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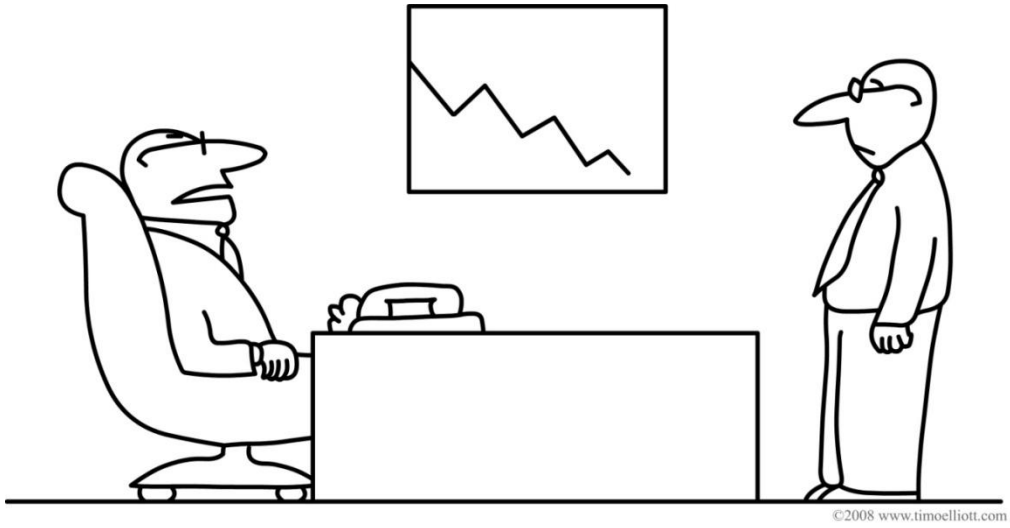
A short introduction to Multiple Criteria Decision Aid (MCDA)

The PROMETHEE method



"It would appear, Hopkins, that your gut feel was only indigestion"

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MCDA

- Usually in the decision making process a perfect option available to suit all the criteria does not exist; therefore a compromise must be found.
- Multi-criteria decision *analysis* (or better *aid*, MCDA) methods have been developed to support the decision makers in their unique and personal decision processes; they place the decision makers at the very centre of the process.
- Subjective information, also known as preference information, is provided by the decision maker, which leads to the compromise solution.
- MCDA is a discipline that encompasses mathematics, management, informatics, psychology, social science and economics.
- In the ranking problem options are ordered from best to worst by means of scores or pairwise comparisons, etc. The order can be partial if incomparable options are considered, or complete.

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MCDA problems and methods*

Choice problems	Ranking problems	Sorting problems	Description problems
AHP	AHP	AHPSort	
ANP	ANP		
MAUT/UTA	MAUT/UTA	UTADIS	
MACBETH	MACBETH		
PROMETHEE	PROMETHEE	FlowSort	GAIA, FS-Gaia
ELECTRE I	ELECTRE III	ELECTRE-Tri	
TOPSIS	TOPSIS		
Goal Programming			
DEA	DEA		

* Table adopted from Ishizaka and Nemery (2013)

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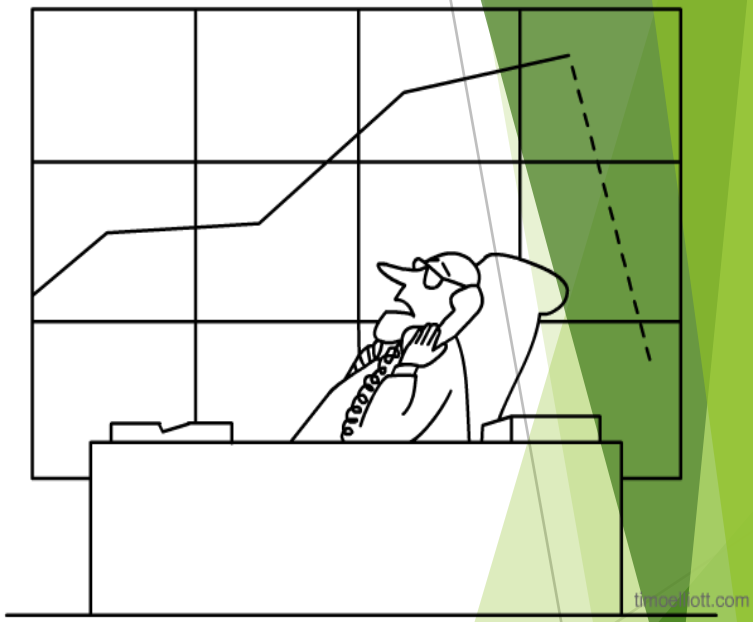
MCDA methods and software*

Problems	MCDA Methods	Software
Ranking, description, choice	PROMETHEE – GAIA	Decision Lab, D-Sight, **Smart Picker Pro**, Visual Promethee
Ranking, choice	PROMETHEE	DECERNS
	ELECTRE	Electre IS, **Electre III-IV**
	UTA	**Right Choice**, UTA+, DECERNS
	AHP	**MakeItRational**, ExpertChoice, Decision Lens, HIPRE 3+, RightChoiceDSS, Criterium, EasyMind, Questfox, ChoiceResults, 123AHP, DECERNS
	ANP	**Super Decisions**, Decision Lens
	MACBETH	**M-MACBETH**
	TOPSIS	DECERNS
	DEA	**Win4DEAP**, Efficiency Measurement System, DEA Solver Online, DEAFrontier, DEA-Solver PRO, Frontier Analyst
Choice	Goal Programming	-
Sorting, description	FlowSort - FS-GAIA	**Smart Picker Pro**
Sorting	ELECTRE-Tri	**Electre Tri**, IRIS
	UTADIS	-
	AHPSort	-



"Yes, I have made a strategic decision. I've decided to ignore the bad news... "

* Table adopted from Ishizaka and Nemery (2013)

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Distribution papers based on application areas*

Application fields	Number of paper	Percentage
Energy, environmental and sustainability	53	13.49
Supply chain management	23	5.85
Material	21	5.34
Quality management	12	3.05
GIS	14	3.56
Construction and project management	18	4.58
Safety and risk management	14	3.56
Manufacturing systems	32	8.14
Information technology management	25	6.36
Operation research and soft computing	109	27.74
Strategic management	8	2.04
Knowledge management	5	1.27
Production management	18	4.58
Tourism management	11	2.80
Other fields	30	7.63
Total	**393**	**100**

* Table adopted from Mardani et al (2015)

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Summary of applications of the DM techniques*

DM techniques	Frequency of application	Percentage
AHP	128	32.57
ELECTRE	34	8.65
DEMATEL	7	1.78
PROMETHEE	26	6.62
TOPSIS	45	11.4
ANP	29	7.38
Aggregation DM methods	46	11.70
Hybrid MCDM	64	16.28
VIKOR	14	3.56
Total	393	100.00

* Table adopted from Mardani et al (2015)

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Growth of MCDA applications in the environmental field*.

