DR. ALVIN'S PUBLICATIONS

# LINEAR PROGRAMMING Part II

## USING EXCEL DR. ALVIN ANG



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#### I. INTRODUCTION

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

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#### **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).

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Figure 2: Solver Add-Ins (Inactive)

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

Add-Ins	? ×
Add-Ins available:	
Analysis ToolPak	OK
Euro Currency Tools	Cancel
Solver Add-in	curren
1	<u>B</u> rowse
	Automation
-	
-	
×	
Solver Add-in	
Tool for optimization and equatio	n solving

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).

DATA		REVIEW	VIEV	V												
ctions ties	21 71		<b>Y</b>	Te Clear	Text to	Elych	Pamoua	<b>⊡</b> ⊘	<b>□</b> Concolidate	What-If					1.10	?₄ Solver
ıks	Â↓	SOIL	Filter	🏷 Advanced	Columns	Fill	Duplicates	Validation *	Consolidate	Analysis *	Keauonships	- T	- -	Subtotal		
		1	Sort & Fil	ter				Data Te	ools				Outline		_	Analysis

Figure 4: Solver Appeared under Data Tab

You can now begin using Excel Solver!

#### **III. USING EXCEL SOLVER**

#### A. STEP 1: SETUP THE EXCEL SPREADSHEET

Setup the Excel Spreadsheet as shown below.

	Α	В	С	D	E	F	G	н	1	J	К	
1			0	bjective								
2												
3	Z	=	\$/unit	X1		\$/unit	X2					
4	0	=	2		+	3						
5												
6	the box h	ere = C4*E	04 + F4*G4									
7												
8												
9							Constrain	ts				
10				LHS							RHS	
11	LHS		per unit	X1		per unit	X2		RHS	units	Constraints	
12	0	=	0.1	0	+	0.2	0	<=	10	kg	Baking Powder	
13	0	=	0.05	0	+	0.1	0	<=	10	hours	Man-Hours	
14	0	=	1	0	+	0	0	<=	25	no. of cupcakes	Demand for Vanilla Cupcakes	
15	0	=	0	0	+	1	0	<=	60	no. of cupcakes	Demand for Chocolate Cupcakes	
16												
17			the b	oxes here	= D4	the b	oxes here	e = G4				
18												
19	the boxes	hore - C10	*D10 + E10	*G10 (and	so forth							
	the buxes	nere - cru	0101110	OTO (anu	30 101 11							

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:  $(0.1)^*(X_1) + (0.2)^*(X_2) \le 10 \text{ kg}$
    - ii. Constraint 2:  $(0.05)^*(X_1) + (0.1)^*(X_2) \le 10$  hours
    - iii. Constraint 3:  $X_1 \leq 25$  Vanilla cupcakes
    - iv. Constraint 4:  $X_2 \leq 60$  Chocolate cupcakes

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#### **B. STEP 2: CONFIGURING THE SOLVER**

DATA		REVIEW	VIEV	V												
ctions ties	21	ZAZ	Y	Te Clear		<b>1</b>	<b>→</b>			<b>?</b>						?⇔ Solver
ıks	Â↓	Sort	Filter	🕏 Advanced	Columns	Fill	Duplicates	Validation - Data Te	Consolidate	Analysis *	Kelationships	- Group	Outline	Subtotal		Analysis
															-	

