LINEAR PROGRAMMING PART II

USING EXCEL

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CONTENTS

I. INTRODUCTION

This article follows after https://www.alvinang.sg/s/Linear-Programming-Part-I-Model-Formulation-By-Dr-Alvin-Ang.pdf

II. SETTING UP EXCEL SOLVER

Lucy's Madame's problem can be solved using Microsoft Excel. You need an add-in package, called "Solver" that comes with every Excel pre-installed. However, you need to activate it before it can be used.

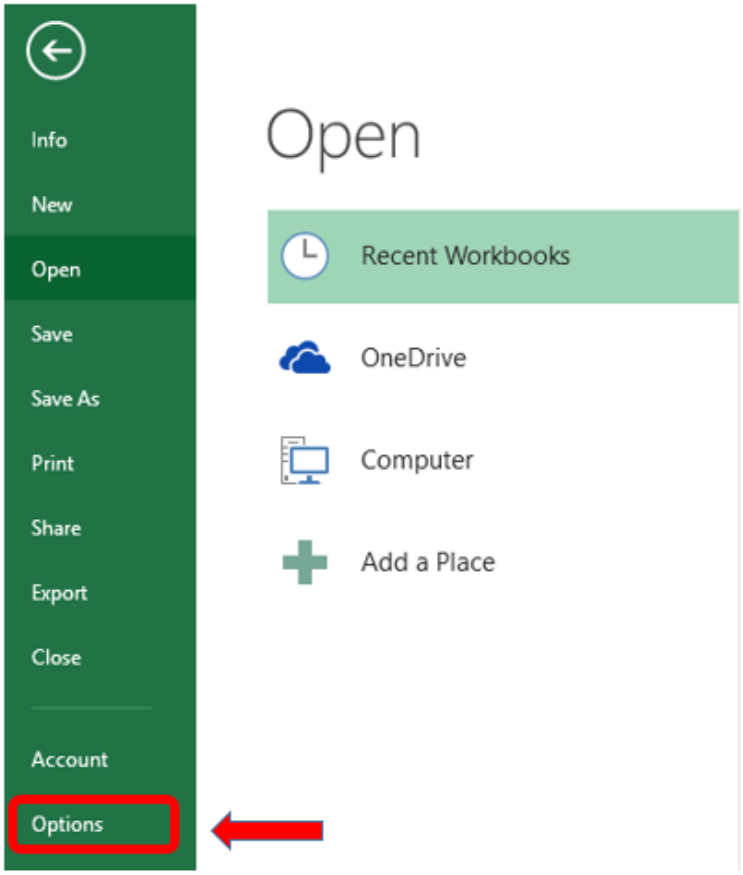


Figure 1: Options in Excel

Open up Microsoft Excel, click on File >> Options (as shown above).

