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40.014 Engineering Systems Architecture

Spring 2020

Lecture 18 Activity

# Q1

**Formulate the problem as a Multi-Objective Linear Program (specify decision variables, objective functions and ALL constraints). Attach a screenshot of the formulation page after you have completed it.**

$$\min f(x) = [f_1(x), f_2(x), f_3(x)]$$

$$= [0.52 x_1 + 1.4 x_2 + 2.1 x_3 + 4.51 x_4,$$

$$0.2 x_1 + 4 x_2 + 1.2 x_3 + 0.3 x_4,$$

$$0.03 x_1 + 0.08 x_2 + 0.1 x_3 + 0.06 x_4]$$

$$\text{s.t. } x_1 + x_2 + x_3 + x_4 \geq 250\ 000$$

$$0 \leq x_1 \leq 70\ 000$$

$$0 \leq x_2 \leq 100\ 000$$

$$0 \leq x_3 \leq 120\ 000$$

$$x_4 \geq 0$$

where  $x^T = [x_1, x_2, x_3, x_4]$  is a vector of four decision variables representing groundwater, surface water, imported water and desalinated water.

## Name of the problem

WaterSupplyPortfolioPlanning

## Description of the problem

Minimise the use of energy, chemicals and manpower while meeting all constraints

## Objective functions

Name	Function	Ideal Criterion Vector (estim.)	Nadir (estim.)
Min Energy	$0.52*x1 + 1.4*x2 + 2.1*x3 + 4.51*x4$	0.0	848200.1
Min Chemicals	$0.20*x1 + 4*x2 + 1.2*x3 + 0.3*x4$	0.0	384091.0
Min Manpower	$0.03*x1 + 0.08*x2 + 0.1*x3 + 0.06*x4$	0.0	250000.0

## Starting points and bounds of the variables

variable lower bound <= starting point <= upper bound Integer values

x1	0	<= 1000	<= 70000	No
x2	0	<= 1000	<= 100000	No
x3	0	<= 1000	<= 120000	No
x4	0	<= 1000	<= 5000000	No

## No nonlinear constraint functions defined

## Linear constraint functions

Name Function

No1  $-1 * x1 - 1 * x2 - 1 * x3 - 1 * x4 <= -250000$

Q2

What is the value of the objective functions obtained at the first iteration?

Energy x1 = 529057.5

Chemicals x2 = 211623.0

Manpower x3 = 17892.56

Q3

For each iteration, report the selected alternative(s) and the corresponding classification for each objective function. For the second iteration, attach a screenshot of the “Analyse Results” page and visualize the alternatives using bar charts (attach screenshot as well).

## 1<sup>st</sup> Iteration

Classification of Objective Functions

Function	Current solution Class: < <= = >= >
Min Energy	529057.5
Min Chemicals	211623.0
Min Manpower	17892.56

## 2<sup>nd</sup> Iteration

Selected Alternative

<input checked="" type="checkbox"/>	■ Alternative3	: Energy : 384091.0
		Chemicals : 384091.0
		Manpower : 18824.82

Classification of Objective Functions

Function	Current solution Class: < <= = >= >
Min Energy	384091.0
Min Chemicals	384091.0
Min Manpower	18824.82

Function	Lowest Value	Highest Value
Min Energy	0.0	800000.0
Min Chemicals	0.0	384091.0
Min Manpower	0.0	250000.0

# Upper and lower bound functions

## Enter boundary values

Min Energy 384091.0 <=  <= 848200.1

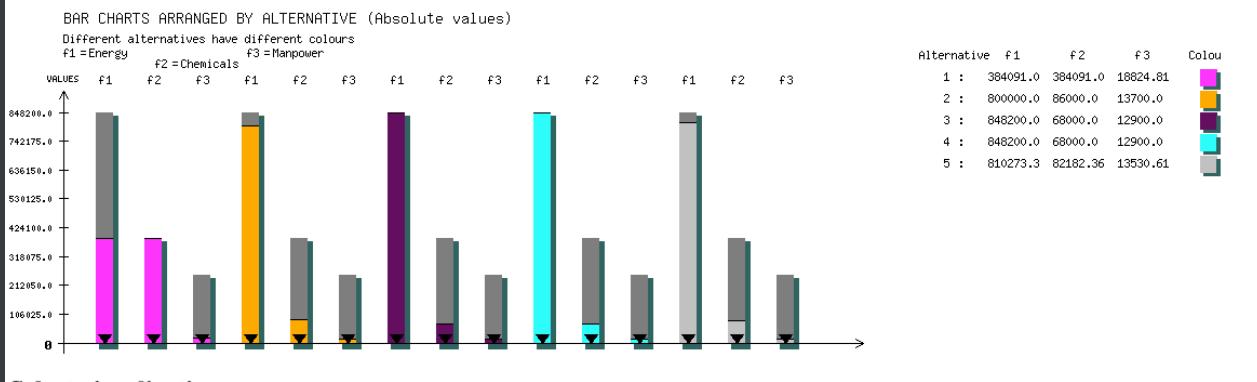
## Select operation

- Another problem
- Save the current problem
- Remove a saved problem
- Calculate a new solution (continue)
- Correct Highest or Lowest values
- Show the whole problem

## 3<sup>rd</sup> Iteration

### Visualisation

### Visualizations



### Selected Alternatives

<input checked="" type="checkbox"/>	<b>Alternative1</b>	Energy : 384091.0
		Chemicals : 384091.0
		Manpower : 18824.82
<input checked="" type="checkbox"/>	<b>Alternative2</b>	Energy : 800000.0
		Chemicals : 860000.0
		Manpower : 13700.0

Generate a solution between the two alternatives in the next iteration.

## 4<sup>th</sup> Iteration

### Selected Alternative

 **Alternative5** : Energy : 716817.4  
Chemicals : 145614.3  
Manpower : 14725.03

## Q4

For the last iteration, report the value of objective functions and decision variables. Provide a brief description/interpretation of your results.

**The final solution is**

<b>Function name</b>	<b>Value</b>
Energy	716817.4
Chemicals	145614.3
Manpower	14725.03

<b>Variable name</b>	<b>Value</b>
x1	70000.0
x2	11246.51
x3	40002.46
x4	128751.0

All groundwater available is used.

Only a fraction of surface and imported water is used.

Main source of water is desalinated water, hence the high energy usage.