

# LINEAR PROGRAMMING (LP): Excel Solver Add-in

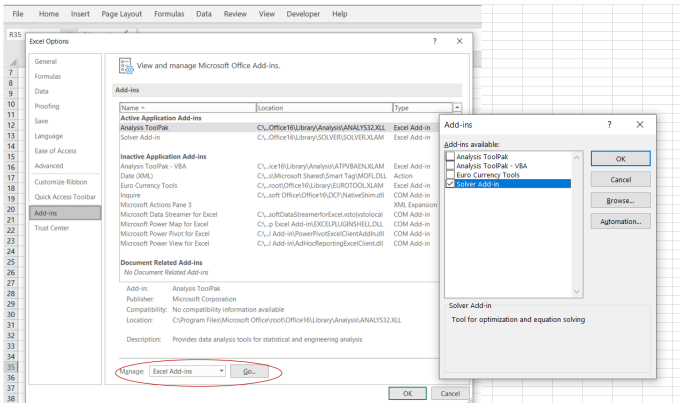


C. B. Vaz

Instituto Politécnico de Bragança

The Solver is an Add-in of Excel that is necessary to install:

- ▶ Select File > Options;
- ▶ Manage Excel Add-ins > Go;
- ▶ Select the Solver Add-in.
- ▶ After the Solver Add-in is available in Data.



## **Solving a LP model using Excel Solver Add-in:**

Consider the following linear programming (LP) model to determine the production plan of three products (1, 2 and 3), using 110, 150 and 200 hours (h) in machines M1, M2 and M3, respectively.

$$\text{Max } Z = 3x_1 + 3x_2 + 2x_3$$

subject to

$$2x_1 + 3x_2 + 4x_3 \leq 110$$

$$3x_1 + 2x_2 + 3x_3 \leq 150$$

$$4x_1 + 2x_2 + 3x_3 \leq 200$$

$$x_1, x_2, x_3 \geq 0.$$

Set the decision variables  $x_1$ ,  $x_2$  and  $x_3$  which are the number of units produced of A, B and C products, respectively.

1st step: To define the model in the workbook, including:

- ▶ Decision variables will be determined through the cells B4 to D4 after run the Solver;
- ▶ Coefficients of the objective function: insert them in the cells B8 to D8.
- ▶ The matrix constraints coefficients: insert them in the cells B12 to D14; the constants of the right side of the constraints: insert them in the cells G12 to G14.

	A	B	C	D	E	F	G
1							
2		<b>Decision Variables</b>					
3		$x_1$	$x_2$	$x_3$			
4							
5							
6		<b>OF Coefficients</b>					
7		$x_1$	$x_2$	$x_3$	<b>Objective function (OF)</b>		
8		3	3	2	0	Maximize	
9							
10		<b>Constraints Coefficients</b>					
11		$x_1$	$x_2$	$x_3$	Hours used		Constraint
12	Machine 1	2	3	4	0	≤	110
13	Machine 2	3	2	3	0	≤	150
14	Machine 3	4	2	3	0	≤	200
15							

2nd step: To define the formulas of the objective function and the left side of each constraint:

- ▶ Objective function (cell E8) - this formula relates the coefficients of the objective function to the decision variables ( $B8 \times B4 + C8 \times C4 + D8 \times D4$ ), using the "SUMPRODUCT" function.
- ▶ Left side of each constraint (cells E12, E13 and E14) - this formula relates the coefficients of each constraint to the decision variables (in E12 is  $B12 \times B4 + C12 \times C4 + D12 \times D4$ ).