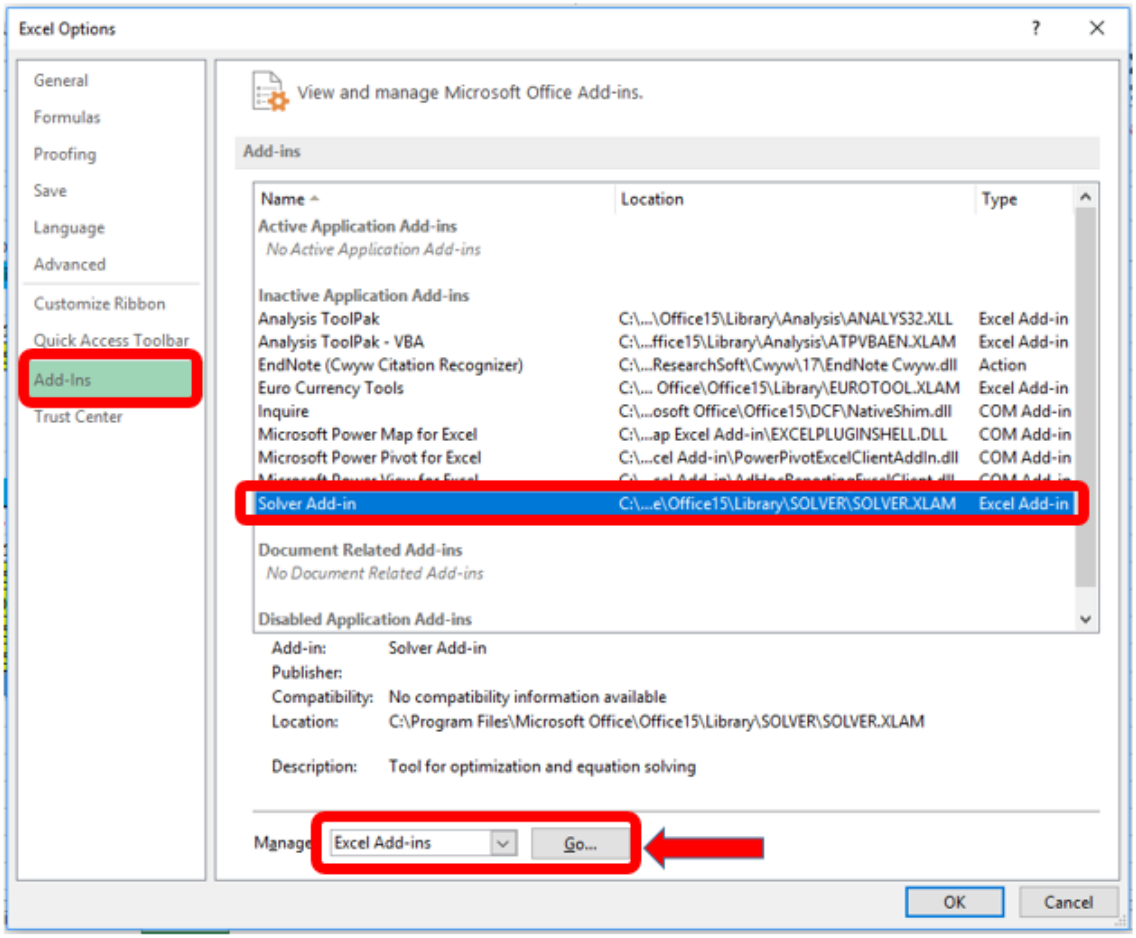


Figure 2: Solver Add-Ins (Inactive)

A pop up will appear. Select Add-Ins >> Excel Add-Ins >> Solver Add-Ins. Then click GO.

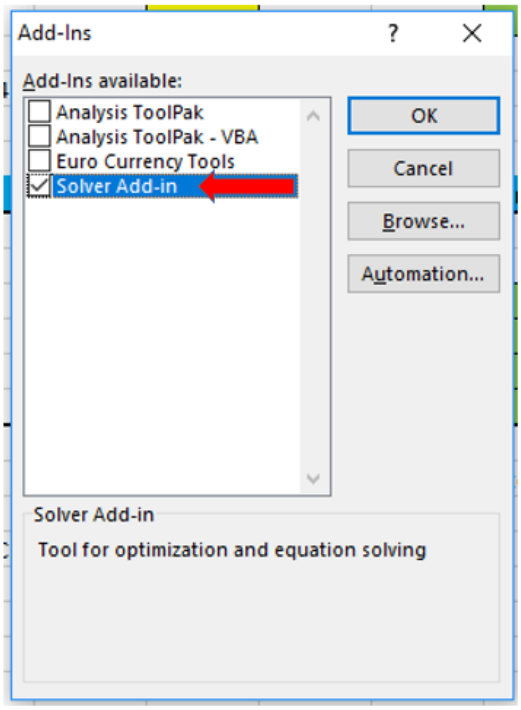


Figure 3: Solver Add-Ins (Activating)

A new pop up will appear. Click on Solver Add-in and click OK.

You will see the package being installed. Wait a moment. Once completed, you will be able to locate the Solver program under the "Data" tab (as shown below).

