EPFL

SUSTAINABILITY ASSESSMENT OF URBAN SYSTEMS

Sustainability Assessment of Urban Systems

(ENV-461)

9: Multi-Criteria Analysis (MCA)

Lecturers:

Dr. Matthias Heinrich

Assistants:

Gloria Serra Coch, Ankita Singhvi, Giulia Frigo, Simon Ladino Cano, Hanbit Lee

Lecture content based on Albert M.S work

Laboratory on Human-Environment Relations in Urban Systems

EPFL

Program of the course

Lectures : BS 170 on Wednesdays, 13:15 – 16:00 (Lecture + Exercise)

n°	Date	Session	Milestones Project
1	19/02/2025	**Introduction** into sustainability and SA	
2	26/02/2025	**Sustainability issues** in **urban systems**	
3	05/03/2025	**Key steps in SA #1**: SSP, normative dimension, frameworks	**Groups formed**
4	12/03/2025	**Key steps in SA #2**: Systemic dimension	
5	19/03/2025	**Key steps in SA #3**: Participatory dimension	**Submission - Outline 19.03**
6	26/03/2025	**Deriving indicators (1/2)**	
7	02/04/2025	**Deriving indicators (2/2)**	
8	09/04/2025	**Influence matrix**	
9	16/04/2025	**Multi-Criteria Analysis**	
	23/04/2025	**Easter break**	
10	30/04/2025	**Deriving policy recommendations**	
11	07/05/2025	**Working session : Poster preparation**	
12	14/05/2025	**Sustainability Assessment in practice** **Roundtable with stakeholders**	
13	21/05/2025	**Exam**	
14	28/05/2025	**Presentation of semester work_2**	

* May be updated depending on the number of students enrolled

A chronological overview of the course

- **Indicator framework**
- **Alternatives, scenarios**

- **Stakeholders**
- **Scales** (system boundaries)
- **System embeddedness**

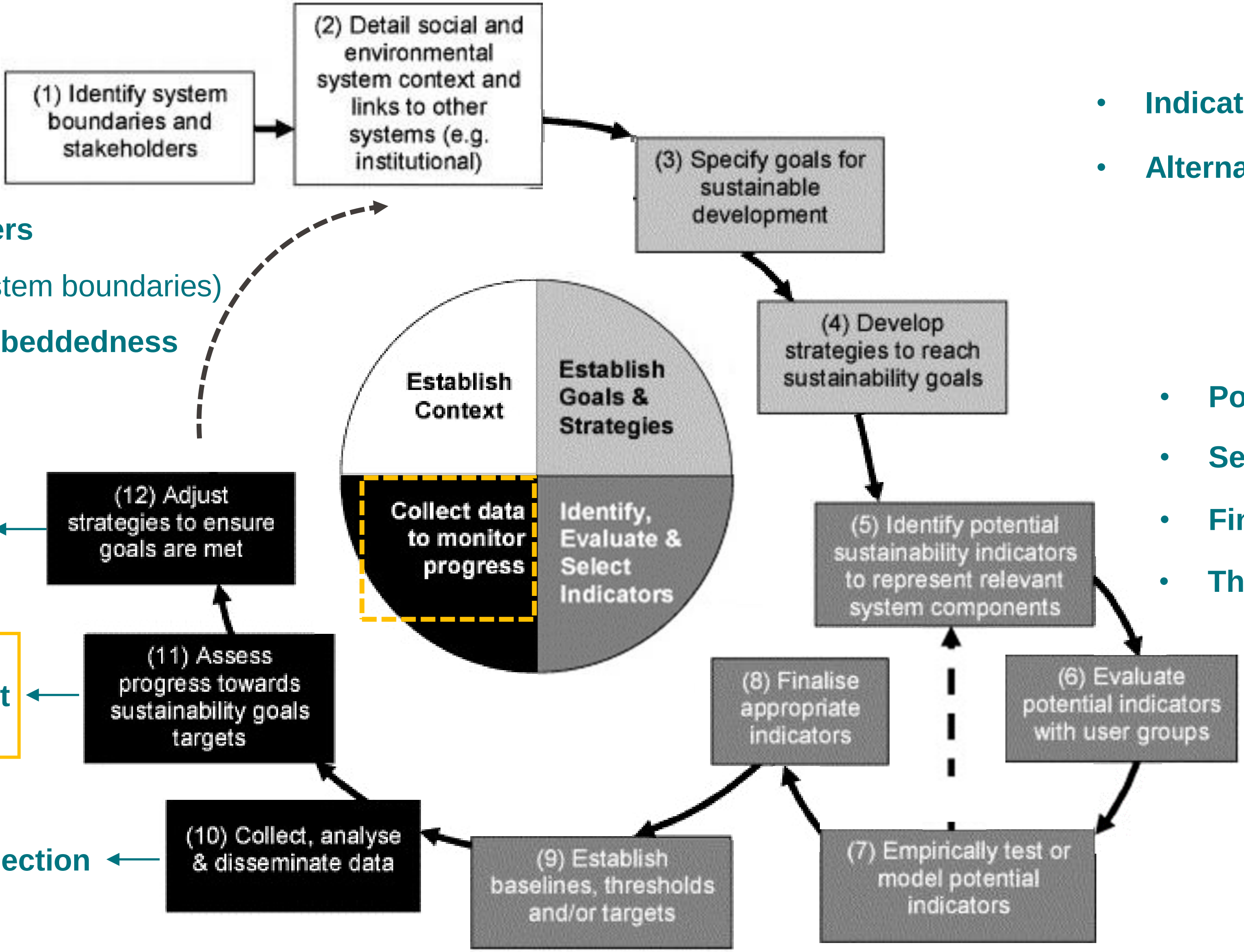
- **Potential indicators**
- **Selection criteria**
- **Final set of indicators**
- **Thresholds & targets**

Lecture 9

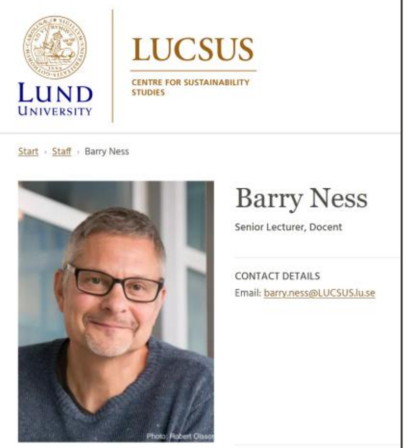
Recommendations ←

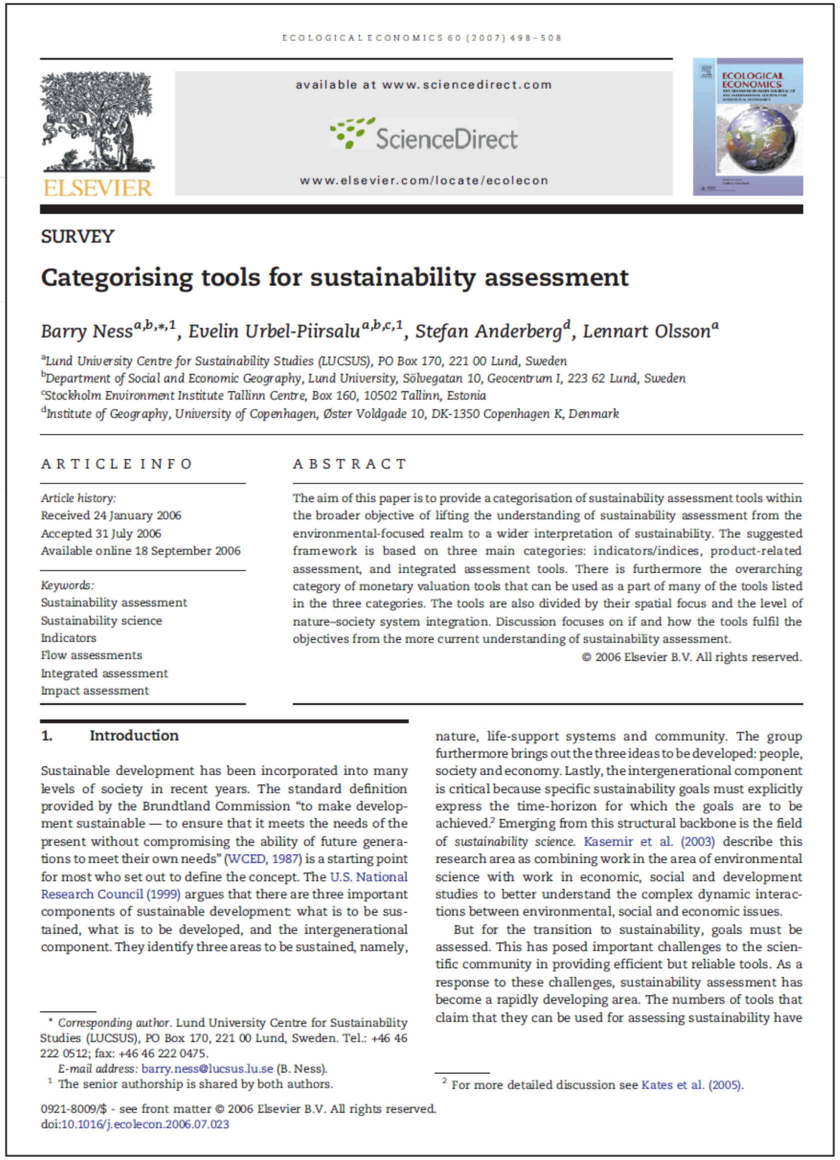
Assessment ←

Data collection ←



Laboratory on Human-Environment Relations in Urban Systems





ECOLOGICAL ECONOMICS 60 (2007) 498–508

available at www.sciencedirect.com
ScienceDirect
www.elsevier.com/locate/ecolecon

