Exercises with **Visual PROMETHEE**

September 2019

1. Locating a power plant

File: Powerplants.vpg

Given the continuously increasing consumption of electricity in Europe, it has been decided to build a new hydro electrical power plant. Six national projects (sites) have been proposed by six European countries, and six evaluation criteria have been defined by the European Commission to select the best project:

Sites	*Criteria*
a_1 : Italy	f_1 : Manpower
a_2 : Belgium	f_2 : Power (10MW)
a_3 : Germany	f_3 : Construction cost (10^6EUR)
a_4 : Sweden	f_4 : Operation cost (10^6EUR)
a_5 : Austria	f_5 : Number of villages to evacuate
a_6 : France	f_6 : Safety level

Some criteria are to maximize; others are to minimize. Preference functions and weights have been associated to the criteria. In a first step, without well-established priorities, all the weights have been set equal (w_j = 1, j=1, 2, …, 6).

All the data are given in Table 1.

Table 1: Power plant location – Data

Criteria Min/Max Type Thresholds Weights	Manpower Min U-shape q=10 1	Power Max V-shape p=30 1	Cost Min Linear q=50, p=500 1	Operation Min Level q=1, p=6 1	Villages Min Usual – 1	Safety Max Gaussian s=5 1
a_1 : Italy	80	90	600	5.4	8	5
a_2 : Belgium	65	58	**200**	9.7	**1**	1
a_3 : Germany	83	60	400	7.2	4	7
a_4 : Sweden	**40**	80	1000	7.5	7	**10**
a_5 : Austria	52	72	600	**2.0**	3	8
a_6 : France	94	**96**	700	3.6	5	6

Figures 1 and 2 show the corresponding **PROMETHEE I** and **II** rankings (arrows indicate preferences).

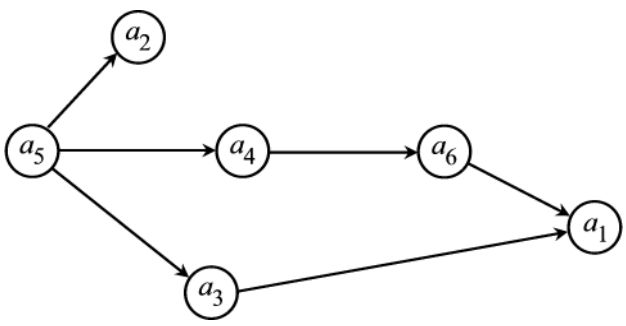

Figure 1: PROMETHEE I partial ranking

Use the Network View in **Visual PROMETHEE** to confirm these two rankings. The software can graphically represent and compare action profiles. Check the incomparability between a_1 (Italy) and a_2 (Belgium) by comparing their profiles (Cf. figure 3).

When the weights of the criteria are modified, the resulting rankings can be quite different. For instance, if a weight of 50 (50%) is allocated to criterion Power and weights of 10 (10%) are allocated to each other criterion, France becomes the best location. If a larger weight is allocated to the Villages criterion (55%, with 9% for each other criterion), Belgium becomes the best choice. Check this using **Visual PROMETHEE**.

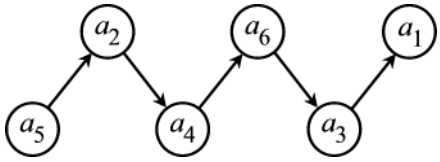

Figure 2: PROMETHEE II complete ranking

Exercises

*Exercise 1: What is the **PROMETHEE II** ranking for the following weights:*
$w_2 = 50$ $w_1 = w_3 = w_4 = w_5 = w_6 = 10$

*Exercise 2: What is the **PROMETHEE II** ranking for the following weights:*
$w_5 = 5.5$ $w_1 = w_2 = w_3 = w_4 = w_6 = 1$