Year	Number of MCDA papers	Total number of environmental papers	Percentage = MCDA/total
1990	2	807	0.25
1991	7	2323	0.30
1992	5	2414	0.21
1993	10	2704	0.37
1994	23	3008	0.76
1995	22	3709	0.59
1996	24	3691	0.65
1997	31	4550	0.68
1998	26	4755	0.55
1999	34	5395	0.63
2000	26	4885	0.53
2001	35	5234	0.67
2002	54	5929	0.91
2003	57	6207	0.92
2004	59	6136	0.96
2005	89	7633	1.17
2006	94	8190	1.15
2007	123	8317	1.48
2008	169	10,791	1.57
2009	211	11,231	1.88
2010	200	12,068	1.66

*I.B. Huang et al. (2011). Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends. Science of the Total Environment 409 3578–3594.

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Different types of water MCDA applications*

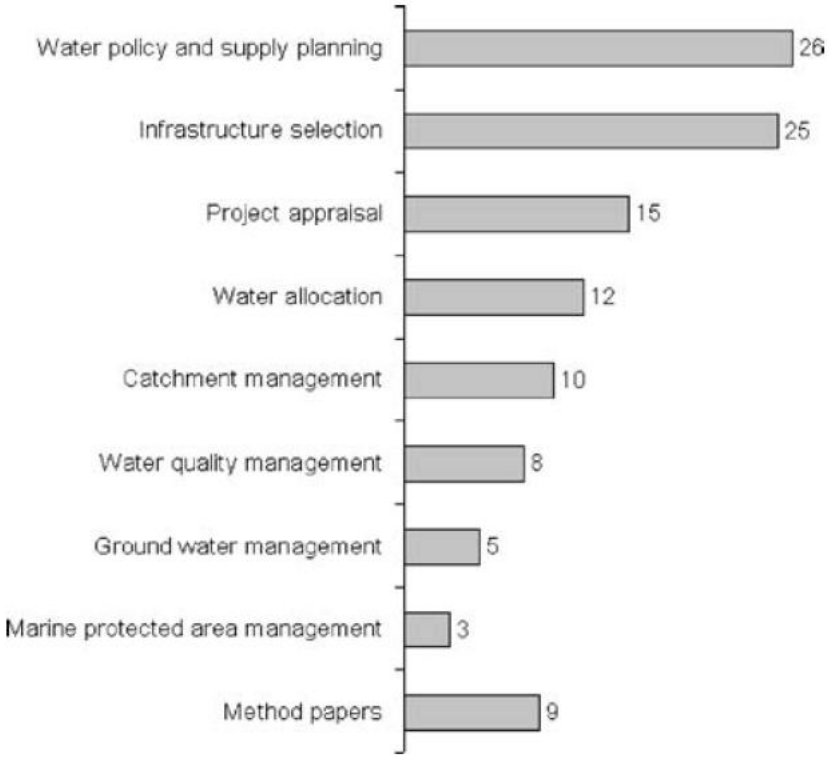

*Figure adopted from: Stefan Hajkowicz & Kerry Collins. "A Review of Multiple Criteria Analysis for Water Resource Planning and Management". Water Resour Manage (2007) 21:1553–1566

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Outranking approach: the PROMETHEE method

"All my decisions are well thought out."

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The acronym PROMETHEE stands for ‘Preference Ranking Organization METHod for Enriched Evaluation’. Thus the PROMETHEE method will provide the decision maker with a ranking of actions (choices or alternatives) based on *preference degrees.*

The method falls into three main steps:

1. the computation of preference degrees for every ordered pair of actions on each criterion;
2. the computation of unicriterion flows;
3. the computation of global flows.

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PROMETHEE fathers

Professor Jean-Pierre Brans

Professor Bertrand Mareschal

http://www.promethee-gaia.net
http://www.port.ac.uk/portsmouth-business-school/events/promethee-days-2017/ (PROMETHEE days 2017)
https://icdsst2017.wordpress.com/ (EWG-DSS 2017 International Conference on Decision Support System Technology)

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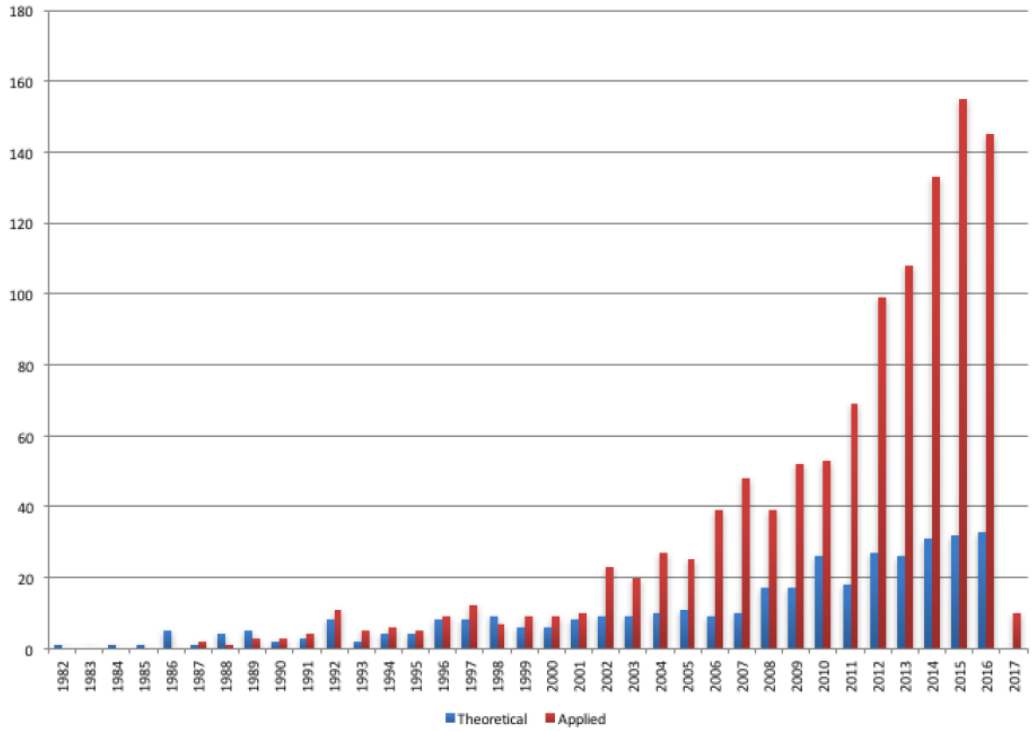
Number of papers published per year from 1982 to 2017*