SURVEY

Categorising tools for sustainability assessment

Barry Ness[a,b,*,1], Evelin Urbel-Piirsalu[a,b,c,1], Stefan Anderberg[d], Lennart Olsson[a]

[a]Lund University Centre for Sustainability Studies (LUCSUS), PO Box 170, 221 00 Lund, Sweden
[b]Department of Social and Economic Geography, Lund University, Sölvegatan 10, Geocentrum I, 223 62 Lund, Sweden
[c]Stockholm Environment Institute Tallinn Centre, Box 160, 10502 Tallinn, Estonia
[d]Institute of Geography, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark

ARTICLE INFO

Article history:
Received 24 January 2006
Accepted 31 July 2006
Available online 18 September 2006

Keywords:
Sustainability assessment
Sustainability science
Indicators
Flow assessments
Integrated assessment
Impact assessment

ABSTRACT

The aim of this paper is to provide a categorisation of sustainability assessment tools within the broader objective of lifting the understanding of sustainability assessment from the environmental-focused realm to a wider interpretation of sustainability. The suggested framework is based on three main categories: indicators/indices, product-related assessment, and integrated assessment tools. There is furthermore the overarching category of monetary valuation tools that can be used as a part of many of the tools listed in the three categories. The tools are also divided by their spatial focus and the level of nature–society system integration. Discussion focuses on if and how the tools fulfil the objectives from the more current understanding of sustainability assessment.

1. Introduction

Sustainable development has been incorporated into many levels of society in recent years. The standard definition provided by the Brundtland Commission "to make development sustainable — to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987) is a starting point for most who set out to define the concept. The U.S. National Research Council (1999) argues that there are three important components of sustainable development: what is to be sustained, what is to be developed, and the intergenerational component. They identify three areas to be sustained, namely, nature, life-support systems and community. The group furthermore brings out the three ideas to be developed: people, society and economy. Lastly, the intergenerational component is critical because specific sustainability goals must explicitly express the time-horizon for which the goals are to be achieved.[2] Emerging from this structural backbone is the field of *sustainability science*. Kasemir et al. (2003) describe this research area as combining work in the area of environmental science with work in economic, social and development studies to better understand the complex dynamic interactions between environmental, social and economic issues.

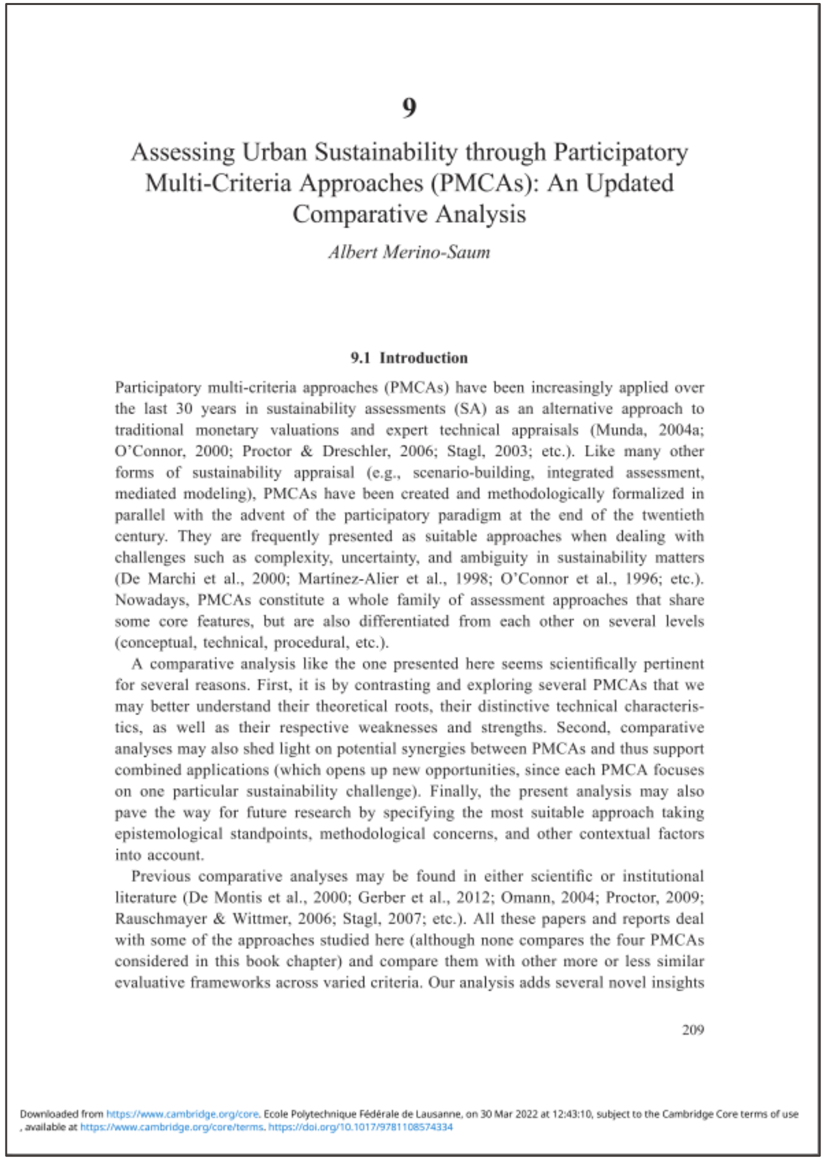
But for the transition to sustainability, goals must be assessed. This has posed important challenges to the scientific community in providing efficient but reliable tools. As a response to these challenges, sustainability assessment has become a rapidly developing area. The numbers of tools that claim that they can be used for assessing sustainability have

* *Corresponding author*. Lund University Centre for Sustainability Studies (LUCSUS), PO Box 170, 221 00 Lund, Sweden. Tel.: +46 46 222 0512; fax: +46 46 222 0475.
E-mail address: barry.ness@lucsus.lu.se (B. Ness).
[1] The senior authorship is shared by both authors.

[2] For more detailed discussion see Kates et al. (2005).

0921-8009/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolecon.2006.07.023

Ness et al. (2007)



9

Assessing Urban Sustainability through Participatory Multi-Criteria Approaches (PMCAs): An Updated Comparative Analysis

Albert Merino-Saum

9.1 Introduction

Participatory multi-criteria approaches (PMCAs) have been increasingly applied over the last 30 years in sustainability assessments (SA) as an alternative approach to traditional monetary valuations and expert technical appraisals (Munda, 2004a; O'Connor, 2000; Proctor & Dreschler, 2006; Stagl, 2003; etc.). Like many other forms of sustainability appraisal (e.g., scenario-building, integrated assessment, mediated modeling), PMCAs have been created and methodologically formalized in parallel with the advent of the participatory paradigm at the end of the twentieth century. They are frequently presented as suitable approaches when dealing with challenges such as complexity, uncertainty, and ambiguity in sustainability matters (De Marchi et al., 2000; Martinez-Alier et al., 1998; O'Connor et al., 1996; etc.). Nowadays, PMCAs constitute a whole family of assessment approaches that share some core features, but are also differentiated from each other on several levels (conceptual, technical, procedural, etc.).

A comparative analysis like the one presented here seems scientifically pertinent for several reasons. First, it is by contrasting and exploring several PMCAs that we may better understand their theoretical roots, their distinctive technical characteristics, as well as their respective weaknesses and strengths. Second, comparative analyses may also shed light on potential synergies between PMCAs and thus support combined applications (which opens up new opportunities, since each PMCA focuses on one particular sustainability challenge). Finally, the present analysis may also pave the way for future research by specifying the most suitable approach taking epistemological standpoints, methodological concerns, and other contextual factors into account.

