ERASMUS+ KA2 Strategic Partnership
2017-1-FI01-KA203-034721
HELP – Healthcare Logistics Education and Learning Pathway

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Multi-criteria decisionmaking

Reginald Dewil

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Multi-criteria decision making

MCDM methods are a set of tools to support decision making in multiple criteria problems concerning different stakeholders with conflicting values.

Also known as Multi-criteria decision analysis (MCDA)

Has a different focus than the related field of Multi-Objective Optimization

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Multi-objective optimization

Consider a problem with 2 conflicting objectives

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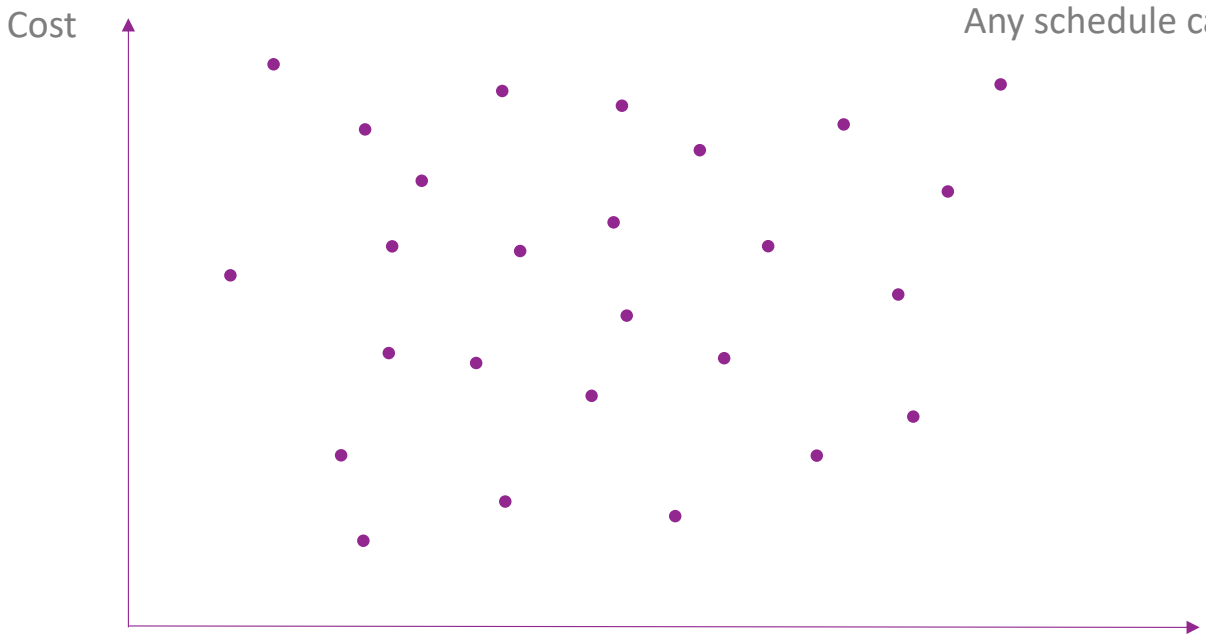
Multi-objective optimization