Figure 6: Click on the Solver

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

Acc	ess Web T G	ext Sourc et External D	es⊤ Conn ata	ections	All - I di E Conne	dit Links ctions		Sort	₩ & Filter	Advar	Solver Parameters X
A4	•	: 🗙	√ fx	c							Set Objective: SASA
	А	В	С	D	E	F	G	н	1		
1			C	bjective							To: <u>Max</u> O Min O <u>V</u> alue Of:
2											By Changing Variable Cells:
3	Z	=	\$/unit	X1		\$/unit	X2				SD\$4 \$G\$4
4	0	=	2		+	3					
5	•										Subject to the Constraints:
6	the box h	here = C4*E	04 + F4*G4								SAS12 <= SIS12
7										-	SASIS <= SISIS SASI4 <= SISI4
8										-	SA\$15 <= \$I\$15
9							Constrair	nts T			Delete
10				LHS			222		DUIC		Detere
12	LHS	_	per unit	X1		perunit	×2	1-	10		Borst All
12	0	-	0.05	0	-	0.2	0	~	10		
14	0		1	0	+	0.1	0	~-	25	n	↓ Load/Save
15	0	-	0	0	+	1	0	<=	60	n	Make Unconstrained Variables Non-Negative
16			, ,	, L		-	Ĺ				
17			the b	oxes here	= D4	the b	oxes her	e = G4			Select a solving method: Simplex LP Options
18											Solving Method
19	the boxes	here = C10	)*D10 + F10	*G10 (and	so forth	.)					Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP
20											Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth
21											provem the are notifillout.
22											
23											Help Close Close
	•	Sheet1	(+)							1	

Figure 7: Solver Parameters

- The key parameters to configure here are:
  - o Set Objective: Point it to the Objective Function, Z (Red Box)
  - o *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)
  - o Subject to the Constraints: Point the LHS column comparing it with the RHS column.

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- 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.

Wer results	~									
Solver found a solution. All Constraints and conditions are satisfied.	optimality Reports									
⊙ Keep Solver Solution ○ Restore Original Values	Answer Sensitivity Limits									
Return to Solver Parameters Dialog	Outline Reports									
<u>O</u> K <u>C</u> ancel	<u>S</u> ave Scenario									
Reports										
Creates the type of report that you specify, and places each report on a separate sheet in the workbook										

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.

		0	bjective										
Z	=	\$/unit	<b>X1</b>		\$/unit	X2							
162.5	=	2	25	+	3	37.5							
the box h	ere = C4*C	)4 + F4*G4											
						Constrain	ts						
			LHS						RHS				
LHS		per unit	X1		per unit	X2		RHS	units	Constraints			
10	=	0.1	25	+	0.2	37.5	<=	10	kg	Baking Powder			
5	=	0.05	25	+	0.1	37.5	<=	10	hours	Man-Hours			
25	=	1	25	+	0	37.5	<=	25	no. of cupcakes	Demand for Vanilla Cupcakes			
37.5	=	0	25	+	1	37.5	<=	60	no. of cupcakes	Demand for Chocolate Cupcakes			
						•							
		tho b	oves here	= D4	the b	the boxes here = G4							
		uie b	oxes nere										
		the b	oxes nere										
the boxes	here = C10	*D10 + F10	*G10 (and	so forth	.)								

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.

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#### 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)													
Integer													
ontin													
ontin													

Figure 10: Solver's Results (Answer Report)

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

- 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.

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#### 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.

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

Constraints

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

1.  $1^{st}$  Row – [Cell Value = 10 | Status = Binding | Slack = 0]

- Recall Constraint 1:  $(0.1)^*(X_1) + (0.2)^*(X_2) \le 10 \text{ kg}$
- 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 1<sup>st</sup> resource (Baking Powder) was fully utilized. All 10 kg was used up.
- Since all 10kg was used, this inequality is bonded to 10 kg.
- o Hence, there is No Slack meaning no extra resources for use anymore.

2. 2<sup>nd</sup> Row – [Cell Value = 5 | Status = Not Binding | Slack = 5]

- Recall Constraint 2:  $(0.05)^*(X_1) + (0.1)^*(X_2) \le 10$  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 2<sup>nd</sup> 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.

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- 3.  $3^{rd}$  Row [Cell Value = 25 | Status = Binding | Slack = 0]
  - Recall Constraint 3:  $X_1 \le 25$  Vanilla cupcakes
  - Recall Optimal Solution:  $(X_1 = 25)$
  - Substitute Optimal Solution into Constraint 3:  $25 \le 25$
  - This means that the 3<sup>rd</sup> 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:  $X_2 \le 60$  Chocolate cupcakes
  - Recall Optimal Solution:  $(X_2 = 37.5)$
  - Substitute Optimal Solution into Constraint 4:  $37.5 \le 60$
  - This means that the 4<sup>th</sup> 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

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#### 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 <u>www.AlvinAng.sg</u>

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