Previous comparative analyses may be found in either scientific or institutional literature (De Montis et al., 2000; Gerber et al., 2012; Omann, 2004; Proctor, 2009; Rauschmayer & Wittmer, 2006; Stagl, 2007; etc.). All these papers and reports deal with some of the approaches studied here (although none compares the four PMCAs considered in this book chapter) and compare them with other more or less similar evaluative frameworks across varied criteria. Our analysis adds several novel insights

Merino-Saum (2020)

Sustainability Assessment of Urban Systems

Laboratory on Human-Environment Relations in Urban Systems

Putting MCA into context…

Laboratory on Human-Environment Relations in Urban Systems

MCA: one tool among others…

The number of tools and approaches that claim that they can be used for assessing sustainability has rapidly grown in the last 20 year…

Risk Analysis

Contingent Valuation Method

Environmental Impact Assessment

Conceptual Modelling

Human Appropriation of Net Primary Production (HANPP)

Vulnerability Analysis

Life Cycle Assessment (LCA)

Scenario Development & Analysis

Multi-Criteria Analysis (MCA)

Emergy Analysis

Ecological Footprint

Exergy Analysis

System Dynamics

Cost-Benefit Analysis (CBA)

Material Flow Analysis (MFA)

Travel Cost Method

Hedonic Pricing

Input-Output Analysis

Focus on **flows** in connection with production and consumption of **goods and services**

Ex-post analysis (descriptive)

Ex-ante analysis (change-oriented)

3 "**umbrella**" categories of sustainability assessment tools

Unidimensional sets of indicators

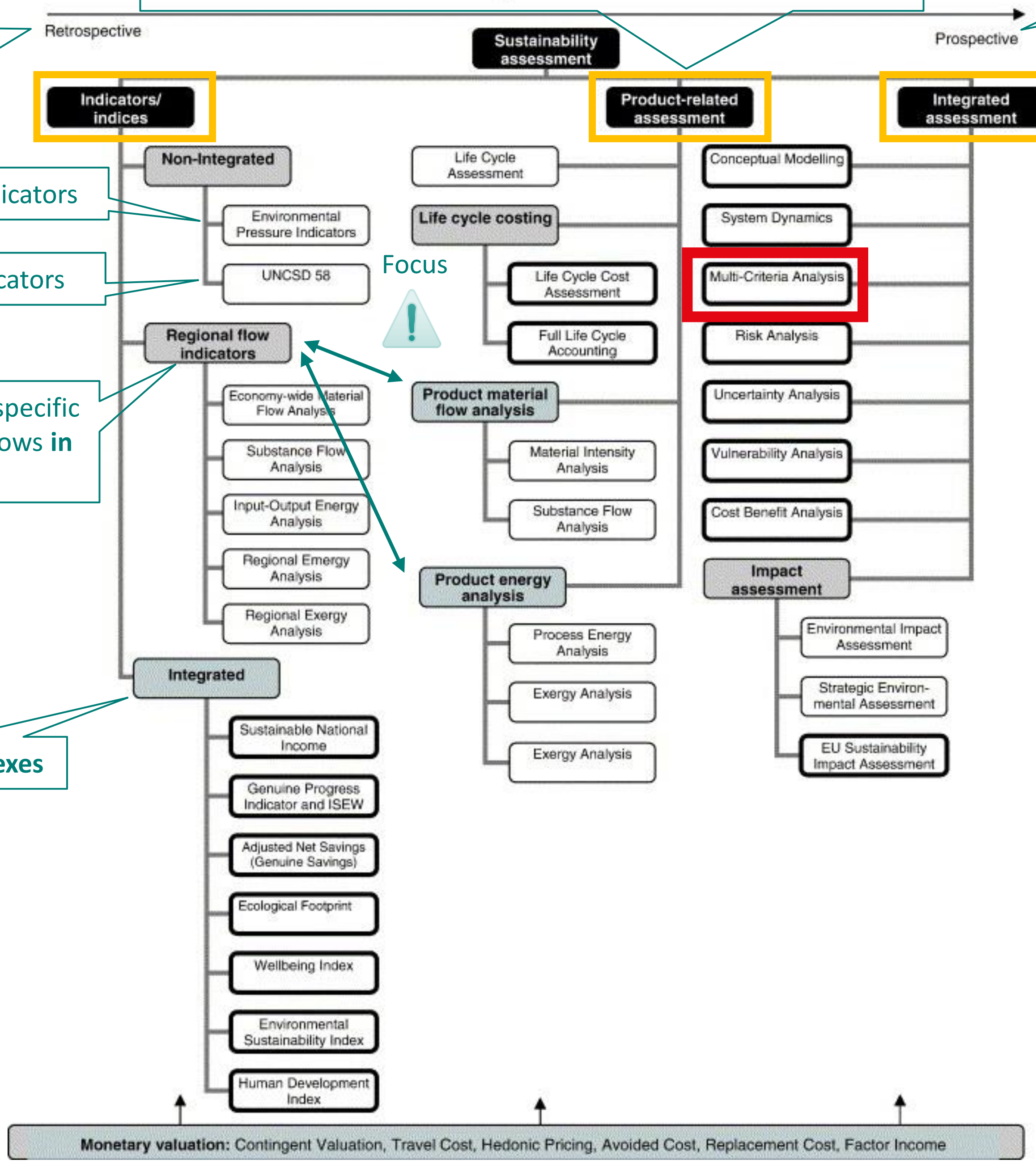
Disaggregated sets of indicators

Focus on: (i) materials, (ii) specific substances or (iii) energy flows **in a particular region**.

Composite **indexes**

Focus

Often carried out in the form of **scenarios**. Many of them rely on **system analysis** approaches and **integrate** nature and society concerns

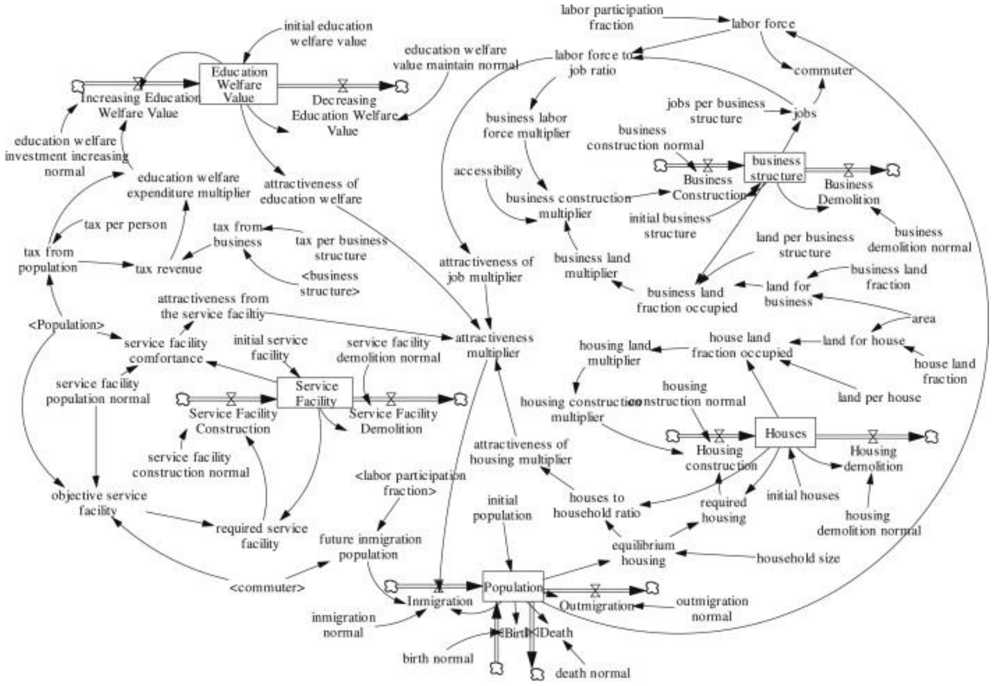


Integrated tools

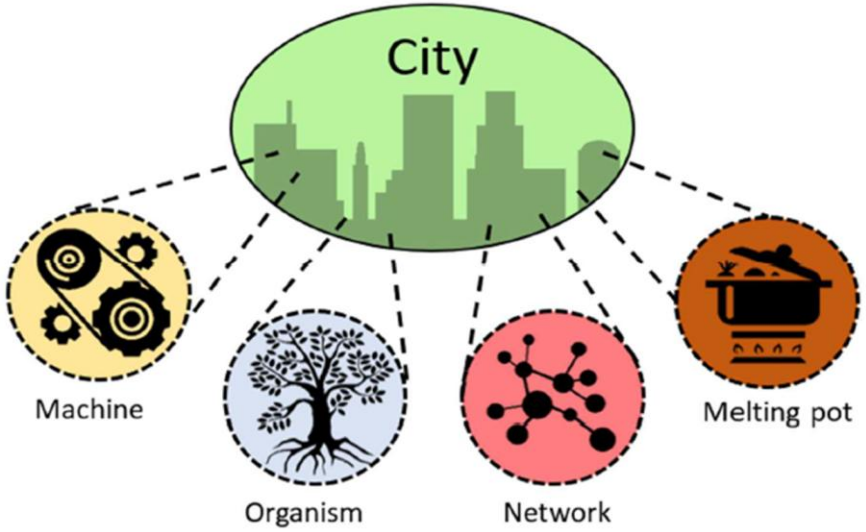
NON-integrated tools

Ness et al. (2007)

The overarching objective of MCA is the study of decision problems in which **several points of view (or evaluative criteria) must be simultaneously taken into consideration** (Roy & Vincke 1981)



(Park et al. 2020)



(Halla et al. 2020)

MCA: a (very brief) historical overview...