*PROMETHEE-GAIA Statistics, 18/12/2016, http://www.promethee-gaia.net

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Fields of interest *

- 371 papers (25.0%) are theoretical papers about the PROMETHEE methodology, including many proposals for extensions or new models.
- 1141 papers (76.9%) are related to applications of PROMETHEE in different fields. They belong to various fields:
  - 317 papers (21.4%) are related to environmental problems.
  - 265 papers (17.9%) are related to services and/or public applications.
  - 240 papers (16.2%) are related to industrial applications.
  - 122 papers (8.2%) are related to energy.
  - 95 papers (6.4%) are related to finance.
  - 93 papers (6.3%) are related to water.
  - 57 papers (3.8%) are related to transportation.
  - 46 papers (3.1%) are related to procurement.
  - 23 papers (1.5%) are related to health care.
  - 16 papers (1.1%) are related to mining.
  - 23 papers (1.5%) are related to other fields of application.

(note: some papers are related to multiple fields so that the total of the above percentages is larger than 100%)

*PROMETHEE-GAIA Statistics, 18/12/2016, http://www.promethee-gaia.net

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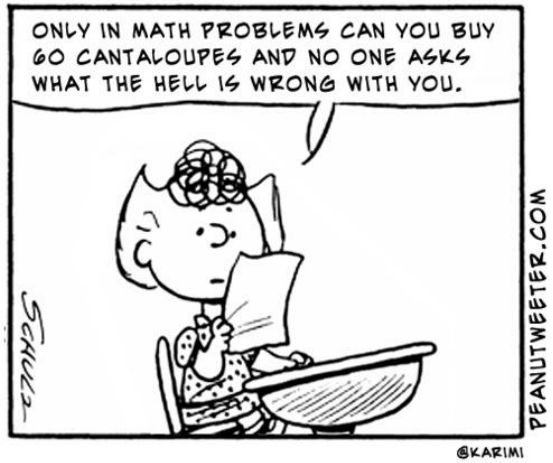
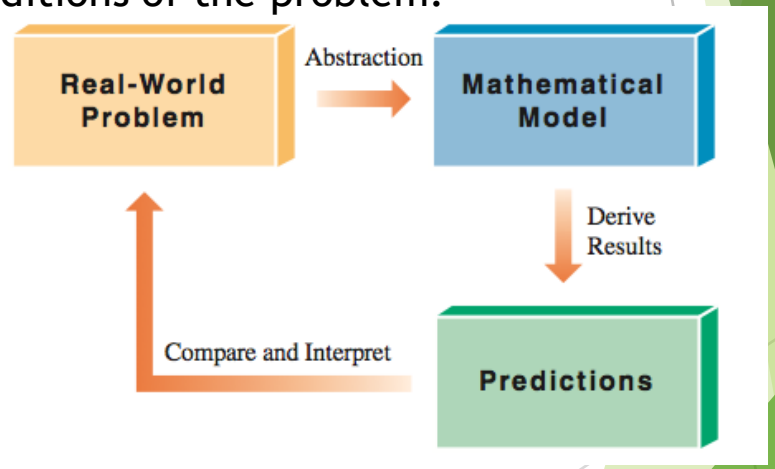
Models*

An idealized — abstract and simplified — representation of a real-world situation that is to be studied and/or analyzed.

A mathematical description of (usually) a real-world problem. In operations research/management science, mathematical models take on varied forms (e.g., linear programming, queueing, Markovian systems), many of which can be applied across application areas. The basic OR/MS mathematical model can be described as the decision problem of finding the maximum (or minimum) of a measure of effectiveness (objective function) E = F(X, Y), where X represents the set of possible solutions (alternative decisions) and Y the given conditions of the problem.





*Gass, SI, Fu, MC, 2013 (eds). Encyclopedia of Operations Research and Management Science. Springer US

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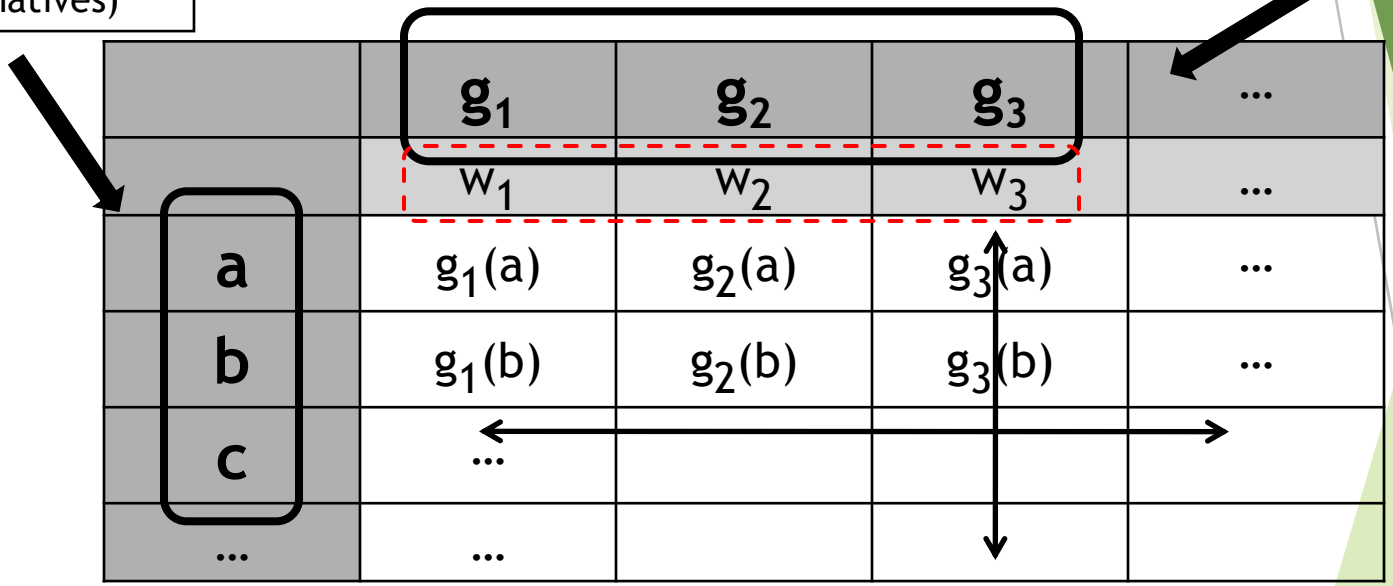
PROMETHEE model

