Working Group 3, task 3.2 'Options for integrating EST indicators'

Multi Criteria Evaluation

Working paper
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Outline

- Goals and scope;
- Fundamental assumptions
- Overview of MCDA methods
  - Classification frameworks.
- Evaluation of MCDA methods
  - Approaches, results & conclusions.
- Open questions;
- Next steps;
- References.

Goals and scope: Task 3.2

No	Title	Main purpose	Output	Activities needed to deliver output	Change from MoU
Task 3.1	Defining requirements of EST indicators from the planning and decision making point of view	• To define (from literature) functional criteria for indicators to be used in various policy making frameworks for sustainable transport (including ex ante assessment/scenarios, continuous monitoring and ex post evaluation) • To identify (from literature) factors that matter for making indicators actually useful, applied, and influential in planning and decision making	A report with a framework for understanding 'policy and decision making related' conditions for indicator use	Review of literature built on the output of the task 1.3.	Revised from MoU 3.1 which is formulated somewhat over-ambitious
Task 3.2	Options for integrating EST indicators	To analyse options and methods for aggregation (e.g. cost-benefit, multi-criteria decision methods), or selection (e.g. based on participatory process), or other ways to create integrated measures of environmentally sustainable transport, based on individual (non-aggregated) impact indicators	A report with: • Pros and cons of the aggregation or selection methods available in the social sciences literature • A choice of the 'best' methods or/and proposals of building of new ones	• Review of literature • A selection procedure	This task corresponds to the Task 2.2 of the MoU.
Task 3.3	Case studies: Applications of EST indicators in decision making	• To select practical sustainable transport assessments examples /cases, including EU, national and local projects • To review the examples/cases with regard to the identification and application of environmental sustainability indicators and indicator systems • To analyse in each case the potential application of relevant indicators as reviewed in tasks 2.3 and 3.2, while taking into account criteria and research reviewed in both tasks 2.2 and 3.1	A report with case study results and recommendations for the application of indicators and indicator systems in policy making	Undertaking analysis of the ability of environmental indicators (non-aggregated, integrated) to be used for each (relevant) case of assessment.	Revised by combining parts of MoU 3.2 and 3.3. But 'Development of EST scenarios' as mentioned in the MoU will not be understood as production of original analytical scenarios.

Stockholm meeting: Agreement on next steps

Next steps		Responsible persons	Support by / Interface	Deadline
3.2-1	▪ Generate a systematic list of aggregation methods. This includes the definition of the scope for the methods (aggregation, selection, numerical visual) and of a generic characterization framework (objectives of the particular method, application contexts, known strengths and weaknesses, …).	S. Mancebo	▪ M. Svitek ▪ P. Wäger ▪ other WG3 participants welcome!) ▪ task 2.3	▪ 1st draft until August 20 (input for Turin meeting preparation)
3.2-2	▪ Identify specific contexts, against which the aggregation methods should be assessed. This includes an identification of the context-specific user needs regarding aggregation methods.	M. Ruzicka	▪ other WG3 participants welcome! ▪ task 3.3	▪ 1st draft until Aust 20 (input for Turin meeting preparation)
3.2-3	▪ Identify aggregation experts that should be integrated into task 3.2 or invited to Working Group meetings.	F. Ramjerdi	▪ P. Wäger ▪ other WG3 participants welcome! ▪ task 3.2-2	▪ 1st draft until August 20 (input for Turin meeting preparation)

Goals and scope: Purpose of this presentation

- Give a (general) overview of
  - fundamental assumptions associated with multi criteria evaluation (MCE);
  - multi criteria decision analysis (MCDA) methods frequently applied in the context of sustainable development and transportation;
    - characterisation;
    - Evaluation;

…as a starting point for discussions on

  - goals and scope of task 3.2;
  - the next steps.

Goals and scope: Definition of a multi criteria problem

- A typical multicriteria problem (with a discrete number of alternatives) may be described in the following way:
  - A is a finite set of n feasible actions a_j (j=1,2,…, n);
  - G is the set of evaluation criteria g_i (i=1,2,…,m) considered relevant in a decision problem;
  - an action a_1 is evaluated to be better than action a_2 (both belonging to the set A) according to the ith criterion if $gi(a_1) > gi(a_2)$.
- In this way a decision problem may be represented in a tabular or matrix form.

Example of an impact matrix — Table 1.

Alternatives					
Criteria	Units	a_1	a_2	a_3	a_4
g_1		$g_1(a_1)$	$g_1(a_2)$		$g_1(a_4)$
g_2					
g_3					
g_4					
g_5					
g_6		$g_6(a_1)$	$g_6(a_2)$		$g_6(a_4)$

- The impact matrix (evaluation table) may include quantitative, qualitative or both types of information.

From: Funtowicz et al. (1999), Janssen and Munda (1999), Munda et al. (1994), Munda (1995)

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Fundamental assumptions: Need for multi criteria methods (I)

- Environmental policy deals with ‘reflexive’ phenomena since an effective assessment, in order to be realistic, should consider not merely the measurable and contrastable dimensions of the simple part of the system, that even if complicated may be technically simulated. It should deal as well with the higher dimensions of the system, those in which power relations, hidden interests, social participation, cultural constraints, and other ‘soft’ values, become relevant and unavoidable variables that heavily, but not deterministically, affect the possible outcomes of the strategies to be adopted.
- In the context of transport project appraisal in the EU, there is a strong consensus on the treatment of a number of direct impacts, where monetary valuation and inclusion in cost benefit analysis is usual. There is less agreement on the treatment of the environmental and social impacts. Recent developments are in the direction of comprehensive multimodal approaches and a greater use of multi-criteria analysis.

From: Funtowicz et al. (1999); Martinez-Alier et al. (1998); Bristow and Nellthorp (2000)

Fundamental assumptions: Need for multicriteria methods (II)

- It has been argued that the presence of qualitative information in evaluation problems concerning socio-economic and physical planning is a rule, rather than an exception. Thus there is a clear need for methods that are able to take into account information of a ‘mixed’ type (both qualitative and quantitative measurements).
- Another issue related to the available information concerns the uncertainty contained in this information. Ideally, the information should be precise, certain, exhaustive and unequivocal. But in reality, it is often necessary to use information which does not have those characteristics, so that one has to face the uncertainty of a stochastic and/or fuzzy nature present in the data.

From: Funtowicz et al. (1999); Munda et al. (1994)

Fundamental assumptions: Philosophical foundations (I)

- Weak comparability can be considered to be the philosophical base of multicriteria evaluation. Multi criteria evaluation methods based on the ‘incommensurability principle’ are an evaluation methodology alternative to traditional cost benefit analysis (CBA).

Strong comparability

- One single comparative term exists, by which all different options can be ranked.

Weak comparability

- Conflicts between the different consequences of an option exist. It is not possible to define a status of preference and indifference between two options as one option is better than another one in terms of some criteria, but worse for others.

Strong commensurability

- There is a common measure of the different consequences of an option based on a cardinal scale of measure.

Weak commensurability

- There is a common measure of the different consequences of an option based on an ordinal scale of measure.

Incommensurability

- Options cannot be compared, but this does not necessarily lead to a situation where no decision making is possible. It simply means that additional approaches have to be used.

