

Quick Tutorial for Spreadsheet Solver

The Solver Tool has the capability to solve linear (and often nonlinear) programming problems. Linear and non-linear solvers are available in most commercially available spreadsheets to include Excel, LibreOffice, GoogleSheets, etc. Our Solver Tutorial takes you **step by step** through the process of creating a Solver model, using a Product Mix example. We'll first show you how to (1) load the solver into your spreadsheet, (2) define the problem and write out formulas for the objective and constraints, and (3) solve the problem. We will focus on Microsoft Excel (Mac and PC) and LibreOffice. At the end of the document you find a quick guide on how to debug the Solver.

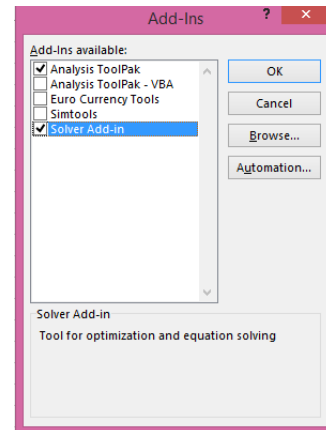
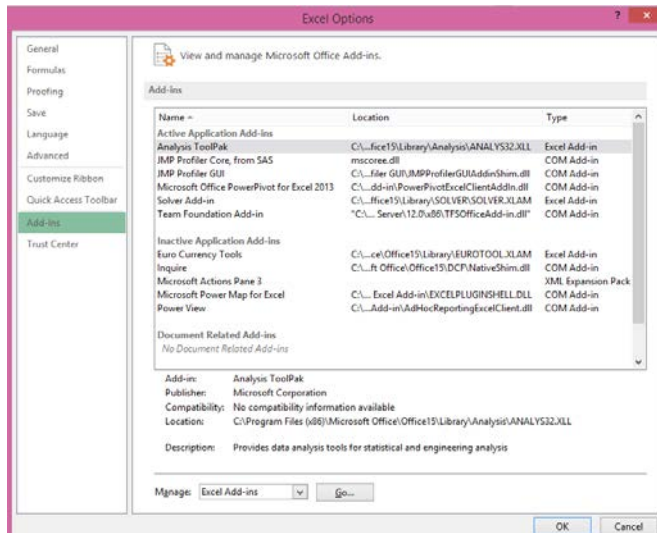
Step 1. Loading the Solver Into Your Spreadsheet

The first step is to make sure you have the correct add-in or solver loaded into your spreadsheet. This process differs by Spreadsheet, operating system, and sometimes version!

Microsoft Excel for PC

Excel does not usually come with the solver loaded. It is considered an Add-In – it is available, you just need to download it. As with most Microsoft tools, it differs whether you are on a Mac or using a PC.

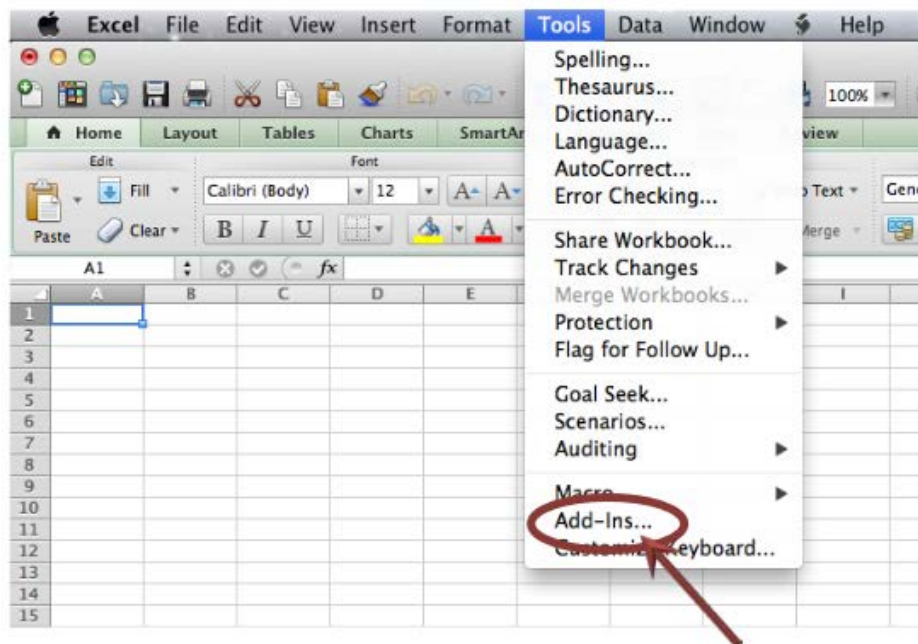
1. Click the Microsoft Office Button, and then click Excel Options.
2. Click Add-Ins, and then in the Manage box, select Excel Add-ins and click Go.
3. In the Add-Ins available box, select the Solver Add-in check box, and then click OK.
4. If Solver Add-in is not listed in the Add-Ins available box, click Browse to locate the add-in.
5. If you get prompted that Solver is not currently installed, click Yes to install it.
6. After you load Solver, the Solver command is available in the Analysis group on the Data tab.