1. Define the actions (alternatives)

2. Define the criteria



3. Define model preferences

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	Crit. 1 (/20)	Crit. 2 (rating)	Crit. 3 (qual.)	Crit. 4 (Y/N)
Action 1	18	135	G	Yes
Action 2	9	147	B	Yes
Action 3	15	129	VG	No
A(				
A(				

	Investment (M€)	Costs (k€)	Environm. (impact)	…
Site 1	18	135	G	…
Site 2	9	147	B	…
Site 3	15	129	VG	…
			VB	…
			G	…
			…	…

	Price (€)	Reliability (days)	Maintenance (estimate)	…
Product A	18	135	G	…
Product B	9	147	B	…
Product C	15	129	VG	…
Product D	12	146	VB	…
Product E	7	121	G	…
…	…	…	…	…

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The facility location problem

- Where is the best possible location for each of the new facilities
- How is market demand allocated among new and existing facilities
- What will happen to the already existing facilities
- What are the interactions among the new facilities
- Which are the precise criteria for optimization
- What will happen to new and existing facilities under certain future scenarios
- What should the production capacity of each new facility be
- What will be the impact on the environment

- Owen SH, Daskin MS (1998) Strategic facility location: A review. European Journal of Operational Research 111(3):423-447
- ReVelle CS, Eiselt HA (2005) Location analysis: A synthesis and survey. European Journal of Operational Research 165(1):1-19

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Problem Statement

The local authorities of a municipality are cooperating with the central government in order to identify the best site out of 6 possible choices for locating a major water infrastructure supply facility for a city or a region, taking into account a number of criteria, namely:

1. the investment size,
2. the employment requirements,
3. the social impact and
4. the environmental impact.

The first two criteria are quantitative variables with deterministic values, while the other two are qualitative and rated as a typical Likert scale, ranging from 1 (worst) to 7 (best).

'The chocolate bar isn't smaller, it's just you're bigger'

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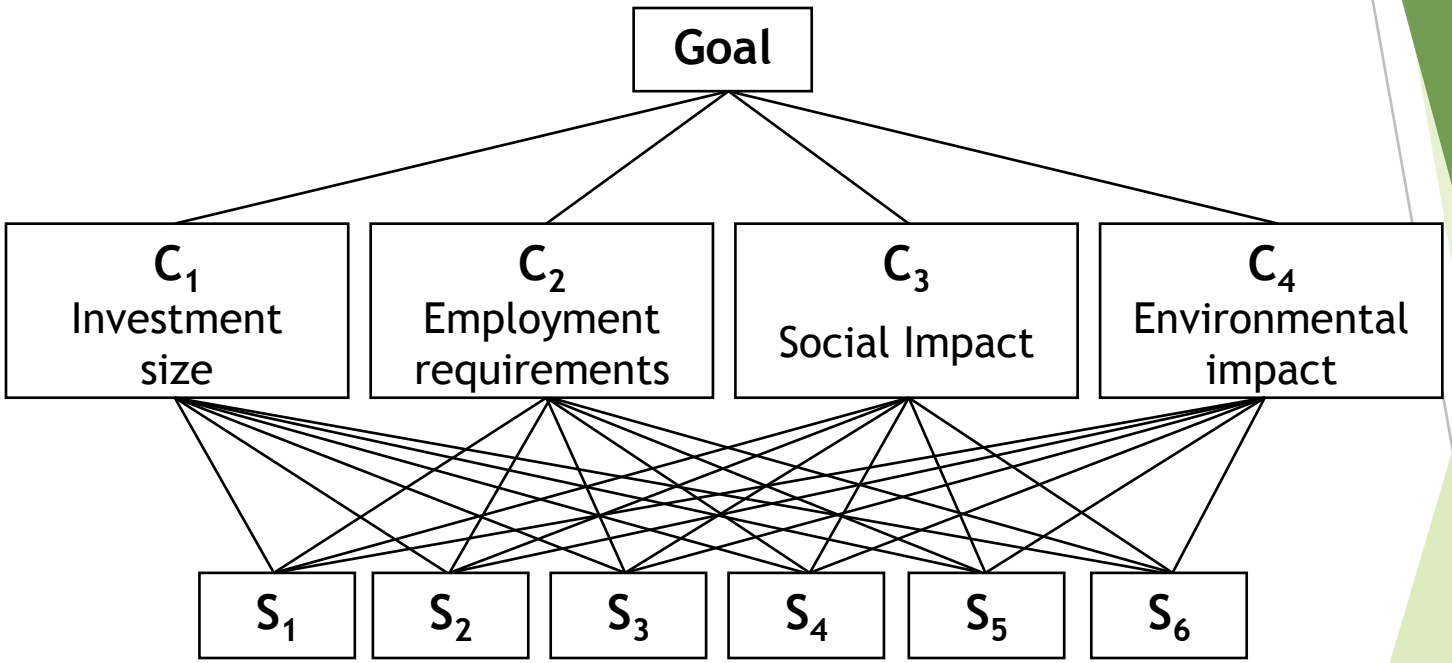
The problem hierarchical structure



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Data for the numerical example

	Investment (million €)	Employment (hundred employees)	Social Impact (1 to 7)	Environmental impact (1 to 7)
Weight	0.25	0.25	0.25	0.25
Site 1	8	7	2	1
Site 2	5	3	7	5
Site 3	7	5	6	4
Site 4	9	9	7	3
Site 5	11	10	3	7
Site 6	6	9	5	4

