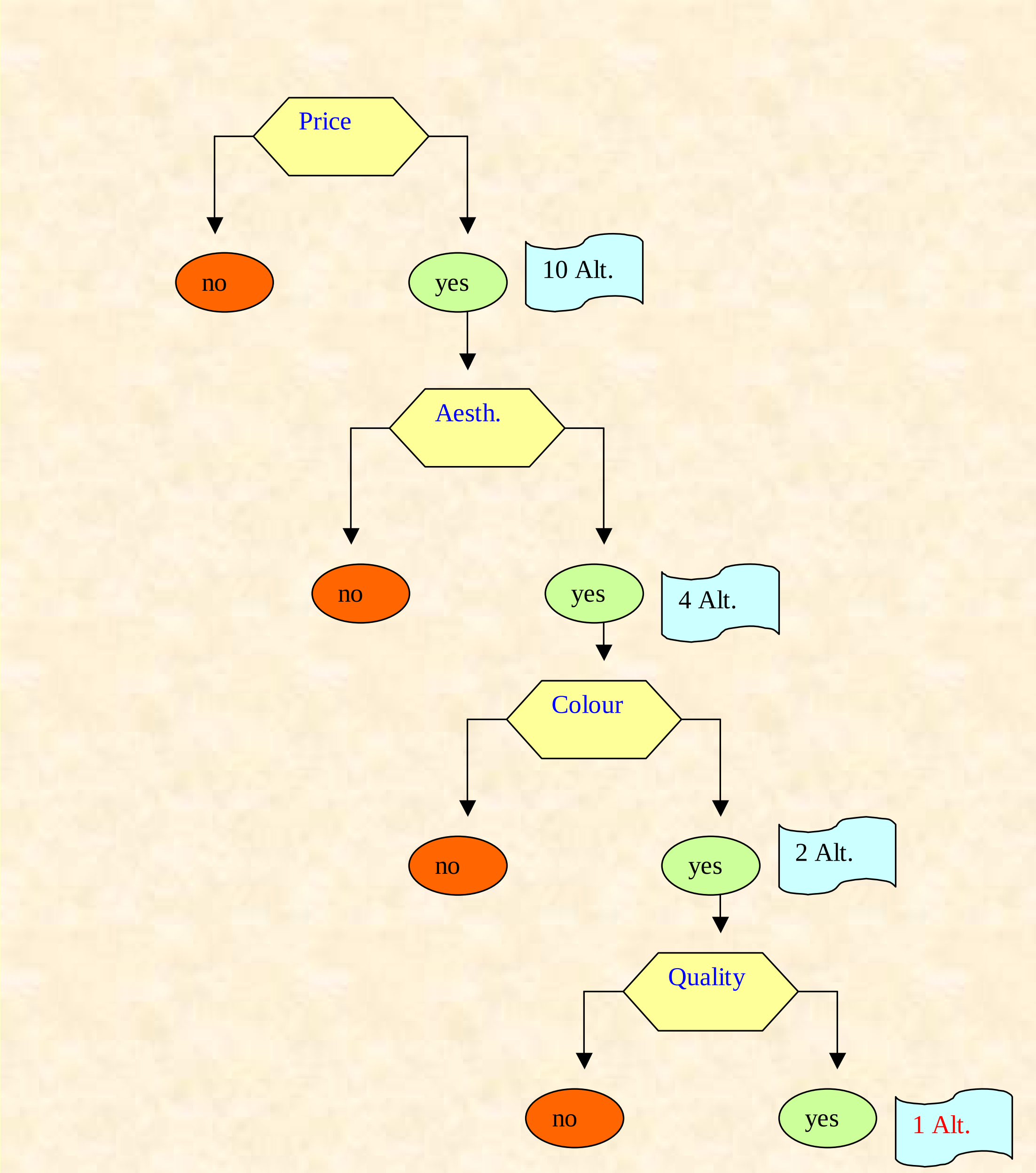


Figure 1. A lexicographic Decision Process

The Lexicographic Model

- LEARNING
- PROCESS
- WEIGHTS
- COMPENSABILITY

COST-BENEFIT ANALYSIS (CBA)