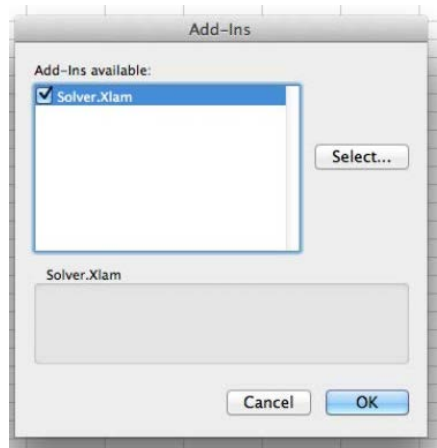


Microsoft Excel for Mac

Loading solver for the Mac differs a little depending on the version of Excel being used. For Excel for Mac 2011 and later, this process works:

1. Open Excel for Mac and begin by clicking on the Tools menu.
2. Click Add-Ins, and then in the Add-Ins box, check Solver.xlam and then click OK.



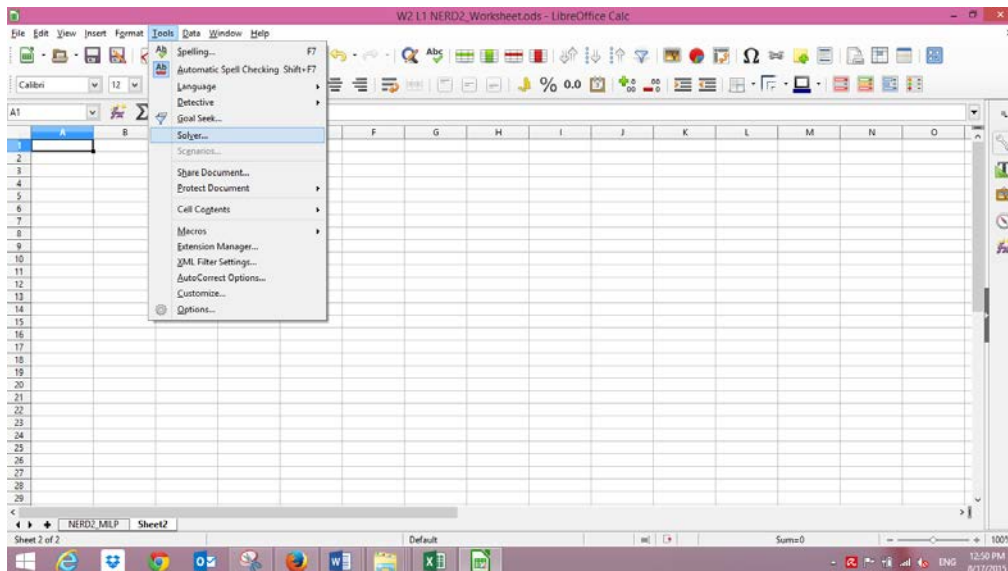


3. After restarting Excel for Mac (fully Quit Excel), select the Data tab, then select Solver to launch. Now on the Tools menu, you should see the Solver command.