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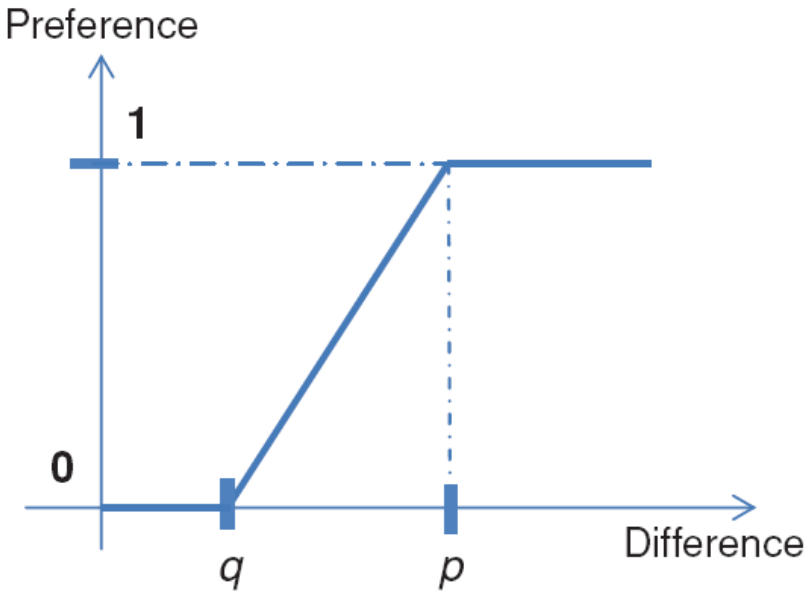

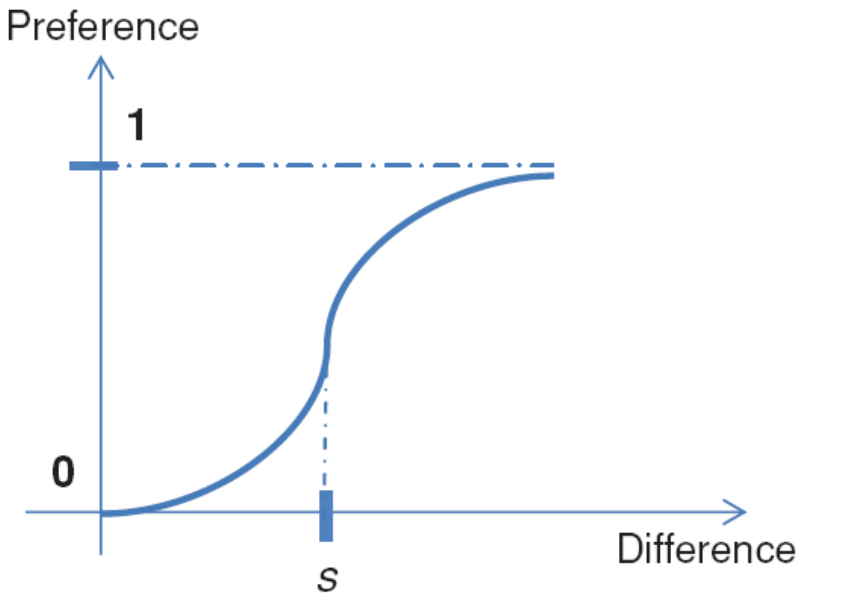

Linear (left) and Gaussian (right) preference functions

q: indifference threshold

p: preference threshold

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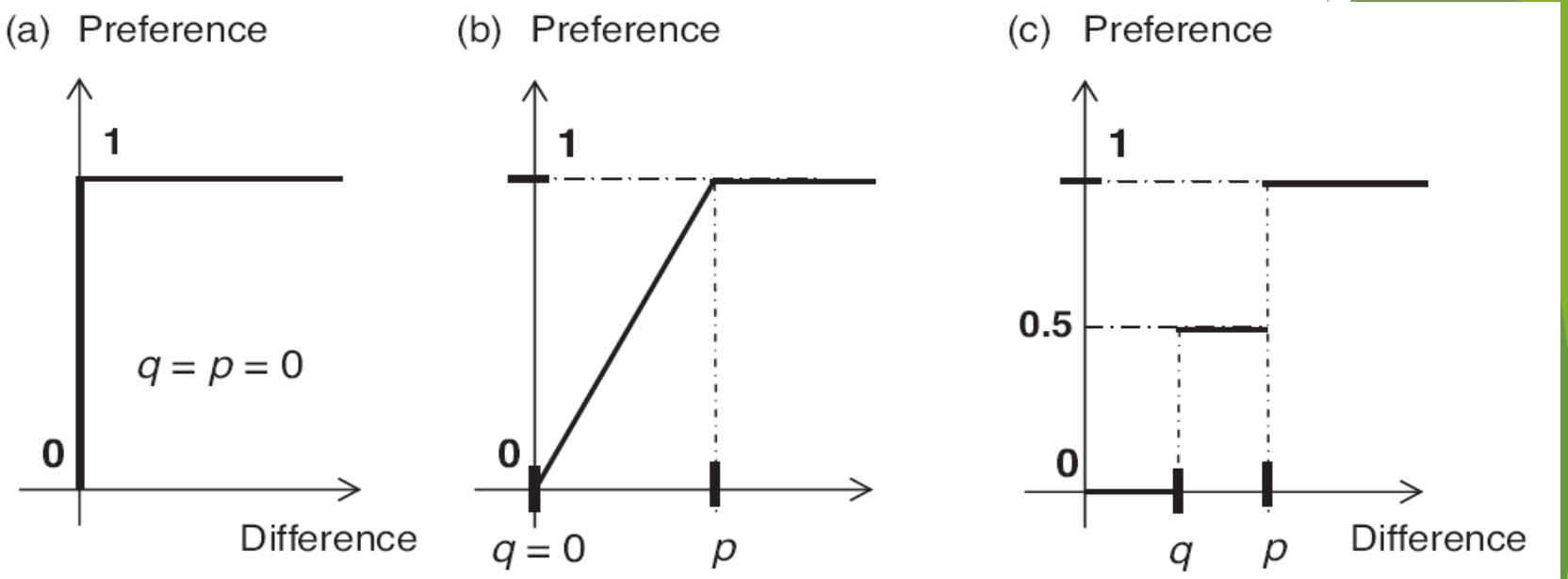

