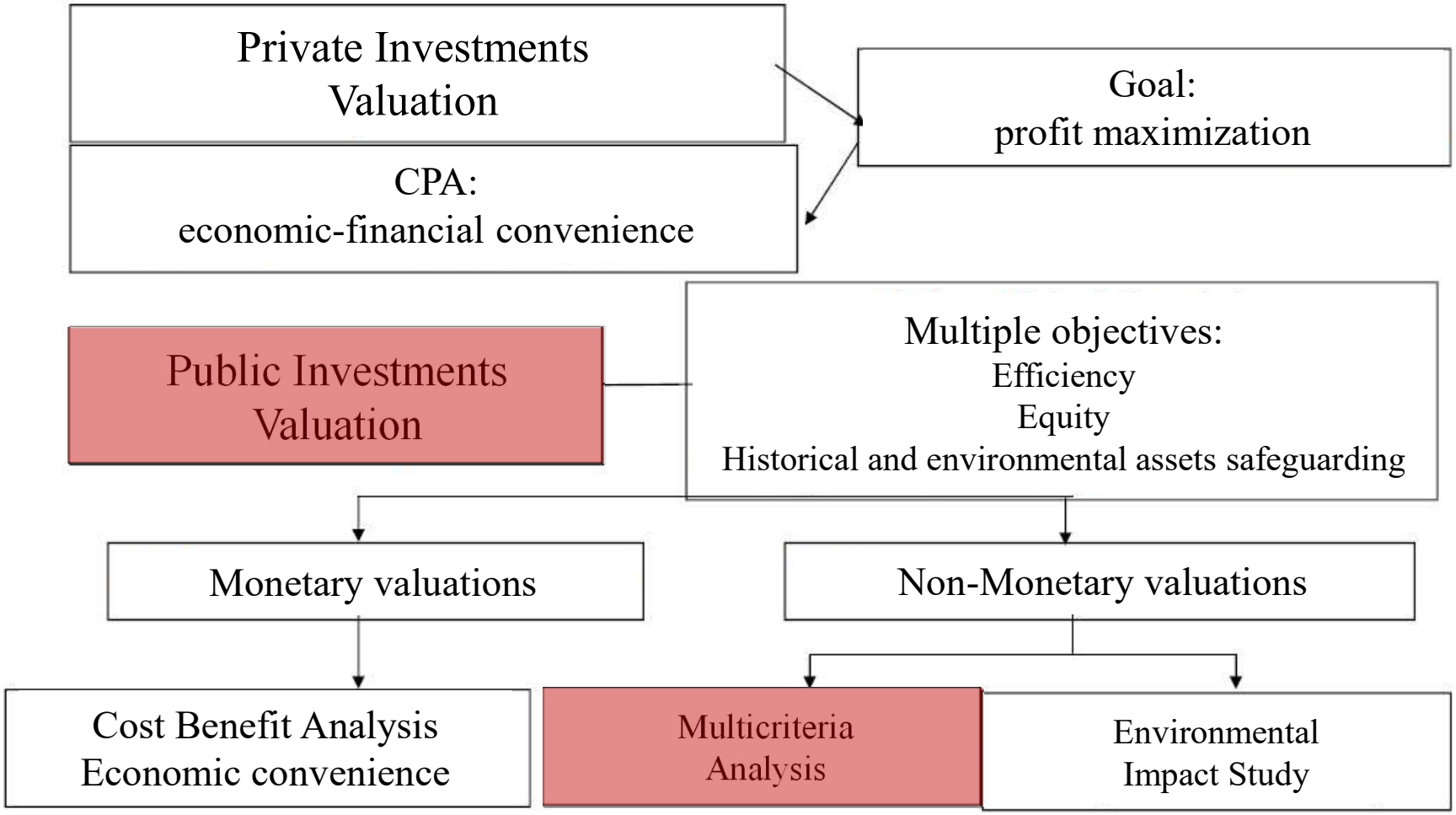
Multiple Criteria Decision Aid

Public Decision Processes and MCDA: Basics and Definitions

MCDA


Private Investments
Valuation
CPA:
economic-financial convenience
Goal:
profit maximization
Public Investments
Valuation
Multiple objectives:
Efficiency
Equity
Historical and environmental assets safeguarding
Monetary valuations
Non-Monetary valuations
Cost Benefit Analysis
Economic convenience
Multicriteria
Analysis
Environmental
Impact Study

… Hard Choices … How to make it!!!