Consider a scheduling problem with 2 conflicting objectives



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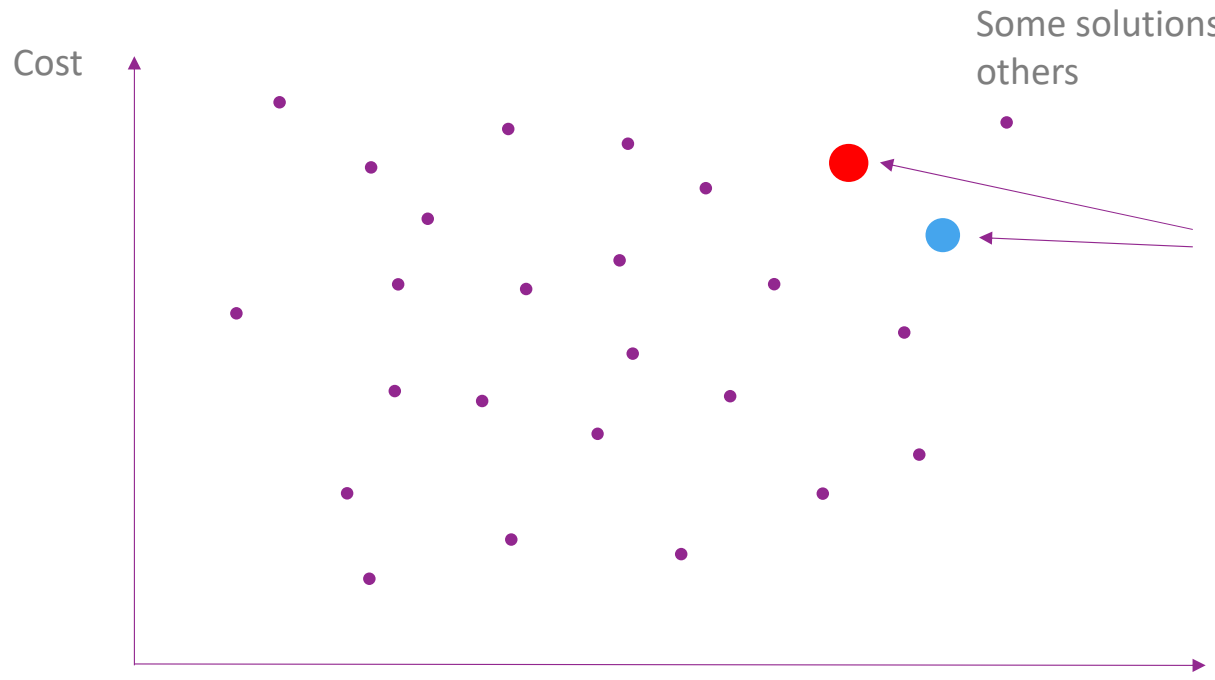
Multi-objective optimization

Consider a scheduling problem with 2 conflicting objectives



Some solutions are definitely better than others

The blue one is lower cost **AND** has higher quality

The blue solution *dominates* the red solution

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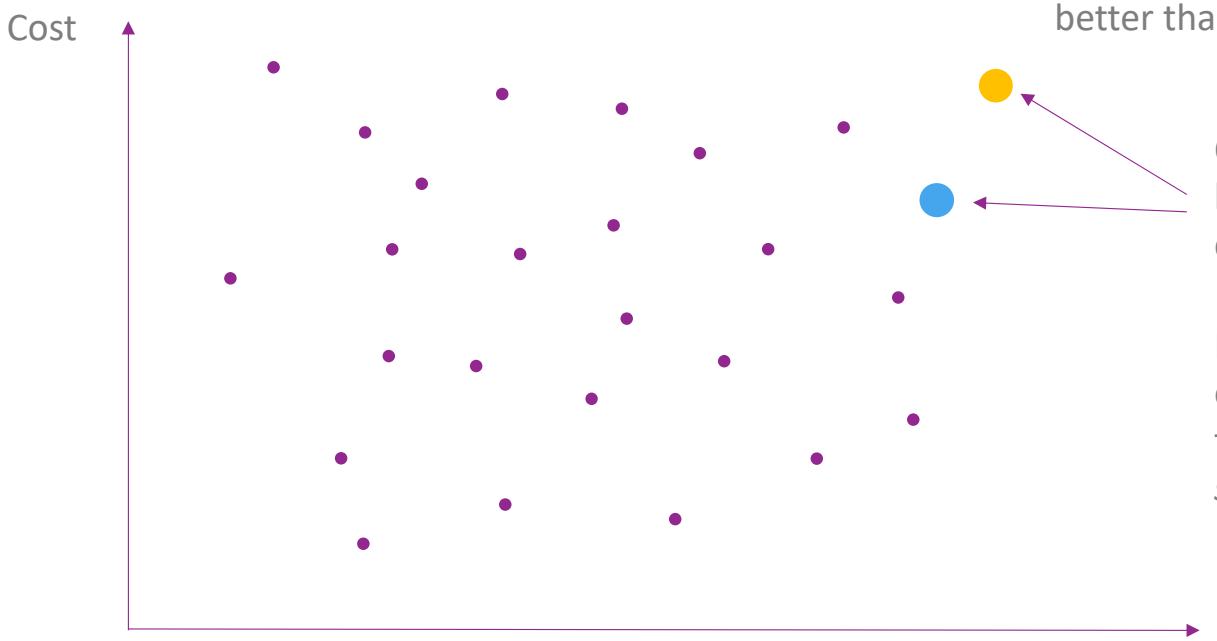
Multi-objective optimization

Consider a scheduling problem with 2 conflicting objectives



For some other combinations: we cannot make a statement on whether one is better than the other

Orange has higher quality, but it comes at greater cost !