Three linear preference functions

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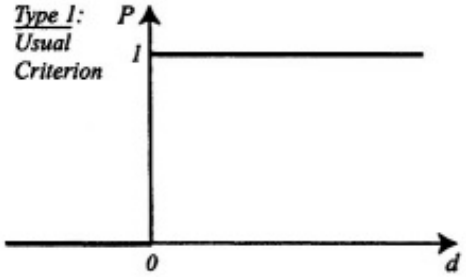
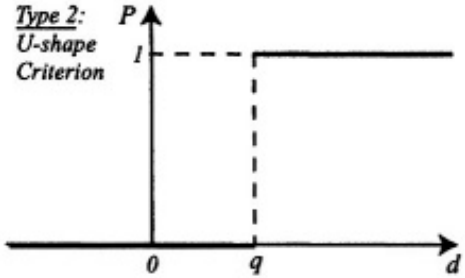
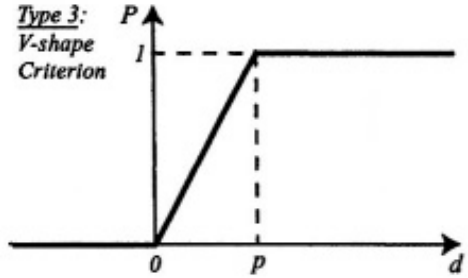
Generalised criterion	Definition	Parameters to fix
Type 1: Usual Criterion 	$P(d) = \begin{cases} 0 & d \leq 0 \\ 1 & d > 0 \end{cases}$	–
Type 2: U-shape Criterion 	$P(d) = \begin{cases} 0 & d \leq q \\ 1 & d > q \end{cases}$	q
Type 3: V-shape Criterion 	$P(d) = \begin{cases} 0 & d \leq 0 \\ \frac{d}{p} & 0 \leq d \leq p \\ 1 & d > p \end{cases}$	p

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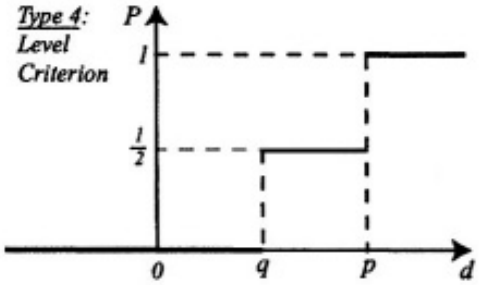
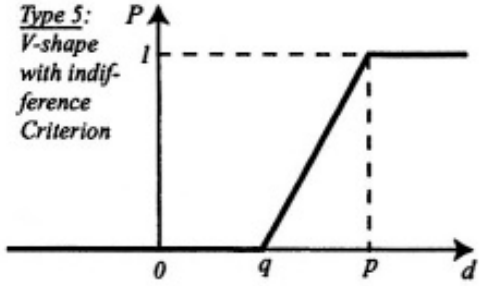
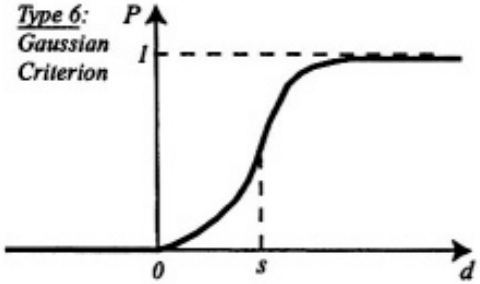
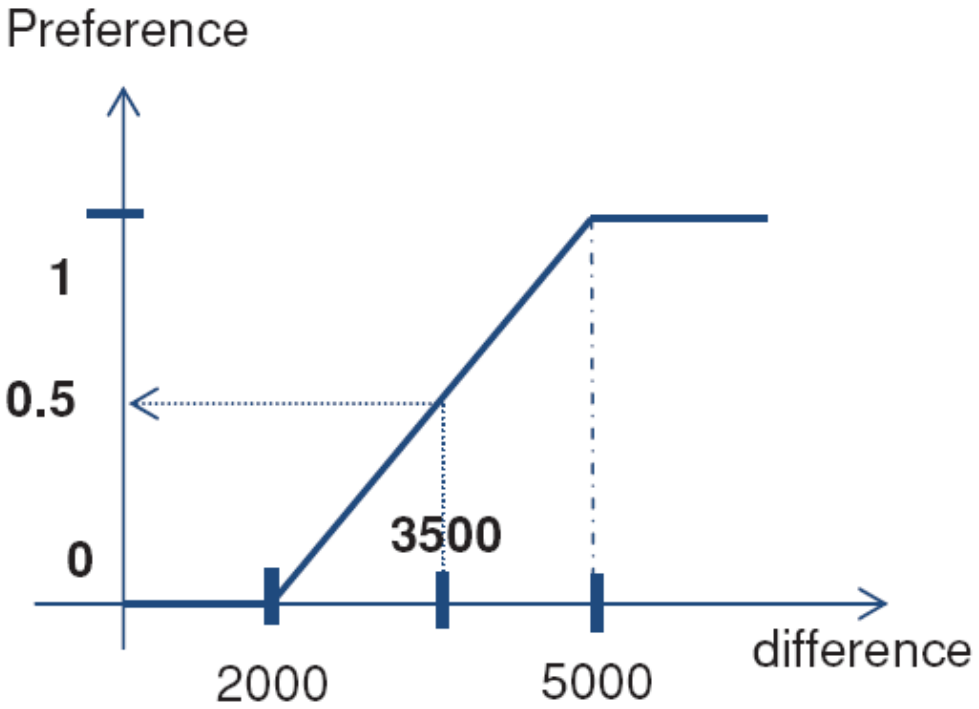
Generalised criterion	Definition	Parameters to fix
Type 4: Level Criterion 	$P(d) = \begin{cases} 0 & d \le q \\ \frac{1}{2} & q < d \le p \\ 1 & d > p \end{cases}$	p, q
Type 5: V-shape with indifference Criterion 	$P(d) = \begin{cases} 0 & d \le q \\ \frac{d-q}{p-q} & q < d \le p \\ 1 & d > p \end{cases}$	p, q
Type 6: Gaussian Criterion 	$P(d) = \begin{cases} 0 & d \le 0 \\ 1 - e^{-\frac{d^2}{2s^2}} & d > 0 \end{cases}$	s



Computation of the preference degree when the difference is 3500 and q = 2000 and p = 5000