Our lives are the sum of our decisions, whether in business or in personal spheres.

Often, WHEN we decide is as important as WHAT we decide.

To be a person is to be a decision maker.

Thomas Saaty

DECISION THEORY IN COMPLEX CONTEXT

There is no single solution

In simple choices one alternative is better than the others.

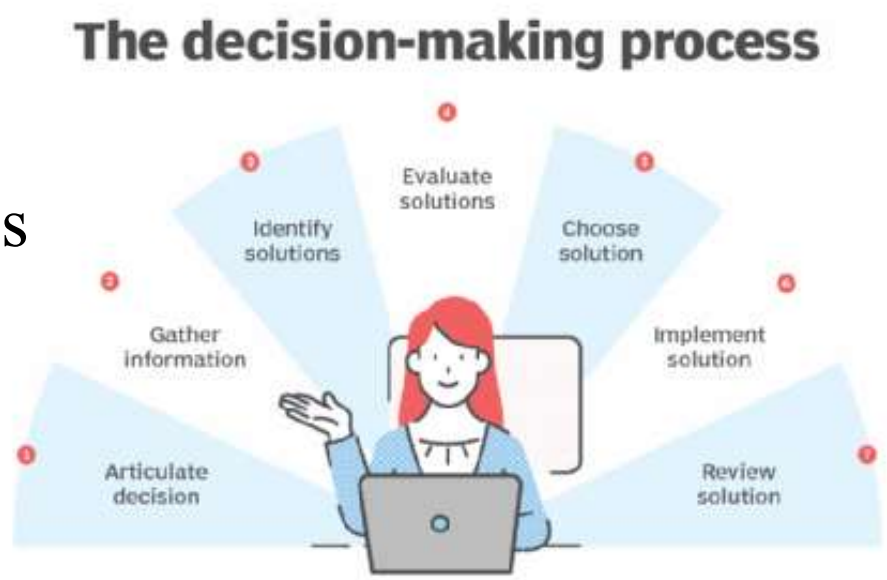
In complex problems one alternative may be better than the others in one situation and not in other situations

Ultimately in complex problems different alternatives may be equally valid

A LEGITIMATION ISSUE

Policymakers feel lacking legitimation in their decision-making process:

- Mistrust between public opinion, experts and policymakers
- Social fragmentation
- Short agendas vs long term concerns



WHAT IS A PUBLIC DECISION PROCESS?

- Different types of actors are involved
- Participation
- Public deliberation
- Social outcomes
- Long term horizons

PECULIARITIES

Distributed decision power (several stakeholders)

- Political Actors (short-term political agendas)
- Officials and Experts (medium-term knowledge-based agendas)
- Social groups

Different stakes

- ranging from long-term to short-term and/or affecting from large territories and population to small
- short term ‘opportunistic’ stakes

Heterogeneous resources (e.g. money, knowledge, trust, land, etc.)

CONSEQUENCES

- Conflicting opinions, priorities, actions
- Conflicting information and interpretations
- Different language and communication patterns
- Mutually adaptive behaviour over time

Accountability, Legitimation, Consensus, Evidence

FORMAL MODELS

PROS	DRAWBACKS
• Common language • Improved accountability • Basis for participative decision making • Exploring less ‘obvious aspects’ (better insight) • Avoiding intuitive errors	• Possible loss of a global insight • Possible loss of creative thinking • Too much structuring of the decision process • Does everybody understand formal models? • Cost of using formal models

WHAT IS EVALUATION?

- What does it mean evaluation? **Measuring values**
- What does it mean measuring?
- What is **value**?
  - ✓ Value of what?
  - ✓ Value for whom?
  - ✓ Value for doing what?
  - ✓ Is there an ‘objective’ value?
  - ✓ Value as a social agreement
  - ✓ Economic value
  - ✓ Use values and marginal values
  - ✓ Personal values
  - ✓ Values as ethics and norms

E.g. Did air quality improve?

pollutant	CO_2	SO_2	O_3	Dust
sub-index	x	y	w	z

- ATMO index= Max(x,y,w,z)

pollutant	CO_2	SO_2	O_3	Dust
t_1	3	3	8	8
t_2	2	3	8	8

- Air quality improved, but the ATMO index did not
- What is the truth?

