Choosing a cooling system for a power plant

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The problem

- Proposed by the lab associated with the power generation sector in Belgium
- more precisely, the department of the lab in charge of environmental issues
- Their goal: see how (if) MCDA can help take into account environmental and societal issues

Test case: choice of cooling system on a specific site

- ex post validation of a decision already made
- test for MCD analysis

The alternatives

A_1 Once through.

A_2 After cooling à tirage naturel.

A_3 Semi-fermé avec facteur de concentration fixe et à tirage forcé.

A_4 Semi-fermé avec facteur de concentration fixe et à tirage hybride.

A_5 Semi-fermé avec facteur de concentration fixe et à tirage naturel.

A_6 Semi-fermé avec facteur de concentration glissant et à tirage naturel.

A_7 Aérocondenseur à tirage forcé.

The criteria

A. Cost

This criterion integrates all forms of costs: investment, maintenance, exploitation dismantling, taxes, impact on efficiency on the power plant. Evaluated by an expert (engineering consultancy firm)

B. Society

7 sub-criteria reflecting the relevant aspects from a societal viewpoint

br $\equiv$ noise: generated by the cooling system in operation

vu $\equiv$ view : integration of the system in the landscape

im $\equiv$ image : perception of the system by the people

sp $\equiv$ health of personnel : risk for the health of the workers due to the equipment

sr $\equiv$ health of people in the neighborhood : risk for the health of the persons living around the site

ps $\equiv$ safety of personnel : risk of accidents for the personnel

rs $\equiv$ safety of the persons around the site : risk of accidents due to the equipment

C. Environment

4 sub-criteria reflecting the relevant aspects from the environmental point of view

pm $\equiv$ material drawn from the milieu and not fully returned to the milieu or altered

dp $\equiv$ release of chemicals : impact of cleaning products released in the environment

ac $\equiv$ release of heath : impact of heath released in river or air

ib $\equiv$ biological impacts : impact on local ecosystem

Assessment scales

For all criteria (but cost): numerical scale from 0 to 10
with anchor points (2 ; 5 ; 8)

2 = very unsatisfactory level

8 = very unsatisfactory level

5 = limit point between satisfactory and unsatisfactory.

In assessing the alternatives on each criterion, the experts were asked "to try to reflect the differences as they perceive them"

Weights associated to the criteria

- Relative importance of the criteria evaluated on a similar scale (0 to 10 with anchor points)
- One weight for each group of criteria (3 groups)
- In each group, a weight for each sub criterion

Deriving weights for each sub-criterion: proportion

Collecting the data

- 12 questionnaires: 12 experts from various departments of the lab
- 11 usable responses
- cost not assessed on the same scale but computed by the expert of the engineering consultancy firm

Costs

Relative costs

A_1	6.551
A_2	9.531
A_3	6.779
A_4	8.482
A_5	7.989
A_6	8.002
A_7	10

Example of data: respondent R1

eco	soc							env			
8	6							7			
	br	vu	im	sp	sr	ps	rs	pm	dp	ac	ib
	9	2	5	8	9	8	9	5	8	8	6

	br	vu	im	sp	sr	ps	rs	pm	dp	ac	ib
A_1	9	9	9	8	9	8	8	4	1	3	1
A_2	7	2	1	6	7	6	8	2	2	3	3
A_3	2	5	4	6	7	6	8	6	6	5	6
A_4	3	4	4	6	7	6	8	6	6	5	6
A_5	5	2	2	6	7	6	8	6	4	3	4
A_6	2	5	4	6	7	6	8	6	6	5	6
A_7	2	6	7	6	9	6	8	9	9	7	8

Two approaches to deal with the data

- hypothesis 1: the differences correctly reflected $\rightarrow$ weighted sum
- hypothesis 2: ordinal interpretation of the data $\rightarrow$ outranking

Main difficulty:

- Cost is not evaluated on the same scale as the other criteria

Weighted sum approach

We worked under 3 different hypotheses:

Hypo (α) working with relative costs : the ideal cost would be 0 and the costs of the actual alternatives are evaluated as a fraction of the cost of the most expensive solution