↓

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

EIA

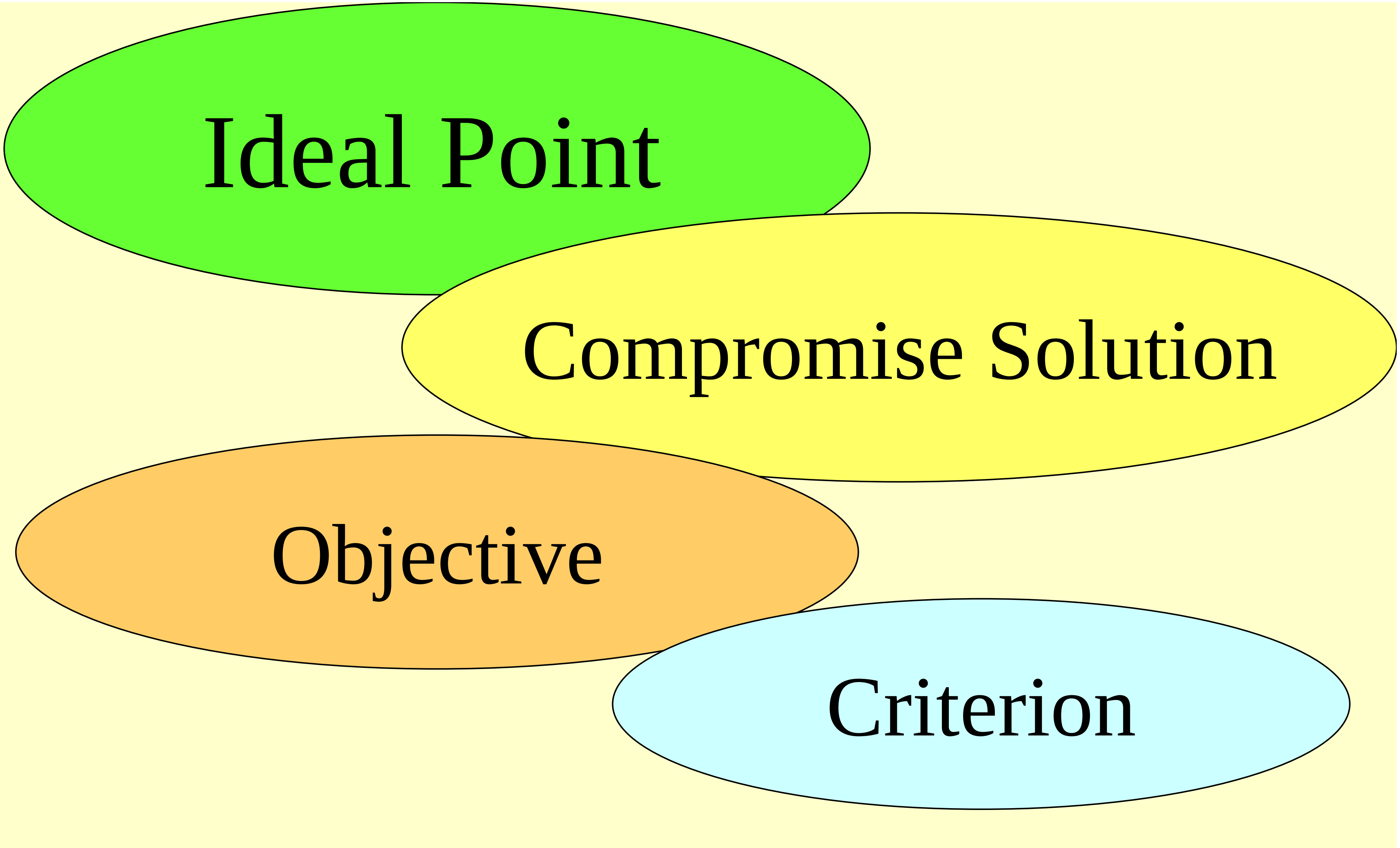
↓

CBA

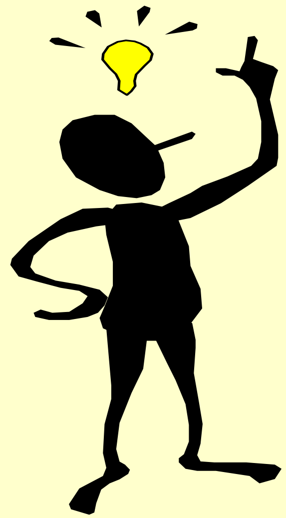
CBA ↔ EIA

Example of an impact matrix

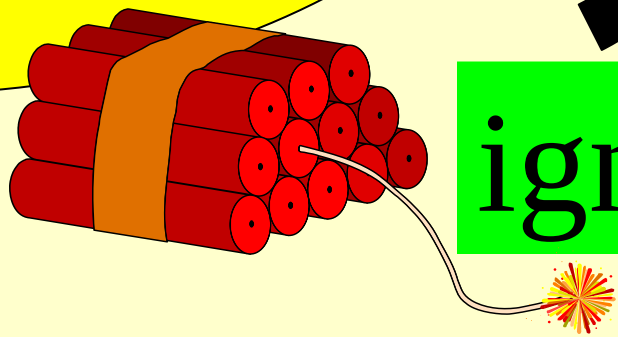
	Alternatives			
Criteria	$\mathbf{a_1}$	$\mathbf{a_2}$	$\mathbf{a_3}$	$\mathbf{a_4}$
$\mathbf{g_1}$	$g_1(a_1)$	$g_1(a_2)$	.	$g_1(a_4)$
$\mathbf{g_2}$	.	.	.	.
$\mathbf{g_3}$	.	.	.	.
$\mathbf{g_4}$	.	.	.	.
$\mathbf{g_5}$	.	.	.	.
$\mathbf{g_6}$	$g_6(a_1)$	$g_6(a_2)$	.	$g_6(a_4)$


Ideal Point
Compromise Solution
Objective
Criterion

addressed



**Complexity
is an inherent property
of natural and
social systems**



ignored

COMPLEXITY

COMPLEX SYSTEMS

CANNOT BE CAPTURED

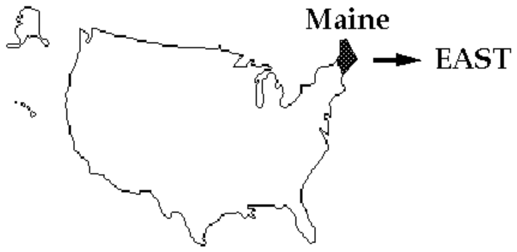
BY A SINGLE

DIMENTION/PERSPECTIVE

Complexity: the ontological dimension

the existence of *different levels and scales* at which a hierarchical system can be analyzed implies the unavoidable existence of non-equivalent descriptions of it

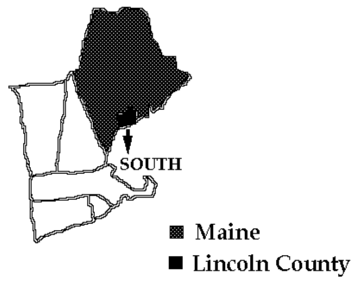
Orientation of the coastal line of Maine



Hierarchical Levels:

Federation (whole country)/State

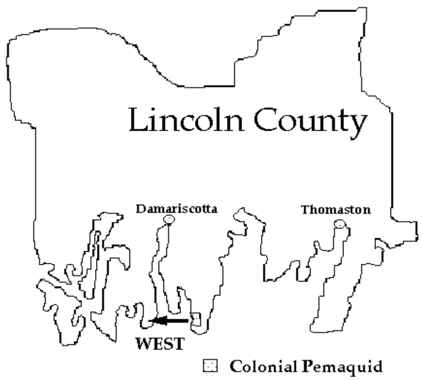
a.



Hierarchical Levels:

State/County

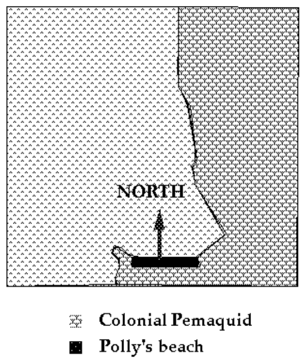
b.



Hierarchical Levels:

County/Village

c.