From: Funtowicz et al. (1999); Martinez-Alier et al. (1998; Omann (2005)

Fundamental assumptions: Philosophical foundations (II)

COMPARABILITY OF VALUES	MACROECONOMICS	MICROECONOMICS AND ENVIRONMENTAL POLICY	PROJECT EVALUATION
STRONG COMPARABILITY			
Strong commensurability of values	'Weak' sustainability	Internalisation of externalities at 'optimum' social level (Turvey's diagram, 1963)	Cost-benefit analysis (including Krutilla's modification of discount rates applied to 'commodities' and 'amenities')
	Solow-Hartwick rule	Coasian bargaining and fusions	
	Pearce-Turner 'constant capital stock' and 'constant natural capital stock'	Hotelling's rule (1931)	
	Green GNP (El Serafy's correction)	Renewable resource management (Gordon-Scott, etc.)	
	Green GNP (Repetto's correction)	Cobb-Douglas, CES and other standard production functions	
	Biological and physical indicators of sustainability (e.g. HANPP, MIPS, ecospace, energy cost of energy, etc.)	Contingent valuation and similar methods	
		Conventional utility theory, use value, existence value	

From: Funtowicz et al. (1999)

Fundamental assumptions: Philosophical foundations (III)

COMPARABILITY OF VALUES	MACROECONOMICS	MICROECONOMICS AND ENVIRONMENTAL POLICY	PROJECT EVALUATION
STRONG COMPARABILITY			
Weak commensurability of values	Green GNP (Hueting's correction)	Cost-effectiveness analysis (and related instruments: Markets in emission permits, etc.)	Cost-benefit analysis (with ordinal rankings only)
	ISEW (Daly & Cobb)	Lexicographic ordering of consumer's preferences	Cost-effectiveness analysis
		Industrial ecology and industrial metabolism (Ayres, Ruth, etc.)	Compensatory multicriteria evaluation based on utility functions
		Biophysical production functions	Discrepancies between WTP and WTA

From: Funtowicz et al. (1999)

Fundamental assumptions: Philosophical foundations (IV)

COMPARABILITY OF VALUES	MACROECONOMICS	MICROECONOMICS AND ENVIRONMENTAL POLICY	PROJECT EVALUATION
WEAK COMPARABILITY			
Incommensurability of values	'Strong' sustainability (in physical accounts), 'satellite' accounts	Social evaluation of environmental limits or standards	Non-compensatory multicriteria decision aid
	Simultaneous use of monetary and non-monetary indicators by means of reflexive complexity and macroeconomic multicriteria evaluation	Integrated assessment of sectoral indicators of sustainability (in physical accounts) for urban planning, agriculture, water management, etc.	Environmental impact assessment techniques Sagoff's 'consumers' versus 'citizens'
	Co-evolution	Precautionary principle, liability rule, environmental bonds, and other methods for dealing with uncertainty and 'surprises'	
		Eco-auditing, product-life cycle analysis and other methods of physical environmental accounting at firm's level	

From: Funtowicz et al. (1999)

Fundamental assumptions: Philosophical foundations (V)

- Incommensurability, i.e. the absence of a common unit of measurement across plural values, entails the rejection not just of monetary reductionism but also any physical reductionism (e.g. eco-energetic valuation). However it does not imply incomparability. It allows that different options are weakly comparable, that is comparable without recourse to a single type of value.

- The aggregation of several dimensions implies taking a position on the problem of compensability. Intuitively, compensability refers to the existence of trade-offs, i.e. the possibility of offsetting a disadvantage on some attribute by a sufficiently large advantage on another attribute, whereas smaller advantages would not do the same.
  - Clearly, the convention underlying, e.g. the additive utility model (and cost-benefit analysis) is completely compensatory.

From: Martinez-Alier et al. (1998)

Fundamental assumptions: Philosophical foundations (VI)

- There is no doubt that there is a lot of complexity and fuzziness inherent in the sustainability concept. A possible reduction of this complexity, a pre-condition for management and planning actions, introduces the problem of the descriptors used: indicators and indices. Often, some indicators improve while others deteriorate. This is the classical conflictual situation dealt with in multi-criteria decision theory; in particular non-compensatory methods are quite relevant, since compensability implies substitutability between different types of capital.

From: Munda (2005)

Fundamental assumptions: Strengths of multi criteria methods

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- The main advantage of multi criteria models is that they make it possible to consider a large number of data, relations and objectives which are generally present in a specific real-world policy problem, so that the problem at hand can be studied in a multi-dimensional fashion;
- From an operational point of view, the major strength of multi criteria methods is their ability to address problems marked by various conflicting evaluations. Multicriteria evaluation techniques cannot solve all conflicts, but they can help to provide more insight into the nature of conflicts and into ways to arrive at political compromises in case of divergent preferences so increasing the transparency of the choice process.

From: Funtowicz et al. (1999); Martinez-Alier et al. (1998); Munda (2005)

Fundamental assumptions: Limitations of multi criteria methods

- The results of a multicriteria analysis depend on
  - the available data;
  - structured information;
  - the chosen aggregation method;
  - decision-maker’s preferences.
- As a general rule, *we do not believe in algorithmic solutions of multicriteria problems*. In our view, multicriteria methods useful for environmental policy must offer a consistent framework aimed at helping the structuring of the problem and the evolution of the ‘decision process’, so that ‘soft’ approaches such as for example, discursive ethics can more easily be implemented.
- In general, in a multicriteria problem, there is no solution optimising all the criteria at the same time and therefore the decision-maker has to find compromise solutions. In the absence of a unique ‘correct’ policy as the product, the focus is on the quality of the process.

From: Funtowoicz et al. (1999); Munda et al. (1999)

Fundamental assumptions: Desirable properties of multi criteria models

- Desirable properties for mathematical procedures useful for a sustainability exercise are:
  - to avoid the aggregation of all the indicators in one single aggregate function;
    - this approach is not desirable because it does not give useful information on the behaviour of the single indicators so that its policy usefulness is very limited.
  - to avoid complete compensability, i.e. the possibility that a good score on one indicator can always compensate a very bad score on another indicator;
    - Economic development implies the creation of new assets in terms of physical, social and economic structures. At the same time, like in any process of ‘creative destruction’, traditional physical, social and cultural assets derived from our common heritage may disappear. Complete compensability implies that an excellent performance on the economic dimension can justify any type of very bad performance on the other dimensions, which is exactly what the concept of sustainability tries to avoid.
  - to be as much transparent as possible to the general public.
    - In sustainability management and planning distributional issues play a central role. If a given policy option is evaluated to be ‘good’ or to be ‘bad’, key questions are ‘good’ or ‘bad’ for which point of view? For whom? How long? Any policy option always implies winners and losers, thus it is important to check if a policy option looks good just because some dimensions (e.g. the environmental) or some social groups (e.g. the lower income groups) are not taken into account.

From: Munda (2005)

Fundamental assumptions: MCDA vs. MCDM

- *Multiple criteria decision-making (MCDM)* models assume that the decision-maker's preferences are made perfectly explicit, so that the only thing left to do is to consider a well-formulated mathematical model.
- But "in general [it] is impossible to say that a decision is a good one or a bad one by referring only to a mathematical model: organizational, pedagogical and cultural aspects of the whole decision process which leads to a given decision also contribute to its quality and success.. . " As a consequence, it is necessary to move over from an MCDM analysis to a *multiple criteria decision aid (MCDA)* one, whose principal aim is not to discover a solution, but "to construct or create something which is viewed as liable to help an actor taking part in a decision process either to shape, and/ or to argue, and/ or to transform his preferences".