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Preference parameters of all the criteria

Criterion	Function	w_i	q_i	p_i
Investment (million €)	Usual	0.25	0	0
Employment (hundred employees)	Usual	0.25	0	0
Social Impact (1 to 7)	Usual	0.25	0	0
Environmental impact (1 to 7)	Usual	0.25	0	0

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Step 1: Differences between the evaluations of the sites on the investment criterion

Difference	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Site 1	0	3	1	-1	-3	2
Site 2	-3	0	-2	-4	-6	-1
Site 3	-1	2	0	-2	-4	1
Site 4	1	4	2	0	-2	3
Site 5	3	6	4	2	0	5
Site 6	-2	1	-1	-3	-5	0

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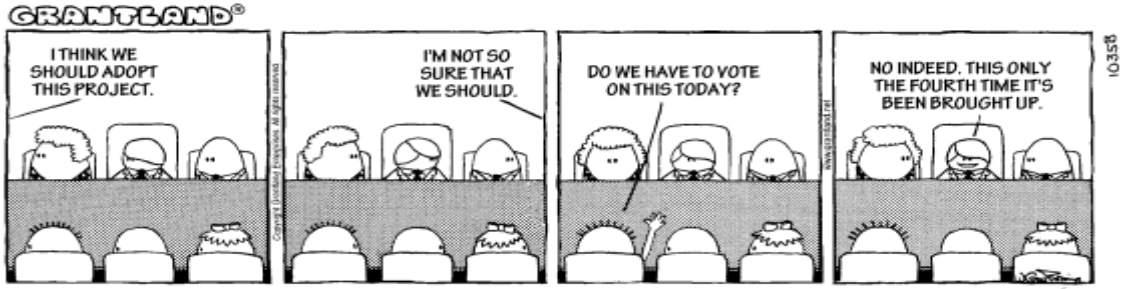
Step 2: Pairwise comparison matrix for the criterion investment

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Site 1	0	1	1	0	0	1
Site 2	0	0	0	0	0	0
Site 3	0	1	0	0	0	1
Site 4	1	1	1	0	0	1
Site 5	1	1	1	1	0	1
Site 6	0	1	0	0	0	0



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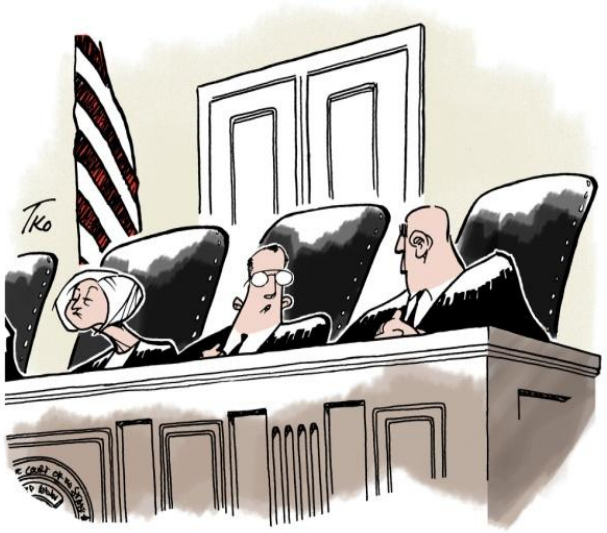
Computation of the unicriterion net flows

Sites	Investment Net Flows
Site 1	0.2
Site 2	-1
Site 3	-0.2
Site 4	0.6
Site 5	1
Site 6	-0.6



"Don't spread it around, but on the really tough ones, I just go with 'eenie, meenie, minie, moe.'"

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Total net flows

Rank	action	Phi	Phi+	Phi-
1	Site 5	**0.6000**	0.8000	0.2000
2	Site 4	**0.3000**	0.6000	0.3000
3	Site 6	**-0.1000**	0.4000	0.5000
4	Site 2	**-0.1500**	0.4000	0.5500
5	Site 3	**-0.1500**	0.4000	0.5500
6	Site 1	**-0.5000**	0.2500	0.7500

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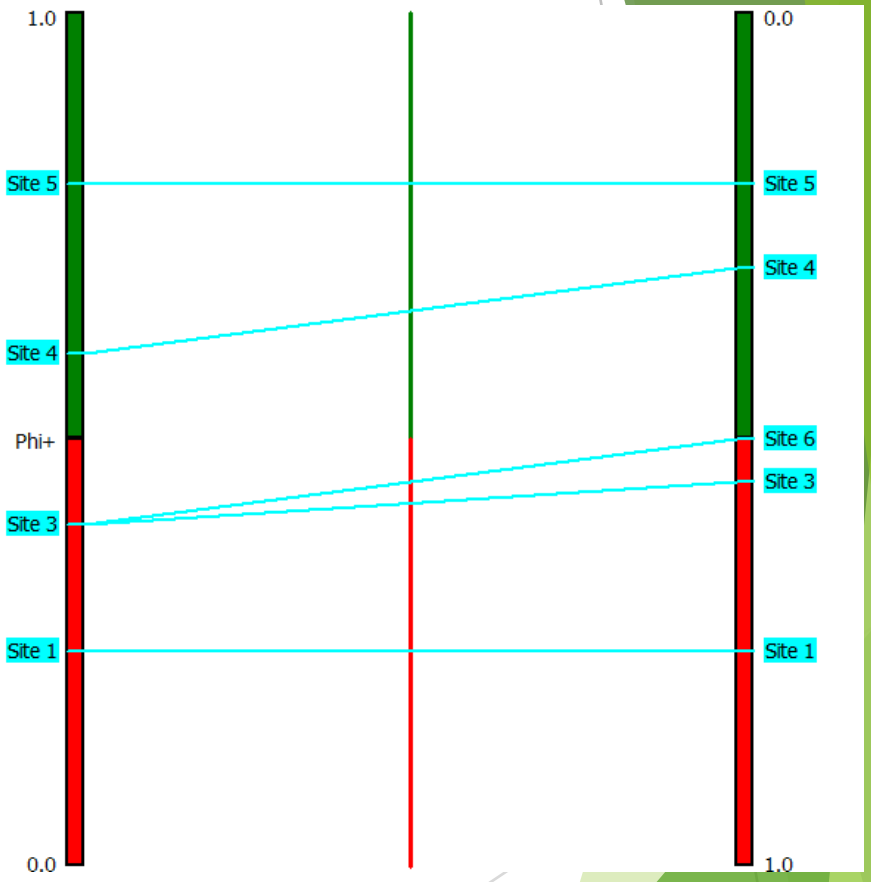
PROMETHEE I partial ranking