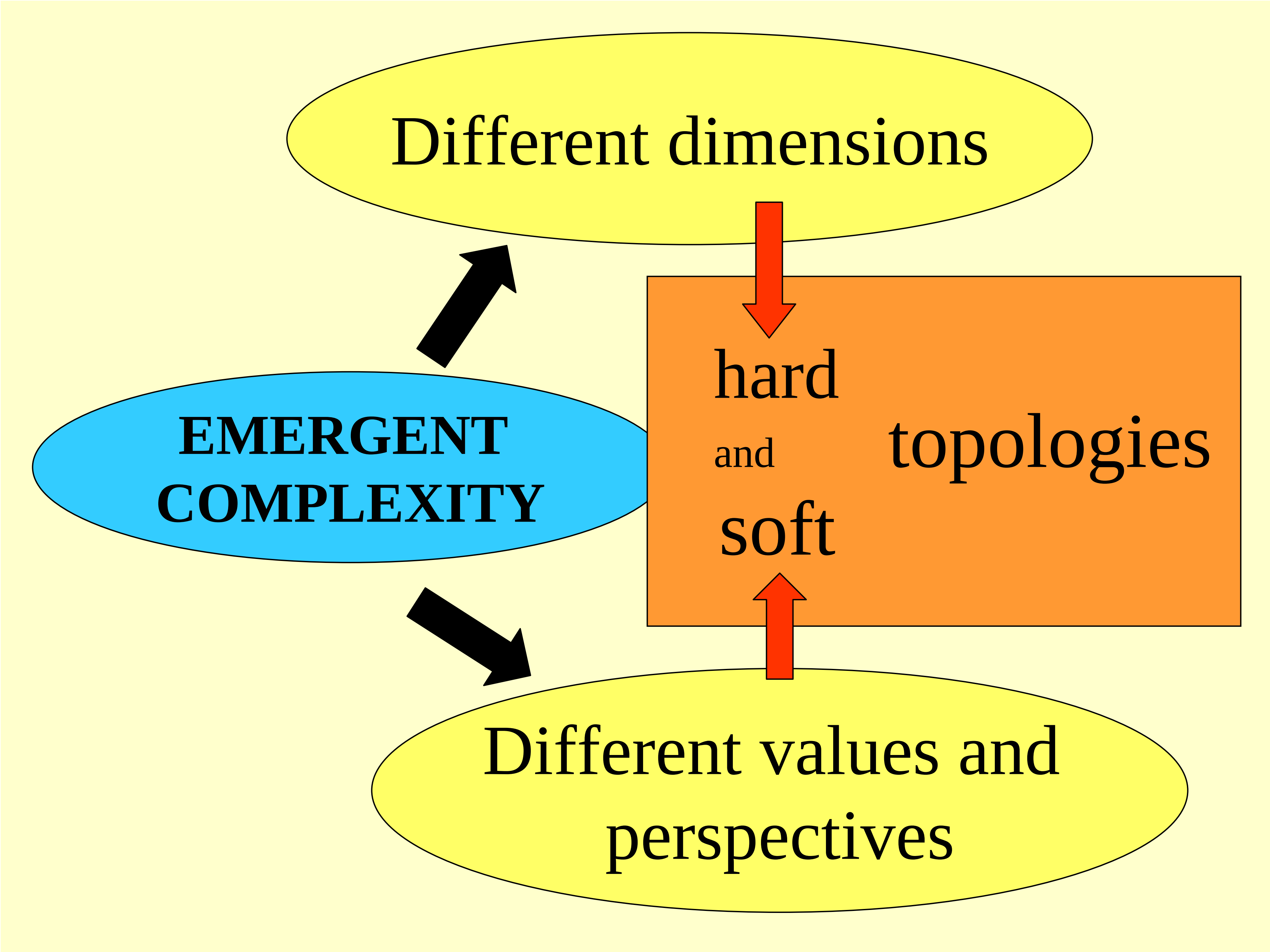


Hierarchical Levels:

Village/specific beach

d.

Complexity: the epistemological dimension


Different dimensions
EMERGENT
COMPLEXITY
hard
and
soft
topologies
Different values and
perspectives