From: Munda et al. (1994)

Fundamental assumptions: MCDA vs. CBA

- Cost benefit analysis (CBA) has some drawbacks, which are, among others:
  - there are often considerable difficulties in measuring all relevant impacts of a project or plan in money terms. Although many efforts have been made to produce values for intangibles and/or externalities, it is almost impossible in practice to arrive at totally reliable and fully accepted monetary values for such impacts.
  - political priorities cannot be taken into explicit account in such a monetary evaluation;
  - if certain goals are to be reached, normative approaches are needed, which cannot be derived from empirical evidence, as is suggested in CBA (willingness to pay, hedonistic or prevention costs); see the naturalistic fallacy.
- The debate on conventional CBA and multi criteria analysis tends to regard these two approaches as complementary rather than competitive analytical tools.

From: Borken (2005); Tsamboulas et al. (1999)

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Overview of MCDA methods: Characterisation frameworks

	Characteristics	Examples
Discrete methods		
Single criterion methods	■ convert impacts concerning the different criteria into one criterion or attribute.	■ Multiple attribute utility theory (MAUT) ■ Analytical hierarchy process (AHP) ■ Evaluation matrix (Evamix)
Outranking methods	■ less strong assumptions (about existence of utility functions, additivity, …); ■ allow for incomparability of options; ■ avoid complete ranking being identified too early (interaction between model and decision makers is encouraged); ■ aim is not so much to identify an optimal solution but rather to facilitate the identification of compromise solutions in a transparent and fair way.	■ ELECTRE III ■ Regime ■ NAIADE
Continuous methods		
Programming methods	■ programming methods do not choose from a finite number of alternatives, but the alternatives are generated during the solution process on the basis of a mathematical model formulation.	■ Multi-Objective-Programming (MOP) ■ Goal Programming (GP)

From: de Montis et al. (2005)

Overview of MCDA methods: Characterisation frameworks

	Characteristics	Examples
Quantitative methods	■ Require quantitative information about scores of each criterion.	■ Weighted summation; ■ Value and utility analysis; ■ Ideal point method; ■ Outranking methods; ■ Analytical hierarchy process.
Qualitative methods	■ Only qualitative information on scores or a mixture of quantitative and qualitative scores is available	■ Evamix; ■ Regime; ■ Permutation.

From: Janssen and Munda (1999)

Overview of MCDA methods: Characterisation frameworks

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	Characteristics	Examples
Vectorial models	■ based on the assumption that all feasible solutions of a decision problem can be represented as vectors in a vectorial space of dimension equal to the number of evaluation criteria. ■ may prove helpful when only qualitative information is available, or lead to a considerable loss of information when quantitative data also exist.	■ Regime
Superiority graph models	■ based on concept of partial comparability; ■ treat preferences as ordered outranking relations.	■ ELECTRE group

Additive models	■ i.e. models that establish a performance norm, which is usually linear.
	■ preassumptions:
	    ■ all decision alternatives are comparable;
	    ■ transitivity of preference and indifference relations holds.
		■ Analytical hierarchy process (AHP)
		■ Multi attribute utility approach
		■ ADAM type

From: Tsamboulas et al. (1999)

TABLE 1. Relative Classification of Candidate Methods

Mathematical structure (1)	Decision-Theory Typology: Weighted linear additive models (2)	Outranking methods (3)	Multiattribute utility theory (MAUT) (4)	Ideal-point approach (5)
Vectorial model	REGIME	—	—	—
Superiority graph model	—	ELECTRE Group	—	—
Additive model	AHP	—	Multiattribute utility approach	ADAM type

From: Tsamboulas (1999)

Overview of MCDA methods: Characterisation frameworks

MADM method	Input	Output	Decision types	DM interaction	Assumptions	MCDM software
Scoring	Attribute scores, weights	Ordinal ranking	Individual DM, deterministic	Moderate	Nonrestrictive	Spreadsheets
Multiattribute value	Value functions, weights	Cardinal ranking	Individual and group DMs, deterministic, fuzzy	High	Very restrictive	Logical decisions, MATS, spreadsheets
Multiattribute utility	Utility functions, weights	Cardinal ranking	Individual and group DMs, probabilistic, fuzzy	High	Very restrictive	Logical decisions, HIPRE3+, spreadsheets
Analytic hierarchy process	Attribute scores, pairwise comparisons	Cardinal ranking (ratio scale)	Individual and group DMs, deterministic, probabilistic, fuzzy	High	Moderately restrictive	Expert choice, HIPRE3+, Which&why, spreadsheets
Ideal point	Attribute scores, weights, ideal point	Cardinal ranking	Individual and group DMs, deterministic, probabilistic, fuzzy	Moderate	Nonrestrictive	AIM, spreadsheets
Concordance	Attribute scores, weights	Partial or ordinal ranking	Individual and group DMs, deterministic, probabilistic, fuzzy	Moderate	Nonrestrictive	ELECTRE III and IV, spreadsheets
Ordered weighted averaging	Fuzzy attribute, weights, order weights	Cardinal or ordinal ranking	Individual and group DMs, fuzzy	Moderate	Moderately restrictive	spreadsheets

From: Malczewski (1999); excerpt prepared by E. Ortega and S. Mancebo

Overview of MCDA methods: Characterisation frameworks

Classification/Method	Weighted Sum	MACBETH	PROMETHEE	MAUT	AHP	NAIADE
Discrete/Continuous	discrete	discrete	discrete	discrete	discrete	discrete
Outranking/single criterion/interactive	single	single	outranking	single	single	outranking
Quantitative/ qualitative/mixed data	mixed → quant.	qualitative	mixed	mixed → quant.	mixed	mixed
Form of solution	choice, ranking	choice, ranking	ranking	choice, ranking	ranking	ranking

From: Omman (2004)

Overview of MCDA methods: Characterisation frameworks

Classification/Method	ELECTRE I, IS	ELECTRE II, III, IV	ELECTRE TRI	Regime and Evamix	GP/MOP
Discrete/Continuous	discrete	discrete	discrete	discrete	discrete
Outranking/single criterion/interactive	outranking	outranking	outranking	outranking	interactive
Quantitative/ qualitative/mixed data	mixed	mixed	mixed	qualitative	quantitative
Form of solution	choice	ranking	sorting	ranking	choice, ranking

From: Omman (2004)

Multiattribute utility

- In the utility function procedure, the decision's maker attitude toward risk is incorporated into assessment of a single-attribute utility function. Thus utility is a convenient method of including uncertainty (risk preference) into decision-making process. The concept of a utility function is inherently probabilistic in nature. The utility function model can be written:

$$U_i = \sum_j w_j \cdot u_{ij}$$

where U_i is the overall value of the *i*th alternative, *u*ij is the utility of the *i*th alternative with respect to the *j*th attribute measured by means of the utility function, and the weight *w*j is a normalized weight or scaling constant for attribute *j*, so that ∑ *w*j = 1.