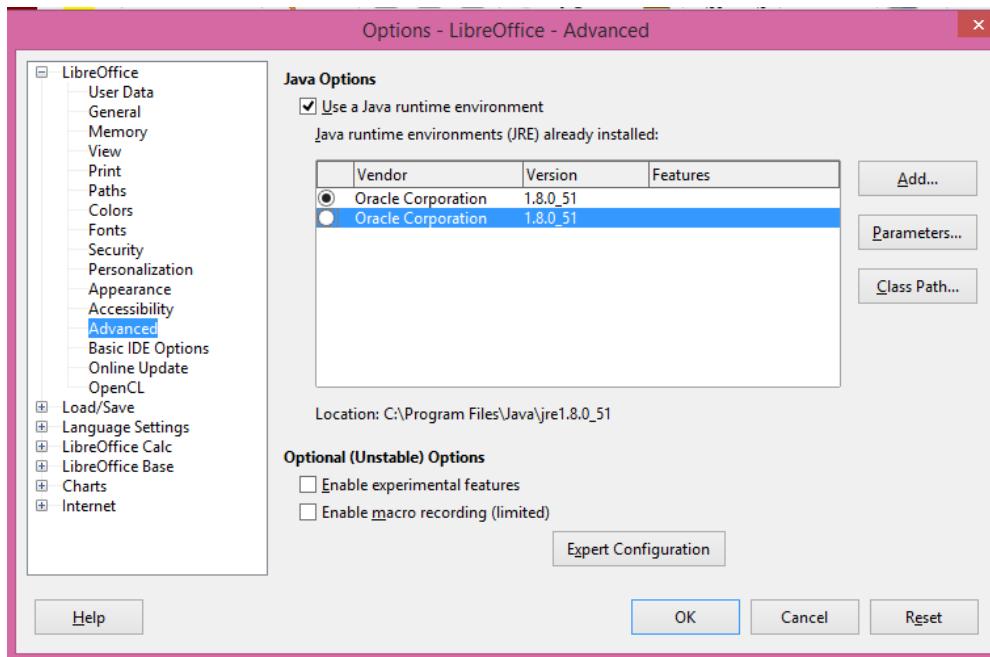
If you have an earlier version of Excel - then see <https://support.microsoft.com/en-us/kb/2431349> for details on where you can locate them.

LibreOffice

The Solver is found at **Tools -> Solver** from the main menu. The solver will then show up as a separate window. At the bottom left of this window you'll find an **Options...** -button. Click this button and make sure **LibreOffice Linear Solver** is selected as the solver engine.



You might also need to define your JAVA JRE client (sometimes an error occurs when launching the solver). In the same **options** tab, go to **Advanced** and select one of the Java Run time Environment installed on your computer and **click OK**



Step 2. Setting up the Problem

The Example Problem

Imagine that you manage a factory that produces **four different types** of wood paneling. Each type of paneling is made by gluing and pressing together a different mixture of pine and oak chips. The following table summarizes the required amount of gluing, pressing, and mixture of wood chips required to produce a pallet of 50 units of each type of paneling:

	Resources Required per Pallet of Paneling Type			
	Tahoe	Pacific	Savannah	Aspen
Glue (quarts)	50	50	100	50
Pressing (hours)	5	15	10	5
Pine chips (pounds)	500	400	300	200
Oak chips (pounds)	500	750	250	500

In the next production cycle, you have 5,800 quarts of glue; 730 hours of pressing capacity; 29,200 pounds of pine chips; and 60,500 pounds of oak chips available. Further assume that each pallet of Tahoe, Pacific, Savannah, and Aspen panels can be sold for profits of \$450, \$1,150, \$800, and \$400, respectively.

