Using Excel to Conduct What-if Analysis

File: `TL5_What-if Analysis.xlsx`
Save As: `TechLab5_YYYMMDD_LastnameFirstName.xlsx`

Purpose:

This lab is designed to increase your proficiency with Excel for analysis. You will:

- Learn how to change the names of cells.
- Use Excel Solver to solve an LP and conduct What-if Analysis.
- Use a Sensitivity Report from Excel Solver to do What-if Analysis.

The Wyndor Glass Co. produces high-quality glass products, including windows and glass doors. The company has three plants that simultaneously produce the components of its products. There are three plants that produce these items for the company. Doors require one hour of production time at Plant 1 and three hours of production time at Plant 3. Windows require two hour each at Plants 2 and 3. Plant 1 has 4 hours available each week, Plant 2 has 12 hours available each week, and Plant 3 has 18 hours available each week.

If Wyndor makes $300 profit on each door they sell and $500 profit on each window they sell, how many windows and doors should Wyndor Glass Co. produce each week to maximize profit?

Let,
x_1 = the number of doors produced each week
x_2 = the number of windows produced each week

The algebraic formulation for this problem as a linear program is:

$$
\begin{array}{llcl}
\text{Maximize} & 300x_1 + 500x_2 & & \\
\text{subject to} & x_1 & \leq 4 & \text{(Plant 1)} \\
& 2x_2 & \leq 12 & \text{(Plant 2)} \\
& 3x_1 + 2x_2 & \leq 18 & \text{(Plant 3)} \\
& x_1 & \geq 0 & \\
& x_2 & \geq 0 &
\end{array}
$$

1. Open Excel and save the file.
2. Understand the file: all of the blue colored cells are where you will need to enter given values into the spreadsheet. The orange-y colored cells are where you will need to input equations. The yellow cells represent your decision variables.
3. In cell `C4` and `D4`, enter the coefficients for the decision variables in the objective function.
4. In cells `C8:D10`, enter the coefficients of the decision variables for the functional constraints.
5. In cells `I8:I10`, enter the right-hand side of the functional constraints.

6. Enter 0 as the value for the decision variables in cells `E8` and `E9`.

7. In cell `G4`, enter the following formula: `=MMULT(C4:D4,E8:E9)`. This calculates the value of the objective function.

8. In cell `G8`, enter the following formula: `=MMULT(C8:D10,E8:E9)`. This calculates resource usage based on the decision variables.

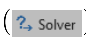
9. Before we solve, let's change the name of the cells, so they are easier to reference in the report we are going to generate:

   (a) Select `E8`. In the top left corner of the spreadsheet to the left of the formula bar, you should see a "Name Box" that displays the cell selected. It should read `E8`.

   (b) Click on the Name Box and type in the word `doors`. Then hit `ENTER`. Now when you click off and back on to cell `E8`, the name box should show the word `doors`.

   (c) Change the names for each of the following cells:
   - `E9` → `windows`
   - `G8` → `Plant1`
   - `G9` → `Plant2`
   - `G10` → `Plant3`

10. Solve the LP using Excel Solver.

    (a) Click on the `Solver` button in the Data Tab (

) and it should open a new dialog box.

    (b) In the `Set Objective` cell, delete the current reference, then click on cell `G4`.

    (c) We want to maximize our objective function, so click on `Max` underneath the `Set Objective:` cell.

    (d) Click on the cell under the words `By Changing Variable Cells:` and highlight cells `E8:E9`.

    (e) Click on the `Add` button next to the cell labeled `Subject to the Constraints:`. This will open a new dialog box.

       i. Click on the cell under the words `Cell Reference:` and highlight cells `G8:G10`.

       ii. All of these constraints have a $\leq$ sign in them, so ensure the sign in the drop down menu is <=. *Note: If you have a constraint with a $\geq$ sign you would need to add that constraint separately.*

       iii. Click on the cell under the word `Constraint:` and highlight cells `I8:I10`.

       iv. Select `OK`.

    (f) Ensure the box next to the words `Make Unconstrained Variables Non-Negative` is checked.

    (g) In the drop down menu next to the words `Select a Solving Method:`, select `Simplex LP`.

    (h) Click on `Solve` at the bottom of the dialog box.

11. In the new dialog box that opens with the Solver Results, locate the `Reports` box on the right hand side.

12. Highlight the word `Sensitivity`, then click `OK`.

13. You should see a new spreadsheet tab labeled `Sensitivity Report 1` populate at the bottom of the Excel Window.

14. Before we investigate this report, let's investigate what-if analysis using Solver.

15. Write down the optimal solution and associated weekly profit:

16. **Changing constraints:** Let's adjust the right-hand side value of the Plant 1 constraint. For each instruction below, re-solve the LP and fill out the table writing in the optimal solution resulting from the change and whether or not the solution is changed from the original.