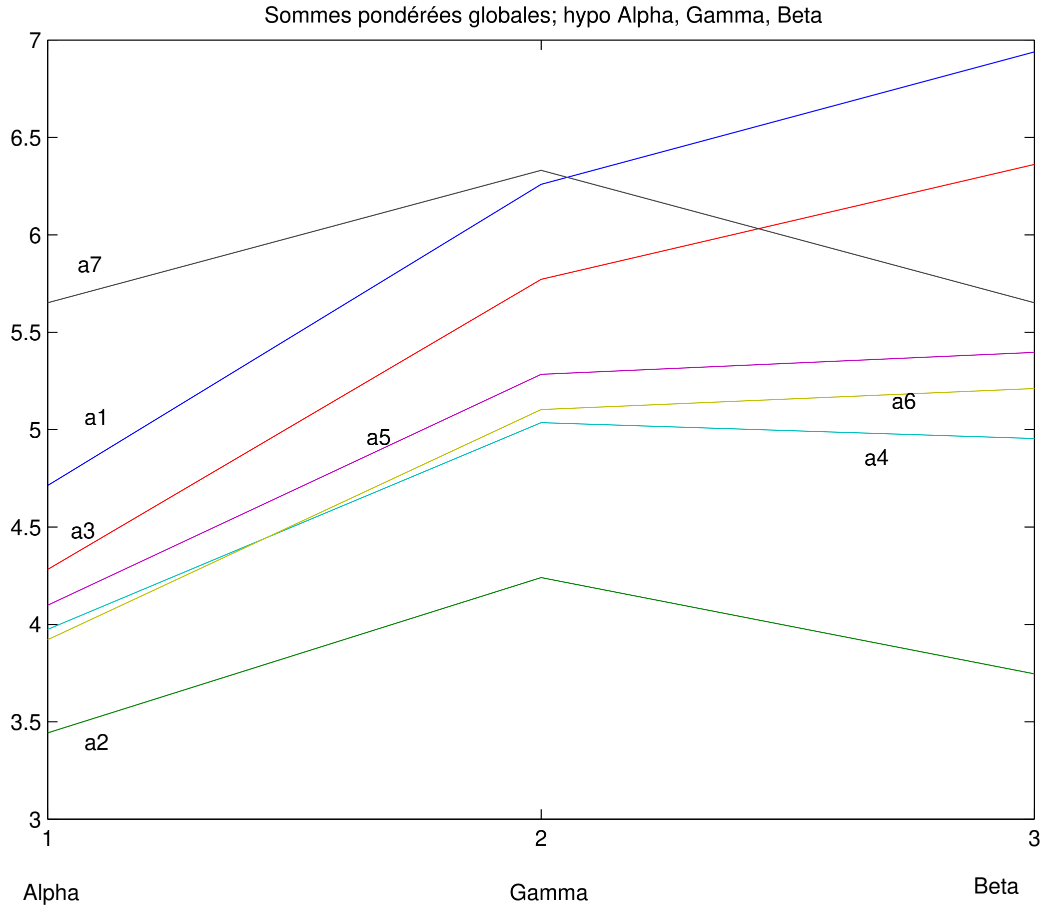
Hypo (β) most expensive solution = 0; less expensive solution = 10

Hypo (γ) most expensive solution = 2; less expensive solution = 8

Range of values of recoded cost under the various hypotheses: maximal for (A_7); minimal for (A_1)

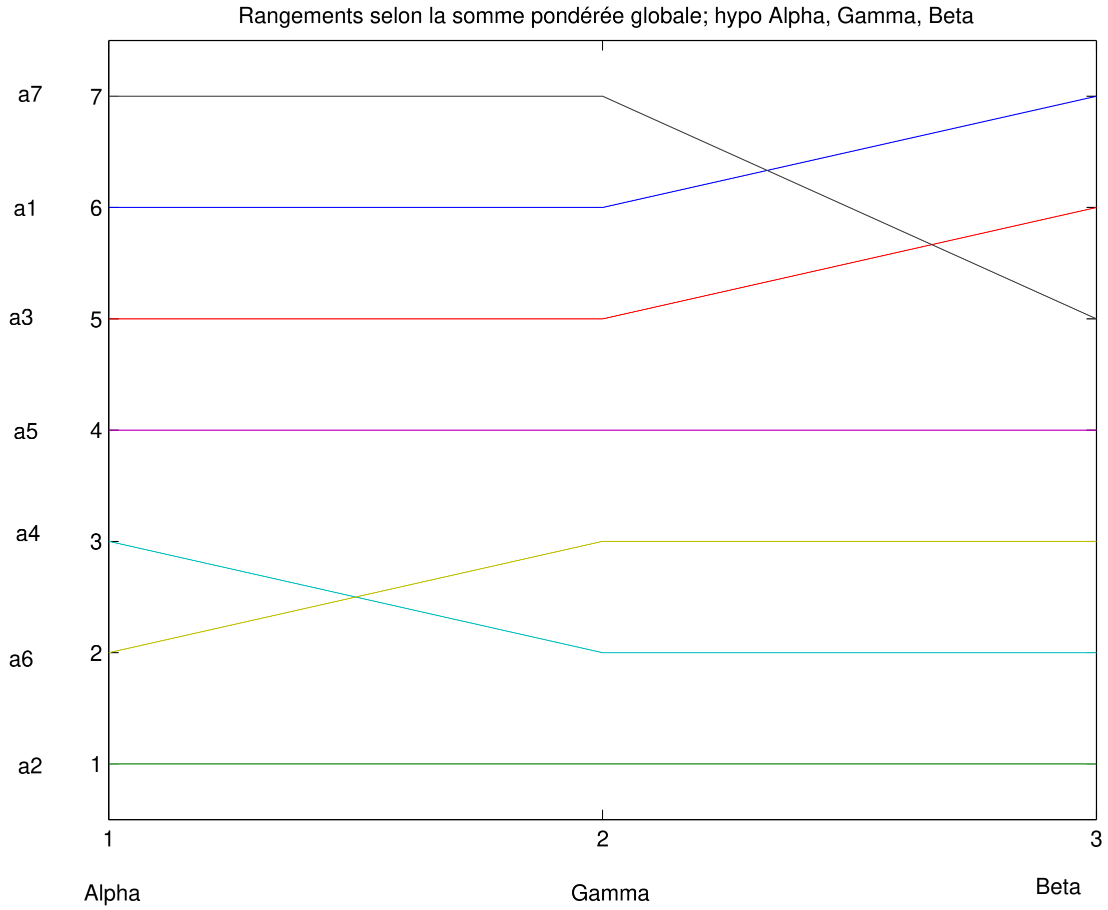
Hypotheses	α	γ	β
A_7	0	2	0
A_1	3.449	8	10
Length	3.449	6	10
Ratio	1	1.74	2.9