1 measurable property: MONETARY

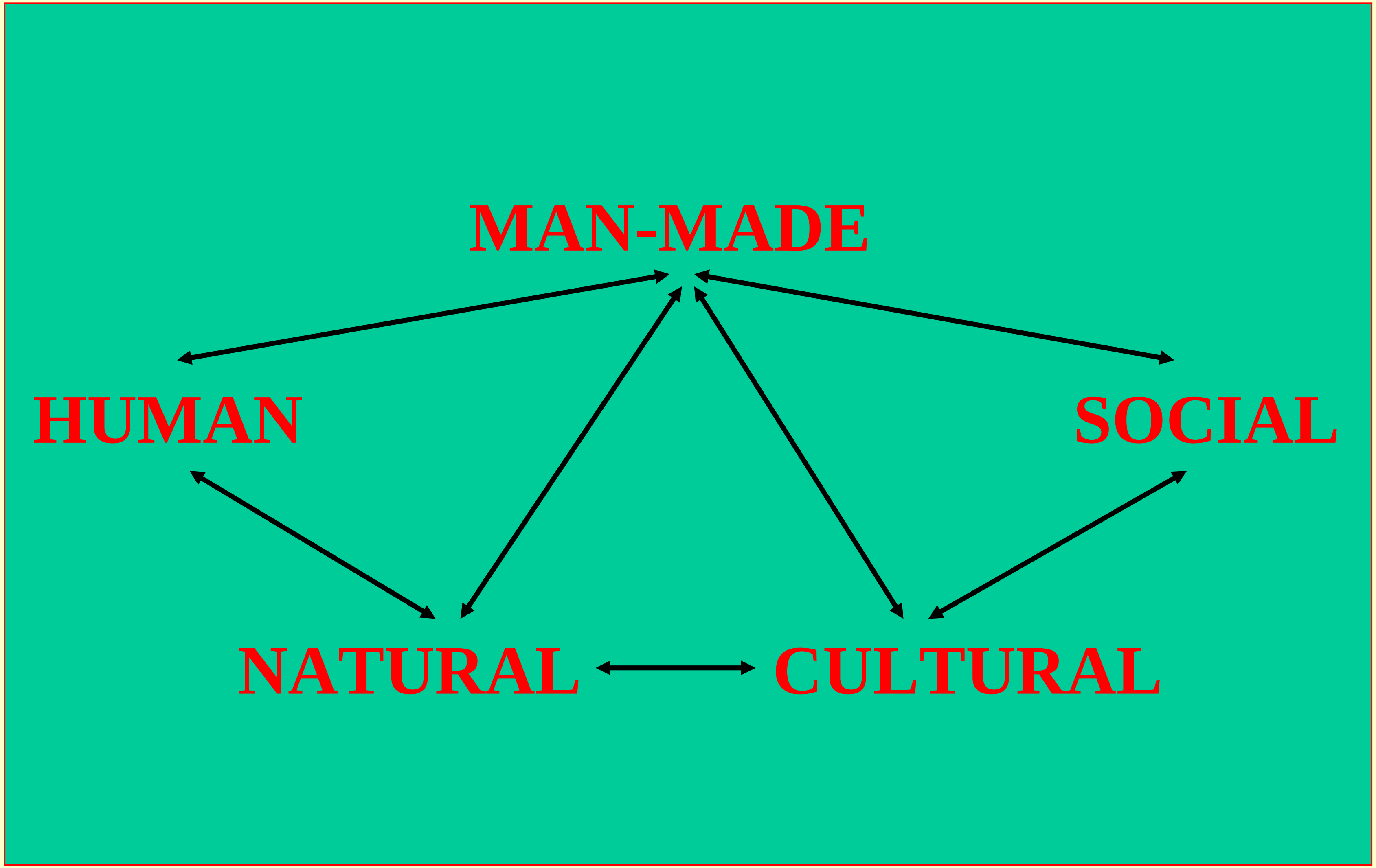
1 particular perspective: EFFICIENCY

hard topology only

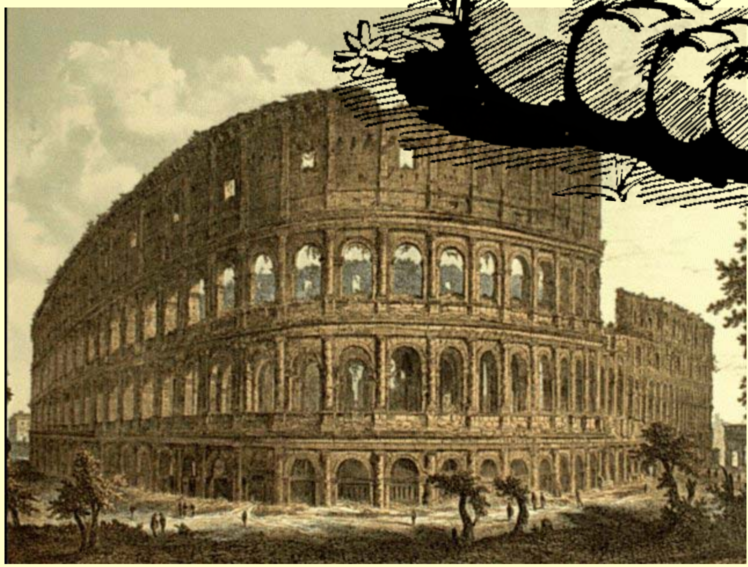
MONETARY REDUCTIONISM

IPCC

statistical value of human life



A co-evolutionary interpretation of a city

"The issue is not whether it is only the marketplace that can determine value, for economists have long debated other means of valuation; our concern is with the assumption that in any dialogue, all valuations or "numeraires" should be reducible to a single one-dimension standard".

(Funtowicz and Ravetz, 1994, p. 198)

Strong comparability

Weak commensurability

Strong commensurability

Weak comparability

incommensurability

GOVERNANCE in a COMPLEX world

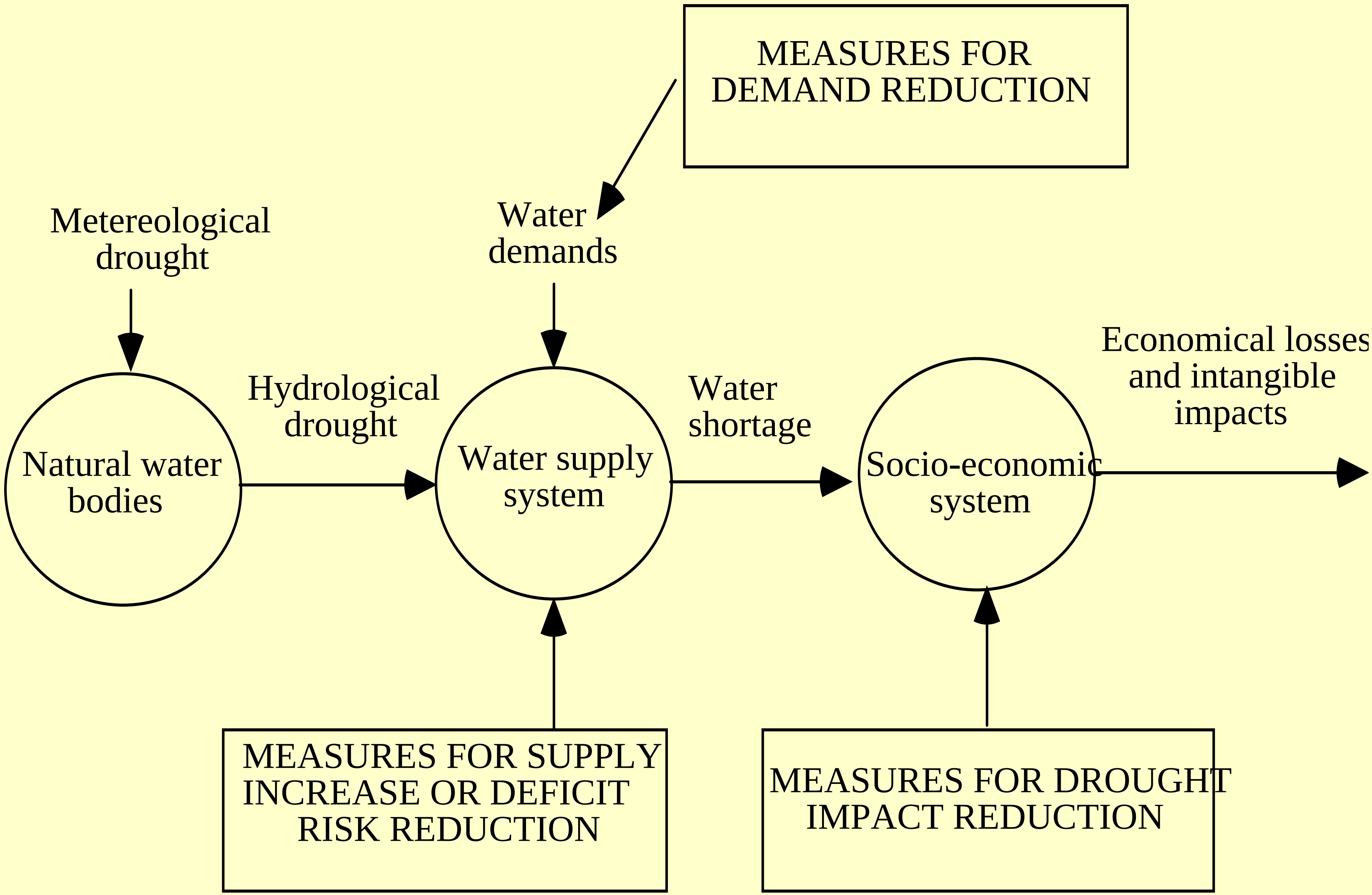
Contradictory scientific findings and lay opinions must be integrated into the policy.