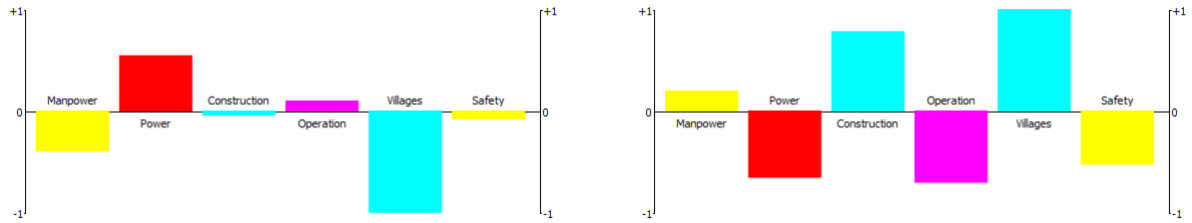

Figure 3: Profiles of actions a_1 and a_2

*Exercise 3: What is the **PROMETHEE II** ranking for the following weights:*
$w_1 = 1$ $w_2 = 5$ $w_3 = 1$ $w_4 = 4$ $w_5 = 1$ $w_6 = 5$

*Exercise 4: Set all preference functions to the "Usual" type and compare the **PROMETHEE I** and **II** rankings (with equal weights).*

*Exercise 5: Starting from the initial data, change $f_2(a_2)$ to 100, $f_4(a_2)$ to 2 and $f_6(a_2)$ to 8. What is the new **PROMETHEE II** ranking? Does it conform to your prediction?*

*Exercise 6: Progressively increase the weight of the « Power » criterion (f_2) up to 7. Look at the π decision axis in the **GAIA** plane. What is finally the best action?*

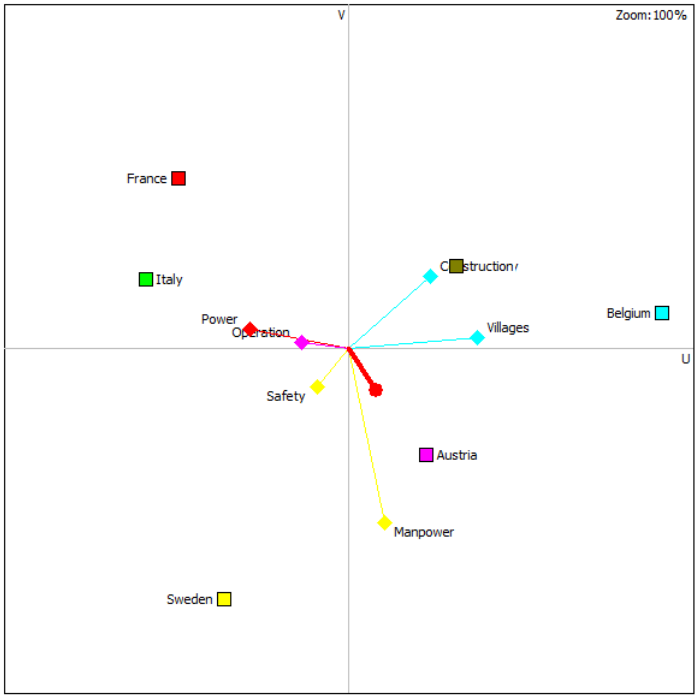

Figure 4: GAIA plane: Power plant location

Exercise 7: Use the following weight distribution:
$w_1=1$ $w_2=5$ $w_3=1$ $w_4=4$ $w_5=1$ $w_6=5$
*to build a new **PROMETHEE II** ranking.*

Exercise 8: Move the decision axis in order to rank Germany as the best choice. (It is not easy!)

2. Hypermarkets

File: Hypermarkets.vpg

A Greek distribution company (Μαρινόπουλος) wants to develop a hypermarket network in Belgium. 12 potential locations are considered: 2 in the region of Antwerp, 3 in the region of Bruges, 4 in the region of Brussels and 3 in the region of Namur.

Antwerp and Brussels are large cities, where construction costs are high, space is scarce, but many potential customers are available. On the contrary, Bruges and Namur are smaller cities, with more space available and lower construction costs.

Five evaluation criteria are considered: construction cost expressed in millions of Euros, potential customers (thousands), number of parking places available, access to the road network (qualitative 1 to 6 scale), and the number of close competitors.

Data are given in table 2, together with the preference functions and the weights of the criteria.

The **PROMETHEE I** partial ranking doesn't include any particularly significant incomparabilities. The **PROMETHEE II** ranking is more interesting (see Figure 5).

The twelve locations are almost perfectly ranked by cities. The three Bruges sites are ranked first, followed by the ones in Namur, finally we find the ones in Antwerp and in Brussels. This can be explained by the geographical characteristics of each city.