MEANINGFULNESS and DIFFERENCES OF PERSPECTIVE

- Different standards and thresholds
- Different cultures
- Different stakeholders
- Different concerns
- Different resources

Is it good or bad? E.G.:

- ✓ The h-index of X is 19. Is she/he a good researcher?
- ✓ Who is a good researcher?
- ✓ What good research means?
- ✓ Who decides and for what purpose about research quality?

What do we take into account?

- Values and preferences of relevant stakeholders
- Individual values and social values
- Judgements (experts, politicians, opinions)

Example: who is the winner?

- 10 voters have preferences ***a***P***b***P***c***
- 6 voters have preferences ***b***P***c***P***a***
- and 5 voters have preferences ***c***P***b***P***a***

Who is the winner?

- Most electoral systems will choose a, which is the one the majority does not want

Voters/Votes	3 points	2 points	1 points
10	a	b	c
6	b	c	a
5	c	b	a

Voters	a	b	c
10	30	20	10
6	6	18	12
5	5	10	15
Total	**41**	**48**	**37**

- Actually the Condorcet winner is ***b***

DIFFERENT WAYS TO CONSTRUCT EVIDENCE

- Different ways to establish a majority
- Different ways to compute an average
- Different ways to take into account the importance of ...
- Positive and Negative reasons/arguments

WHAT IS A DECISION AIDING PROCESS?

The interactions between somebody involved in the decision process (the client) and somebody able to support him/her in the decision process

- *Consensual construction of shared cognitive artifacts*
- *A Decision Aiding Process makes sense only with respect to a Decision Process in which the Client is involved and for which the Client demands advice*

WHAT IS A DECISION AIDING PROCESS?

- A Decision Aiding Process is a Decision Process where at least **two actors are involved** (i.e., the client and the analyst), with at least two concerns (i.e., the client's 'problem' and the analyst's job), mobilizing at least the following resources: the client's domain knowledge and the analyst's methodological knowledge

- A Decision Aiding Process becomes part of the Decision Process for which it has been established

- The analyst enters **as an actor** such a Decision Process

- *Its aim is, above all, to enable us to enhance the degree of conformity and coherence between the evolution of a decision-making process and the value systems and objectives of those involved in this process (Roy, 1985)*

HOW IS A DECISION AIDING PROCESS STRUCTURED?

STEPS:

1. Representation of the Problem Situation: $PS = \langle A, O, RS \rangle$
2. Problem Formulation: $\Gamma = \langle \hat{A}, V, \Pi \rangle$
3. Evaluation Model: $M = \langle \tilde{A}, D, S, C, U, P \rangle$
4. Meaningfulness
5. Final Recommendation

VOCABULARY (people inveolved in the process)

Actor

Any individual or group of individuals, who has a role, direct or otherwise, in the decision-making process

Stakeholder

Any individual or group of individuals who has, consciously or unconsciously, an interest in the decision-making process

Decision maker

Actor for whom decision support tools are developed and implemented

Action

"Object" that is analysed, evaluated, compared with other objects during the decision-making process. It is a general term (an asset, a scenario, a plan, a project, an investment…)

Set of actions

- Set of "objects/decisions" that will be analysed during the decision-making process
- The definition of A may be progressively elaborated during the decision-aid procedure

Alternative

- Action that can be implemented separately and independently from the others
- The concept of alternative depends on the set of actions that has been defined

Example: Decision problem: hiring an engineer

- *If the set of actions is made up of the list of candidates, each single name in the list is an alternative*
- *If I have to hire a pair of architects, each single name in the list does not represent an alternative*
- *Each pair represents an alternative*