	A	B	C	D	E	F	G
1							
2			Decision Variables				
3		$x_1$	$x_2$	$x_3$			
4							
5							
6			OF Coefficients				
7		$x_1$	$x_2$	$x_3$	Objective function (OF)		
8		3	3	2	=SUMPRODUCT(B8:D8,\$B\$4:\$D\$4)	Maximize	
9							
10			Constraints Coefficients				
11		$x_1$	$x_2$	$x_3$	Hours used		
12	Machine 1	2	3	4	=SUMPRODUCT(B12:D12,\$B\$4:\$D\$4)	≤	110
13	Machine 2	3	2	3	=SUMPRODUCT(B13:D13,\$B\$4:\$D\$4)	≤	150
14	Machine 3	4	2	3	=SUMPRODUCT(B14:D14,\$B\$4:\$D\$4)	≤	200

3rd step: To open the Solver in Data to insert:

- ▶ Objective function: select the cell E8
- ▶ By Changing Variable Cells: select the cells B4 to D4
- ▶ Add for each constraint: selecting the cell on the left side, the sign and the cell on right side. In the example, for the 1st to 3rd constraints: select the cells E12 to E14, the sign  $\leq$  and the cells G12 to G14.
- ▶ Select a solving method: chose the Simplex LP

The screenshot shows the 'Solver Parameters' dialog box with the following settings and annotations:

- Set Objective:** \$E\$8 (Annotated: Objective function)
- To:** ☒ Max ☐ Min ☐ Value Of: 0
- By Changing Variable Cells:** \$B\$4:\$D\$4 (Annotated: Decision Variables)
- Subject to the Constraints:** \$E\$12:\$E\$14 <= \$G\$12:\$G\$14 (Annotated: Constraints)
- ☒ Make Unconstrained Variables Non-Negative (Annotated: The Nonnegativity Constraint is met)
- Select a Solving Method:** Simplex LP (Annotated: Select "Simplex LP")
- Solving Method:** Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.
- Buttons:** Add (Annotated: Click Add to add constraints), Change, Delete, Reset All, Load/Save, Help, Solve (Annotated: Click "Solve" to obtain the solution), Options, Close.

4th step: To obtain the optimum solution: the optimum profit is 156€ which is achieved if the company produces 46 units of A and 6 units of B. There are 4 hours available in the machine M3.

	A	B	C	D	E	F	G	H	I	J	K
1											
2		<b>Decision Variables</b>									
3		$x_1$	$x_2$	$x_3$							
4		46	6	0							
5											
6		<b>OF Coefficients</b>									
7		$x_1$	$x_2$	$x_3$	<b>Objective function (OF)</b>						
8		3	3	2	156	Maximize					
9											
10		<b>Constraints Coefficients</b>									
11		$x_1$	$x_2$	$x_3$	Hours used		Constraints				
12	Machine 1	2	3	4	110	≤	110				
13	Machine 2	3	2	3	150	≤	150				
14	Machine 3	4	2	3	196	≤	200				
15											
16											

5th step: To obtain the Answer and the Sensitivity reports

Solver Results ✕

Solver found a solution. All Constraints and optimality conditions are satisfied.

☒ Keep Solver Solution  
☐ Restore Original Values

☐ Return to Solver Parameters Dialog ☐ Outline Reports

**Reports**

Answer  
Sensitivity  
Limits

**OK** **Cancel** **Save Scenario...**

**Reports**

Creates the type of report that you specify, and places each report on a separate sheet in the workbook



### Answer Report

Objective Cell (Max)

Cell	Name	Original Value	Final Value
\$E\$8	Z	0	156

Variable Cells

Cell	Name	Original Value	Final Value	Integer
\$B\$4	x1	0	46	Contin
\$C\$4	x2	0	6	Contin
\$D\$4	x3	0	0	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
\$E\$12	Hours used in M1	110	\$E\$12<=\$G\$12	Binding	0
\$E\$13	Hours used in M2	150	\$E\$13<=\$G\$13	Binding	0
\$E\$14	Hours used in M3	196	\$E\$14<=\$G\$14	Not Binding	4

4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21

# Sensitivity Report

## Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
\$B\$4	$x_1$	46	0	3	1,5	1
\$C\$4	$x_2$	6	0	3	1,5	1
\$D\$4	$x_3$	0	-2,2	2	2,2	1E+30

## Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
\$E\$12	Hours used in M1	110	0,6	110	115	10
\$E\$13	Hours used in M2	150	0,6	150	2,5	76,66666667
\$E\$14	Hours used in M3	196	0	200	1E+30	4

## **Reference**

Hillier F. S., & Lieberman G.R. (2010). Introduction to operations research (9th ed.). New York: McGraw-Hill.