Homework # 3 - Solution

CIVE 646 - Water Resources Systems: Planning and Management

(Fall 2011-12)

Topics: 5) Multicriteria Decision Analysis

Problems

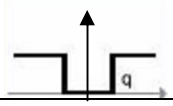
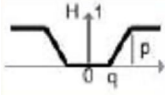
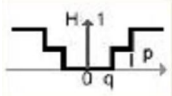
5.1 The following performance matrix is for a multicriteria decision making problem related to a water resources project:

	g_1	g_2	g_3	g_4	g_5	g_6
Min/Max	Min	Max	Min	Min	Min	Max
a_1	80	90	600	54	8	5
a_2	65	58	200	97	1	1
a_3	83	60	400	72	4	7
a_4	40	80	1000	75	7	10
a_5	52	72	600	20	3	8
a_6	94	96	700	36	5	6

A is the set of alternatives and ***G*** is the set of criteria.

g_1: estimated annual maintenance cost (M US$)
g_2: technical value (rating score out of 100)
g_3: construction cost (M US$)
g_4: annual operation cost (M US$)
g_5: environmental impact (rating score out of 10)
g_6: estimated water supply (10^3 m^3/day)

Rank the alternatives using Promothee method. Apply the following parameters:

Criterion	Type	Parameters	Weight
g_1		q = 10	1
g_2		p = 30	1
g_3		q = 50, p = 500	1
g_4		q = 10, p = 60	1
g_5		-	1
g_6		p = 2	1

Solution:

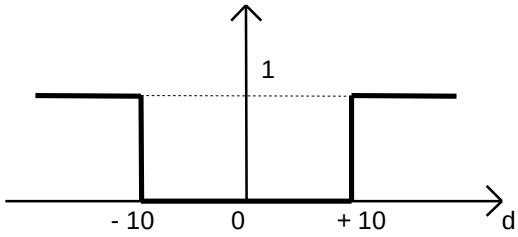
g1(a):

Criterion to be minimized:

g1(a1) – g1(a2) = 15

and therefore:

c1(a1,a2) = 0
c1(a2,a1) =1



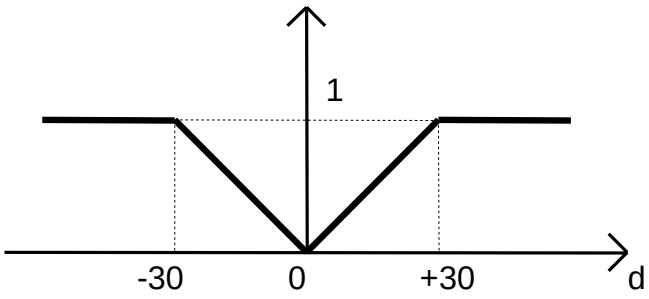
g2(a):

Criterion to be maximized:

g2(a1) – g2(a2) = 32

and therefore:

c2(a1,a2) = 1
c2(a2,a1) =0



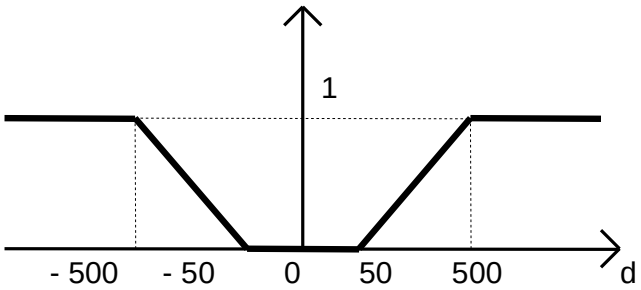
g3(a):

Criterion to be minimized:

g3(a1) – g3(a2) = 32

and therefore:

c3(a1,a2) = 1
c3(a2,a1) = 0.778



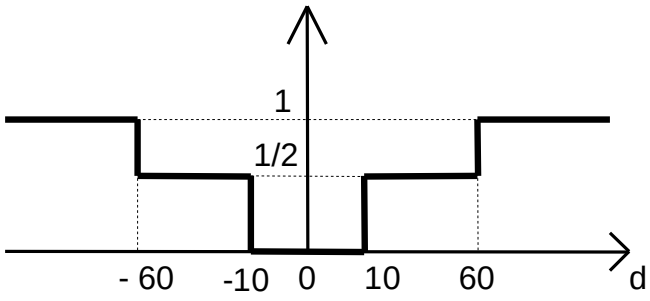
g4(a):

Criterion to be minimized:

g4(a1) – g4(a2) = - 43

and therefore:

c4(a1,a2) = 0.5
c4(a2,a1) = 0



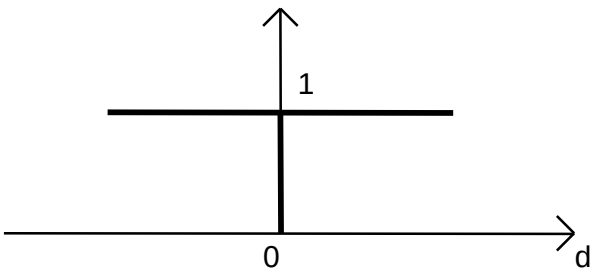
g5(a):