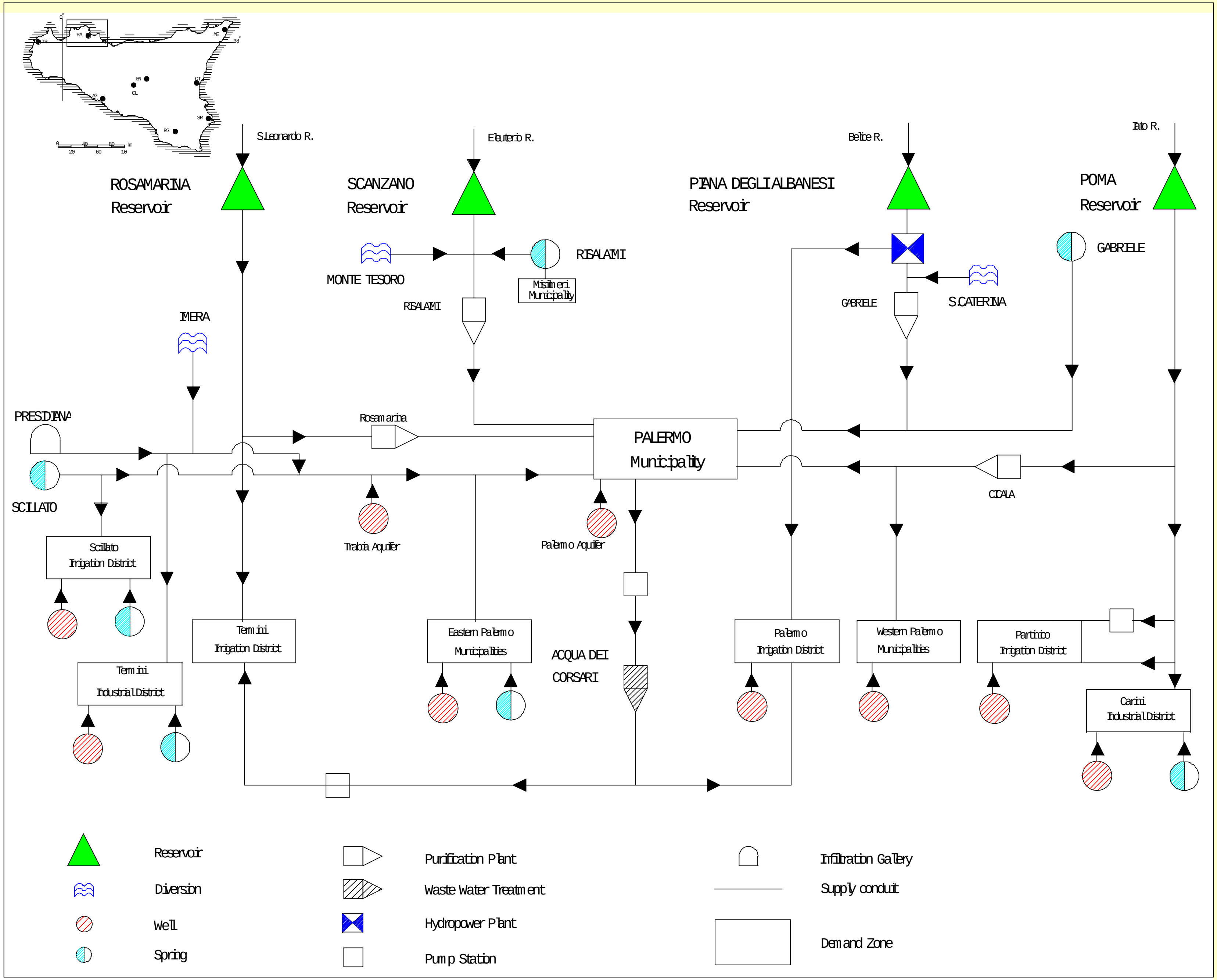
- ***Who has the power to impose a language of valuation?***
- ***Who has the power to privilege one analytical level or time-space scale?***
- ***Who has the power to simplify the complexity?***

Multi-, inter-, trans-disciplinarity?

- Multi-: each expert takes his part
- Inter-: methodological choices are discussed across the disciplines
  - Informing the others about object matter
  - Criticism, reflexivity
- Trans-: What is it? ....

Consequences: 1) MULTIDISCIPLINARITY




S.Leonardo R.
Eleuterio R.
Belice R.
Jato R.
ROSAMARINA Reservoir
SCANZANO Reservoir
PIANA DEGLI ALBANESI Reservoir
POMA Reservoir
MONTE TESORO
RISALAMI
Misilmeri Municipality
RISALAMI
GABRIELE
S.CATERINA
GABRIELE
IMERA
PRESIDIANA
SCILLATO
Rosamarina
PALERMO Municipality
CIDALA
Trabia Aquifer
Palermo Aquifer
Scillato Irrigation District
Termini Irrigation District
Termini Industrial District
Eastern Palermo Municipalities
ACQUA DEI CORSARI
Palermo Irrigation District
Western Palermo Municipalities
Partinico Irrigation District
Carini Industrial District
Reservoir
Diversion
Well
Spring
Purification Plant
Waste Water Treatment
Hydropower Plant
Pump Station
Infiltration Gallery
Supply conduit
Demand Zone

Consequence:

2) PARTICIPATIVE TECHNIQUES

- ***In-Depth Interviews***
- ***Focus Groups***
- ***Questionnaires***
- ***Institutional Analysis***
- ***e_democracy***

Objectives and Methodology of DIAFANIS

1. Why a conflict exists?
2. Which alternatives exist?
3. Which system dimensions can be affected?
4. How alternatives can be evaluated?
5. What means transparency?