Scores



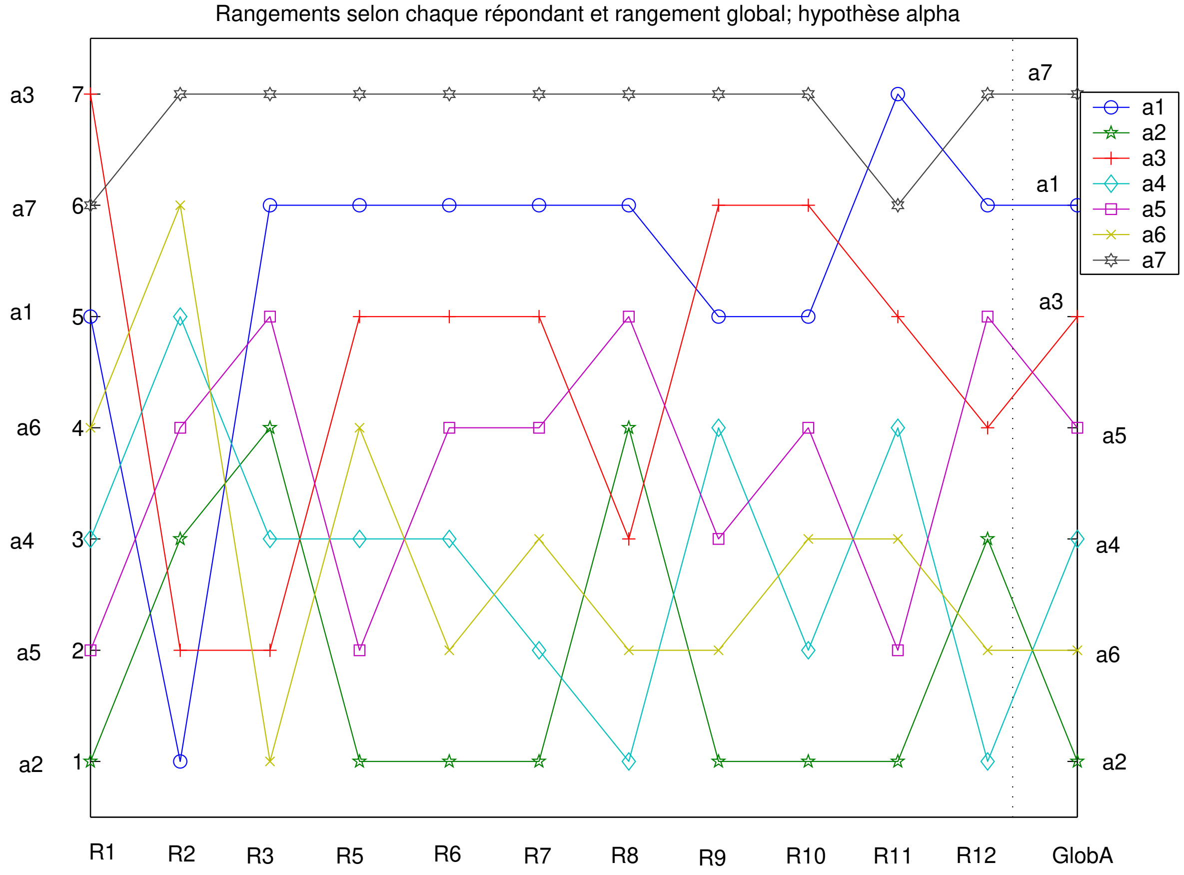
Average scores under hypotheses α, γ et β