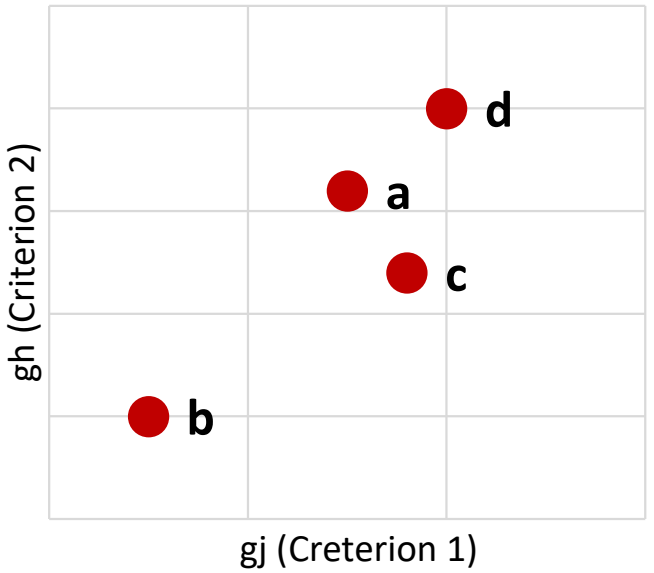
Criterion

- A function ***gi*** defined on **A** taking its values in a totally ordered set and representing the decision maker's preferences according to some point of view $g_i: A \rightarrow \Re$
- The evaluation of action according to criterion ***j*** is $g_j(a)$
- compare actions a and b from the *j-th* point of view, $g_j(a)$ vs $g_j(b)$

Indicator

- A (qualitative or quantitative) synthesis of information defining characteristics, attributes or consequences of actions from a particular point of view, independently from the decision maker's preferences
- An indicator can associate **a characteristic or state to an action** *(e.g. the age of a candidate, whenever age is one of the criteria:20 years, 30 years, …e.g. the typology of a street/road, whenever the typology is a criterion: highway, freeway, country road,….)* **or a number** *(e.g. cost, area, length)*

Dominance relation



- Given two elements **a** and **b** of A, **a** dominates **b** (**aDb**) if

$$g_j(a) \geq g_j(b) \qquad j=1, 2, \ldots, n$$

where at least one of the inequalities is strict

- The dominance relation is a strict partial order (asymmetric and transitive relation)
- Generally, few pairs of actions satisfy fully dominance relationship, difficult to estimate and determine the dominance relationship when the number of criteria is large

Efficient Action

- Action **a** is efficient if no action in **A** dominates it
- The set of efficient actions coincides with A when the dominance relation is empty

MULTICRITERIA DECISION AIDING (MCDA)

- The objective of MCDA is to help decision-makers to make better decisions.
- What does ‘better’ mean?
- This meaning is not independent from the process by which the decision is made and implemented.
- Nevertheless, methodological decision-aiding based on appropriate concepts and procedures can play a significant and beneficial role in guiding a decision-making process

MULTICRITERIA DECISION AIDING (MCDA)

We can expect that decision-aiding contributes to:

- analysing the decision-making context by **identifying actors, potential actions**, their **consequences, stakes**, etc.
- organizing and/or structuring how **decision-making unfolds** in **order to increase coherence** among the values underlying objectives and goals
- **getting the actors to cooperate** by proposing keys to a **better mutual understanding** and frameworks favourable to **debate**
- **elaborating recommendations** using results taken from models and computational procedures within the framework of a working hypothesis
- **participating** in the **final decision legitimation**