Step 1: Evaluation of alternatives

1. Alternatives Generation

Historical analysis

Institutional analysis

Alternatives

A1 | A2 | An

Citizen Participation

2. Information Structuring

System Dimensions and Hierarchical Scales

Environmental | Economical | Social

International, National, Regional, Local

Data Collection and Participation

3. MCE Algorithm

Citizen Participation

Criteria Selection

Mixed Information

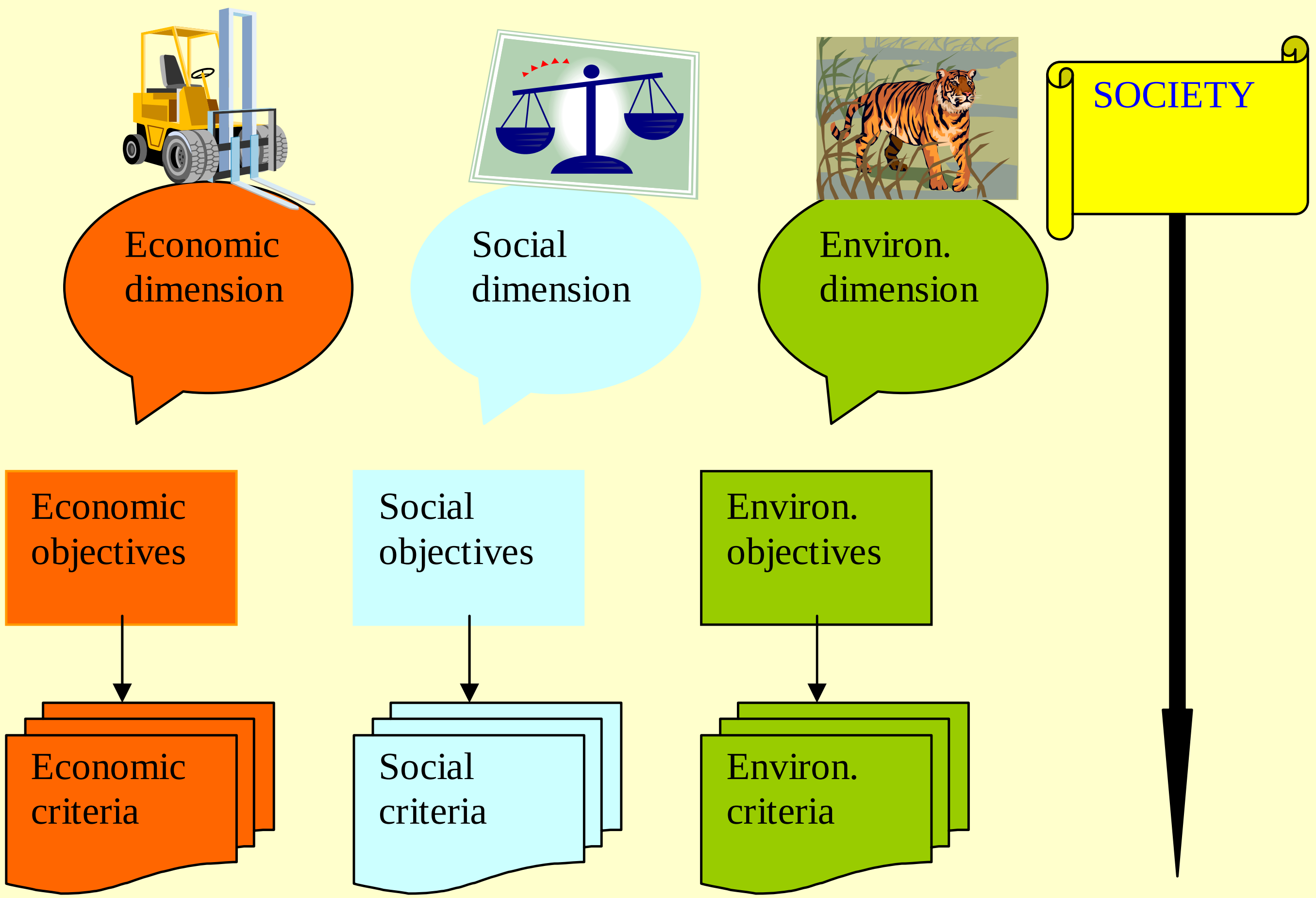
Alternatives Evaluation

Technical and Social Rankings

Step 2: Diffusion of results

1. Existence of multiple values	2. School visits
3. Citizens meetings	4. International Symposium

Consequences: 3) ETHICS MATTERS



Weights in a social framework

Political Democracy

Economic Democracy

Sustainability

Precautionary Principle

K. Arrow, H. Raynaud (1986):
"Social choice and multicriterion decision making"

Consequence:
4)THE AXIOMATIZATION ISSUE

The Plurality Rule

Number of criteria	3	5	7	6
	a	*a*	*b*	*c*

The Plurality Rule!

Number of criteria	3	5	7	6
	a	***a***	*b*	*c*
	b	*c*	*d*	*b*
	c	*b*	*c*	*d*
	d	*d*	***a***	***a***

An Original Condorcet's Numerical Example

Number of criteria	23	17	2	10	8
	a	*b*	*b*	*c*	*c*
	b	*c*	*a*	*a*	*b*
	c	*a*	*c*	*b*	*a*

The Borda Solution

	Alternatives	***a***	***b***	***c***	
Ranking					**Points**
1-st		23	19	18	2
2-nd		12	31	17	1
3-rd		25	10	25	0

$$a = 58,\ b = 69,\ c = 53$$

The Condorcet Solution

$$\begin{array}{c} \\ a \\ b \\ c \end{array}\begin{bmatrix} a & b & c \\ 0 & 33 & 25 \\ 27 & 0 & 42 \\ 35 & 18 & 0 \end{bmatrix}$$

It is: aPb, bPc and cPa, thus due to the transitive property a cycle exists and no alternative can be selected!

Fishburn Numerical Example on Borda Rule

Number of criteria	3	2	2
	c	*b*	*a*
	b	*a*	*d*
	a	*d*	*c*
	d	*c*	*b*

Fishburn Numerical Example on Borda Rule

	Alternatives	***a***	***b***	***c***	***d***	
Ranking						**Points**
1-st		2	2	3	0	3
2-nd		2	3	0	2	2
3-rd		3	0	2	2	1
4-th		0	2	2	3	0

$$a = 13,\ b = 12,\ c = 11,\ d = 6$$

Fishburn Numerical Example on Borda Rule

- Let's now suppose that alternative ***d*** is removed from the analysis. Since *d* was at the bottom of the ranking, nobody should have any reasonable doubt that alternative *a* is still the best alternative. Let's check if this assumption is correct.

Fishburn Numerical Example on Borda Rule

	Alternatives	*a*	*b*	*c*	
Ranking					**Points**
1-st		2	2	3	2
2-nd		2	3	2	1
3-rd		3	2	2	0

Frequency Matrix Without *d*

$$a = 6,\ b = 7,\ c = 8$$

thus alternative c is now chosen!

- Both social choice literature and multi-criteria decision theory agree that whenever the majority rule can be operationalized, it should be applied. However, the majority rule often produces undesirable intransitivities, thus ***"more limited ambitions are compulsory. The next highest ambition for an aggregation algorithm is to be Condorcet"*** (Arrow and Raynaud, 1986, p. 77).