Period	Approach	Characteristics	Application
1960–1970	Multi-Criteria Decision **Making** (MCDM)	Perfect **mathematical axiomatization** An **optimal** solution is determined	AMC is mostly applied in **Management**
1980–1990	Multi-Criteria Decision **Aid** (MCDA)	New paradigms of rationality Identification of **acceptable** solutions Existing conflicts are made explicit	AMC is mostly applied in **policy-making**
2000–2015	Participatory Multi-Criteria Approaches (PMCA)	**Participation** becomes an imperative Criticisms towards the opacity of some MCA	AMC applied in **Environmental Governance**

MCA: a (very brief) historical overview…

Period	Approach	Characteristics	Application
1960–1970	Multi-Criteria Decision **Making** (MCDM)	Perfect **mathematical axiomatization** An **optimal** solution is determined	AMC is mostly applied in **Management**
1980–1990	Multi-Criteria Decision **Aid** (MCDA)	New paradigms of rationality Identification of **acceptable** solutions Existing conflicts are made explicit	AMC is mostly applied in **policy-making**
2000–2015	Participatory Multi-Criteria Approaches (PMCA)	**Participation** becomes an imperative Criticisms towards the opacity of some MCA	AMC applied in **Environmental Governance**

MCA: core elements

Several **alternatives**

A finite set of **evaluative criteria**

Performance scores

Aggregative procedure

(Martel & Rousseau 1993; Banville et al. 1998)

MCA: core elements – Impact matrix

A is a finite **set of options** a_j *(j=1,2,…,n)*

G is a finite **set of evaluative criteria** seen as being pertinent g_i *(i=1,2,…,m)*,

		Options			
Criteria	**Units**	$a_{j=1}$	$a_{j=2}$	(…)	$a_{j=n}$
$g_{i=1}$		$g_1(a_1)$	$g_1(a_2)$	…	$g_1(a_n)$
$g_{i=2}$		…	…	…	…
(…)		…	…	…	…
$g_{i=m}$		$g_m(a_1)$	$g_m(a_2)$	…	$g_m(a_n)$

Performance scores

Option a_1 is seen as being better than option a_2 according to criterion g_1, when the performance score that a_1 gets for this criterion is higher than the performance score that a_2 gets for the same criterion; i.e. $g_i(a_1) > g_i(a_2)$.

EPFL

MCA: core elements – Impact matrix

"INFLUENCE" Matrix

		Environmental aspects			Economic aspects			Social aspects		
		Indicator Env.1	Indicator Env. 2	Indicator Env. 3	Indicator Econ.1	Indicator Econ. 2	Indicator Econ. 3	Indicator Soc. 1	Indicator Soc. 2	Indicator Soc. 3
Environmental aspects	Indicator Env. 1		0	1	0	1	0	-2	1	0
	Indicator Env. 2	0		1	0	1	0	2	1	0
	Indicator Env. 3	1	1		0	1	0	-1	1	0
Economic aspects	Indi. Econ. 1	1	1	1		1	0	1	1	-1
	Ind. Econ. 2	-1	1	1	2		0	1	1	0
	Ind. Econ. 3	1	-1	1	2	0		1	0	0
Social aspects	Indicator Soc. 1	1	1	-2	0	0	0		1	0
	Indicator Soc. 2	2	2	2	1	0	0	2		1
	Indicator Soc. 3	1	1	1	1	1	0	2	1	

"IMPACT" Matrix

		Options			
Criteria	Units	$a_{j=1}$	$a_{j=2}$	(...)	$a_{j=n}$
$g_{i=1}$		$g_1(a_1)$	$g_1(a_2)$	...	$g_1(a_n)$
$g_{i=2}$		...	...	...	...
(...)		...	...	...	...
$g_{i=m}$		$g_m(a_1)$	$g_m(a_2)$	...	$g_m(a_n)$

MCA: core elements – Impact matrix

Illustration 1: Windfarm location in Catalonia (Northern Spain).

Table 19
Multi-criteria impact matrix

Options

Criteria	Units	Dir.	CB-Pre	CB	ST	CBST	L	R	NP
Owners' income	€/year	5	48,000	33,000	99,000	132,000	78,000	72,000	—
Economic activity tax	€/year	5	~12,750	~15,470	~46,410	~61,880	~36,570	~33,750	—
Construction tax	€	5	~61,990	~55,730	~96,520	~152,250	~81,890	~67,650	—
Number of jobs		5	2	1	4	5	3	3	—
Visual impact	km^2	6	76.570	71.465	276.550	348.015	220.400	163.290	—
Forest lost	ha	6	8.4	8.1	6.6	14.7	3.9	2.6	—
Avoided CO_2 emissions	ton CO_2/year	5	4680	6010	19,740	25,750	14,740	13,760	—
Noise	dB(A)	6	14.64	23.86	18.6	23.84	20.88	14.66	—
Installed capacity	MW	5	13.6	16.5	49.5	66	39	36	—

Criteria

Performance scores

Gamboa & Munda (2006)

MCA: core elements – Impact matrix

Illustration 2: Urban water management (Troina, Italy).

Table 1
Multicriteria impact matrix for the policy options

Options

Criteria	Alternatives							
	Business as usual	Mineral water	Mineral water +recreation	Information campaign	Implementation of the Galli law	Self-sufficiency	Compensation	Change irrigation structure in CT
Use of water	Moderate	More or less good	More or less good	Moderate	Good	Good	Moderate	Very good
Returns	Moderate	Good	Good	Moderate	Moderate	Good	Moderate	Moderate
Financial constraint	Very good	Moderate	Moderate	Very good	Very good	Moderate	Very good	Very bad
Employment	Moderate	More or less good	Good	Moderate	Moderate	Moderate	Moderate	Moderate
Community vulnerability	Very high	High	More or less high	More or less high	Very high	More or less high	High	Very high
Community identity	Bad	Good	Good	Good	Bad	More or less good	Good	Bad
Transparency	Very bad	Very bad	Very bad	Very good	Bad	More or less good	More or less bad	Bad
Participation	Bad	Bad	Bad	More or less good	Bad	Moderate	Bad	Bad
Precautionary principle	More or less good	More or less bad	More or less bad	More or less good	More or less good	Moderate	More or less good	Good

Criteria

Performance scores

De Marchi et al. (2000)

MCA as a way of life…

Disposable budget: 60€/trip

- Critical thresholds
- Lexicographic preferences
- Total commensurability

…We all face **complex problems in our current life** and we all tackle them (more or less explicitly) through a multi-criteria reasoning…!!

Travelling to Paris… — **Options**

Criteria	Units	Own [redacted]car	Car sharing	Plane	Tr[redacted]in	Bus
Economic costs	Euros	85 [redacted]ros	40 euros	50 euros	79 [redacted]ros	37 euros
Carbon impact	kg eq. CO_2	138.[redacted]3 kg	46.11 kg	159.37 kg	20.[redacted]5 kg	21.60 kg
Time	Hours	5[redacted]0	5h30	1h	3[redacted]5	7h30
Comfort	Qualitative scale	Very[redacted]igh	High	Medium	H[redacted]h	Low
Social interactions (possibility of meeting people)	Subjective scale		7	3		3
Reliability	Probability of delay (subj. scale)		+	++	+[redacted]+	+
Possibility of working	Hours of work (estimation)	[redacted]	0h	30min	[redacted]h	4h
Fidelity programs	Ex: miles (Airfrance)	Not p[redacted]ssible	Easy	Easy	Ver[redacted]easy	Not possible

Weighted sum methods

MCA: Aggregative procedures

Several **alternatives**

A finite set of **evaluative criteria**

Performance scores

Aggregative procedure

1. Weighted sum methods

2. Outranking methods

3. Analytical Hierarchy Process (AHP)

Weighted sum methods

Weighted sum methods are particularly **straightforward** (Janssen & Munda 1999: 841; Dodgson et al. 2009: 25; etc.).

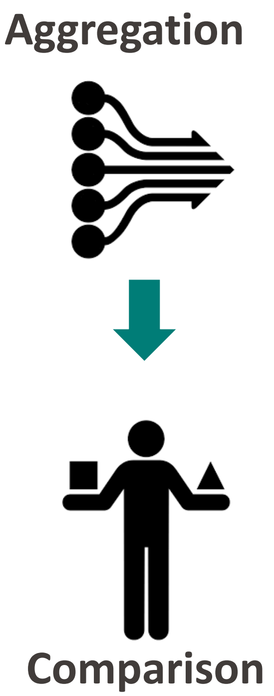
In weighted sum methods, all performance scores obtained by an option are aggregated and then integrated within an overall score.

The aggregation relies on **THREE STEPS**:

(i) **Standardizing** performance scores;

(ii) **Multiplying** such scores by their respective **weights**;

(iii) **Adding** all the resulting scores.



Weighted sum methods

From a mathematical point of view, such a process implies to apply the following equation :

$$I_j = \sum_{i=1}^{n} w_i \cdot p_{ij}$$

Where:

I_j express the **overall value** associated to option *j* ;

w_i is the **weight** given to criterion *i* ;

p_{ij} signals the **normalized score** for option *j* according *to* criterion *i* ;

With $\sum_{i=1}^{N} w_i = 1$; $0 \leq w_i \leq 1$; and $i = 1,2,\ldots,n$.

Thanks to weighted sum methods, **all the options may be ranked and compared to each other**.

The best option is the one with the **highest normalized overall score**.