Writing the Formulas on the spreadsheet

Before we implement this problem statement in either Excel, let's **write out formulas** corresponding to the verbal description above. If we use the symbol X_1 for the number of Tahoe pallets produced, X_2 for the number of Pacific pallets produced, and X_3 for the number of Savannah pallets produced, and X_4 for the number of Aspen pallets produced, the objective (calculating total profit) is:

$$\text{Maximize: } 450 X_1 + 1150 X_2 + 800 X_3 + 400 X_4$$

In the worksheet below, we have reserved cells B4, C4, D4 and E4 to represent our **decision variables** X_1 , X_2 , X_3 , and X_4 representing the number of pallets of each type of panel to produce. The Solver will determine the optimal values for these cells.

	Panel Type						
	Tahoe	Pacific	Savannah	Aspen			
4 Pallets	0	0	0	0	Total Profit		
5 Profit	\$450	\$1,150	\$800	\$400	\$0		
	Resources Required per Pallet Type				Used	Available	
8 Glue	50	50	100	50	0	5,800	quarts
9 Pressing	5	15	10	5	0	730	hours
10 Pine chips	500	400	300	200	0	29,200	pounds
11 Oak chips	500	750	250	500	0	60,500	pounds

The Objective function on cell F5 is:

$$= \text{SUMPRODUCT}(B4:E4, B5:E5)$$

which is equivalent to :

$$= B5*B4+C5*C4+D5*D4+E5*E4$$

A pallet of each type of panel requires a certain amount of glue, pressing, pine chips, and oak chips. The constraints for this problem are expressed as follows:

Subject to:

$$50 X_1 + 50 X_2 + 100 X_3 + 50 X_4 \leq 5800 \text{ (Glue)}$$

$$5 X_1 + 15 X_2 + 10 X_3 + 5 X_4 \leq 730 \text{ (Pressing)}$$

$$500 X_1 + 400 X_2 + 300 X_3 + 200 X_4 \leq 29200 \text{ (Pine chips)}$$

$$500 X_1 + 750 X_2 + 250 X_3 + 500 X_4 \leq 60500 \text{ (Oak chips)}$$

In cells B8:E11, we've entered the amount of resources needed to produce a pallet of each type of panel. Formula for cell F8: =SUMPRODUCT(B8:E8,\$B\$4:\$E\$4)

We can copy this formula to cells F9:F11 to compute the total amount of pressing, pine chips, and oak chips used.

In cells G8:G11, we've entered the available amount of each type of resource (corresponding to the right hand side values of the constraints). This allows us to express the constraints shown earlier as: F8:F11<=G8:G11

Since the number of products built cannot be negative, we'll also have non-negativity conditions on the variables: $X_1, X_2, X_3, X_4 \geq 0$.

We can enter this set of constraints directly in the Solver dialogs along with the non-negativity conditions: B4:E4 >= 0

Step 3. Solving the Problem

Microsoft Excel (both Mac & PC)

To let the Excel Solver know which cells on the worksheet represent the decision variables, constraints and objective function, we click Solver button on the Excel Data tab. In the **Set Objective** edit box, we type or click on cell F5, the objective function. In the **By Changing Variable Cells** edit box, we type B4:E4 or select these cells with the mouse.