From: Malczewski (1999); excerpt prepared by E. Ortega and S. Mancebo

Analytic hierarchy process

- The analytical hierarchy process (AHP) method, developed by Saaty (1980), is based on tree principles: decomposition, comparative judgment and synthesis of priorities.
  - the *decomposition principle* requires that the decision problem be decomposed into a hierarchy that captures the essential elements of the problem;
  - the *principle of comparative judgment* requires assessment of pairwise comparisons of the elements within a given level of the hierarchical structure, with respect to their parent in the next-higher level;
  - the *synthesis principle* takes each of the derived ratio-scale local priorities in the various levels of the hierarchy and constructs a composite set of priorities for the elements at the lowest level of the hierarchy. In this final step, the goal is aggregate the relative weights of the levels obtained in the previous step to produce composite weights, this is done by means of a sequence of multiplications of the matrices of relative weights at each level of the hierarchy.

From: Malczewski (1999); excerpt prepared by E. Ortega and S. Mancebo

Concordance / outranking methods

- Concordance methods are based on a pairwise comparison of alternatives. They provide an ordinal ranking of the alternatives; that is, when two alternatives are compared, these methods can only express that alternative A is preferred to alternative B, but cannot indicate by how much. The most known concordance approach is the ELECTRE method and its modifications.
- The outranking approach leads to different order structures, depending on the preference relations considered, the hypotheses about the properties of these relations (transitivity, etc.) and the use of thresholds (veto, preference, etc.).

From: Guitouni and Martel (1998); Malczewski (1999); excerpt prepared by E. Ortega and S. Mancebo

Ideal point methods

- Ideal point methods order a set of alternatives on the basis of their separation from the ideal point. This point represents a hypothetical alternative that consists of the most deliverable weighted standardized levels of each criterion across the alternatives under consideration. The alternative that is closed to the ideal point is the best alternative. The separation is measured in terms of a distance metric. The ideal point decision rule is:

$$s_{i+} = \left[\sum_j w_j^p \left(v_{ij} - v_{+j} \right)^p \right]^{1/p}$$

where s_{i+} is the separation of the *i*th alternative from the ideal point, w_j is a weight assigned to the *j* criterion, v_{ij} is the standardized criterion value of the *i*th alternative, v_{+j} is the ideal value for the *j*th criterion, and *p* is a power parameter ranging from 1 to ∞.

From: Malczewski (1999); excerpt prepared by E. Ortega and S. Mancebo

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Evaluation of MCDA-methods: Goal and scope (de Montis et al., 2005)

- Compare the different, frequently used multi criteria decision analysis methods (MCDA) by using a set of quality criteria, in order to identify their strengths and weaknesses, *in the light of the issues relevant for sustainable development.*

From: de Montis et al. (2005)

Evaluation of MCDA methods: Quality criteria (De Montis et al., 2005) (I)

Quality Criterion	Description
Operational Components	
Criteria	
▪ Interdependence	Allowance for the interdependence of different criteria
▪ Completeness	Need for the completeness of the criteria
▪ Non-linear preferences	Possibility to express non-linear valuation patterns
Weights	
▪ Transparency of process, type of weights	Type of the procedure of deriving values for the weights
▪ Meaning	Interpretation and role of weights in the evaluation process
Solution finding procedure	Type of procedure used for the comparison of alternatives
Issues addressed by results	Interpretation of the results generated by the use of method

From: de Montis et al. (2005)

Evaluation of MCDA methods: Quality criteria (De Montis et al., 2005) (II)

Quality Criterion	Description
Applicability of MCDA Methods – User Context	
Project Constraints	
▪ Costs	Implementation costs in the specific user situation
▪ Time	Implementation time in the specific user situation
Structure of problem solving process	
▪ Stakeholder participation	Possibility to include more than one person as decision maker
▪ Problems structuring	Existence of mechanisms supporting the structuring of the problem
▪ Tool for learning	Support of learning processes
▪ Transparency	Promotion of transparency in the decision making process
▪ Actors communication	Support of the communication between opposing parties

From: de Montis et al. (2005)

Quality Criterion	Description
Applicability of MCDA methods – Problem Structure	
Indicator characteristics	
▪ Geographical scale	Applicability of different geographical scales for one case
▪ Micro-macro-link	Applicability of different institutional scales for one case
▪ Societal/technical issues	Possibility for the consideration of both societal and technical issues
▪ Methods combination	Possibility of methods' combination
Data situation	
▪ Type of data	Type of data supported as values for the indicators
▪ Risk/Uncertainties	Possibilities for the consideration of evaluation risk and/or uncertainties
▪ Data processing amount	Processing amount needed to compile the data required for the method
▪ Non-substitutability	Possibility to consider sustainability standards and non-substitutability

From: de Montis et al. (2005)

Evaluation of MCDA methods: Results (de Montis et al., 2005) (I)

		MAUT	AHP	Evamix	Electre III	Regime	NAIADE	MOP/GP
Operational components of methods								
Criteria	Interdependence	Not allowed	Allowed	Not allowed	Not allowed	Not allowed	Not allowed	Not allowed
	Completeness	Allowed	Allowed	Allowed	Allowed	Allowed	Allowed	Required
	Non-linear preferences	Allowed	Not allowed	Not allowed	Not allowed	Not allowed	Allowed	Allowed for some variants
Weights	Transparency of process, type of weights	Cardinal weights assigned	Cardinal weights assigned	Ordinal weights assigned	Cardinal weights assigned	Ordinal weights assigned	No weights assigned	Weights assigned for some variants
	Meaning	Trade-offs	Importance	Importance	Importance	Importance	No weights	Importance
Solution finding procedure		Complete ranking	Complete ranking	Complete ranking	Non-dominated option/s calculated	Complete ranking	Non-dominated option/s calculated	Non-dominated option/s calculated
Applicability in user context								
Project constraints	Costs	Depending on the numbers of attributes, stakeholders involved, etc.	Depending on the numbers of attributes, stakeholders involved, etc.	Depending on the numbers of attributes, stakeholders involved, etc.	Depending on the numbers of attributes, stakeholders involved, etc.	Depending on the numbers of attributes, stakeholders involved, etc.	Depending on the numbers of attributes, stakeholders involved, etc.	Depending on the numbers of attributes, stakeholders involved, etc.
	Time	Depending on the numbers of attributed, stakeholders involved, etc.	Depending on the numbers of attributed, stakeholders involved, etc.	Depending on the numbers of attributed, stakeholders involved, etc.	Depending on the numbers of attributed, stakeholders involved, etc.	Depending on the numbers of attributed, stakeholders involved, etc.	Depending on the numbers of attributed, stakeholders involved, etc.	Depending on the numbers of attributes, stakeholders involved, etc.
Structure of problem solving process	Stakeholder participation	Necessary	Necessary	Supported	Supported	Supported	Necessary	Supported by a few variants
	Problems structuring	Via the construction of utility functions	Via the construction of suitable hierarchies	Via the construction of the evaluation matrix	Sometimes cumbersome	Vie the construction of the Regime vector	Via the construction of the evaluation matrix	Model based
	Tool for learning		Appropriate	Not appropriate			Appropriate	interactive MOP
	Transparency	High	High	High	Medium	Medium	High	Low
	Actors communication	Via the integration of stakeholders	Via the integration of stakeholders	Via the integration of stakeholders	Via the integration of stakeholders	Via the integration of stakeholders	Via the integration of stakeholders	Via the integration of stakeholders

From: de Montis et al. (2005)

Evaluation of MCDA methods: Results (de Montis et al., 2005) (II)