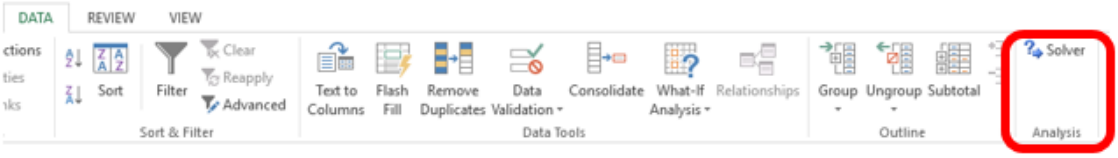


Figure 4: Solver Appeared under Data Tab

You can now begin using Excel Solver!

A. STEP 1: SETUP THE EXCEL SPREADSHEET

Setup the Excel Spreadsheet as shown below.

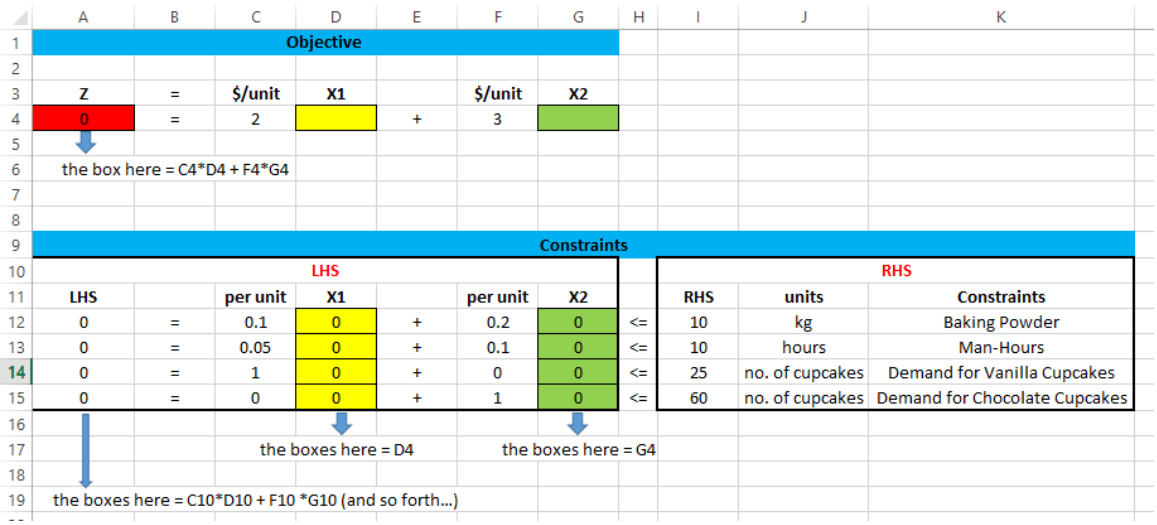


Figure 5: Setting up the Excel Spreadsheet

There are 2 segments to this spreadsheet.

1. The Objective function
    a. It translates the objective function, Max Z = $\$2X_1 + \$3X_2$, into Excel.

2. The Constraints segment
    a. It translates the following constraints into Excel:
        i. Constraint 1: $(0.1)*(X_1) + (0.2)*(X_2) \leq 10$ kg
        ii. Constraint 2: $(0.05)*(X_1) + (0.1)*(X_2) \leq 10$ hours
        iii. Constraint 3: $X_1 \leq 25$ Vanilla cupcakes
        iv. Constraint 4: $X_2 \leq 60$ Chocolate cupcakes

B. STEP 2: CONFIGURING THE SOLVER

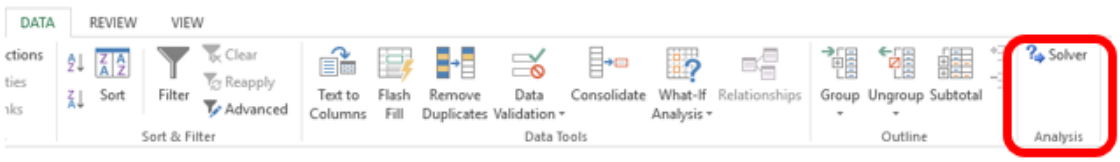


Figure 6: Click on the Solver

Go to Data >> Solver. Click on it. The Solver Parameters will appear.