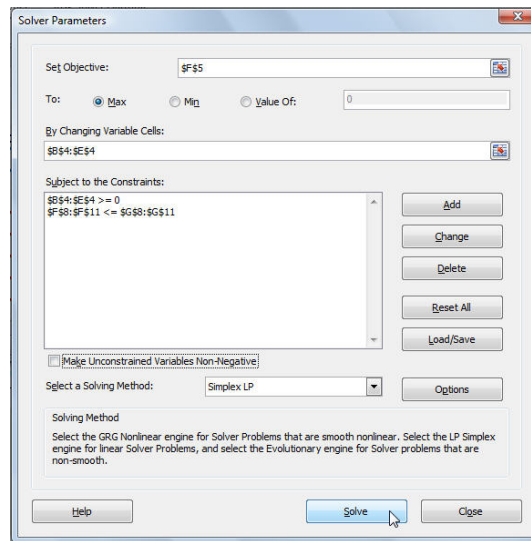
Panel Type					
	Tahoe	Pacific	Savannah	Aspen	
4 Pallets	0	0	0	0	Total Profit
5 Profit	\$450	\$1,150	\$800	\$400	\$0
Resources Required per Pallet Type					Used Available
8 Glue	50	50	100	50	0 5,800
9 Pressing	5	15	10	5	0 730
10 Pine chips	500	400	300	200	0 29,200
11 Oak chips	500	750	250	500	0 60,500

To add the constraints, we click on the **Add** button in the **Solver Parameters** dialog and select cells F8:F11 in the Cell Reference edit box (the *left hand side*), and select cells G8:G11 in the Constraint edit box (the *right hand side*); the default relation \leq is OK. (Click on the image to see it full-size.)

Panel Type					
	Tahoe	Pacific	Savannah	Aspen	
4 Pallets	0	0	0	0	Total Profit
5 Profit	\$450	\$1,150	\$800	\$400	\$0
Resources Required per Pallet Type					Used Available
8 Glue	50	50	100	50	0 5,800 quarts
9 Pressing	5	15	10	5	0 730 hours
10 Pine chips	500	400	300	200	0 29,200 pounds
11 Oak chips	500	750	250	500	0 60,500 pounds

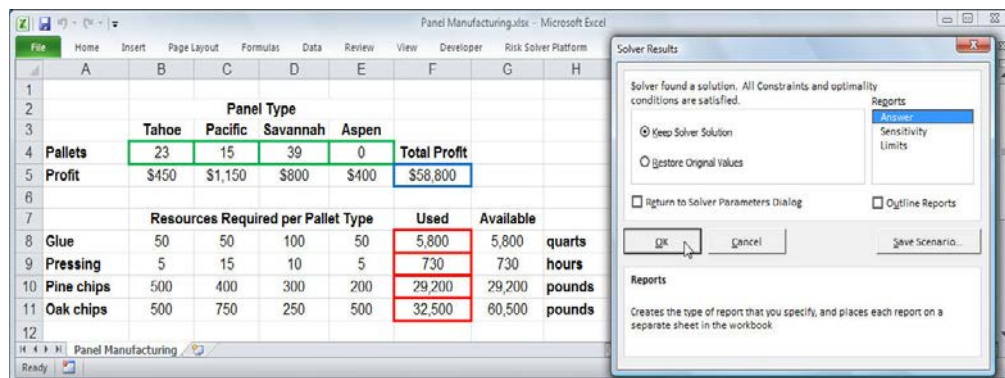
We choose the **Add** button again (either from the Add Constraint dialog above, or from the main Solver Parameters dialog) to define the non-negativity constraint on the decision variables.

When we've completely entered the problem, the Solver Parameters dialog appears as shown below.



Finding and Using the Solution

To find the optimal solution, we simply click on the **Solve button**. After a moment, the Excel Solver returns the optimal solution in cells B4 through E4. This means that we should build 23 pallets of Tahoe panels, 15 pallets of Pacific panels, 39 pallets of Savannah panels, and 0 pallets of Aspen panels. This results in a total profit of \$58,800 (shown in cell F5).