		MAUT	AHP	Evamix	Electre III	Regime	NAIADE	MOP/GP
		Applicability for problem structure						
Indicator characteris-tics	Geographical scale	Different can be treated	Different can be treated	Different can be treated	Different can be treated	Different can be treated	Different can be treated	Different can be treated
	Micro-macro-link	Possible	Possible	Possible	Possible	Possible	Possible	Possible
	Societal/technical issues	Different issues are possible	Different issues are possible	Different issues are possible	Different issues are possible	Different issues are possible	Different issues are possible	Different issues are possible
	Methods combinations	Possible	Possible	Possible	Possible	Possible	Not possible	Possible
Data situation	Type of data	Qualitative and quantitative possible	Qualitative and quantitative possible	Qualitative and quantitative possible	Mainly quantitative	Qualitative and quantitative possible	Qualitative and quantitative possible	Mainly quantitative
	Risk/Uncertainties	Risky outcomes: probabilities, sensitivity analysis	Via sensitivity analysis	Via ordinal criteria only	Via thresholds		Via stochastic and fuzzy numbers	Via sensitivity analysis and fuzzy numbers
	Data processing amount	High	Medium	Low	High	Medium	Medium	Medium
	Non-substitutability	Not possible	Not possible	Not possible	Not possible	Not possible	Not possible	Possible via constraints or lexicographic ordering

Table 4. Summary of method comparison

From: de Montis et al. (2005)

Evaluation of MCDA-methods: Conclusions (de Montis et al., 2005) (I)

- Without reference to the specific characteristics of the case study for which the methods should be applied, the selection of the best applicable method is not possible.
- For a general comparison regarding sustainability issues, the following four groups of criteria are most crucial:
  - possibility to deal with complex situations (criteria, consideration of different scales and aspects, i.e. geographical scales, micro-macro-link, societal/technical issues, type of data, uncertainties);
  - possibility to consider non-substitutability (strong sustainability) issues;
  - possibility to involve more than one decision maker (stakeholder participation, actors communication, and transparency);
  - information of stakeholders in order to increase their knowledge and change their opinion and behaviour (problem structuring, tool for learning, transparency, type of weights).

From: de Montis et al. (2005)

Evaluation of MCDA-methods: Conclusions (de Montis et al., 2005) (II)

- Some rough guidelines which can be given from the methods comparison are:
  - If the respective decision problem is such that relying upon social welfare theory and its assumptions is possible and if the data to build utility functions is available (risk and qualitative data are possible), then MAUT is a good choice.
  - If working with different conflicting interest groups is important for the case, NAIADE and AHP provide the best performance.
  - If the involved decision makers should primarily learn from the application of the MCDA tool, it is advisable to use MAUT or AHP.
  - If thresholds and constraints are central for the problem under investigation, which means that there is non-substitutability of some criteria, Electre III or GP/MOP should be chosen.
  - If the problem is a continuous one, i.e. there is not a discrete number of alternatives which comes out of the specific situation, GP or MOP should be chosen.
  - If a complete ranking of the given alternatives as result of the analysis is indispensable MAUT, AHP, Evamix, or Regime should be applied.

From: de Montis et al. (2005)

Evaluation of MCDA-methods: Goal and scope (Tsamboulas et al., 1999)

- Compare the most commonly applied multicriteria methods to be used *in the assessment of transport infrastructure projects*.

From: Tsamboulas et al. (1999)

Evaluation of MCDA methods: Results (Tsamboulas et al., 1999)

TABLE 5. Summary of Performances of Five Multicriteria Methods

	Criteria (1)	REGIME (2)	ELECTRE (3)	MAUT (4)	AHP (5)	ADAM (6)
Transparency	(Q_1)	***	**	**	***	**
	(Q_2)	*	**	***	***	***
	(Q_3)	*	**	**	***	**
	(Q_4)	*	**	***	***	*
Simplicity	(S)	**	*	**	***	**
Robustness	(P)	**	**	***	***	***
	(C)	*	***	***	***	***
	(U)	*	*	***	**	**
	(D)	**	*	*	***	*
	(V)	*	**	***	***	***
Accountability	(A)	*	***	**	**	**

Note: *** very good, ** good, * not good. (Q_1) Copes better with real world situations; (Q_2) Offers decision analysis closest to human-rational approach; (Q_3) Is well structured and easy to follow; (Q_4) Uses straightforward mathematical approximations to represent reality; (S) Simplicity; (P) Treatment of any number of projects; (C) Treatment of any number of criteria; (U) Treatment of uncertainty; (D) Encouragement of special interests group; (V) Sensitivity; (A) Accountability.

From: Tsamboulas et al. (1999)

Evaluation of MCDA-methods: Conclusions (Tsamboulas et al., 1999) (I)

- The theoretical background of each method is philosophically consistent with the decision-making framework of transport planning;
- The methods are capable of receiving inputs concerning preferences of the actors involved, and they can generate outputs permitting the evaluation of direct impacts as well as the assessment of indirect effects on social and physical environment;
- The methods are relatively easy to use by the decision makers and have the potential to be a decision support tool for the selection among different transport initiatives.
- Each method presents a series of unique features allowing for a high degree of flexibility, consistency, and reliability;
- The methods' performance depends on the characteristics of the decision situation.

From: Tsamboulas et al. (1999)

Evaluation of MCDA-methods: Conclusions (Tsamboulas et al., 1999) (II)

- In summary, the main positive and negative aspects of each method are the following:
  - *REGIME*: Useful when ordinal information is available for criteria weights and projects' scores. The method is a powerful tool with the ability to manage a large variety of evaluation problems. The number of criteria plays an important role in determining the implementation difficulty.
  - *ELECTRE family*: They are based on the partial comparability axiom. ELECTRE I may lead to inconsistent results when ''nontransitive'' outranking relations are used. Most of these problems have been solved in latter versions.
  - *Additive Methods*: The most straightforward - close to human, rational - methods to treat transportation decision problems. There is a variety of decision tools using utility or value functions (MAUT and AHP) or the notion of the ideal point (ADAM type). The additive models are usually linear and allow for complete compensation. However, this is not desirable in all decision situations.

From: de Montis et al. (2005)

Evaluation of MCDA methods: Results (Borken, 2005)

EMPA
Materials Science & Technology

	AHP	Evamix	ELECTRE III	Regime	NAIADE	MOP / GP
Iteration	angemessen	nicht ange-messen	-/-	-/-	angemessen	interaktiv
Partizipation	stakeholder	stakeholder	stakeholder	stakeholder	stakeholder	stakeholder
Transparenz	hoch	hoch	mittel	mittel	hoch	niedrig
Unsichere Daten	Sensitivitäts-analyse	nur durch ordinale Kriterien	durch Schwellen-werte	-/-	durch sto-chastische und fuzzy Zahlen	Sensitivitäts-analyse und fuzzy Zahlen
Nicht-Substituier-barkeit	nein	nein	durch Schwellen-werte	nein	nein	durch Rand-bedingungen und lexiko-graph. Ord-nung

AHP: Analytic Hierarchy Process; Evamix: Evaluation matrix; REGIME: NAIADE: Novel approach to imprecise as-sessment and decision environments; MOP / GP: Multi-objective programming / Goal programming.