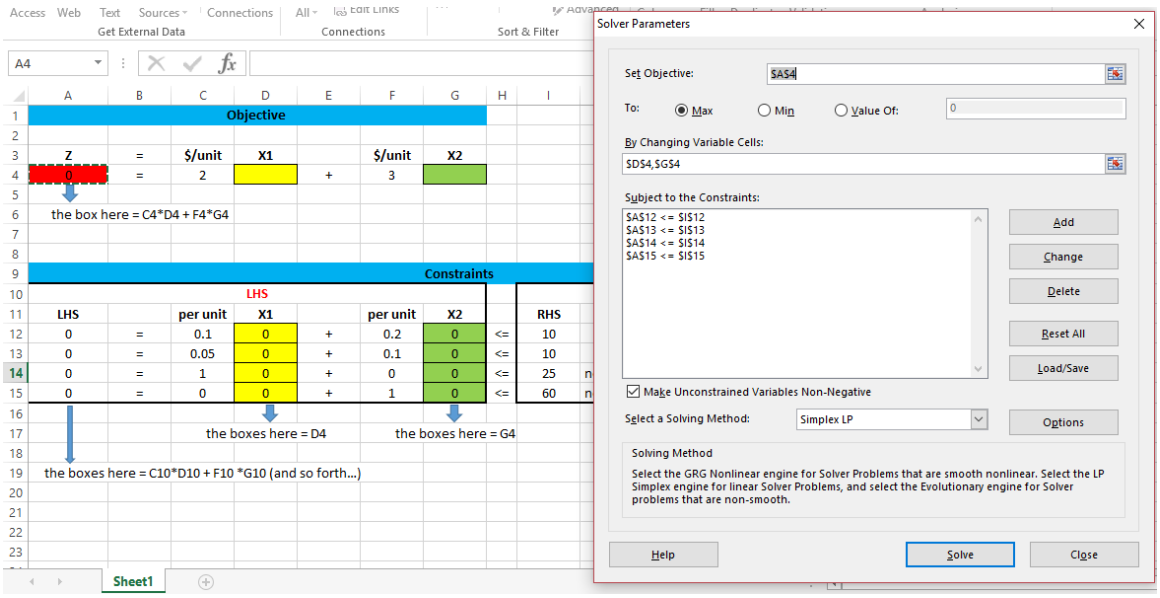


Figure 7: Solver Parameters

- The key parameters to configure here are:
    - *Set Objective*: Point it to the Objective Function, Z (Red Box)
    - *Set to MAX*: Since we are Maximizing Profits here.
    - *Changing Variable Cells:* Point the cells to the relevant two yellow and green boxes (the objective function row only)
    - *Subject to the Constraints:* Point the LHS column comparing it with the RHS column.

- Ensure that the *"Make Unconstrained Variables Non-Negative"* check box is ticked. This is actually Constraint 5: the Non-negativity constraint.

- Choose the Solving Method as Simplex.

Once done, click on Solve! Thereafter, another pop up will appear.