    (a) Increase the value by 2 and re-solve.

    (b) Now decrease the value by 2 (from 4 to 2) and re-solve.

    (c) Decrease the value to 1 and re-solve.

    (d) Increase the value to 8 and re-solve.

    (e) Increase the value to 100 and re-solve.

Original Value	Updated Value	Optimal Solution	Change? (Y/N)
$b_1 = 4$	$b_1 = 6$		
$b_1 = 4$	$b_1 = 2$		
$b_1 = 4$	$b_1 = 1$		
$b_1 = 4$	$b_1 = 8$		
$b_1 = 4$	$b_1 = 100$		

    (f) What can we say about this constraint? Is it binding or non-binding? How much can it increase or decrease to maintain the current optimal solution?

17. **Changing constraints:** Reset the Plant 1 right-hand side value to 4. Now, let's adjust the right-hand side value of the Plant 3 constraint. For each change fill out the table with the following information: the new optimal solution, the new optimal objective value, is the Plant 3 constraint binding, and whether the optimal solution is at the same corner point.

    (a) Increase the value to 20 and re-solve.

    (b) Now decrease the value to 12 and re-solve.

    (c) Decrease the value to 11 and re-solve.

    (d) Increase the value to 24 and re-solve.

    (e) Increase the value to 25 and re-solve.

    (f) Increase the value to 19 and re-solve.

Original Value	Updated Value	Optimal Solution	Obj. Value	Binding (Y/N)	Same Corner (Y/N)
$b_3 = 18$	$b_3 = 20$				
$b_3 = 18$	$b_3 = 12$				
$b_3 = 18$	$b_3 = 11$				
$b_3 = 18$	$b_3 = 24$				
$b_3 = 18$	$b_3 = 25$				
$b_3 = 18$	$b_3 = 19$				

    (g) What can we say about this constraint? At what values does it cease to be binding? What do you notice about the objective function value?

18. **Objective Functions:** Reset the right-hand side of Plant 3 constraint to 18. Now let's look at changing the profit value for windows. For each change below, write the optimal solution and whether it changes from the original.

    (a) Increase the profit from $500 to $750.

    (b) Now decrease the profit to $200 and re-solve.

    (c) Decrease the profit to $150 and re-solve.

(d) Increase the profit to $2,000 and re-solve.

(e) Decrease the profit to $201 and re-solve.

(f) Decrease the profit to $200.05 and re-solve.

Original Value	Updated Value	Optimal Solution	Change? (Y/N)
$c_2 = 500$	$c_2 = 750$		
$c_2 = 500$	$c_2 = 200$		
$c_2 = 500$	$c_2 = 150$		
$c_2 = 500$	$c_2 = 2000$		
$c_2 = 500$	$c_2 = 201$		
$c_2 = 500$	$c_2 = 200.05$		

(g) If we want to maintain the current optimal solution, what is the range for the profit value per window that will maintain the current optimal solution?

19. Let's explore the Sensitivity Report generated by Excel Solver, and see how it compares to what we've done through re-solving the problem.

(a) Click on the tab for `Sensitivity Report 1`. You should see a table that looks like this:

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
E8	doors	2	0	300	450	300
E9	windows	6	0	500	1E+30	300

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
G8	Plant1	2	0	4	1E+30	2
G9	Plant2	12	150	12	6	6
G10	Plant3	18	100	18	6	6

(b) Let's start with the **Variable Cells** portion of the table. We can see the cells associated with the decision variables, the names we gave them, the final value, and a couple of other pieces of information.

i. From the `Objective Coefficient` column we see the objective coefficients (profit values) we used to originally solve the problem, \$300 and \$500 for doors and windows, respectively.

ii. Look at the `Allowable Increase` and `Allowable Decrease` columns. What do these values represent?

(c) Let's move to the **Constraints** portion of the table. Just as with the variable portion, we can see the cell reference and the name we've given the cells to annotate what constraint they represent.

i. Look at the row for Plant 3. What is the shadow price, and how does it compare to what we found in Problem 17f?

ii. Look at the allowable increase and decrease columns for Plant 3. How does it compare to what we found in Problem 17g?

iii. Next look at the allowable increase and decrease columns for Plant 1. How does it compare to what we found in Problem 16f?

iv. What then can we infer about the sensitivity of the constraint for Plant 2 from this report?