Rankings



Rankings under hypotheses α, γ and β

Respondents vs. global



Hypothesis α

Outranking approach

We used a version of the ELECTRE II method

- ordinal approach
- majoritarian rule

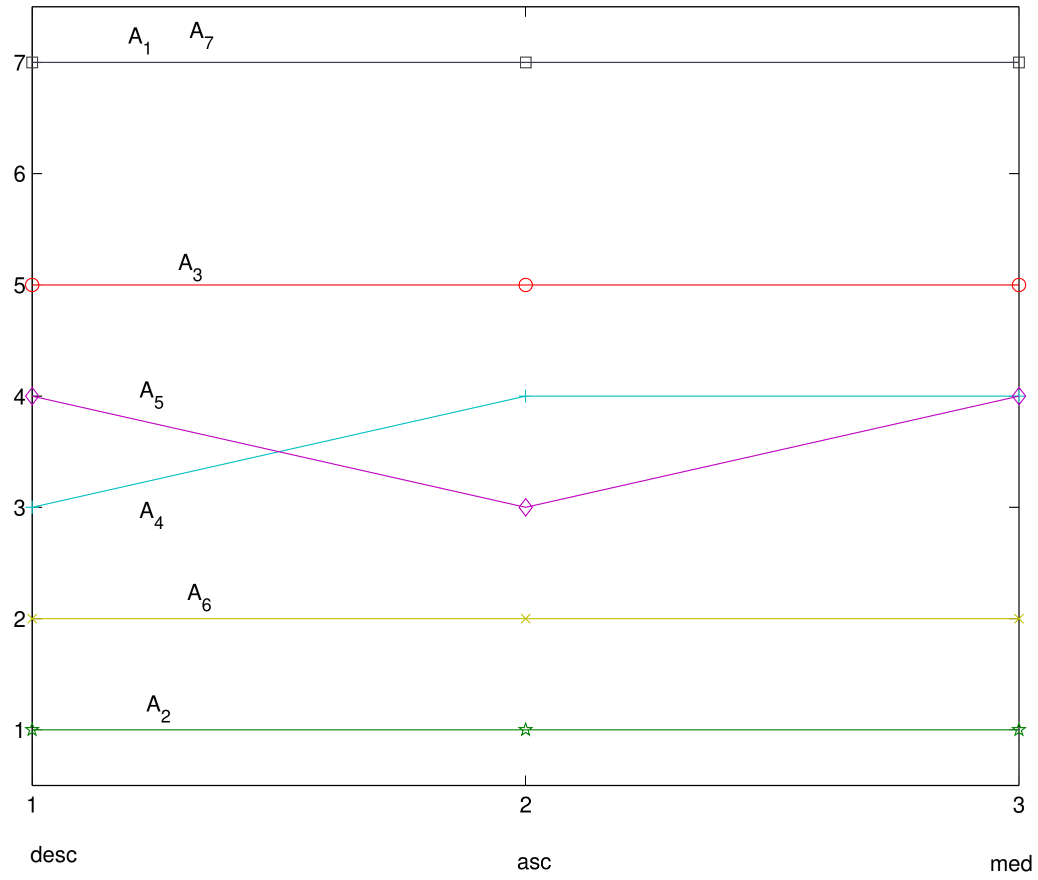
Crucial parameter: majority threshold

- Average weight of the Cost criterion $\approx .34$ $(= .3398)$
- If majority threshold is larger than $1 - .34 = .66$, the more expensive never outranks the less expensive
- $\ldots$ and A7 doesn't outrank any alternative

Crucial question: "Can an alternative outrank another if it is more expensive ? "

We worked under the hypothesis that the answer was "Yes"

Global rankings (Electre II



Descending, ascending and median rank-ordering obtained with

Electre II

c_1	c_2	Sans veto			Seuil de veto = 6		
		desc	asc	med	desc	asc	med
.6	.501	(17)3	(17)3	(17)3	713	713	713
.613	.501	173	(17)3	173	173	713	(17)3
.6	.519	713	713	713	713	713	713
.6	.527	(17)3	(17)3	(17)3	(17)3	(17)3	(17)3
.613	.519	173	713	(17)3	173	713	(17)3
.613	.527	173	(17)3	173	173	(17)3	173
.661	.501	135...	(17)3	137	135...	713	137

Sensitivity analysis on the obtained rankings when majority threshold (and veto threshold) is varied

Conclusion

- We have been lucky
- Both approaches converge to the same conclusions
- Interesting: two different formulations of the crucial question "importance" of Cost