Applying the maximum likelihhod ranking procedure to the original Condorcet Example

a	*b*	*c*	100
b	***c***	***a***	**104**
c	*a*	*b*	86
b	*a*	*c*	94
c	*b*	*a*	80
a	*c*	*b*	76

Sustainability Indicator

Indic.		GDP	Unemp. Rate	Solid wastes	Inc. disp.	Crime rate
Country						
A		25,000	0.15	0.4	9.2	40
B		45,000	0.10	0.7	13.2	52
C		20,000	0.08	0.35	5.3	80
weights		0.165	0.165	0.333	0.165	0.165

	A	B	C
A	0	0.666	0.333
B	0.333	0	0.333
C	0.666	0.666	0

ABC = 0.666 + 0.333 + 0.333 = 1.333

BCA = 0.333 + 0.666 + 0.333 = 1.333

CAB = 0.666 + 0.666 + 0.666 = 2

ACB = 0.333 + 0.666 + 0.666 = 1.666

BAC = 0.333 + 0.333 + 0.333 = 1

CBA = 0.666 + 0.333 + 0.666 = 1.666

The Computational problem

Moulin (1988, p. 312) clearly states that the Kemeny method is ***"the correct method"*** for ranking alternatives, and that the "*only drawback of this aggregation method is the difficulty in computing it when the number of candidates grows*".

One should note that the number of permutations can easily become unmanageable; for example when 10 alternatives are present, it is 10!=3,628,800.

A NP-hard problem

- The *complexity class* of *decision problems* that are intrinsically harder than those that can be solved by a *nondeterministic Turing machine* in *polynomial time*. When a decision version of a combinatorial *optimization problem* is proved to belong to the class of *NP-complete* problems, then the optimization version is NP-hard.
- (definition given by the National Institute of Standards and Technology, http://www.nist.gov/dads/HTML/nphard.html)

- This NP-hardness has discouraged the development of algorithms searching for exact solutions, thus the majority of the algorithms which have been proposed in the literature; are mainly
- ***heuristics based on artificial intelligence,***
- ***branch and bound approaches and***
- ***multi-stage techniques***

(see e.g., Barthelemy et al., 1989; Charon et al., 1997; Cohen et al., 1999; Davenport and Kalagnam, 2004; Dwork et al., 2001; Truchon, 1998b).

- A ***new numerical algorithm*** aimed at solving the computational problem connected to linear median orders by finding ***exact solutions*** has been proposed by Munda (2005). Main characteristics of this algorithm are that linear median orders are computed by using their ***theoretical equivalence with maximum likelihood rankings*** and that ***outranking matrixes*** are used as a starting computational step.

$$
\left\{
\begin{array}{lll}
a_j P a_k & \Leftrightarrow & g_m(a_j) > g_m(a_k) + p \\
a_j Q a_k & \Leftrightarrow & g_m(a_k) + p \geq g_m(a_j) > g_m(a_k) + q \\
a_j I a_k & \Leftrightarrow & \left\{ \begin{array}{l} g_m(a_k) + q \geq g_m(a_j) \\ g_m(a_j) + q \geq g_m(a_k) \end{array} \right.
\end{array}
\right\}
$$

Taking into account *<u>intensity of preference</u>*

A Real-World Application for 146 Countries

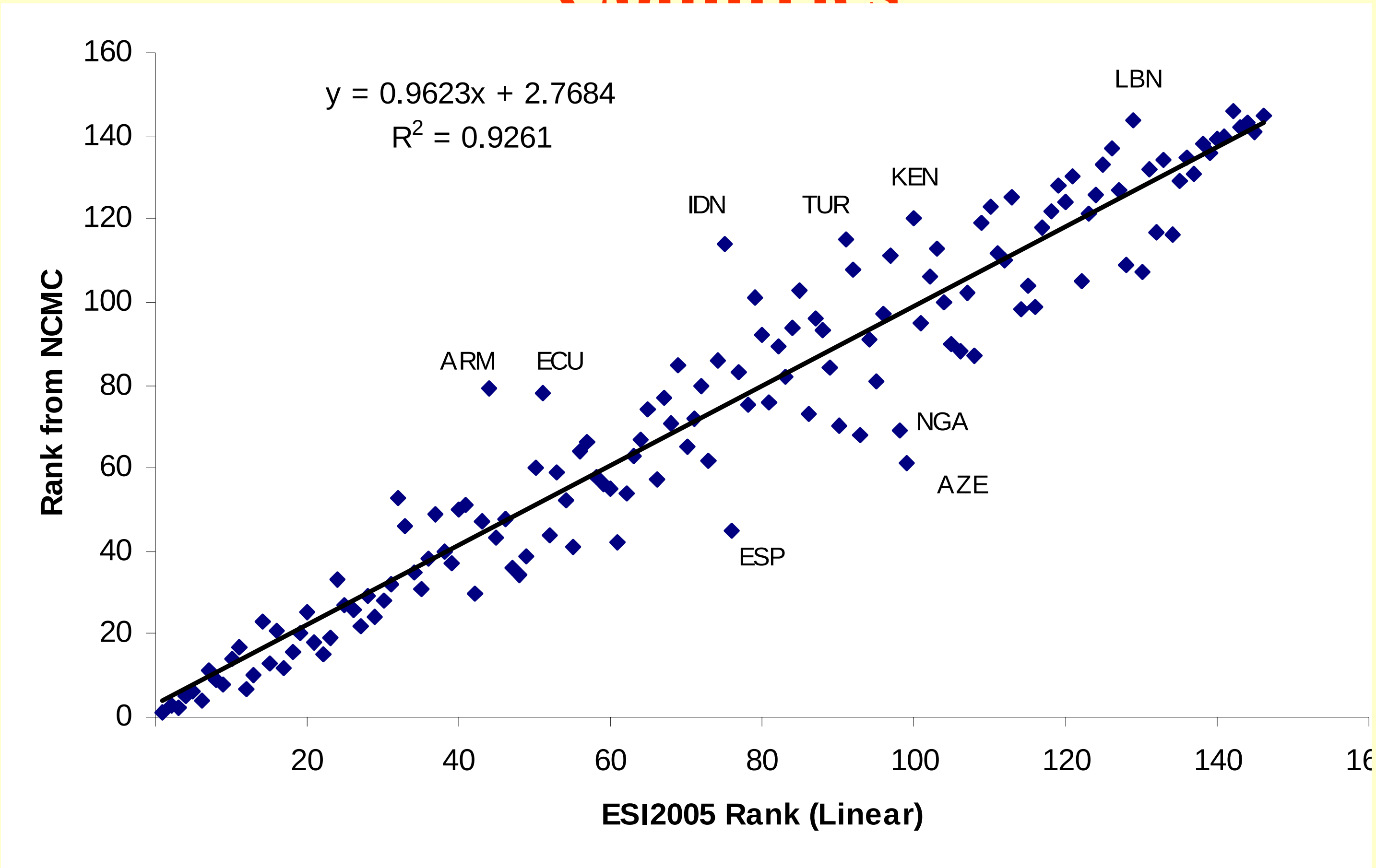


Figure 1. Comparison of rankings obtained by the linear aggregation (ESI2005) and the non-compensatory (NCMA) rules