Table 2: Data – Hypermarkets

Criteria	f_1 Constr. Cost	f_2 Population	f_3 Parking	f_4 Road network	f_5 Competitors
	min	max	max	max	min
Type	Linear q= 0.5 p= 3.2	Gaussian s= 75	Gaussian s= 225	Level q= 1 p= 2	V-shape p= 3
Weight	3	1	1	1	2.5
Actions					
a_1: Antwerp1	21.0	425	500	2	1
a_2: Antwerp2	21.3	475	522	2	0
a_3: Bruges1	8.2	120	860	5	2
a_4: Bruges2	6.6	45	722	3	1
a_5: Bruges3	4.9	52	1050	4	3
a_6: Brus.1	21.3	755	850	3	5
a_7: Brus.2	17.9	625	200	2	5
a_8: Brus.3	17.3	524	780	2	5
a_9: Brus.4	14.2	540	690	4	6
a_{10}: Namur1	10.4	80	675	4	3
a_{11}: Namur2	12.9	310	786	5	2
a_{12}: Namur3	9.6	275	1020	2	3

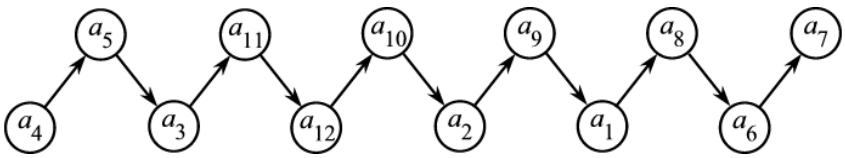

Figure 5: PROMETHEE II

If the company were to select a single location, it should of course select it in the region of Bruges. Actually, the problem is not a single selection problem, the company wants to develop a nationwide network including several locations. It would be therefore absurd two make the selection on the sole basis of the **PROMETHEE II** ranking. Indeed, the first six sites would be competing with each other's in the Bruges and Namur regions while Brussels and Antwerp regions wouldn't be covered. A more satisfactory solution can be provided by **PROMETHEE V** considering possible additional choice constraints. Let us suppose that the company want to select between 5 and 9 locations, considering the following additional constraints:

1. Global expected return at least 4000 k€.
2. Total manpower at least 500 persons.
3. One and only one location must be selected in Antwerp.
4. Maximum two locations in Bruges.
5. At least two locations in Brussels.
6. At least one location in Namur.
7. Brus.2 and Brus.4 cannot be selected together.
8. Namur2 and Namur3 cannot be selected together.

Expected returns and manpower requirements are given in the next table:

Location	Ant1	Ant2	Brg1	Brg2	Brg3	Bsl1	Bsl2	Bsl3	Bsl4	Na1	Na2	Na3
Return	426	645	76	226	275	822	1026	692	601	464	516	602
Manpower	118	130	85	61	52	152	180	130	151	66	76	50

What is then the best selection according to **PROMETHEE V**?

Exercises

*Exercise 9: What is the **PROMETHEE I** ranking?*

*Exercise 10: If the preference function associated to f_4 is changed to the level type with q = 1.5 and p = 2.5, is the **PROMETHEE II** ranking modified?*

*Exercise 11: What is the first ranked **PROMETHEE II** location when the weight of criterion f_2 is increased from 1 to 10? Is this what you were expecting?*

The **GAIA** plane retains 86% of the information. It is thus particularly reliable. Criterion f_2 (population) shows a large discriminating power and is strongly conflicting with most other criteria. On the other hand, construction costs (f_1), parking (f_3) and road network access (f_4) are expressing similar preferences.

Actions are geographically grouped:

1. Bruges (a_3, a_4 and a_5),
2. Namur (a_{10}, a_{11} and a_{12}),
3. Antwerp (a_1 and a_2),
4. Brussels (a_6, a_7, a_8 and a_9).