From: Borken (2005)

Evaluation of MCDA methods: Results (Adolphe, 2007)

Famille de méthodes d'agrégation	Principes	Hypothèses	Exemples	Avantages	Inconvénients	Domaine d'application
Sans Agrégation			Diagramme radar	Très simple	Pas d'agrégation	Contraintes techniques Critères exclusifs très peu nombreux (<7)
Sans Compensation	Définition de seuils binaires par critère	Poids dictatorial des critères principaux	Hiérarchie de critères : approches lexicographiques	Simple, rapide	Effet de seuil Pas de compensation	Contraintes techniques Critères exclusifs
Agrégation Complète	Indice de synthèse	Commensurabilité des critères Comparabilité (préordre total) Compensation	Notes scolaires Moyenne pondérée Fonctions d'utilité (UTA) Goal Programming	Efficace Robuste	Hypothèses contraignantes Pb d'exhaustivité, Pb de représentativité Pb de légitimité (cas de la monétarisation : biais focalisation du questionnement, valeur d'usage ?, compensation entre domaines hétérogènes : forte subjectivité introduite	Problématiques bien délimitées à objectif unique ou convergents (économie, logistique, militaire)
Agrégation Partielle	Comparaison 2 à 2 de variantes Indice de surclassement Analyse relations de surclassement	Non commensurabilité Incomparabilité (préordre partiel) Intransitivité des préférences	Electre Prométhée…	Critères qualitatifs Insensible aux échelles	Performance Forme des résultats	Critères de nature différente. Décisions complexes (incomparabilité) Implication des décideurs

From: Adolphe (2007)

Evaluation of MCDA-methods: Goal and scope (Janssen, 2001)

- Provide an overview of the type and complexity of decision problems supported in the Netherlands, and the MCA approach selected to analyse these problems.
- Analyse the role of MCA in the decision process.

From: Janssen (2001)

Evaluation of MCDA-methods: Conclusions (Janssen, 2001)

- A survey of evaluation tables shows that the absence of a consistent evaluation framework leads to doublecounting, confusion between means and ends in the criteria, dependencies among criteria, missing criteria, and inconsistencies in spatial and temporal scales.
- The main methodological challenge is not in the development of more sophisticated MCA methods. Simple methods, such as weighted summation, perform well in most cases.
- More important is the support of problem definition and design. […] methods should be developed to provide more systematic support for building a consistent evaluation framework.
- Methods to support design are rare in the MCA circuit. Development of methods that could use the results of evaluation to support the design of new alternatives could make a major contribution to the EIA decision process.

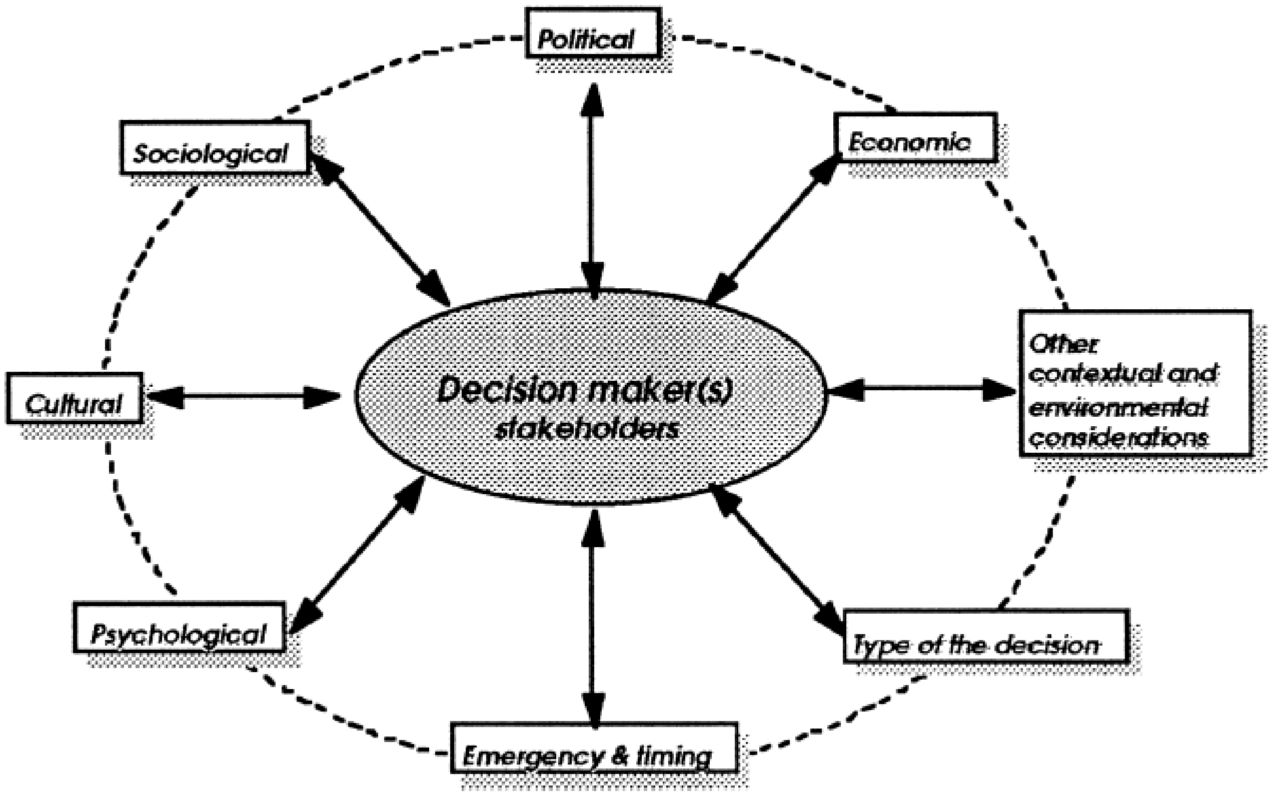
From: Janssen (2001)

Evaluation of MCDA-methods: Goal and scope (Guitouni and Martel, 1998)

- draw a conceptual framework for articulating tentative guidelines to choose an appropriate MCDA method;
- compare well known multicriterion aggregation procedures (MCAP) on the basis of these guidelines.

