

## Exercises with Visual PROMETHEE

July 2017

### 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 ( $10^6$ EUR)
$a_4$ : Sweden	$f_4$ : Operation cost ( $10^6$ EUR)
$a_5$ : 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 ( $w_j = 1, j=1, 2, \dots, 6$ ).

All the data are given in Table 1.

Table 1: Power plant location – Data

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

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

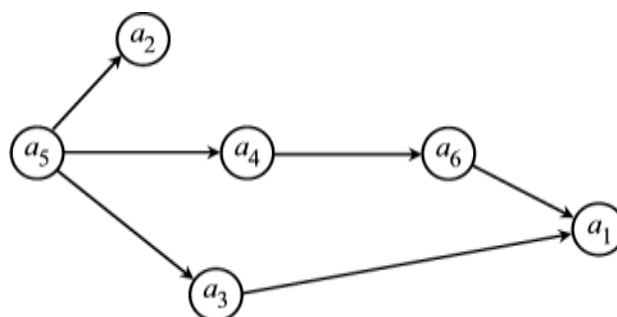


Figure 1: PROMETHEE I partial ranking

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**.

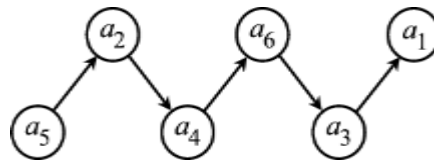


Figure 2: PROMETHEE II complete ranking

**Exercises**

*Exercise 1: What is the **PROMETHEE II** ranking for the following weights:*

$$w_2 = 50 \quad w_1 = w_3 = w_4 = w_5 = w_6 = 10$$

*Exercise 2: What is the **PROMETHEE II** ranking for the following weights:*

$$w_5 = 5.5 \quad w_1 = w_2 = w_3 = w_4 = w_6 = 1$$



Figure 3: Profiles of actions  $a_1$  and  $a_2$

*Exercise 3: What is the **PROMETHEE II** ranking for the following weights:*

$$w_1 = 1 \quad w_2 = 5 \quad w_3 = 1 \quad w_4 = 4 \quad w_5 = 1 \quad w_6 = 5$$

*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  $\pi$  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:*

$$w_1=1 \quad w_2=5 \quad w_3=1 \quad w_4=4 \quad w_5=1 \quad w_6=5$$

*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	$f_1$	$f_2$	$f_3$	$f_4$	$f_5$
Type	Constr. Cost min Linear $q=0.5$ $p=3.2$	Population max Gaussian $s=75$	Parking max Gaussian $s=225$	Road network max Level $q=1$ $p=2$	Competitors min V-shape $p=3$
Weight	3	1	1	1	2.5
<i>Actions</i>					
$a_1$ : 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

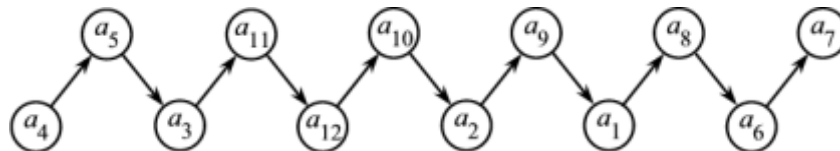


Figure 5: PROMETHEE II

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 to 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  $a_9$ ).

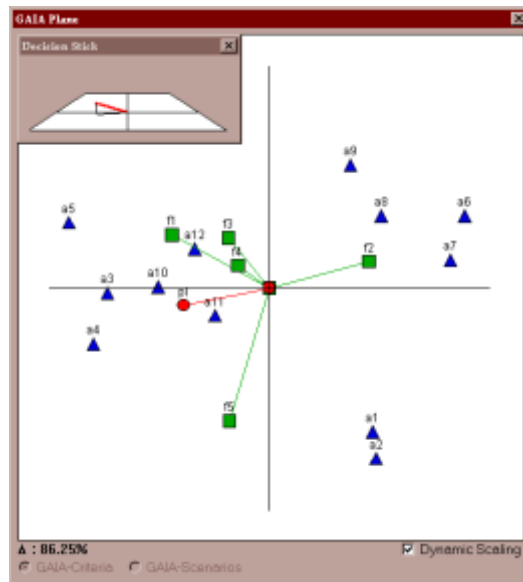


Figure 6: GAIA plane - Hypermarkets

**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
Type	min	max	max	max	min
	Linear	V-shape	U-shape	Gaussian	usual
	$q = 5$ $p = 50$	$p = 300$	$q = 10$	$s = 30$	
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 ( $\pi$ ) 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!)*

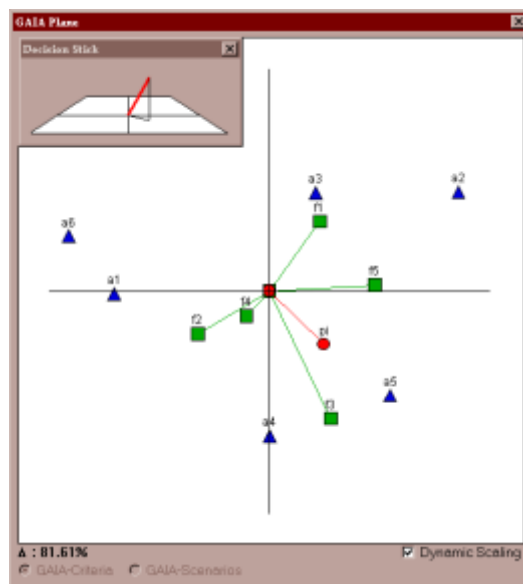


Figure 7: GAIA plane - Marketing