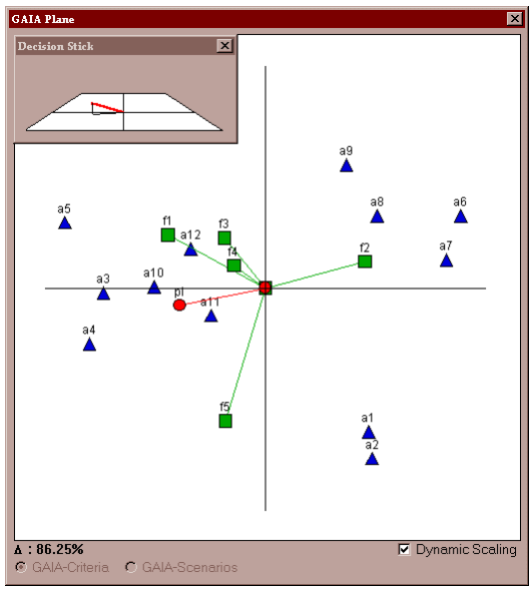

Figure 6: GAIA plane - Hypermarkets

Exercises

*Exercise 12: Progressively increase the weight of the population criterion (f_2). What is the minimum weight required to put a Brussels location at the top of the **PROMETHEE II** ranking?*

Exercise 13: Starting from the initial weight distribution, increase now the weight of the "competitors" criterion (f_5). For a value of $w_5 = 5$, is Antwerp leading the ranking?

*Exercise 14: Find a weight distribution such that the decision is almost orthogonal to the **GAIA** plane.*

3. A marketing problem

File: Hypermarkets.vpg

A company that manufactures bicycles wants to advertise their products. Six different supports are considered: two newspapers (a_1: News and a_2: Herald), large boards (a_3), a personalized mailing (a_4), two TV channels (a_5: CMM and a_6: NCB). Six criteria are expressing the objectives of the management: the cost (k$), the target (0,000 people), the duration (days), the efficiency and the human resources requirement (number of full time employees).

The corresponding data are gathered in table 3.

Exercises

*Exercise 15: Use **Visual PROMETHEE** to obtain the **PROMETHEE I** and **II** rankings.*

Table 3: Data - Marketing

Criteria	f_1	f_2	f_3	f_4	f_5
	Cost	Target	Duration	Efficiency	Personnel
	min	max	max	max	min
Type	Linear	V-shape	U-shape	Gaussian	usual
	$q = 5$	$p = 300$	$q = 10$	$s = 30$	
	$p = 50$				
Weights	1	1	1	1	1
Actions					
a_1 : News	60	900	22	51	8
a_2 : Herald	30	520	31	13	1
a_3 : Boards	40	650	20	58	2
a_4 : Mailing	92	750	60	36	3
a_5 : CMM	52	780	58	90	1
a_6 : NCB	80	920	4	75	6

Exercise 16: How many actions have a positive net flow? How many have a negative net flow?

Exercise 17: Is it possible to lower the position of CMM (a_5) in the ranking by modifying the weights of the criteria? If so, give several examples.

The **GAIA** plane contains 82%. Criteria are not strongly conflicting besides the opposition of f_1 and f_2. The decision axis (π) is rather long and indicates the best compromise direction. CMM (a_5) appears clearly as the best choice for the current weight distribution.

Exercises

*Exercise 18: Move the decision axis in order to put action a_4 at the top of the **PROMETHEE II** ranking. Give one weight distribution for which this is achieved.*

Exercise 19: Move the decision axis to put a_3 at the top of the ranking. Give a corresponding weight distribution. (It is not easy!)

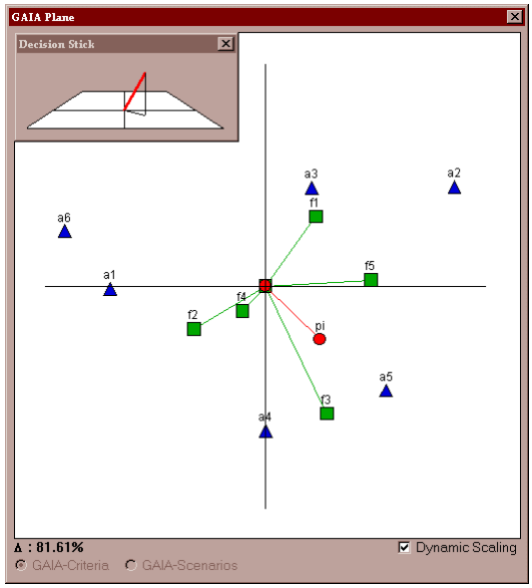

Figure 7: GAIA plane - Marketing