Weighted sum methods

Most frequent **Normalization techniques** (Saisana & Tarantola 2002; OECD 2003; Munda 2008):

1. **“Standard deviation from the mean”** (imposing a standard normal distribution):

$$\uparrow: \frac{\text{actual value} - \text{mean value}}{\text{standard deviation}}$$

$$\downarrow: -\left(\frac{\text{actual value} - \text{mean value}}{\text{standard deviation}}\right)$$

Positive (negative) values for a given city indicate above (below)-average performance

2. **“Distance from the group leader”** (it assigns 100 to the leading alternative while other alternatives are ranked as percentage points from the leader):

$$\uparrow: 100\left(\frac{\text{actual value}}{\text{best value}}\right)$$

$$\downarrow: 100\left(\frac{\text{best value}}{\text{actual value}}\right)$$

Weighted sum methods

3. "Distance from the mean" (the mean value is given 100, and alternatives receive scores depending on their distance from the mean):

$$\uparrow: 100\left(\frac{\boldsymbol{actual\ value}}{\boldsymbol{mean\ value}}\right)$$

$$\downarrow: 100\left(1 - \frac{\boldsymbol{actual\ value - mean\ value}}{\boldsymbol{mean\ value}}\right)$$

Values higher than 100 indicate above-average performance

4. "Distance from the best and worst performers" (positioning is in relation to the global maximum and minimum; the index takes values between 0 -laggard- and 100 -leader-):

$$100\left(\frac{\boldsymbol{actual\ value - worst\ value}}{\boldsymbol{best\ value - worst\ value}}\right)$$

EPFL

Weighted sum methods

Standardization

1. "Standard deviation from the mean"
2. "Distance from the group leader"
3. "Distance from the mean"
4. "Distance from the best and worst performers"

Travelling to Paris…

Criteria	Units	Options: Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	85 euros	40 euros	50 euros	79 euros	37 euros
Carbon impact	kg eq. CO_2	138.33 kg	46.11 kg	159.37 kg	20.26 kg	21.60 kg
Time	Hours	5h30	5h30	1h	3h15	7h30
Comfort	Qualitative scale	Very high	High	Medium	High	Low
Social interactions (possibility of meeting people)	Subjective scale	1	7	3	5	3
Reliability	Probability of delay (subj. scale)	+	+	++	+++	+
Possibility of working	Hours of work (estimation)	0h	0h	30min	3h	4h
Fidelity programs	Ex: miles (Airfrance)	Not possible	Easy	Easy	Very easy	Not possible

Weighted sum methods

Very low	1
Low	2
Medium	3
High	4
Very high	5

Goods/Bads

Travelling to Paris...

Criteria	Units		Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	↓	85	40	50	79	37
Carbon impact	kg eq. CO_2	↓	138.33	46.11	159.37	20.26	21.60
Time	Hours	↓	5.5	5.5	1	3.25	7.25
Comfort	Qualitative scale	↑	5	4	3	4	2
Social interactions (possibility of meeting people)	Subjective scale	↑	1	7	3	5	3
Reliability	Probability of delay (subj. scale)	↑	1	1	2	3	1
Possibility of working	Hours of work (estimation)	↑	0	0	0.5	3	4
Fidelity programs	Ex: miles (Airfrance)	↑	1	2	2	3	1

Options

Likert Scales

1. Standard deviation from the mean

↑: $\frac{actual\ value - mean\ value}{standard\ deviation}$

↓: $-\left(\frac{actual\ value - mean\ value}{standard\ deviation}\right)$

= (4 - 3,6) / 1,02

= - [(85 - 58,2) / 22,35]

Travelling to Paris…

Criteria	Units		Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	↓	-1,20				
Carbon impact	kg eq. CO_2	↓					
Time	Hours	↓					
Comfort	Qualitative scale	↑		0,39			
Social interactions (possibility of meeting people)	Subjective scale	↑					
Reliability	Probability of delay (subj. scale)	↑					
Possibility of working	Hours of work (estimation)	↑					
Fidelity programs	Ex: miles (Airfrance)	↑					

(Column group heading over Own car to Bus: Options)

1. Standard deviation from the mean

$$\uparrow: \frac{actual\ value - mean\ value}{standard\ deviation}$$

$$\downarrow: -\left(\frac{actual\ value - mean\ value}{standard\ deviation}\right)$$

Travelling to Paris…			Options				
Criteria	**Units**		Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	↓	-1,20	0,81	0,37	-0,93	**0,95**
Carbon impact	kg eq. CO_2	↓	-1,03	0,52	-1,38	**0,95**	0,93
Time	Hours	↓	-0,46	-0,46	**1,62**	0,58	-1,27
Comfort	Qualitative scale	↑	**1,37**	0,39	-0,59	0,39	-1,57
Social interactions (possibility of meeting people)	Subjective scale	↑	-1,37	**1,57**	-0,39	0,59	-0,39
Reliability	Probability of delay (subj. scale)	↑	-0,75	-0,75	0,50	**1,75**	-0,75
Possibility of working	Hours of work (estimation)	↑	-0,90	-0,90	-0,60	0,90	**1,49**
Fidelity programs	Ex: miles (Airfrance)	↑	-1,07	0,27	0,27	**1,60**	-1,07
			-5,40	**1,45**	**-0,20**	**5,83**	**-1,68**

2. Distance from the group leader

↑: $100 \left(\frac{actual\ value}{best\ value} \right)$ ↓: $100 \left(\frac{best\ value}{actual\ value} \right)$

Travelling to Paris…

= 100 (4/5)

= 100 (37/85)

= 100 (37/79)

Options

Criteria	Units		Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	↓	43,5			46,8	
Carbon impact	kg eq. CO_2	↓					
Time	Hours	↓					
Comfort	Qualitative scale	↑		80,0			
Social interactions (possibility of meeting people)	Subjective scale	↑					
Reliability	Probability of delay (subj. scale)	↑					
Possibility of working	Hours of work (estimation)	↑					
Fidelity programs	Ex: miles (Airfrance)	↑					

EPFL

2. Distance from the group leader

↑: $100 \left(\frac{actual\ value}{best\ value} \right)$ ↓: $100 \left(\frac{best\ value}{actual\ value} \right)$

Travelling to Paris...			Options				
Criteria	**Units**		**Own car**	**Car sharing**	**Plane**	**Train**	**Bus**
Economic costs	Euros	↓	43,5	92,5	74	46,8	**100,0**
Carbon impact	kg eq. CO_2	↓	14,6	43,9	12,7	**100,0**	93,8
Time	Hours	↓	18,2	18,2	**100,0**	30,8	13,3
Comfort	Qualitative scale	↑	**100,0**	80,0	60,0	80,0	40,0
Social interactions (possibility of meeting people)	Subjective scale	↑	14,3	**100,0**	42,9	71,4	42,9
Reliability	Probability of delay (subj. scale)	↑	33,3	33,3	66,7	**100,0**	33,3
Possibility of working	Hours of work (estimation)	↑	0,0	0,0	12,5	75,0	**100,0**
Fidelity programs	Ex: miles (Airfrance)	↑	33,3	66,7	66,7	**100,0**	33,3
			257,2	**434,6**	**435,5**	**604,0**	**456,6**

EPFL

3. Distance from the mean

↑: $100\left(\frac{actual\ value}{mean\ value}\right)$

↓: $100\left(1 - \frac{actual\ value - mean\ value}{mean\ value}\right)$

= 100(4/3,6)

= 100 [1 -(85-58,2)/58,2]

Travelling to Paris…

Criteria	Units		Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	↓	53,95				
Carbon impact	kg eq. CO_2	↓					
Time	Hours	↓					
Comfort	Qualitative scale	↑		111,11			
Social interactions (possibility of meeting people)	Subjective scale	↑					
Fiability	Probability of delay (subj. scale)	↑					
Possibility of working	Hours of work (estimation)	↑					
Fidelity programs	Ex: miles (Airfrance)	↑					

Options

3. Distance from the mean

↑: $100\left(\frac{actual\ value}{mean\ value}\right)$

↓: $100\left(1 - \frac{actual\ value - mean\ value}{mean\ value}\right)$

Travelling to Paris…

Criteria	Units		Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	↓	53,95	131,27	114,09	64,26	**136,43**
Carbon impact	kg eq. CO_2	↓	20,66	140,22	-6,61	**173,73**	172,00
Time	Hours	↓	77,78	77,78	**177,78**	127,78	38,89
Comfort	Qualitative scale	↑	**138,89**	111,11	83,33	111,11	55,56
Social interactions (possibility of meeting people)	Subjective scale	↑	26,32	**184,21**	78,95	131,58	78,95
Reliability	Probability of delay (subj. scale)	↑	62,50	62,50	125,00	**187,50**	62,50
Possibility of working	Hours of work (estimation)	↑	0,00	0,00	33,33	200,00	**266,67**
Fidelity programs	Ex: miles (Airfrance)	↑	55,56	111,11	111,11	**166,67**	55,56
			435,65	**818,20**	**716,98**	**1162,63**	**866,54**

Options: Train 🏆

EPFL

4. Distance from best and worst performers

$$100\left(\frac{actual\ value - worst\ value}{best\ value - worst\ value}\right)$$

= 100 [(4-2)/(5-2)]

= 100 [(85-85)/(37-85)]

Travelling to Paris…

Criteria	Units		Options: Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	↓	0,0				
Carbon impact	kg eq. CO_2	↓					
Time	Hours	↓					
Comfort	Qualitative scale	↑		66,7			
Social interactions (possibility of meeting people)	Subjective scale	↑					
Reliability	Probability of delay (subj. scale)	↑					
Possibility of working	Hours of work (estimation)	↑					
Fidelity programs	Ex: miles (Airfrance)	↑					