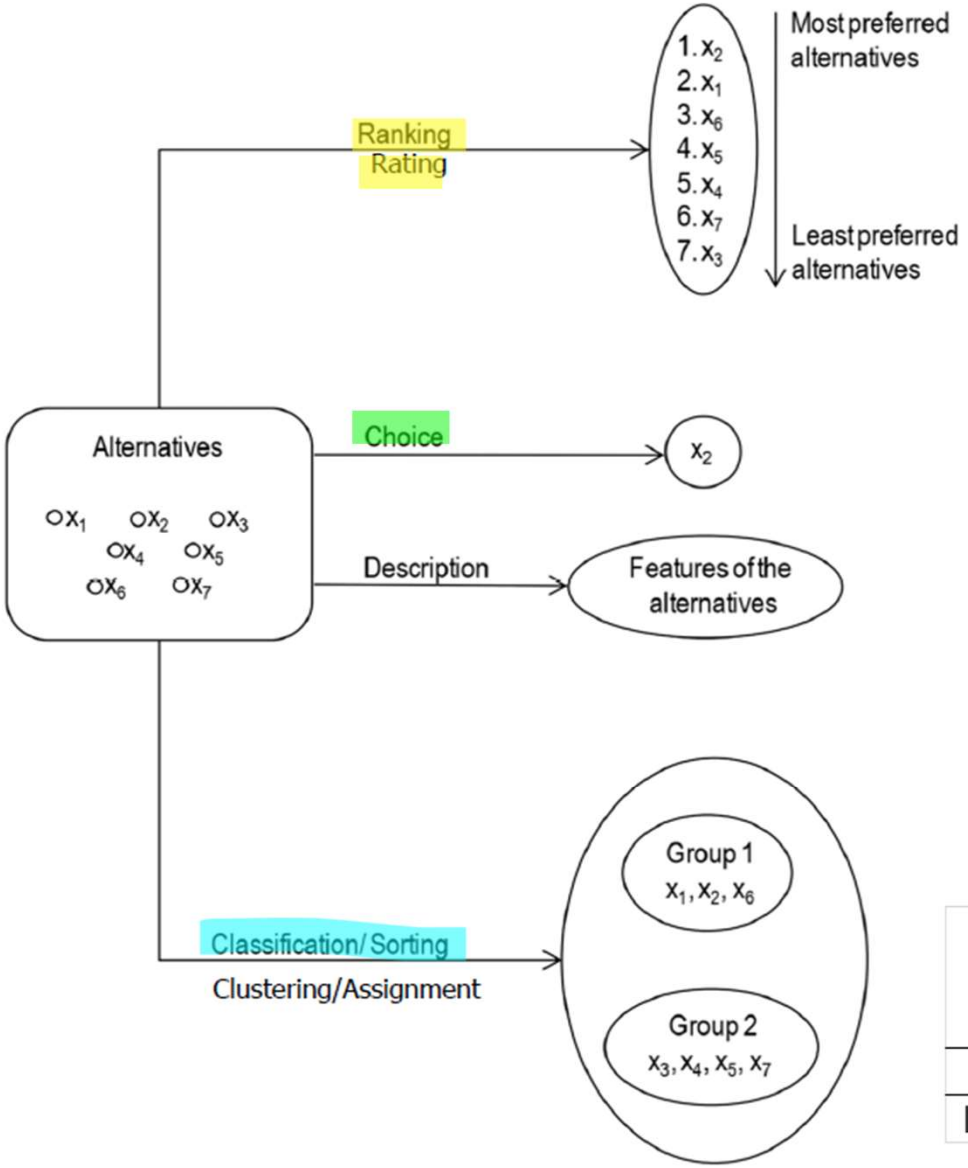
Multicriteria Problem (1/2)

Definition: a multicriteria decision problem is a situation in which, having defined a set A of actions

and a consistent family F of criteria on A, one wishes:

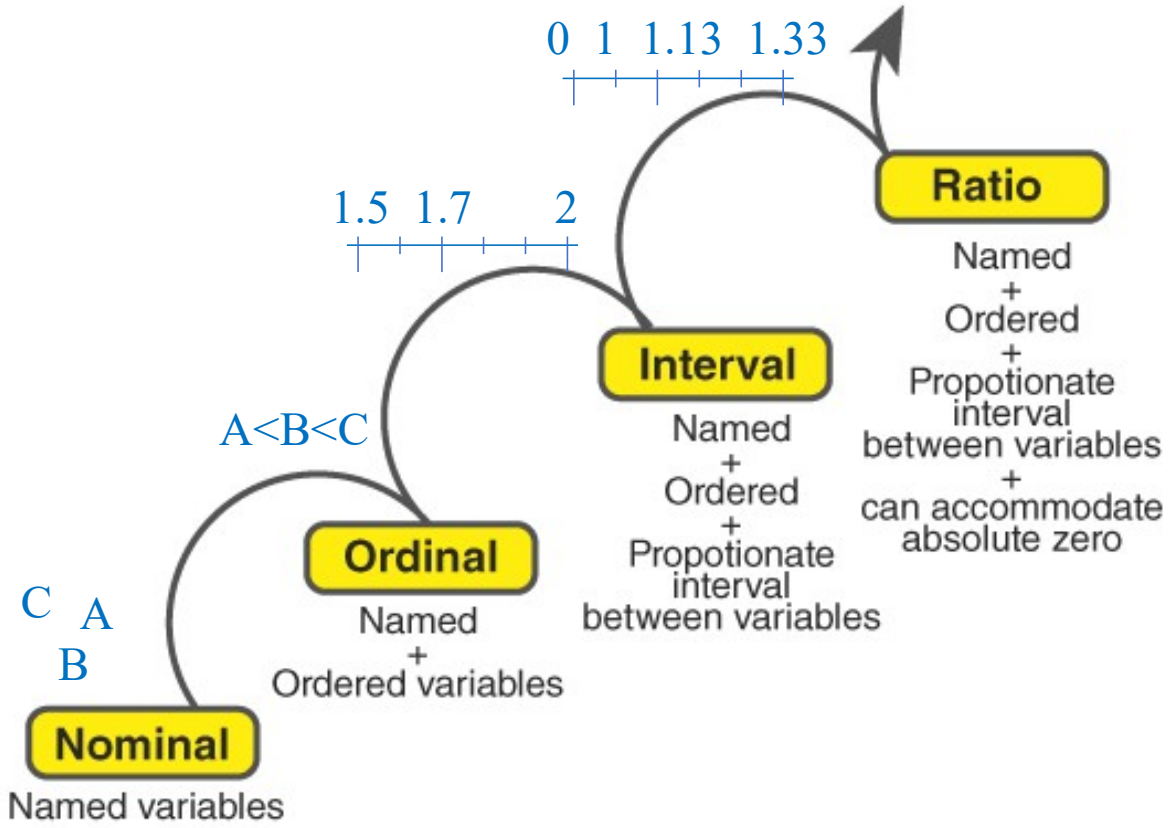
- ✓ to determine a subset of actions considered to be the best with respect to F (**choice problem**)
- ✓ to divide A into subsets according to some norms (**sorting/classification problem**)
- ✓ to rank the actions of a from best to worst (**ranking/rating problem**)

Multicriteria Problem (2/2)



	Predefined wrt some external norms	Defined only through pairwise comparisosn
Ordered	Rating	Ranking
Non ordered	Assigning	Clustering

Measurement scales



- **Nominal scale**: preserves equality. It is the most unrestricted assignment of numerals. Numerals are used as labels or tags (words or letters would serve as well)
- **Ordinal scal**e: preserves equality and ordinality. No origin. The interval is not intrinsically equal between successive points on the scale

METRIC

- **Interval scale:** preserves equality, ordinality, and interval ratios. Any state is compared to a sequence of standards/units, with respect a common origin. Independently from the origin and the unit, the ratio among the differences of units remains constant
- **Ratio scale**: preserves equality, ordinality, interval ratios, and value ratios. Any object is compared to a sequence of standards/units. Independently from what the standard/unit is, the ratio of units between any two objects remains constant

Multicriteria Problem

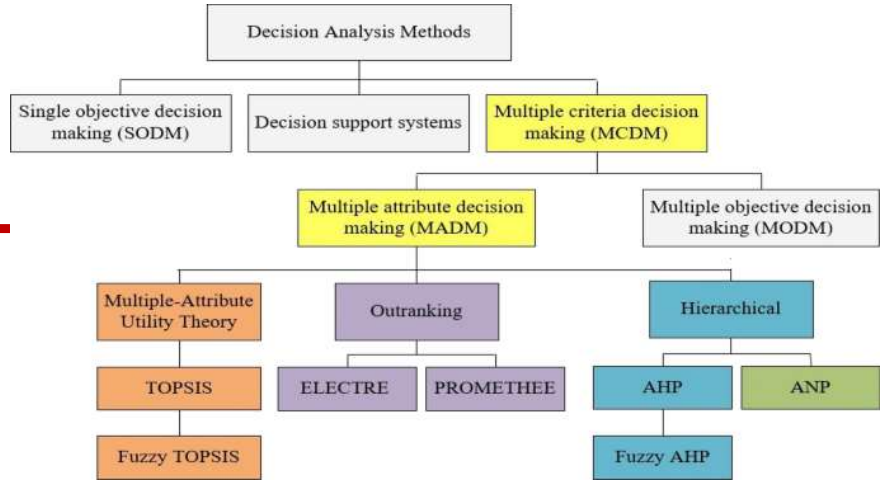
- In a Multicriteria Decision **RANKING** Problem **binary relations need to be defined**
- 'Solving' a multicriteria decision problem is rather **helping the decision maker to 'master'** the (often complex) data involved in his/her problem and advance toward a solution (Roy, 1990)
- The 'solution' will thus be a '**compromise action**' and will strongly depend on the decision maker's personality, on the circumstances in which the decision aiding process takes place, on the way the problem is presented, on the method which is used
- A well-formulated mathematical problem: by referring to U (explicitly known or implicitly present in the decision maker's mind), 'discover' $a^* \in A$ such that:

$$U(a^*) \geq U(a), \forall\ a\ \in A$$

- Why MCDA is not Social Choice

Social Choice	MCDA
Total orders	Any type of order
Equal importance of voters	Variable importance of criteria
As many voters as necessary	Few coherent criteria
No prior information	Existing prior information

MCDM methods, e.g.:



- Aggregated Indices Randomization Method (AIRM)
- Analytic hierarchy process (AHP) + Fuzzy AHP
- Analytic network process (ANP)
- Balance Beam process
- Best worst method (BWM)
- Brown–Gibson model
- Characteristic Objects METhod (COMET)
- Conjoint Value Hierarchy (CVA)
- Data envelopment analysis
- Decision EXpert (DEX)
- Disaggregation – Aggregation Approaches (UTA*, UTAII, UTADIS)
- Rough set (Rough set approach)
- Dominance-based rough set approach (DRSA)
- ELECTRE (Outranking)
- Evaluation Based on Distance from Average Solution (EDAS)[56]
- Evidential reasoning approach (ER)
- Goal programming (GP)
- Grey relational analysis (GRA)
- Inner product of vectors (IPV)
- Measuring Attractiveness by a categorical Based Evaluation Technique (MACBETH)
- Multi-Attribute Global Inference of Quality (MAGIQ)
- Multi-attribute utility theory (MAUT)
- Multi-attribute value theory (MAVT)
- New Approach to Appraisal (NATA)
- Nonstructural Fuzzy Decision Support System (NSFDSS)
- Ordinal Priority Approach (OPA)
- Potentially All Pairwise RanKings of all possible Alternatives (PAPRIKA)
- PROMETHEE (Outranking)
- Simple Multi-Attribute Rating Technique (SMART)
- Stochastic Multicriteria Acceptability Analysis (SMAA)
- Superiority and inferiority ranking method (SIR method)
- System Redesigning to Creating Shared Value (SYRCS)[60]
- Technique for the Order of Prioritisation by Similarity to Ideal Solution (TOPSIS)
- Value analysis (VA)
- Value engineering (VE)
- VIKOR method[61]
- Weighted product model (WPM)
- Weighted sum model (WSM)
- ……

Find the most relevant **Multiple Criteria Decision Analysis** (MCDA) **methods** for a decision-making problem with the tool: MCDA Methods Selection Software (MCDA-MSS) *https://mcda.cs.put.poznan.pl/*

MCDA – EXERCISE: Structuring a Problem for MCDA

Remember: The goal is to structure your problem in a way that facilitates systematic analysis and comparison of alternatives, leading to a well-informed decision. Content:

1. PROBLEM IDENTIFICATION (Structuring the decision problem)

- Define the decision context
- Clearly state the main issue or challenge (formulate the question)
- Specify the objectives to be achieved (choice problem, sorting/classification problem, ranking/rating problem)

2. STAKEHOLDERS ANALYSIS

- Identify all relevant stakeholders
- Determine the expertises' needed by focus group participants

3. ALTERNATIVES SELECTION

- List all possible courses of Alternatives
- Ensure alternatives are mutually exclusive
- Verify that alternatives are feasible and realistic

4. CRITERIA/SUBCRITERIA SELECTION

- Define the criteria and eventually subcriteria
- Ensure criteria are measurable and independent
- Specify the measurement scale and the unit of measure for each criteria/subriteria

5. ASSESSMENT

- Define the proper and more efficient and effective MCD method
- Evaluate each alternative against all criteria interrogating the focus group/Choose appropriate weighting methods
- Scoring alternatives and weighting the criteria
- Testing consistency and performing sensitivity analysis

6. SUPPORTING DECISION-MAKING

- Use the MCDA outputs to support decision-making – i.e. ranking or selecting alternatives (depending on the application).