Decision makers should only be interested in these *non-dominated solutions*

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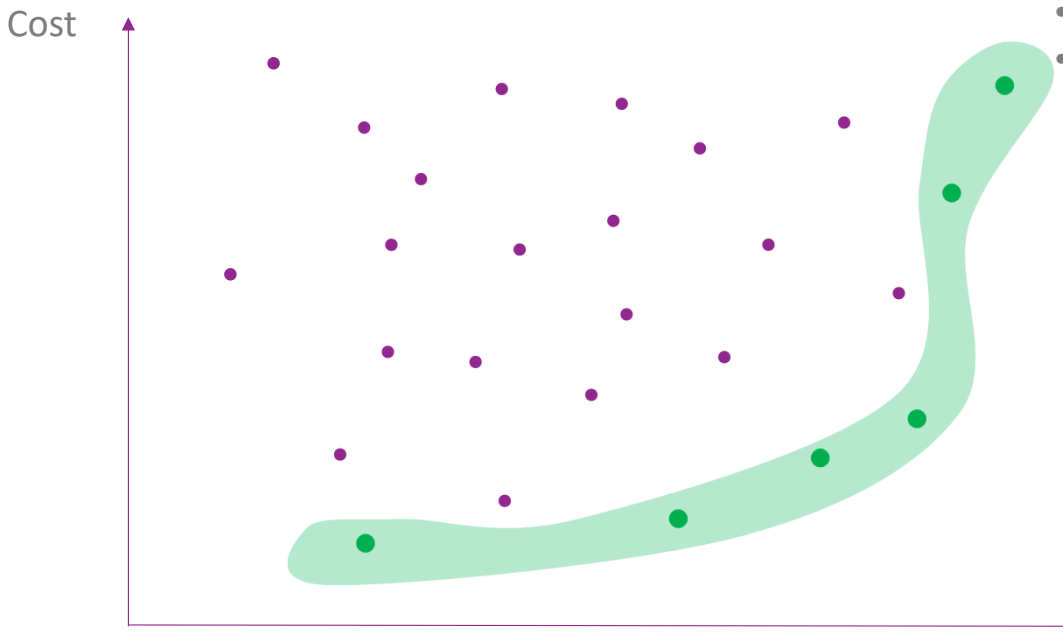
Multi-objective optimization

Consider a scheduling problem with 2 conflicting objectives



These solutions are called:

- *Pareto front*
- *Pareto optimal solutions*
- *The efficient frontier*

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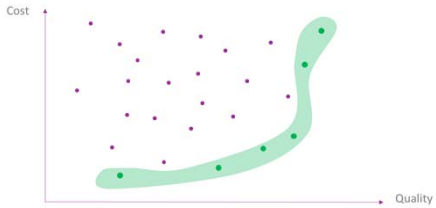
Multi-objective optimization



- Finding this efficient frontier is not easy for many problem settings
  - Employ Mathematical Programming, Heuristics, and Meta heuristics
- MODM optimization can limit the number of options to choose from
  - Only Pareto-optimal solutions
  - In many applications, the number of pareto-optimal solutions is limited when dealing only with 2 objectives
  - Many multi-disciplinary problems involve 3,4,5, … 10+ criteria
- Still:
  1. A trade-off needs to be made
  2. Decision-makers can value different criteria differently
  3. Transparancy sometimes required on how a decision was