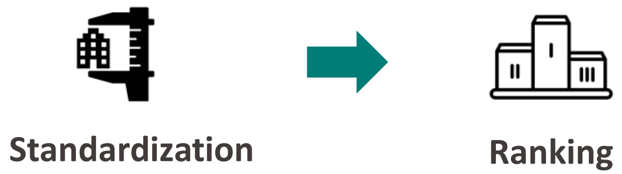
Laboratory on Human-Environment Relations in Urban Systems

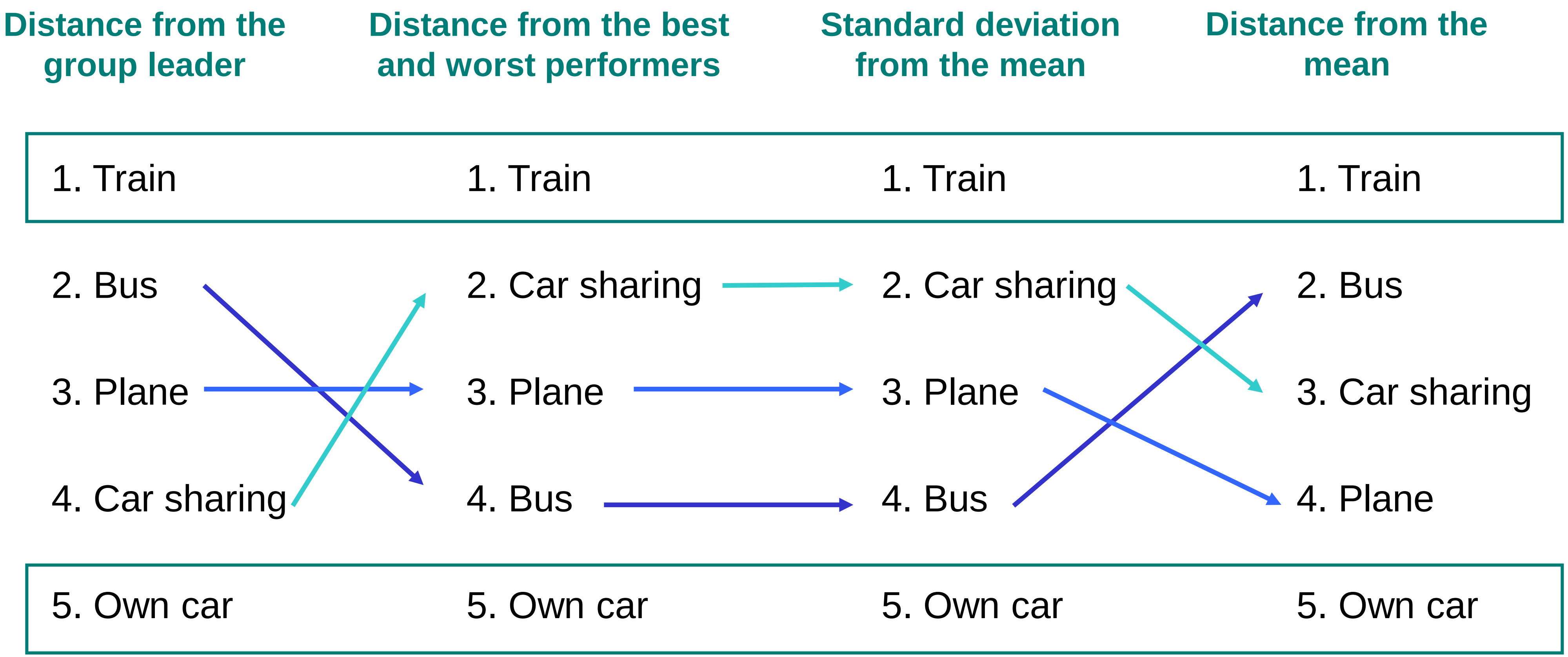
4. Distance from best and worst performers

$$100\left(\frac{actual\ value - worst\ value}{best\ value - worst\ value}\right)$$

Travelling to Paris…			Options				
Criteria	**Units**		**Own car**	**Car sharing**	**Plane**	**Train**	**Bus**
Economic costs	Euros	↓	0,0	93,7	72,9	12,5	100,0
Carbon impact	kg eq. CO_2	↓	15,1	81,4	0,0	100,0	99,0
Time	Hours	↓	30,8	30,8	100,0	65,4	0,0
Comfort	Qualitative scale	↑	100,0	66,7	33,3	66,7	0,0
Social interactions (possibility of meeting people)	Subjective scale	↑	0,0	100,0	33,3	66,7	33,3
Reliability	Probability of delay (subj. scale)	↑	0,0	0,0	50,0	100,0	0,0
Possibility of working	Hours of work (estimation)	↑	0,0	0,0	12,5	75,0	100,0
Fidelity programs	Ex: miles (Airfrance)	↑	0,0	50,0	50,0	100,0	0,0
			145,9	**422,6**	**352,0**	**519,6**	**332,3**

Weighted sum methods





Weighted sum methods

Travelling to Paris…				Options				
Criteria	**Units**		W_i	**Own car**	**Car sharing**	**Plane**	**Train**	**Bus**
Economic costs	Euros	↓		**85** euros	**40** euros	**50** euros	**79** euros	**37** euros
Carbon impact	kg eq. CO_2	↓		**138.33** kg	**46.11** kg	**159.37** kg	**20.26** kg	**21.60** kg
Time	Hours	↓		**5h30**	**5h30**	**1h**	**3h15**	**7h30**
Comfort	Qualitative scale	↑		**Very high**	**High**	**Medium**	**High**	**Low**
Social interactions (possibility of meeting people)	Subjective scale	↑		**1**	**7**	**3**	**5**	**3**
Reliability	// Probability of delay	↑		**+**	**+**	**++**	**+++**	**+**
Possibility of working	Hours of work	↑		**0h**	**0h**	**30min**	**3h**	**4h**
Fidelity programs	Ex: miles	↑		**Not possible**	**Easy**	**Easy**	**Very easy**	**Not possible**

Weighted sum methods

Travelling to Paris…

Criteria	Units		W_i	Options: Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	↓	0,25	85 euros	40 euros	50 euros	79 euros	37 euros
Carbon impact	kg eq. CO_2	↓	0,25	138.33 kg	46.11 kg	159.37 kg	20.26 kg	21.60 kg
Time	Hours	↓	0,10	5h30	5h30	1h	3h15	7h30
Comfort	Qualitative scale	↑	0,05	Very high	High	Medium	High	Low
Social interactions (possibility of meeting people)	Subjective scale	↑	0,05	1	7	3	5	3
Reliability	// Probability of delay	↑	0,05	+	+	++	+++	+
Possibility of working	Hours of work	↑	0,20	0h	0h	30min	3h	4h
Fidelity programs	Ex: miles	↑	0,05	Not possible	Easy	Easy	Very easy	Not possible

EPFL

Weighted sum methods

(Normalization through **"Distance from the group leader"**)

= 100*0,05

= 43,5*0,25

Travelling to Paris…

Options

Criteria	Units		W_i	Own car	Car sharing	Plane	Train	Bus
Economic costs	Euros	↓	0,25	10,88	23,13	18,50	11,70	25,00
Carbon impact	kg eq. CO_2	↓	0,25	3,65	10,98	3,18	25,00	23,45
Time	Hours	↓	0,10	1,82	1,82	10,00	3,08	1,33
Comfort	Qualitative scale	↑	0,05	5,00	4,00	3,00	4,00	2,00
Social interactions (possibility of meeting people)	Subjective scale	↑	0,05	0,72	5,00	2,15	3,57	2,15
Reliability	// Probability of delay	↑	0,05	1,67	1,67	3,34	5,00	1,67
Possibility of working	Hours of work	↑	0,20	0,00	0,00	2,50	15,00	20,00
Fidelity programs	Ex: miles	↑	0,05	1,67	3,34	3,34	5,00	1,67
				25,39	**49,92**	**45,99**	**72,35**	**77,26**

Weighted sum methods… in brief

Strenghts:

(i) Simplicity.

(ii) Transparency.