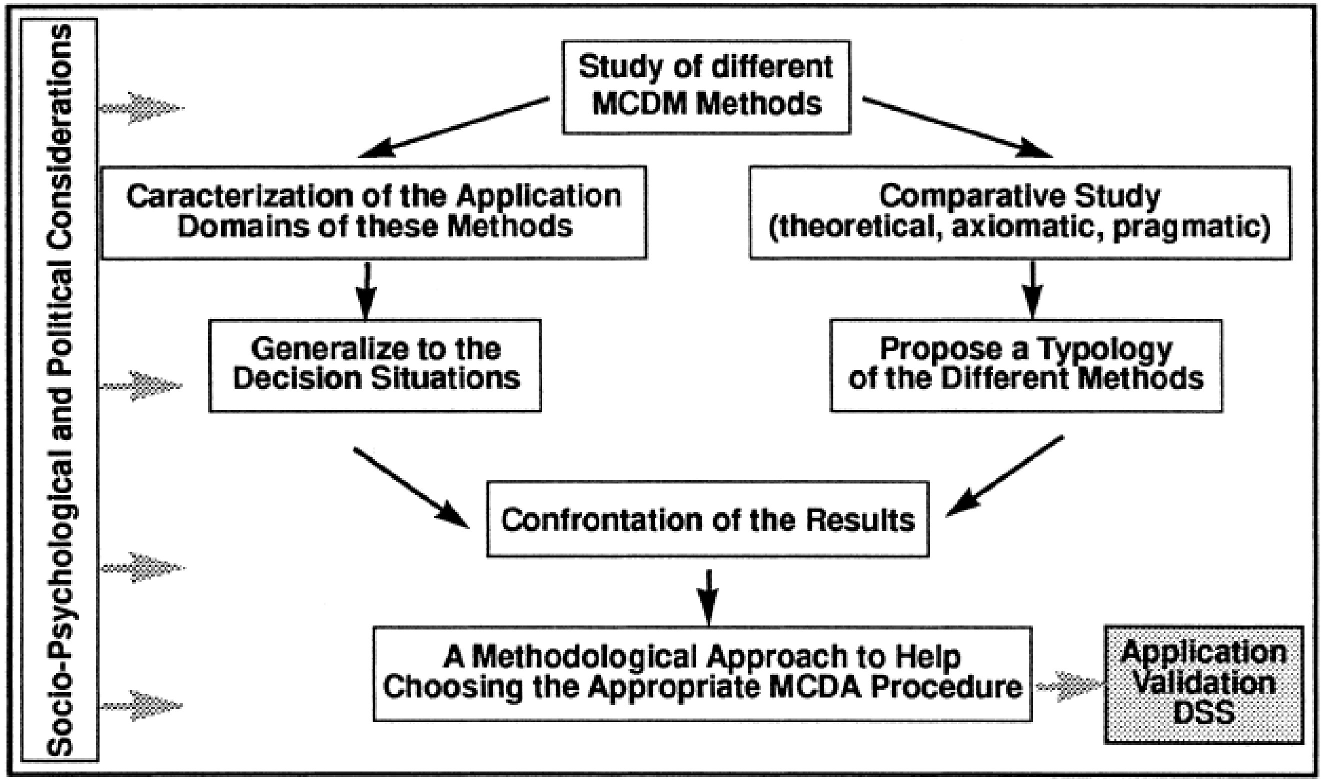
From: Guitoni and Martel (1998)

Evaluation of MCDA-methods: Results (Guitouni and Martel, 1998)



Considerations inherent to a decision making situation

From: Guitouni and Martel (1998)



Framework to choose an appropriate MCDA methodology

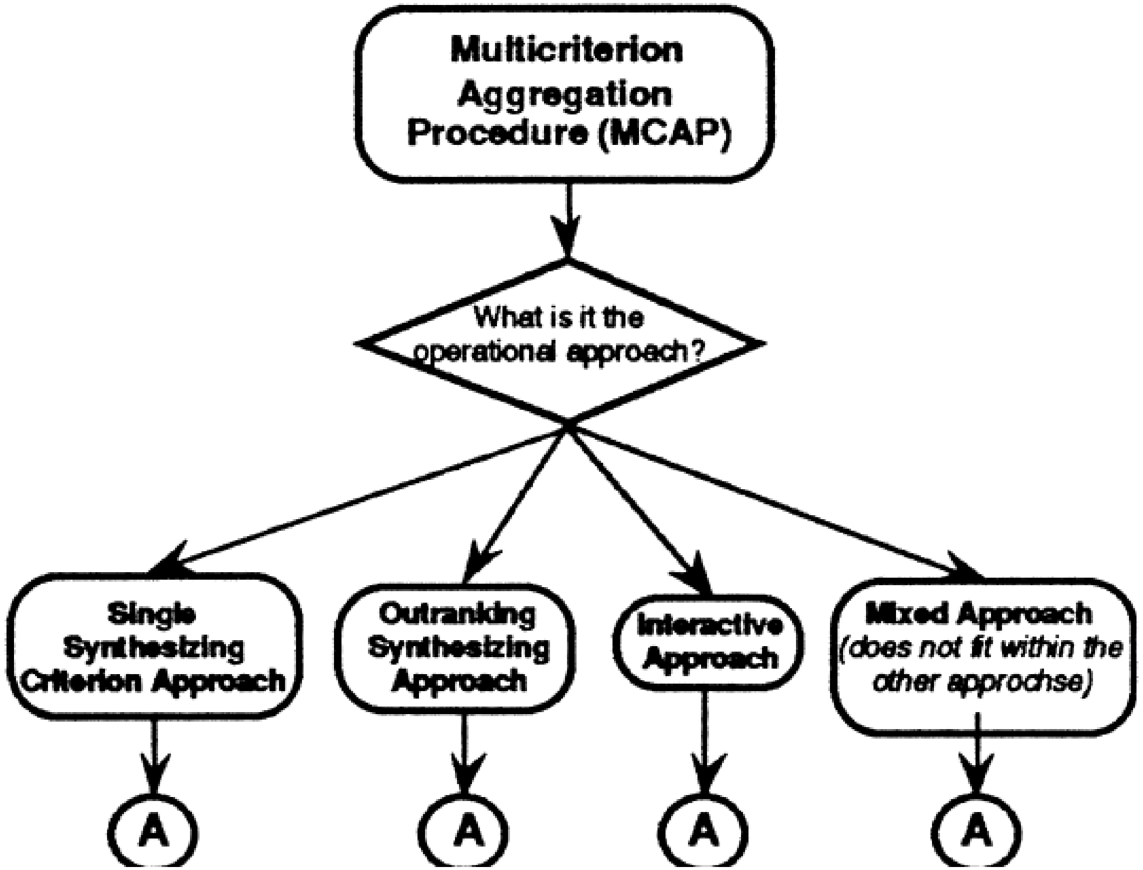
From: Guitouni and Martel (1998)

Evaluation of MCDA-methods: Guidelines (Guitouni and Martel, 1998)

Guideline 1	■Determine the stakeholders of the decision process. If there are many decision makers (judges), one should think about group decision making methods or group decision support systems (GDSS).
Guideline 2	■Consider the DM 'cognition' (DM way of thinking) when choosing a particular preference elucidation mode. If he is more comfortable with pairwise comparisons, why using tradeoffs and vice versa?
Guideline 3	■Determine the decision problematic pursued by the DM. If the DM wants to get an alternatives ranking, then a ranking method is appropriate, and so on.
Guideline 4	■Choose the MCAP that can handle properly the input information available and for which the DM can easily provide the required information; the quality and the quantities of the information are major factors in the choice of the method.
Guideline 5	■The compensation degree of the MCAP method is an important aspect to consider and to explain to the DM. If he refuses any compensation, then many MCAP will not be considered.
Guideline 6	■The fundamental hypothesis of the method are to be met (verifed), otherwise one should choose another method.
Guideline 7	■The decision support system coming with the method is an important aspect to be considered when the time comes to choose a MCDA method.