Rank	action	Phi+	Phi-
1	Site 5	0.8000	0.2000
2	Site 4	0.6000	0.3000
3	Site 6	0.4000	0.5000
4	Site 2	0.4000	0.5500
5	Site 3	0.4000	0.5500
6	Site 1	0.2500	0.7500



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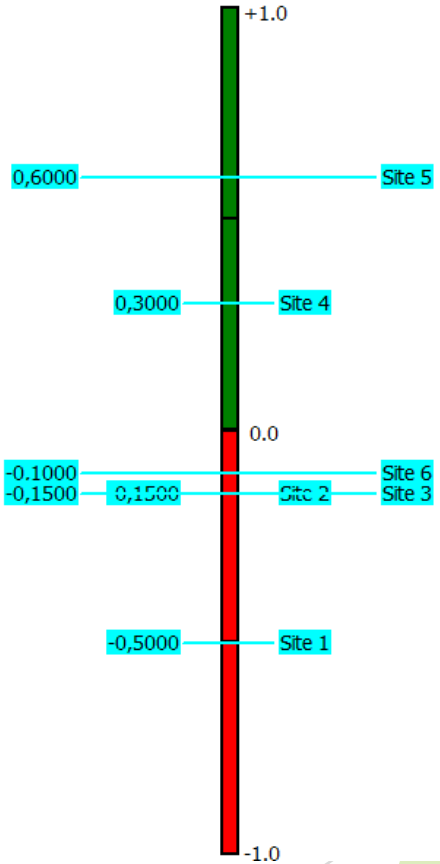
PROMETHEE II complete ranking

Rank	action	Phi
1	Site 5	0.6000
2	Site 4	0.3000
3	Site 6	-0.1000
4	Site 2	-0.1500
5	Site 3	-0.1500
6	Site 1	-0.5000



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Preference parameters of all the criteria

(other weights)

Criterion	Function	w_i	q_i	p_i
Investment (million €)	Usual	0.4	0	0
Employment (hundred employees)	Usual	0.3	0	0
Social Impact (1 to 7)	Usual	0.1	0	0
Environmental impact (1 to 7)	Usual	0.2	0	0

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Final ranking (TOPSIS)

Site 5
↓
Site 4
↓
Site 6
↓
Site 1
↓
Site 3
↓
Site 2

Final ranking (PROMETHEE)

Site 5
↓
Site 4
↓
Site 6
↓
Site 3
↓
Site 1
↓
Site 2

Best

Worst

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Annex I
Group PROMETHEE

"Sometimes I think the collaborative process would work better without you."

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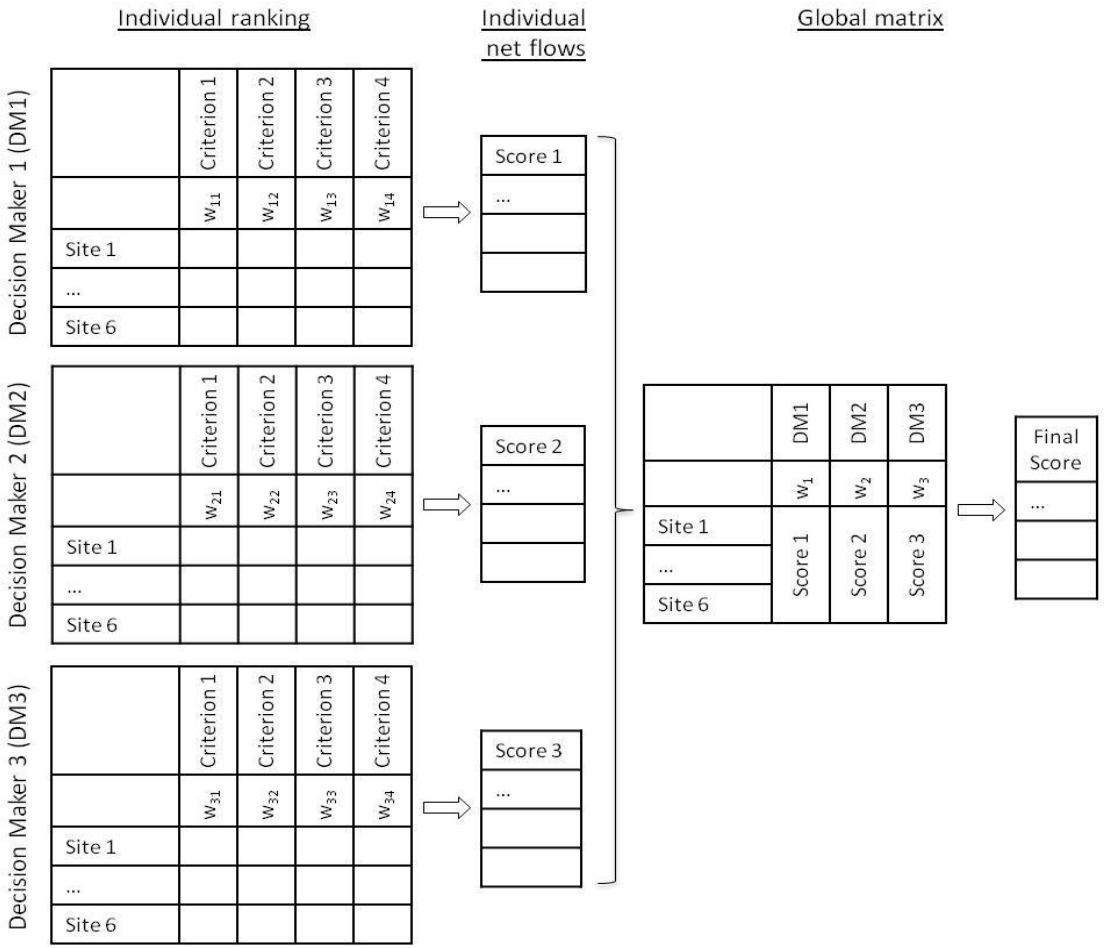

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End of Presentation!

"I created this revolutionary decision making mechanism. Trust me, it'll yield better results than your current process."

Still can't decide if I should adopt this approach

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