Intuition does not always cut it

MCDM to the rescue

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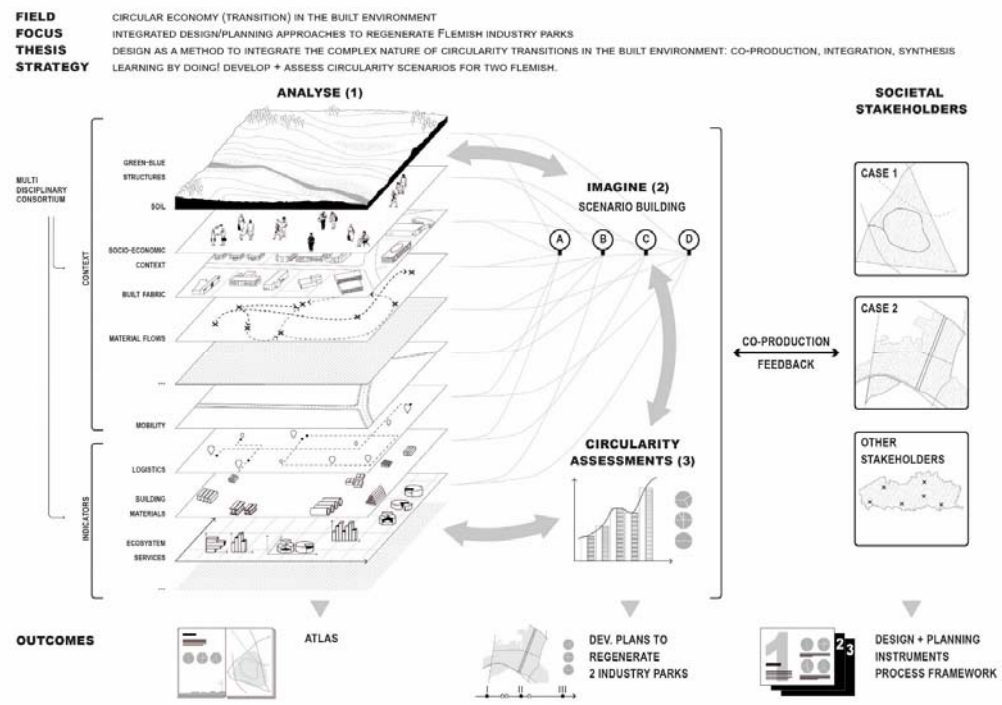
Future planning of industry parks

- Economic
  - Operating cost of industry park
  - Cash requirements for investment
  - Congestion (#hours lost)
  - Impact on modal split
- Environmental
  - CO2 emmissions
  - NOx emmissions
  - Circularity of materials ot the built environment
  - Energy use of the industry park
- Social
  - Integration of industry park with neighborhood
  - Employment options for different social groups
- ….



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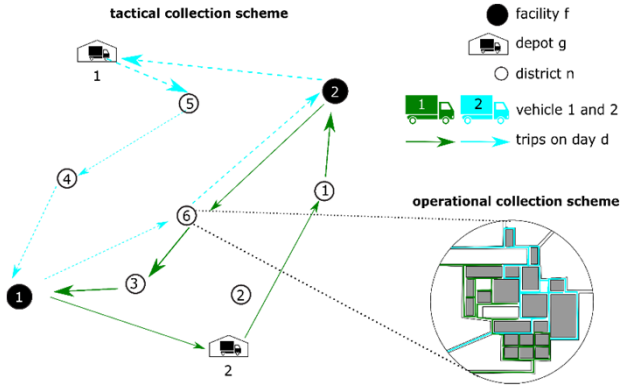
Waste Processing Facility Location Problem

- Location & Processing Type decision affects:
  - operational cost of waste collection
  - investment cost
  - regulatory risk
  - community resistance risk
  - pollution
  - noise
  - smell
  - jobs
  - …



Solve integrated facility location and waste collection routing problems to get reliable estimates

Each criterion has a different value for each type of stakeholder:

- Manager at the company
- Neighbor of potential location
- Citizen that is not a neighbor
- Politican

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MCDM Methods => many techniques

MCDM methods [edit]

The following MCDM methods are available, many of which are implemented by specialized decision-making software:[3][4]