Criterion to be minimized:

g5(a1) – g5(a2) = 7

and therefore:

c5(a1,a2) = 0



c5(a2,a1) = 1

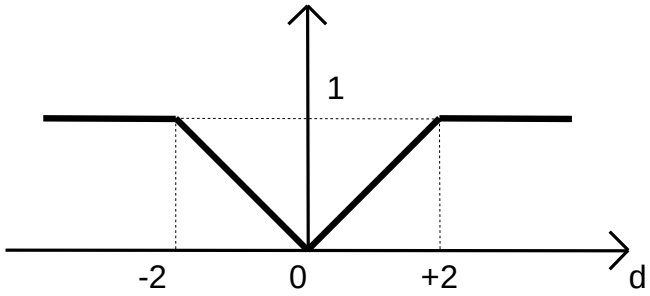
g6(a):

Criterion to be maximized:

g6(a1) – g6(a2) = 4

and therefore:

c6(a1,a2) = 1
c6(a2,a1) = 0



	g1	g2	g3	g4	g5	g6
c(a1,a2)	0	1	0	0.5	0	1
c(a1,a3)	0	1	0	0.5	0	0
c(a1,a4)	0	0.33	0.78	0.5	0	0
c(a1,a5)	0	0.6	0	0	0	0
c(a1,a6)	1	0	0.11	0	0	0
c(a2,a1)	1	0	0.78	0	1	0
c(a2,a3)	1	0	0.33	0	1	0
c(a2,a4)	0	0	1	0	1	0
c(a2,a5)	0	0	0.78	0	1	0
c(a2,a6)	1	0	1	0	1	0
c(a3,a1)	0	0	0.33	0	1	1
c(a3,a2)	0	0.067	0	0.5	0	1
c(a3,a4)	0	0	1	0	1	0
c(a3,a5)	0	0	0.33	0	0	0
c(a3,a6)	1	0	0.55	0	1	0.5
c(a4,a1)	1	0	0	0	1	1
c(a4,a2)	1	0.73	0	0.5	0	1
c(a4,a3)	1	0.67	0	0	0	1
c(a4,a5)	1	0.267	0	0	0	1
c(a4,a6)	1	0	0	0	0	1
c(a5,a1)	1	0	0	0.5	1	1
c(a5,a2)	1	0.47	0	1	0	1
c(a5,a3)	1	0.4	0	0.5	1	0.5
c(a5,a4)	0	0	0.78	0.5	1	0
c(a5,a6)	1	0	0.11	0.5	1	1
c(a6,a1)	0	0.2	0	0.5	1	0.5
c(a6,a2)	0	1	0	1	0	1
c(a6,a3)	0	1	0	0.5	0	0
c(a6,a4)	0	0.53	0.55	0.5	1	0
c(a6,a5)	0	0.8	0	0	0	0

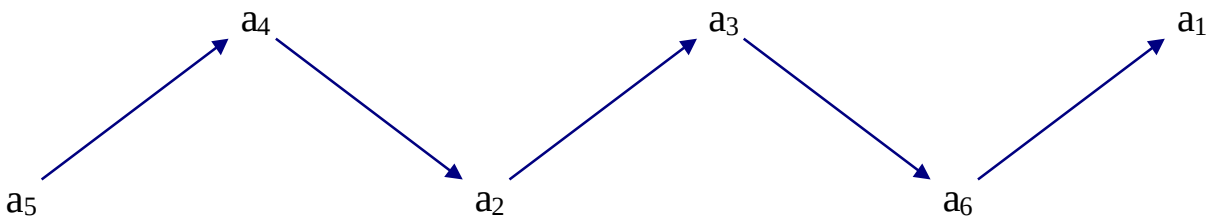
S	**a1**	**a2**	**a3**	**a4**	**a5**	**a6**
a1		0.417	0.25	0.268	0.1	0.185
a2	0.463		0.388	0.33	0.297	0.5
a3	0.388	0.261		0.33	0.055	0.508
a4	0.5	0.538	0.445		0.378	0.33
a5	0.583	0.57	0.567	0.38		0.6
a6	0.367	0.5	0.25	0.43	0.133	

ϕ^+
1.22
1.978
1.542
2.191
2.71
1.68

$\phi = \phi^+ - \phi^-$
- 1.081
- 0.308
- 0.358
0.453
1.74
- 0.443

ϕ^-	**2.301**	**2.286**	**1.9**	**1.738**	**0.962**	**2.123**

Ranking of alternatives:



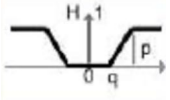
5.2 The Lebanese government intends to construct a treatment plant for wastewater disposal in the Sour drainage Zone (South Lebanon). Four alternatives were identified as follows:

Alternative 1 (A1): Treatment of all wastewater generated in the area at a single WWTP located on the coast.
Alternative 2 (A2): Coastal WWTP plus four smaller inland WWTPs
Alternative 3 (A3): Coastal WWTP plus a WWTP for each interior village
Alternative 4 (A4): Coastal WWTP and upgrading of the existing septic tanks in the interior villages

The decision matrix is as follows:

	Cost (Million $)	Technical rating	Environmental rating
Max/Min	Min	Min	Max
A1	124	16	16
A2	140	26	21
A3	142	24	20
A4	122	15	16

Rank the four alternative using Promothee method using the following parameters:

	Cost (Million $)	Technical rating	Environmental rating
Weight	0.8	0.5	0.5
Preference 	Q = 2, p = 10	q = 2, p = 5	q = 2, p = 6

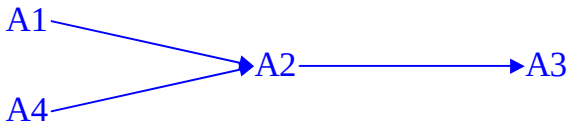
Solution:

	Cost	Technical	Environment
weights	0.8	0.5	0.5
c(A1,A2)	1	1	0
c(A1,A3)	1	1	0
c(A1,A4)	0	0	0
c(A2,A1)	0	0	0.75
c(A2,A3)	0	0	0
c(A2,A4)	0	0	0.75
c(A3,A1)	0	0	0.5
c(A3,A2)	0	0	0

c(A3,A4)	0	0	0.5
c(A4,A1)	0	0	0
c(A4,A2)	1	1	0
c(A4,A3)	1	1	0

S	A1	A2	A3	A4	ϕ^+	$\phi = \phi^+ - \phi^-$
A1		0.722	0.722	0	**1.444**	**1.097**
A2	0.208		0	0.208	**0.416**	**- 1.028**
A3	0.139	0		0.139	**0.278**	**- 1.166**
A4	0	0.722	0.722		**1.444**	**1.097**
ϕ^-	**0.347**	**1.444**	**1.444**	**0.347**		

Ranking of alternatives:



5.3 Reformulate and solve the problem 5.2 by introducing the following environmental concerns:

- Minimize discharge into Mediterranean
- Minimize discharge to surface waters
- Minimize discharge into groundwater
- Highest potential source of irrigation water for interior areas
- Minimize sludge production
- Minimize space requirement
- Minimize impact to areas of high protection value because of rareness of environment
- Minimize impairment of historical or cultural monuments
- Not creating mosquito breeding areas
- Not causing diseases by use of effluent for irrigation

Use a Maximization rating scale between 1 and 4 to evaluate the above mentioned environmental concerns.

Solution:

	A1	A2	A3	A4
Minimize discharge into Mediterranean	4	2	1	1
Minimize discharge to surface waters	1	4	4	2
Minimize discharge into groundwater	1	2	2	4
Highest potential source of irrigation water for interior areas	3	2	2	3
Minimize sludge production	2	2	2	1
Minimize space requirement	1	1	1	1
Minimize impact to areas of high protection value because of rareness of environment	1	1	1	1
Minimize impairment of historical or cultural monuments	1	1	1	1
Not creating mosquito breeding areas	1	3	3	1
Not causing diseases by use of effluent for irrigation	1	3	3	1
Total Environmental rating	**16**	**21**	**20**	**16**

The total Environmental rating of each alternative is the same as problem 5.2

Ranking of alternatives: same as problem 5.2

5.4 A water supply project consists of identifying the most suitable development scenario for water supply in the Sour region. Of necessity the choice of alternatives must consider various criteria; cost (investment, operation and maintenance costs), water quality, water quantity, …

Present water sources:

The existing water supply in Sour area is provided from:

Source	Capacity (m^3/day)
Ras el Ain source	15,000
Er Rachidiye spring	10,000
Ouadi Jilo artesian wells	10,000
Total	45,000

The water demand for the area in the year 2015 is estimated to 90,000 m^3/day.

Two alternatives were identified:

Alternative 1: The concept of alternative 1 is to concentrate the majority of the official water supply at Ras el Ain in order to make maximum use of the good quality water which comes naturally from these springs. The total development for this alternative consists of:

- Extension of WTP for Ras el Ain source to provide an additional capacity of 50,000 m^3/day
- Construction of new pumping station at Ras el Ain
- Construction of new transmission pipelines from Ras el Ain to Hanaouay and Saddiqine regional reservoirs
- Construction of new distribution pipelines

The detailed construction cost of this alternative is as follows:

Construction Works	Cost Million $
Extension of WTP & pumping station	4,1
Transmission networks	8,9
Distribution networks	4,6

Alternative 2: The concept of this alternative is to provide more dispersed sources of supply rather than concentrating on the major source of Ras el Ain. It consists of:

- Extension of WTP for Ras el Ain source to provide an additional capacity of 20,000 m^3/day
- Drilling new artesian wells in different locations in the region of a capacity of 20,000 m^3/day
- Construction of new transmission pipelines
- Construction of new distribution pipelines

The detailed construction cost of this alternative is as follows:

Construction Works	Cost Million $
Extension of WTP & drilling new wells	3,6
Transmission networks	9,9

Distribution networks	4,6
Land	0,2

1- Propose criteria to perform multicriteria decision analysis.
2- Propose methods to evaluate the identified criteria.
3- Construct the performance matrix.
4- Rank the alternatives using Promothee method.

Solution:

Solution depends on criteria and methods of evaluation selected by students