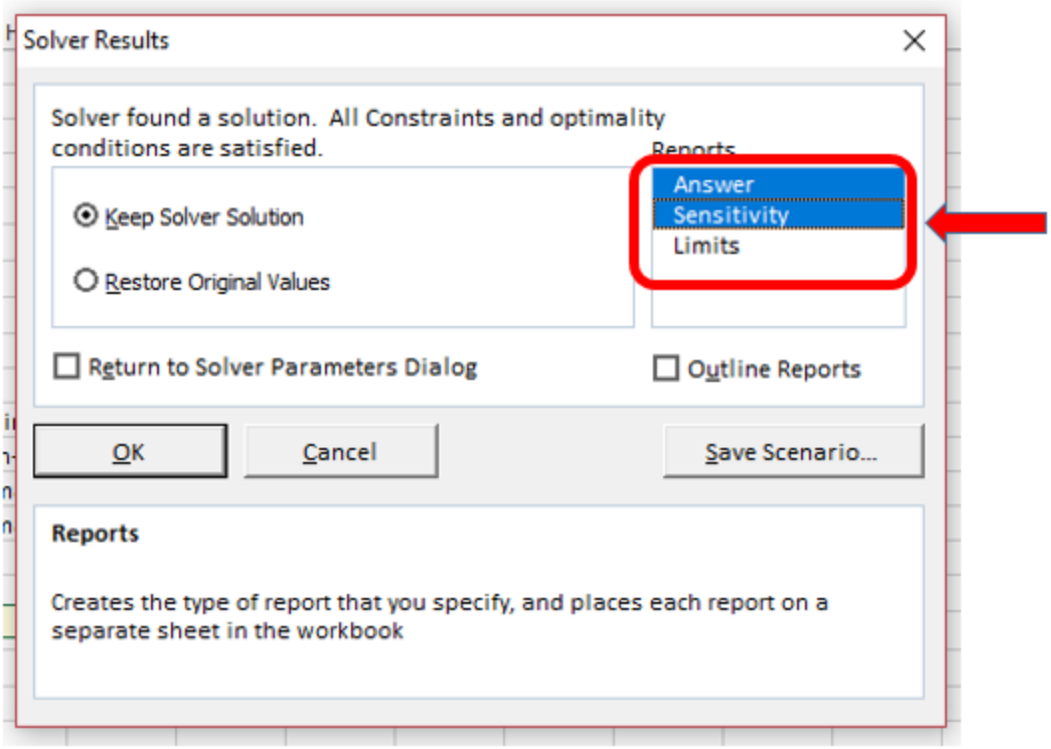


Figure 8: Solver Results Pop Up

Choose the following options:

- Answer and
- Sensitivity and
- Keep Solver Solution

Then click OK.

C. STEP 3: PRELIMARY RESULTS

Immediately, you will see these things appearing:

1. Two new tabs: Answer Report and Sensitivity Report
2. The Red, Yellow and Green Boxes get filled.
3. The LHS column gets filled.

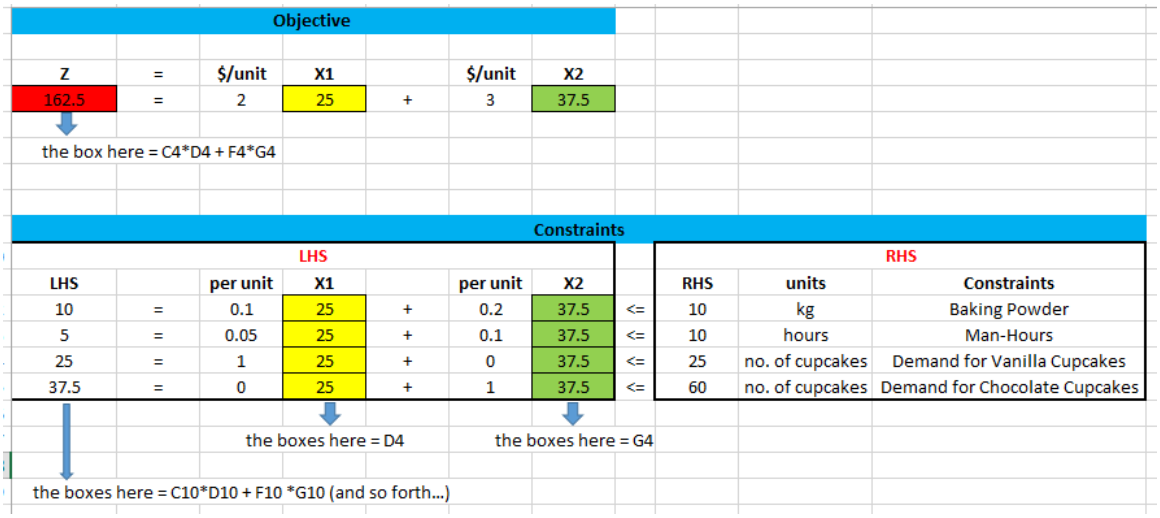


Figure 9: Preliminary Results

The key takeaways from this preliminary results are:

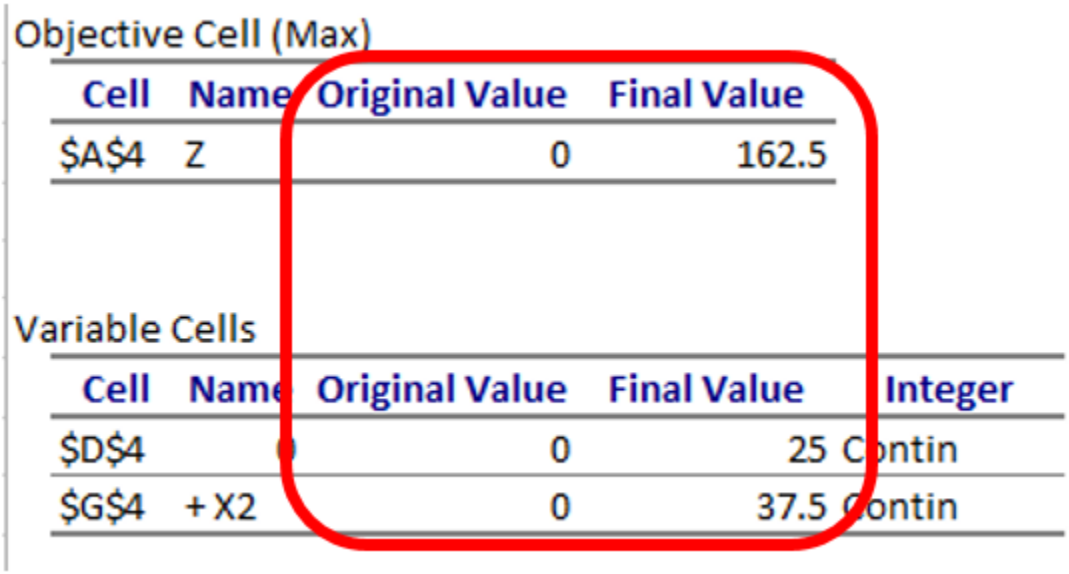
- The Objective Function, Z = $162.50. This means that the maximum profit that Lucy's Madame can expect to make at the fun fair is $162.50, given her current predictions.
- The optimal number of Vanilla cupcakes to bake is 25 and the number of Chocolate cupcakes is 38, given her current resources.

IV. INTERPRETING THE SOLVER'S RESULTS

Even though the preliminary results were shown in the previous section, we will have a deeper analysis of it here.

A. STEP 1: INTERPRETING THE ANSWER REPORT

The Answer Tab shows the Solver's results as shown below.



Objective Cell (Max)

Cell	Name	Original Value	Final Value
$A$4	Z	0	162.5

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$D$4		0	25	Contin
$G$4	+X2	0	37.5	Contin

Figure 10: Solver's Results (Answer Report)

As can be seen in the "Final Value" Columns,

1. The maximum profit that Lucy's Madame can make at the fun fair selling her cupcakes is $162.50.
2. The optimal number of Vanilla cupcakes to bake is 25 while that for Chocolate cupcakes is 38.
3. The "Original Value" column next to the "Final Value" column simply states the values of the cells before Solver was run. In this case they are all zero because the cells were emptied before executing Solver. In other words, cells C8, C6 and D6 were empty before running Solver.

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$18	Constraint 1 LHS	10	$C$18<=$D$18	Binding	0
$C$19	Constraint 2 LHS	5	$C$19<=$D$19	Not Binding	5
$C$20	Constraint 3 LHS	25	$C$20<=$D$20	Binding	0
$C$21	Constraint 4 LHS	37.5	$C$21<=$D$21	Not Binding	22.5

Figure 11: Solver's Results (Answer Report - Constraints)

The Answer Tab also shows the Constraints after solver was run.