- Aggregated Indices Randomization Method (AIRM)
- Analytic hierarchy process (AHP)
- Analytic network process (ANP)
- Balance Beam process
- Base-criterion method (BCM)[44]
- Best worst method (BWM)[45][46]
- Brown–Gibson model
- Characteristic Objects METhod (COMET)[47][48]
- Choosing By Advantages (CBA)
- Data envelopment analysis
- Decision EXpert (DEX)
- Disaggregation – Aggregation Approaches (UTA*, UTAII, UTA
- Rough set (Rough set approach)
- Dominance-based rough set approach (DRSA)
- ELECTRE (Outranking)
- Evaluation Based on Distance from Average Solution (EDAS)
- 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)
- Simple Multi-Attribute Rating Technique (SMART) [50]
- Stratified Multi Criteria Decision Making (SMCDM)
- Multi-Attribute Global Inference of Quality (MAGIQ)
- Multi-attribute utility theory (MAUT)
- Multi-attribute value theory (MAVT)
- Markovian Multi Criteria Decision Making
- New Approach to Appraisal (NATA)
- Nonstructural Fuzzy Decision Support System (NSFDSS)
- Potentially All Pairwise RanKings of all possible Alternatives (PAPRIKA)
- PROMETHEE (Outranking)
- Ranking based on optimal points (RBOP)[51]
- Stochastic Multicriteria Acceptability Analysis (SMAA)
- Superiority and inferiority ranking method (SIR method)
- Technique for the Order of Prioritisation by Similarity to Ideal Solution (TOPSIS)
- Value analysis (VA)
- Value engineering (VE)
- VIKOR method[52]
- Weighted product model (WPM)
- Weighted sum model (WSM)
- Modelo Integrado de Valor para Estructuras Sostenibles (MIVES)[53][54]

Wikipedia,

the one and only

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MCDM

- Feasible alternatives

  Preferably Pareto Optimal – but not always known after e.g. brainstorming solutions or candidates

- Evalution criteria?

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MCDM - criteria

- Avoid overlap
- Be clear and exhaustive
- Some criteria may be divided up into several subcriteria

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MCDM Methods

Linear Additional Methods

Define weights for each criterion

Evaluate each alternative on all its criteria

Total value of an alternative is the weighted sum of criterion scores

Select highest valued alternative

Absolute Methods

In comparison with the ideal situation

> Appreciation specifications
> Concepts to synthesize
> Utility scores (distances)

Relative Methods

In comparison with each other (2 by 2)

> Outranking methods
> Analytical Hierarchy Process (AHP)

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MCDM – Linear Additional Method

Determine criteria weights

Criterion	Description	Weight
C1	Risk	70
C2	Ergonomic Load	50
C3	Cost	30
C4	Service Deliverd	100
C5	Service Experienced	60

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MCDM – Linear Additional Method

Evaluate Alternatives

Criterion	Description	Weight	Alternative 1	Alternative 2	Alternative 3	Alternative 4
C1	Risk	70	10	4	8	7
C2	Ergonomic Load	50	6	8	7	8
C3	Cost	30	5	8	10	8
C4	Service Deliverd	100	7	10	9	8
C5	Service Experienced	60	10	10	6	7
			2450	**2520**	2470	2350

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MCDM – alternative evalution

Evaluate Alternatives

Criterion	Description	Weight	Alternative 1	Alternative 2	Alternative 3	Alternative 4
C1	Risk	70	10	4	8	7
C2	Ergonomic Load	50	6	8	7	8
C3	Cost	30	5	8	10	8
C4	Service Deliverd	100	7	10	9	8
C5	Service Experienced	60	10	10	6	7
			2450	**2520**	2470	2350

Getting consensus on the weights by different stakeholders can be a lengthy process

Some criteria are sometimes hard to objectively score.
Leads to additional possibilities for arguments

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MCDM – relative methods

- Analytic Hierarchy Process

  T.L. Saaty, How to make a decision: The Analytic Hierarchy Process, EJOR 48, pp9-26, 1990

- Outranking
  - E.g. ELECTRE [Roy]
  - E.g. PROMETHEE [Brans]