MCDA – EXERCISE: Structuring a Problem for MCDA

Example: Selecting a Location for a New University Campus

1. **PROBLEM IDENTIFICATION -:** The university needs to expand and build a new campus

   Objective: Find the best location for the new campus that balances various factors

2. **STAKEHOLDERS ANALYSIS:** University administration - Faculty and staff - Current and prospective students - Local community and businesses - City planners and government officials

3. **ALTERNATIVES SELECTION:**

   - Location A: Downtown urban area
   - Location B: Suburban area with large green spaces
   - Location C: Industrial park undergoing redevelopment
   - Location D: Adjacent to the existing campus

4. **CRITERIA/SUBCRITERIA SELECTION:**

CRITERIA	SUBCRITERIA	UNIT OF MEASURE
Economics	Cost of land and construction	Currency
	Cost of maintenance (Economy of scale)	Currency
Environment	Environmental impact in the construction phase (CO_2 emissions)	tons of CO_2 per year
	Potential for future expansion (Available land area)	m2
Location	Accessibility (Distance to public transport stops)	m
	Proximity to the existing campus and university amenities (Distance)	m
	Local Amenities	Number (discrete)
	Safety and security Crime rate	Incidents per 1,000 people

MCDA – EXERCISE: Structuring a Problem for MCDA

Other examples:

Urban Planning and Infrastructure

- **Problem**: Choosing the best site for a new public park.
- **Criteria**:
  - Accessibility (proximity to residential areas and public transport).
  - Environmental impact (preservation of natural habitats).
  - Cost of land acquisition and development.
  - Social benefits (potential usage and community satisfaction).
  - Noise pollution levels.
- **MCDA Application**: Decision-makers can prioritize these criteria based on stakeholder input to identify the most balanced location.

Healthcare

- **Problem**: Selecting the most appropriate treatment plan for a chronic disease.
- **Criteria**:
  - Effectiveness (success rate of the treatment).
  - Side effects (severity and likelihood).
  - Cost (affordability for the patient and healthcare system).
  - Time required for recovery.
  - Patient preference and lifestyle compatibility.
- **MCDA Application**: This helps both healthcare providers and patients weigh the trade-offs and select the optimal treatment plan.

Supply Chain Management

- **Problem**: Choosing the best supplier for a manufacturing process.
- **Criteria**:
  - Cost of materials.
  - Delivery reliability (lead time and on-time delivery rates).
  - Quality standards (defect rates).
  - Sustainability practices (use of eco-friendly materials).
  - Capacity to scale production.
- **MCDA Application**: By assigning weights to these criteria, businesses can identify the supplier offering the best overall value.

MCDA – EXERCISE: Structuring a Problem for MCDA

Other examples:

Environmental Conservation

- **Problem**: Prioritizing conservation projects in a region.
- **Criteria**:
  - Biodiversity importance (endangered species and ecosystem uniqueness).
  - Feasibility (availability of resources and local support).
  - Potential for climate change mitigation.
  - Economic impact on local communities.
  - Long-term sustainability.
- **MCDA Application**: Conservation organizations can objectively evaluate and prioritize projects to maximize ecological and social benefits.

Education Policy

- **Problem**: Designing a scholarship program for students.
- **Criteria**:
  - Academic performance (GPA or standardized test scores).
  - Financial need (household income).
  - Extracurricular involvement (sports, arts, volunteering).
  - Geographic diversity (representation from underserved areas).
  - Future societal impact (commitment to public service).
- **MCDA Application**: Policymakers can balance inclusivity and meritocracy to design effective scholarship criteria.

Disaster Management

- **Problem**: Allocating resources for emergency relief in disaster-affected areas.
- **Criteria**:
  - Severity of damage (number of people affected).
  - Accessibility of the location.
  - Urgency of needs (availability of food, water, medical aid).
  - Cost of intervention.
  - Potential long-term benefits (infrastructure rebuilding).
- **MCDA Application**: Relief organizations can distribute resources efficiently and equitably.

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