	Aggregation	*ESI rank with LIN*	*rank with NCMC*	*Change in Rank*
Improvement	Azerbaijan	99	61	*38*
	Spain	76	45	*31*
	Nigeria	98	69	*29*
	South Africa	93	68	*25*
	Burundi	130	107	*23*
Deterioration	Indonesia	75	114	*39*
	Armenia	44	79	*35*
	Ecuador	51	78	*27*
	Turkey	91	115	*24*
	Sri Lanka	79	101	*22*
	Average change over 146 countries			*8*

Table 3. ESI rankings obtained by linear aggregation (LIN) and non-compensatory rule (NCMC): countries that largely improve or worsen their rank position

Matrix type Impact Case Study

Criteria \ Alternatives	Budapest	Moscow	Amsterdam	New York
Houses owned (%)	50.5	40.2	2.2	10.3
Residential density (pers. /hectare)	123.3	225.2	152.1	72
Use of private car (%)	31.1	10	60	32.5
Mean travel time to work (minutes)	40	62	22	36.5
Solid waste generated per capita (t./year)	0.2	0.29	0.4	0.61
City product per person (US$/year)	4750	5100	28251	30952
Income disparity (Q5/Q!)	9.19	7.61	5.25	14.81
Households below poverty line (%)	36.6	15	20.5	16.3
Crime rate per 1000 (theft)	39.4	4.3	144.05	56.7

$$I = \sum_{i=1}^{N} w_i x_i$$

Normalisation technique used for the different measurement units dealt with.

Scale adjustment used, for example population or GDP of each country considered.

Common measurement unit used (money, energy, space and so on).

100	78.674	0	16.770
33.485	100	52.28	0
42.2	0	100	45
45	100	0	36.25
0	21.95	48.78	100
0	1.335	89.691	100
41.213	24.686	0	100
100	0	25.462	6.018
25.116	0	100	37.495

Normalized Impact Matrix

100	78.674	0	16.770
66.515	0	47.72	100
57.8	100	0	55
55	0	100	63.75
100	78.05	51.22	0
0	1.335	89.691	100
58.787	75.314	100	0
0	100	74.538	93.982
74.884	100	0	62.505

Normalised Impact Matrix Accounting for Minimisation Objectives

Budapest = 512.986

Moscow = 533.373

Amsterdam = 463.169

New York = 492.052

From where are these results coming from?

Information available

Indicators chosen

Direction of each indicator

Relative importance

Aggregation Procedure

- **Weights** in linear aggregation rules have always the meaning of trade-off ratio. In all constructions of a composite indicator, weights are used as importance coefficients; as a consequence, a theoretical inconsistency exists.

- The assumption of **preference independence** is essential for the existence of a linear aggregation rule. Unfortunately, this assumption has very strong consequences which often are not desirable in sustainability indicators. The use of a linear aggregation procedure implies that among the different ecosystem aspects there are not phenomena of synergy or conflict. This appears to be quite an unrealistic assumption.

- In linear aggregation rules, **compensability** among the different individual indicators is always assumed; this implies complete substitutability among the various components considered. For example, in a sustainability index, economic growth can always substitute any environmental destruction or inside e.g., the environmental dimension, clean air can compensate for a loss of potable water. From a descriptive point of view, such a complete compensability is often not desirable.

	Budapest	**Moscow**	**Amsterdam**	**New York**
Budapest	0	4	4	5
Moscow	5	0	5	6
Amsterdam	5	4	0	3
New York	4	3	6	0

Outranking Matrix of the 4 Cities According to the 9 Indicators

B	**A**	**D**	**C**	**31**	C	B	D	A	27
B	**D**	**C**	**A**	**31**	D	B	A	C	27
A	B	D	C	30	D	C	B	A	27
B	D	A	C	30	A	C	B	D	26
B	C	A	D	29	A	D	C	B	26
B	A	C	D	28	D	A	B	C	26
B	C	D	A	28	D	C	A	B	26
C	B	A	D	28	D	A	C	B	25
D	B	C	A	28	C	A	D	B	24
A	B	C	D	27	C	D	B	A	24
A	D	B	C	27	A	C	D	B	23
C	A	B	D	27	C	D	A	B	23

B	**A**	**D**	**C**	**31**
B	**D**	**C**	**A**	**31**

Where A is Budapest, B is Moscow, C is Amsterdam and D is New York.

Economic dimension

City product per person

Environmental dimension

Use of private car

Solid waste generated per capita

Social dimension

Houses owned

Residential density

Mean travel time to work

Income disparity

Households below poverty line

Crime rate

A reasonable decision might be to consider the three dimensions equally important. This would imply to give the same weight to each dimension considered and finally to split this weight among the indicators. That is, each dimension has a weight of 0.333; then the economic indicator has a weight of 0.333, the 2 environmental indicators have a weight of 0.1666 each, and each one of the 6 social indicators receives a weight equal to 0.0555. As one can see, if dimensions are considered, weighting indicators by means of importance coefficients is crucial.

	Budapest	Moscow	Amsterdam	New York
Budapest	0	0.3	0.4	0.4
Moscow	0.7	0	0.5	0.6
Amsterdam	0.6	0.5	0	0.3
New York	0.6	0.4	0.7	0

Weighted Outranking Matrix

B D C A

Where A is Budapest, B is Moscow, C is Amsterdam and D is New York.

CONCLUSION:

Results are heavily dependent on the problem structuring step!!


QUALITY OF PRODUCT
PROCEDURAL RATIONALITY
LEARNING HOLARCHIES
MCDA
ETHICS
RESPONSIBILITY
CONSISTENCY
QUALITY OF “SOCIAL” PROCESS
TRANSPARENCY
PARTICIPATION
MULTI/INTER-DISCIPLINARITY