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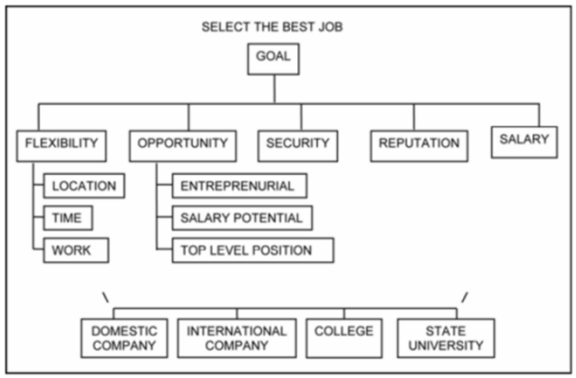
Analytic Hierarchy Process (AHP)

- Weights of criteria are determined through pairwise comparison by the stakeholders
- Steps:
  1. Define objective
  2. Structure the decision hierarchy:
     1. Goal of the decision on top
     2. Then intermediate levels (criteria and sub criteria)
     3. Down to the alternatives
  3. Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it
  4. Calculate weights/priorities. Use the priorities of a given level to weight the priorities of the level below for every element



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Analytic Hierarchy Process (AHP)

- We need a scale to indicate how many times more important one element is over the other

Table 1 The fundamental scale of absolute numbers

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

An example of examination using judgements

Drink consumption in US	*Coffee*	*Wine*	*Tea*	*Beer*	*Sodas*	*Milk*	*Water*
Coffee	1	9	5	2	1	1	1/2
Wine	1/9	1	1/3	1/9	1/9	1/9	1/9
Tea	1/5	2	1	1/3	1/4	1/3	1/9
Beer	1/2	9	3	1	1/2	1	1/3
Soda	1	9	4	2	1	2	1/2
Milk	1	9	3	1	1/2	1	1/3
Water	2	9	9	3	2	3	1

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Analytic Hierarchy Process (AHP)

- Decision-maker executes a pair-wise comparison for a set of elements

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Wine	1/9	1	1/3	1/9	1/9	1/9	1/9
Tea	1/5	3	1	1/3	1/4	1/3	1/9
Beer	1/2	9	3	1	1/2	1	1/3
Soda	1	9	4	2	1	2	1/2
Milk	1	9	3	1	1/2	1	1/3
Water	2	9	9	3	2	3	1

Notice the value for i-j is the inverse for j-i

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Analytic Hierarchy Process (AHP)

- Normalized pair-wise matrix is calculated

(Here, an approximation approach is used.
Exact through eigenfactor maxtrix calculations)

Normalized matrix

	Coffee	*Wine*	*Tea*	*Beer*	*Sodas*	*Milk*	*Water*
Coffee	1/5,81	9/49	5/25,33				
Wine	0,11/5,81	1/49					
Tea	0,2/5,81						
Beer				..			
Soda							
Milk							
Water							

An example of examination using judgements

	Coffee	*Wine*	*Tea*	*Beer*	*Sodas*	*Milk*	*Water*
Coffee	1	9	5	2	1	1	1/2
Wine	1/9	1	1/3	1/9	1/9	1/9	1/9
Tea	1/5	2	1	1/3	1/4	1/3	1/9
Beer	1/2	9	3	1	1/2	1	1/3
Soda	1	9	4	2	1	2	1/2
Milk	1	9	3	1	1/2	1	1/3
Water	2	9	9	3	2	3	1
$\sum$	5,81	49	25,33	9,44	5,36	21,11	2,89

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Analytic Hierarchy Process (AHP)

Normalized matrix

	Coffee	*Wine*	*Tea*	*Beer*	*Sodas*	*Milk*	*Water*	AVERAGE
Coffee	0,17	0,18	0,20	0,21	0,19	0,05	0,17	**0,167**
Wine	0,02	0,02	0,01	0,01	0,02	0,01	0,04	**0,018**
Tea	0,03	0,06	0,04	0,03	0,05	0,62	0,04	**0,124**
Beer	0,09	0,18	0,12	0,11	0,09	0,05	0,12	**0,107**
Soda	0,17	0,18	0,16	0,21	0,19	0,09	0,17	**0,169**
Milk	0,17	0,18	0,12	0,11	0,09	0,05	0,12	**0,119**
Water	0,34	0,18	0,36	0,32	0,37	0,14	0,35	**0,295**

Criteria weights

Additional calculations can be made to test whether the weights are consistent and hence can be used for decision making