From: Guitouni and Martel (1998)

Evaluation of MCDA-methods: Typological tree (Guitouni and Martel, 1998)



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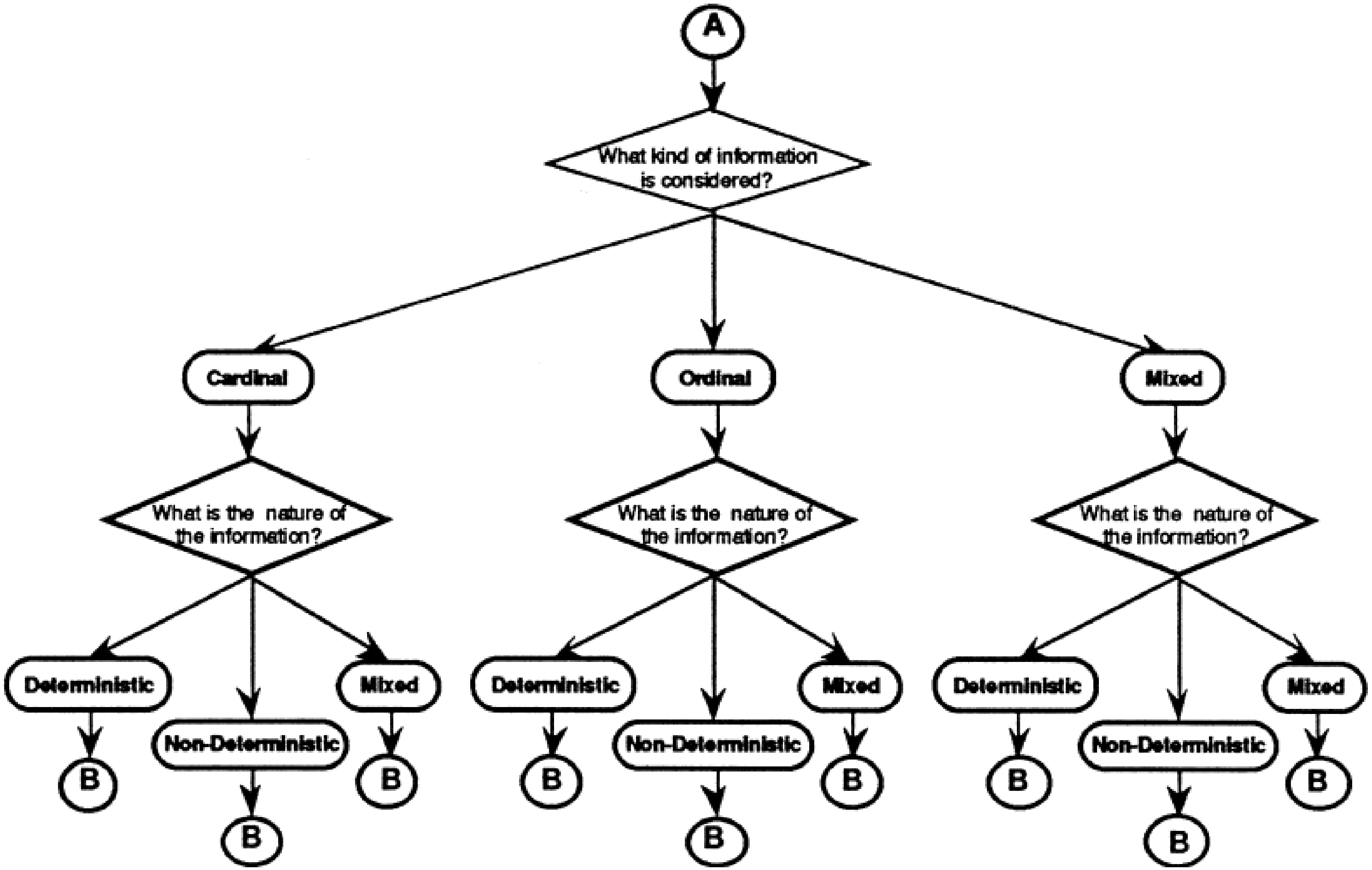
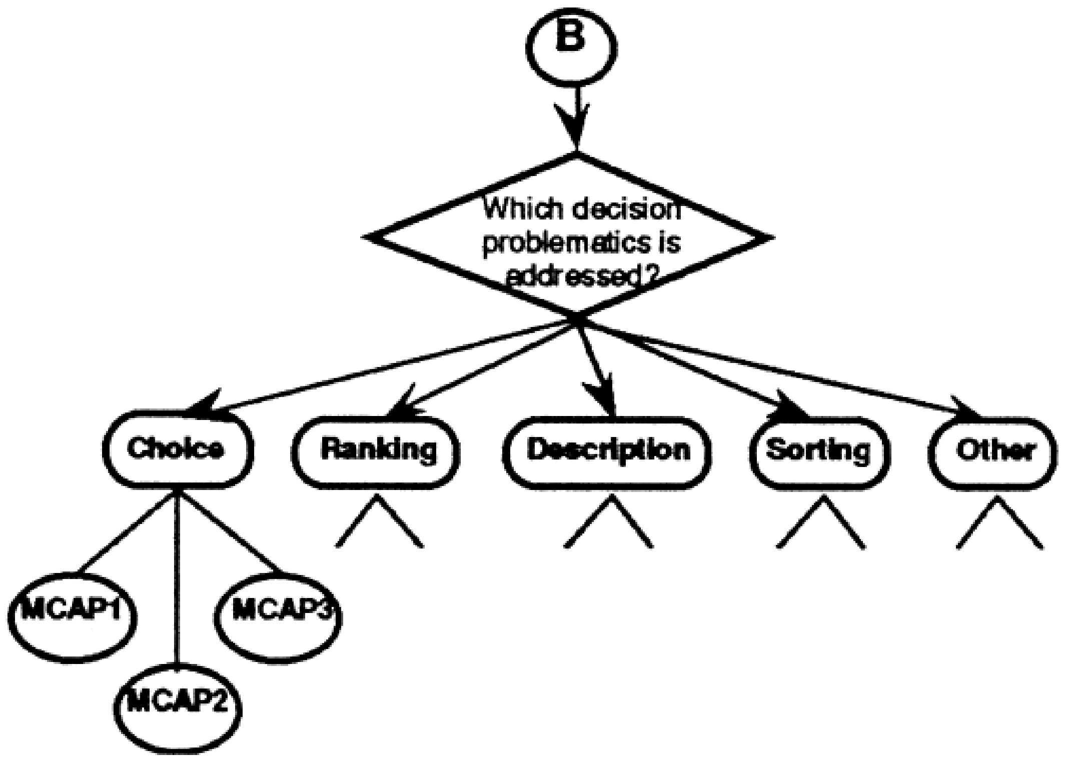


From: Guitouni and Martel (1998)

Evaluation of MCDA-methods: Typological tree (Guitouni and Martel, 1998)



From: Guitouni and Martel (1998)

Evaluation of MCDA-methods: Conclusions (Guitouni and Martel, 1998)

- Structuring the decision making situations and modelling the preferences are important steps of any decision aid methodology, which have not received enough consideration until now.
- The different models are neglecting many aspects of the decision making situation.

From: Guitouni and Martel (1998)

Outline

- Goals and scope;
- Fundamental assumptions
- Overview of MCDA methods
  - Classification frameworks.
- Evaluation of MCDA methods
  - Approaches, results & conclusions.
- Open questions;
- Next steps;
- References.

Open questions

- Which approaches and methods shall we consider within task 3.2?
- What is the interface to tasks 2.3 and 3.3?
- What are the application contexts to consider?
- With which fundamental assumptions regarding MCDA/MCE do we agree, with which not?
- Which characterisation and evaluation framework are the right ones for our purposes?

Outline

- Goals and scope;
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  - Approaches, results & conclusions.
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- References.

Next steps

- What is the innovation/originality of task 3.2?
- What are the outputs of task 3.2?
- What are the contents of task 3.2?
- How to organize work?
  - who is in charge?
  - until when?
  - how to coordinate with the other tasks?
  - how to communicate among others?
  - which experts to invite?
  - is there a necessity for STSM?

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