B. STEP 2: WHAT DO THE CELL VALUES, BINDING AND SLACK COLUMN MEAN?

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$18	Constraint 1 LHS	10	$C$18<=$D$18	Binding	0
$C$19	Constraint 2 LHS	5	$C$19<=$D$19	Not Binding	5
$C$20	Constraint 3 LHS	25	$C$20<=$D$20	Binding	0
$C$21	Constraint 4 LHS	37.5	$C$21<=$D$21	Not Binding	22.5

1. 1st Row – [Cell Value = 10 | Status = Binding | Slack = 0]
    - Recall Constraint 1: $(0.1)*(X_1) + (0.2)*(X_2) \leq 10$ kg
    - Recall Optimal Solution: $(X_1 = 25, X_2 = 37.5)$
    - Substitute Optimal Solution into Constraint 1: $(0.1)*(25) + (0.2)*(37.5) = 10$
    - This means that the 1st resource (Baking Powder) was fully utilized. All 10 kg was used up.
    - Since all 10kg was used, this inequality is bonded to 10 kg.
    - Hence, there is No Slack – meaning no extra resources for use anymore.

2. 2nd Row – [Cell Value = 5 | Status = Not Binding | Slack = 5]
    - Recall Constraint 2: $(0.05)*(X_1) + (0.1)*(X_2) \leq 10$ hours
    - Recall Optimal Solution: $(X_1 = 25, X_2 = 37.5)$.
    - Substitute Optimal Solution into Constraint 2: $(0.05)*(25) + (0.1)*(37.5) = 5$
    - This means that the 2nd resource (man-hours) was NOT fully utilized. Only a total of 5 hours was used for baking (1.25 hours used for baking Vanilla Cupcakes and 3.75 hours used for baking Chocolate Cupcakes).
    - Since not all 10 hours was used, this inequality is not bonded to 10 hours.
    - Hence, there is a Slack of $(10 – 5 = 5)$ hours – meaning an extra 5 hours can still be of use.
    - Meaning, Lucy's Madame can make use of this extra 5 hours to ask Lucy to do other household errands rather than wasting it away like chatting with other maids or playing with her hand phone.

3. 3rd Row – [Cell Value = 25 | Status = Binding | Slack = 0]
    - Recall Constraint 3: $X_1 \leq 25$ Vanilla cupcakes
    - Recall Optimal Solution: $(X_1 = 25)$
    - Substitute Optimal Solution into Constraint 3: $25 \leq 25$
    - This means that the 3rd constraint (maximum number of Vanilla Cupcakes) was fully utilized. All 25 Vanilla Cupcakes should be baked.
    - Since all 25 Vanilla Cupcakes should be baked, this inequality is bonded to 25.
    - Hence, there is No Slack – meaning no additional Vanilla Cupcakes can be baked anymore.

4. 4th Row – [Cell Value = 37.5 | Status = Not Binding | Slack = 22.5]
    - Recall Constraint 4: $X_2 \leq 60$ Chocolate cupcakes
    - Recall Optimal Solution: $(X_2 = 37.5)$
    - Substitute Optimal Solution into Constraint 4: $37.5 \leq 60$
    - This means that the 4th constraint (maximum number of Chocolate Cupcakes) was NOT fully utilized. Only 38 cupcakes should be baked.
    - Since only 38 Chocolate Cupcakes should be baked, this inequality is not bonded to 60.
    - Hence, there is a Slack of $(60 – 37.5 = 22.5)$ Chocolate Cupcakes – meaning 22.5 Chocolate Cupcakes will not be baked.
    - The reason why an optimal solution of 38 Chocolate Cupcakes should be baked and not 60 is due to the following possibilities (in which the solver has already taken into account for all possibilities before giving the optimal answer)
        - ✓ Insufficient resources and/or
        - ✓ Does not maximize profits

V. REFERENCES

- Anderson, D. R., D. J. Sweeney and T. A. Williams (2005). An introduction to management science : quantitative approaches to decision making, Mason, Ohio : Thomson/South-Western, c2005. 11th ed.

- Jargons, B. "Assumptions of Linear Programming." from https://businessjargons.com/assumptions-of-linear-programming.html).

- Wikipedia. (2018). "Linear Programming." from https://en.wikipedia.org/wiki/Linear_programming.

ABOUT DR. ALVIN ANG

Dr. Alvin Ang earned his Ph.D., Masters and Bachelor degrees from NTU, Singapore. He was a Professor as well as a personal/business advisor. More about him at www.AlvinAng.sg