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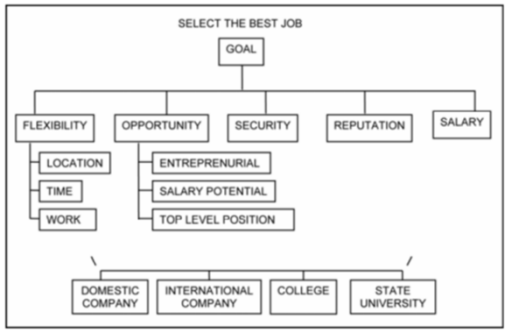
Analytic Hierarchy Process (AHP)



- Applying AHP to larger problem
  1. Define objective
  2. Structure the decision hierarchy:
  3. Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it
  4. Calculate weights/priorities. Use the priorities of a given level to weight the priorities of the level below for every element

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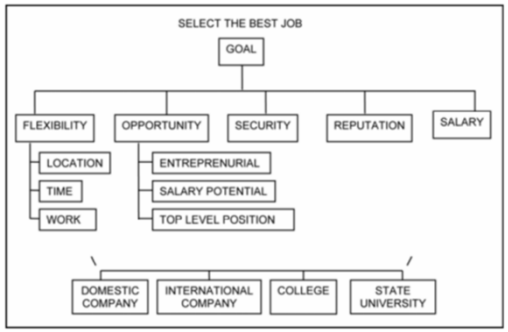

3. Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it

GOAL	flex	opport	security	reputation	salary
flex					
opport					
security					
reputation					
salary					

Flexibility	location	time	work
location			
time			
work			

Opportunity	entrepr	sal. Pot	top. Lvl pos
entrepr			
sal. Pot			
top. Lvl pos			

Entrepreneurial	domestic comp	international comp	college	state university
domestic comp				
international comp				
college				
state university				

Location	domestic comp	international comp	college	state university
domestic comp				
international comp				
college				
state university				

Top Level Position	domestic comp	international comp	college	state university
domestic comp				
international comp				
college				
state university				

Salary	domestic comp	international comp	college	state university
domestic comp				
international comp				
college				
state university				

Work	domestic	international comp	college	state university
domestic comp				
international comp				
college				
state university				

Salary Potential	domestic comp	international comp	college	state university
domestic comp				
international comp				
college				
state university				

Reputation	domestic	international comp	college	state university
domestic comp				
international comp				
college				
state university				

Time	domestic comp	international comp	college	state university
domestic comp				
international comp				
college				
state university				

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Analytic Hierarchy Process (AHP)

4. Calculate weights/priorities. Use the priorities of a given level to weight the priorities of the level below for every element

Criteria / *Subcriteria*	*Flexibility 0.036*			*Future opportunity 0.122*			*Security* 0.262	*Reputation* 0.075	*Salary* 0.506	*Overall Priority*
Global weights (criteria × subcriteria)	*Location* 0.091	*Time* 0.218	*Work* 0.691	*Entrepreneurial* 0.105	*Salary increases* 0.637	*Top level position* 0.258	0.262	0.075	0.506	
Domestic Company	0.003	0.008	0.025	0.013	0.078	0.032	0.225	0.064	0.124	0,134
Internatn'l Company	0.295	0.084	0.062	0.090	0.555	0.591	0.054	0.101	0.547	0,365
College	0.496	0.055	0.115	0.061	0.258	0.274	0.095	0.247	0.289	0,224
State University	0.131	0.285	0.249	0.239	0.124	0.083	0.626	0.588	0.039	0,252

$$0{,}036 * (0{,}003 * 0{,}091 + 0{,}008 * 0{,}218 + 0{,}025 * 0{,}691) + 0{,}122 * (0{,}105 * 0{,}013 + 0{,}637 * 0{,}078 + 0{,}258 * 0{,}032) + 0{,}262 * 0{,}225 + 0{,}075 * 0{,}64 + 0{,}506 * 0{,}124 = 0{,}134$$

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Conclusions

- Four difficulties in MCDM
  1. Generating (non-dominated) alternatives
  2. Agreeing on the evaluation criteria
  3. Agreeing on the criteria weights
  4. Evaluating the alternatives objectively
- Many different tools exist
- Discussion will always take place in setting up the framework
- Tools are transparent

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