Limitations:

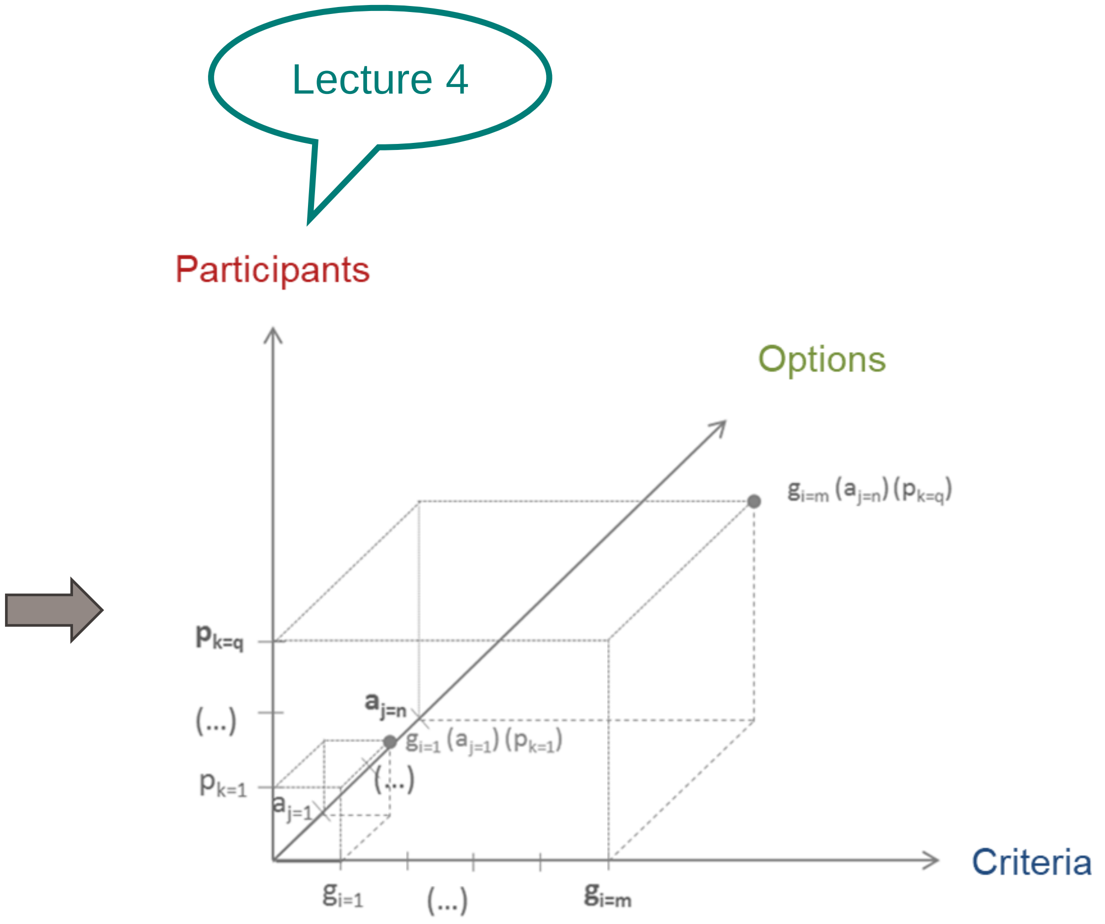
(i) Total **compensability** between evaluative criteria.

(ii) Subjectivity (weights!).

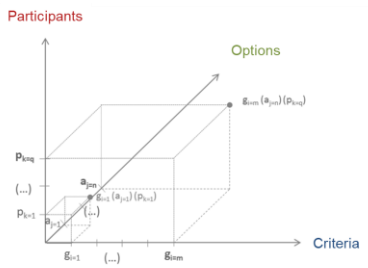
Adding participation to MCA

PMCA: Participatory MCA

Criteria	Units	Options			
		$a_{j=1}$	$a_{j=2}$	(...)	$a_{j=n}$
$g_{i=1}$		$g_1(a_1)$	$g_1(a_2)$	...	$g_1(a_n)$
$g_{i=2}$		...	...	...	...
(...)		...	...	...	...
$g_{i=m}$		$g_m(a_1)$	$g_m(a_2)$	...	$g_m(a_n)$



PMCA: Participatory MCA



Social Multi-Criteria Evaluation (SMCE)

Munda (2004)

A first way to involve experts and the public :
Differentiate roles

(Technical) **Impact Matrix**

set of options

evaluative criteria

Criteria	Units	Dir	Alternatives										
			A1	A2	A3	B1	B2	B3	B4	C1	C2	C3	C4
Employment	People/year	Max	0	31.5	41.8	97.77	97.77	97.77	97.77	79.11	83.11	76.86	83.11
Local incomes	Ordinal	Max	5°	4°	2°	3°	3°	3°	3°	1°	1°	1°	1°
Compatibility of activities	Ordinal	Max	5°	4°	1°	8°	7°	7°	6°	5°	3°	4°	2°
Cost of implementation	€	Min	0	2.442.330	6.186.624	4.925.819	4.925.819	4.925.819	4.925.819	5.325.347	5.325.347	5.325.347	5.325.347
Environmental disturbance	Ordinal	Min	3°	1°	3°	4°	4°	4°	4°	2°	2°	2°	2°
Impact on habitat and fauna	Synthetic index	Min	1327	1327	1455	1064	1200	1193	1202	1203	1311	1303	1289
Stability	Ordinal	Max	3°	3°	7°	9°	8°	6°	5°	4°	4°	4°	2°
Uncertainty	Qualitative	Min	Moderate	Moderate	Low	Very High	Very High	Very High	Very High	High	High	High	High

(Social) **Equity Matrix**

set of options

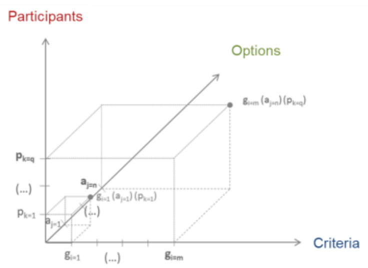
Participants

Social actors	A1	A2	A3	B1	B2	B3	B4	C1	C2	C3	C4
Bird watchers	Good	Good	Very good	Extremely bad	Extremely bad	Extremely bad	Extremely bad	Bad	Moderate	Bad	More less bad
Fishers	Good	Good	Very good	Extremely bad	Extremely bad	Extremely bad	Very bad	Extremely bad	Extremely bad	Very bad	More Less bad
Surfers	Good	Good	Very good	Extremely bad	Extremely bad	Extremely bad	Extremely bad	Very bad	Very bad	Very bad	Bad
Busturia Council	Very bad	Very bad	Perfect	Extremely bad	Very bad	Moderate	Good	Extremely bad	Bad	Good	Perfect
Murueta Council.	Extremely bad	Extremely bad	More less bad	More less good	Good	Very good	Perfect	Bad	Bad	Bad	Bad
Recreational boats	More less good	More less good	Good	Extremely bad	Extremely bad	Very bad	Perfect	Very bad	Extremely bad	Extremely bad	Perfect
Shipyard workers	Very bad	Very good	Very bad	More less good	More less good	Mora less good	Very good	Moderate	Moderate	Moderate	Moderate
Head Coastal Management	Good	Very good	Perfect	Extremely bad	Very bad	Very bad	Very bad	Bad	Bad	Bad	Bad
Env. Ministry (Reserve Director)	More less bad	Good	Vary good	Extremely bad	Extremely bad	Extremely bad	Extremely bad	Bad	Bad	Bad	Bad
Dune Recovery	Good	Good	Perfect	Extremely bad	Very bad	Very bad	Very bad	Bad	Bad	Moderate	Moderate
Environmental Guides	More less good	Very good	Perfect	Extremely bad	Extremely bad	Extremely bad	Extremely bad	Extremely bad	Bad	Very Bad	More less bad
Arteaga Council	Moderate	Moderate	Vary good	Extremely bad	Extremely bad	Very bad	Very bad	Bad	Moderate	Bad	Moderate
Ekologia Tailerra (NGO)	Bad	Very good	Perfect	Extremely bad	Extremely bad	Extremely bad	Extremely bad	Extremely bad	Extremely bad	Extremely bad	Extremely bad
Shipyard Owners	Extremely bad	Moderate	Extremely bad	More less good	More less good	Good	Perfect	Bad	Bad	Bad	Bad
Head Harbors	Good	Good	Good	Extremely	Extremely	Extremely	Extremely	Moderate	Moderate	Moderate	Moderate

Garmendia et al. (2010)

EPFL

PMCA: Participatory MCA



Social Multi-Criteria Evaluation (SMCE)

Munda (2004)

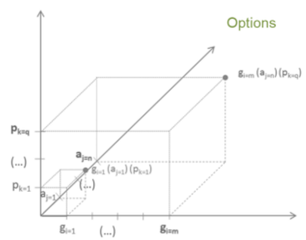
A first way to involve experts and the public : **Differentiate roles**

Inputs

Balance between
- **Objectivity** and **subjectivity**
- **Legitimacy** and **acceptability**

Garmendia et al. (2010)

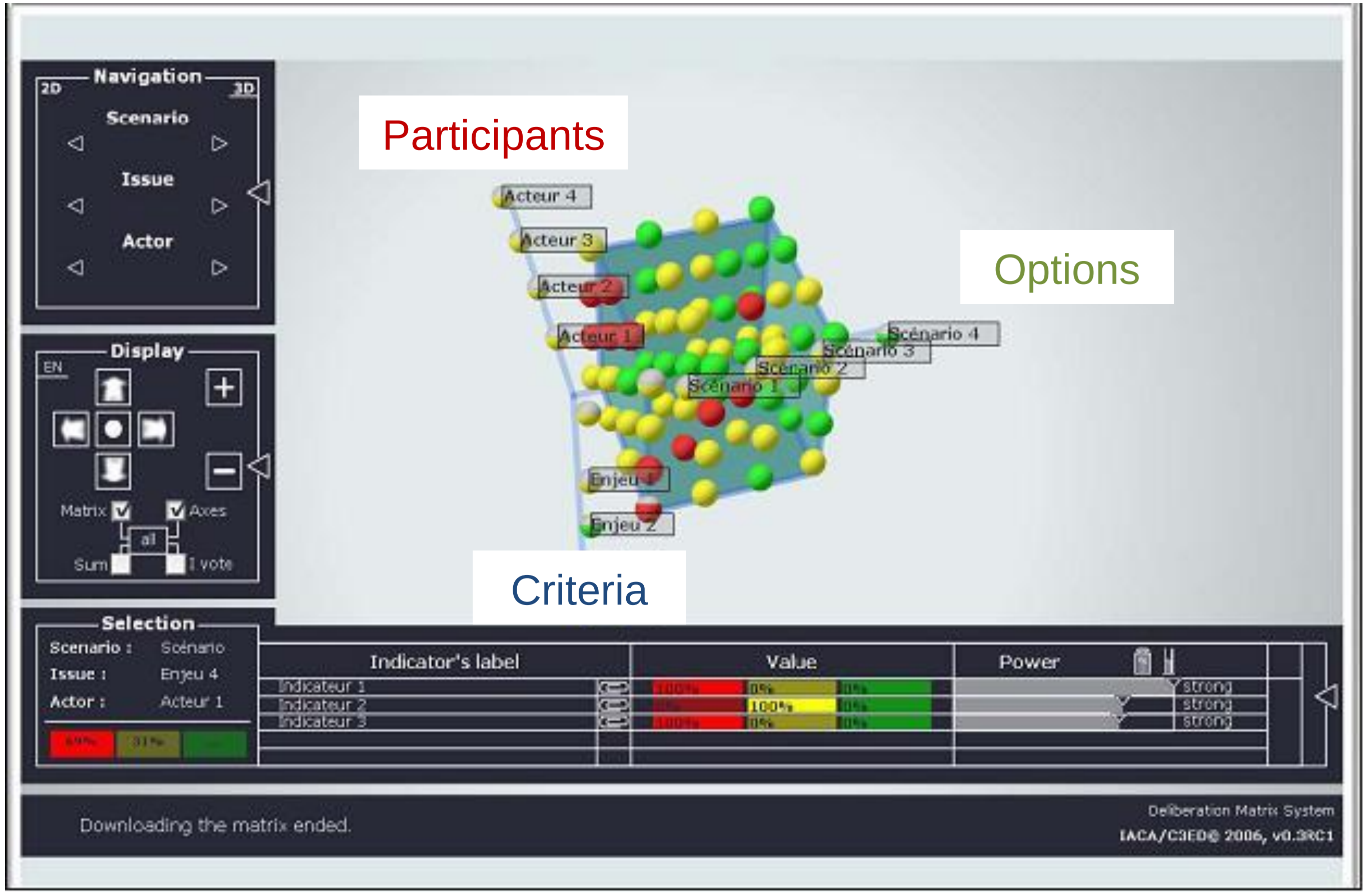
PMCA: Participatory MCA



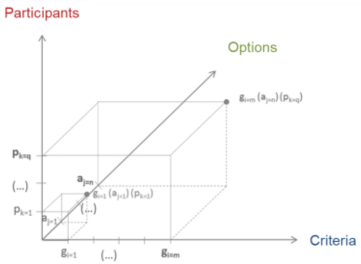
InteGRAAL Approach

O'Connor (2006); O'Connor (2007)

A second way of involving both experts and the public:
ask everyone to assess the performance



PMCA: Participatory MCA



InteGRAAL Approach

O'Connor (2006); O'Connor (2007)

A second way of involving both experts and the public:
ask everyone to assess the performance

Inputs

- **Inclusive participation**: Promotes a democratic approach
- **Perception variability**: Captures diverse opinions on performance + acceptability

But

- **Bias risks**

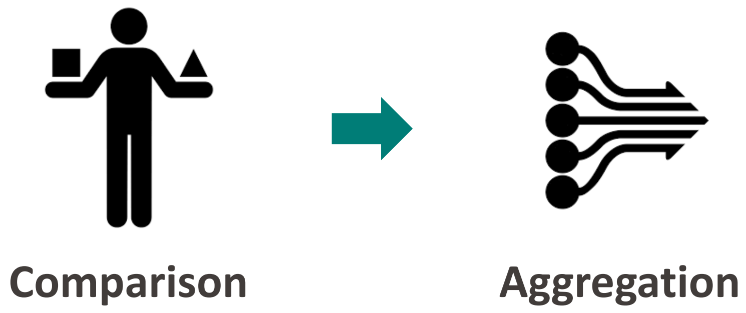
Outranking methods

Laboratory on Human-Environment Relations in Urban Systems

Outranking methods

Outranking methods involve **pairwise comparisons** of all alternative options according to each evaluative criterion

…In very simple terms, the logic behind is similar to a football championship



Outranking methods were mainly developed by **Bernard Roy** in 1970s (e.g. ELECTRE Methods). These methods try to overcome the limitations that are inherent to mono-criterion analysis (compensability, integration of qualitative data, etc.),

Since then, a plethora of methods have been created and subsequently developed: PROMETHEE, MELCHIOR, NAIADE, etc.

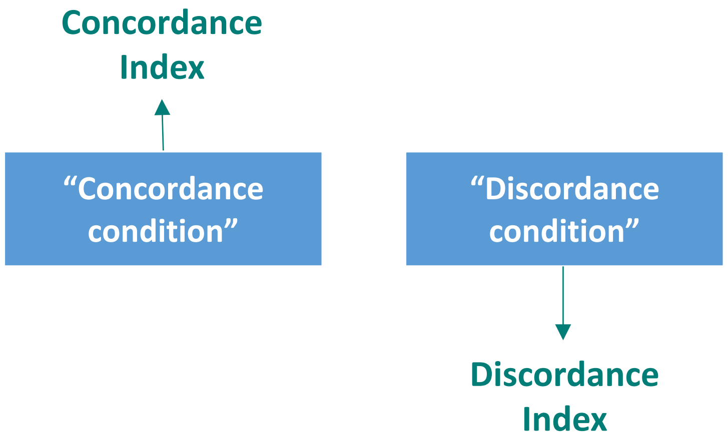
Laboratory on Human-Environment Relations in Urban Systems

Outranking methods

In general terms, we can say that **option *a* "outranks" option *b*** (in formal language, we will write a**S**b) when **TWO conditions** are fulfilled (ex : ELECTRE 1) :

(i) *a* is as good as *b* according to a majority of evaluative criteria (considering their respective relative importance);

(ii) When a**S**b is not fulfilled, the gap between the performance scores got by options *a* & *b* is not excessively important.



EPFL

Outranking methods

- Concordance index : $c(a,b) = \frac{\sum_{i \in (aSb)} w_i}{\sum_{i=1}^{n} w_i} \geq p$

where **numerator** $\sum_{i \in (aSb)} w_i$ corresponds to the sum of weights given to those criteria for which relation a**S**b is fulfilled,

and **denominator** $\sum_{i=1}^{n} w_i$ corresponds to the sum of all weights.

a **minimal threshold of "concordance"** *p* is then determined for c(a,b). Option *a* outranks *b* only if: c(a,b) ≥ *p*

EPFL

Outranking methods

- Discordance index :

Through this second index, we verify that option *a* doesn't get too bad scores for those criteria in which it is not better than option *b*.

The idea behind this index is to limit the compensability between evaluative criteria.

$$g_i(a) - g_i(b) \leq v_i$$

… where $g_i(a)$ and $g_i(b)$ respectively express the performance that options *a* and *b* get according to criterion *i*;

And v_i is a maximal threshold determined in order to both:

(i) limit extreme cases of compensability; and

(ii) warrant the possibility of introducing a veto positioning (*respect* of *minorities principle*).

Outranking methods

Strenghts:

(i) Outranking methods don't involve total compensability.

(ii) Options may be seen as being incomparable to each other.

Limitations:

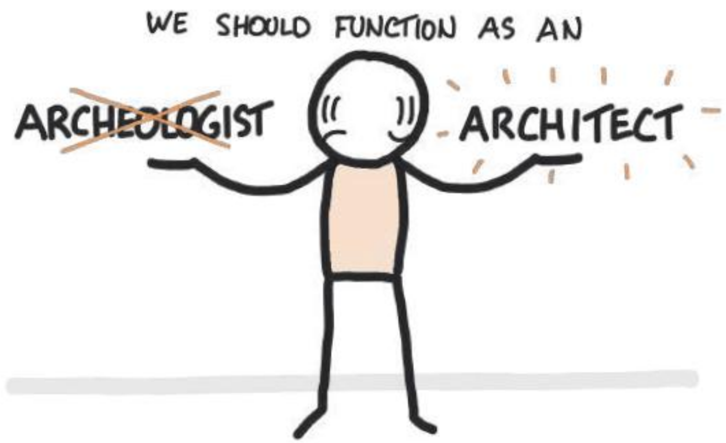
(i) Unavoidable subjectivity when defining outranking relations and indexes.

(ii) Complexity behind algorithms

Wrap-up

Tool selection is most often made by the analyst on the basis of value-laden principles.

Tool selection inevitably frames the assessment and its results!



Researchers and practitioners in the field of Sustainability Assessments should function not as **“archaeologists”**, carefully uncovering what is there, but as **“architects”**, working to build a defensible expression of value…

(Gregory et al. 1993 ; Vatn & Bromley 1994).

Wrap-up

… Some principles to take into account when selecting Sustainability Assessment tools:

1. Transparency

2. Inclusiveness (from the very beginning…)

3. Alignment with available resource and assessment goals

4. Procedural rationality