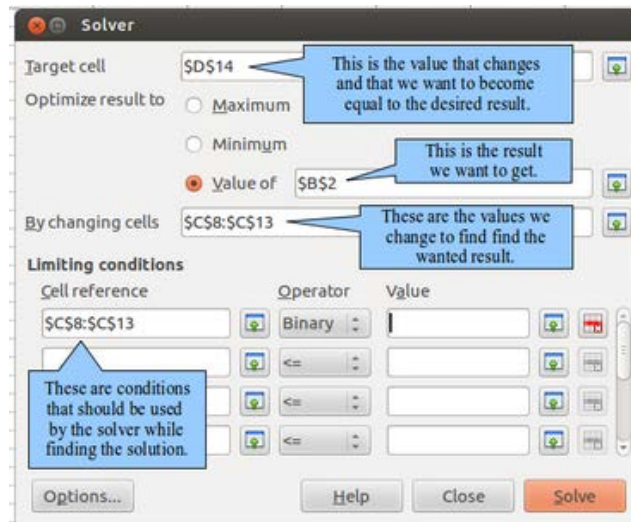
Libre Office

Now we'll start the LibreOffice Solver and insert the **Target Cell, Desired result**, the **Cells that needs changing** and the **Limiting Conditions**. Cell locations are given just as an indication on how to use Libre Office. Follow the same procedure as previously to solve the problem.

Cell **D14** is your objective function will change (**Target Cell**) as the solver changes to 0 or 1 in cell range **C8:C13**.

Changes in the cell range **C8:C13** makes Solver check if **D14** has the same value as **B2**. **Limiting conditions** are your **constraints**.

Have a look at the following figure to see the logic of the solver.



Then you just need to follow the same steps as in the Excel tutorial to optimize your solution. The process is described in part 2.

References

There are many references available. We suggest the following as starting places :

- Solver.com : <http://www.solver.com/solver-tutorial-using-solver>
- MIT Open courseware: <http://ocw.mit.edu>

Debugging the Solver – How to Ask for Solver Help!

This document was from the Discussion Forum post by NaN-2K, Community TA Extraordinaire. .

List of KNOWN problems:

- (1) The Linear solver in Excel 2007 *may* be violating constraints. One student has suggested that clearing the cells of all the decision variables and then invoking solver can help in some cases. We are unable to confirm this (since we don't have Excel 2007) but it may not hurt to try this out.
- (2) Excel 2007 *may* be missing the GRG Non-linear solver used in Week 2 (Weber distance)
- (3) The Linear solver in OpenOffice version of Calc. *may* be violation constraints.
- (4) Excel 2007 and Excel 2008 users must make sure that in the "Solver Options" window, the value for "Tolerance" (or "Integer Tolerance") should be set to 0%. The default value of 5% may be causing Solver to terminate the search prematurely and result in a sub-optimal solution.
- (5) Excel 2007 and Excel 2008 users must make sure that the "Use Automatic Scaling" check-box in the "Solver Options" window is selected. Without this selection, Solver may be terminating its search earlier (or finding the wrong problem because of scaling related numerical precision issues).

Before we get to the instructions, a funny video in case you don't know about "Help Me, Help You":
<https://www.youtube.com/watch?v=Mzfc9rjow9g>

If you have trouble getting the correct answers with Solver, here are some steps that you want to go through to help us, the community TA's, help you! Please read these instructions carefully and provide **ALL** of the information requested. **Your chances of getting a timely and useful reply will improve if you provide ALL of the information requested.**

Step 1 If there is a HINT provided in the problem, make sure that you have already tried to reproduce the results described in the hint

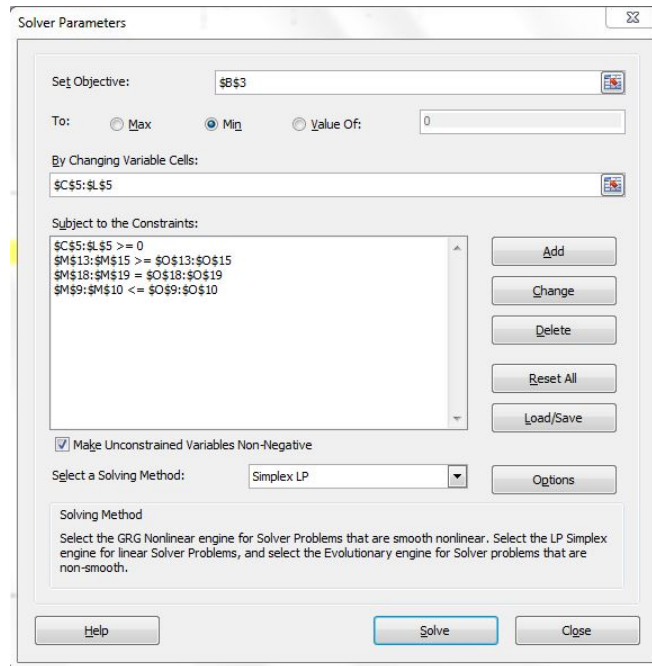
Step 2 If you are unable to reproduce the HINT, or have mismatches with the other models, **then we need screenshots of your spreadsheet to help you further.** Here is the list of the FOUR screenshots that are useful:

1st Screenshot: A screenshot of the spreadsheet including all cells that are relevant (difficult for the larger problems, but please try). Here is a sample from the transshipment problem for SandyCo:

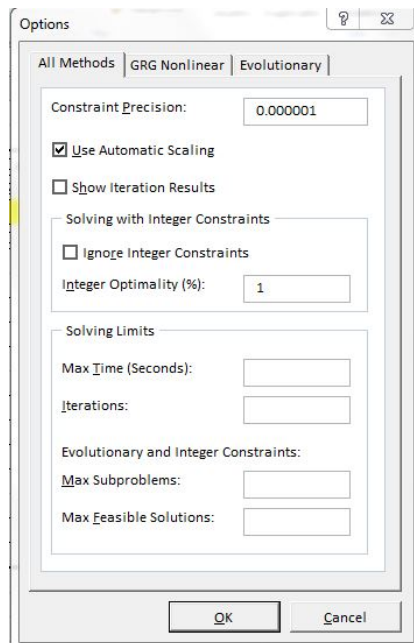
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	SandyCo - Transshipment Problem Example															
2																
3		z =	1820	Plant to Centers				Centers to Regions								
4				x1A	x1B	x2A	x2B	xA1	xA2	xA3	xB1	xB2	xB3			
5		Dec Vars	1	1	1	1	1	1	1	1	1	1	1			
6		Cost \$/ton	190	210	185	205	175	180	165	235	130	145				
7																
8		Supply Constraints												LHS	RHS	
9		Plant 1	1	1										2	≤ 100	
10		Plant 2			1	1								2	≤ 125	
11																
12		Demand Constraints														
13		Region 1					1			1				2	≥ 25	
14		Region 2						1			1			2	≥ 95	
15		Region 3							1			1		2	≥ 80	
16																
17		Conservation of Flow Constraints														
18		Center A	1		1		-1	-1	-1					-1	= 0	
19		Center B		1		1					-1	-1	-1	-1	= 0	
20																

Note how we have included the column and row headers (highlighted in yellow); if you don't include these, then we don't know how to refer to specific cells! It makes our explanation less clear if we cannot give a direct cell reference.

2nd Screenshot: A screenshot of the solver window (where you set up the objective, constraints, decision variables). Here is an example from the same SandyCo transshipment problem:



3rd Screenshot A screenshot of the solver options screen when you click on the options button in the above screen:



Keep in mind that these screens may look different based on the version of Excel or LibreOffice you have; nevertheless, you should be able to access such screens.

4th Screenshot (very useful) A screenshot of your spreadsheet that shows us the formulas (instead of the values). Here is an example with the SandyCo transshipment spreadsheet:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	SandyCo - Transshipment Problem Example														
2															
3		z =	=SUMPRODUCT(C5:L5,C6:L6)				Plant to Centers				Centers to Regions				
4			x1A	x1B	x2A	x2B	xA1	xA2	xA3	xB1	xB2	xB3			
5		Dec Vars	1	1	1	1	1	1	1	1	1	1			
6		Cost \$/ton	190	210	185	205	175	180	165	235	130	145			
7															
8	Supply Constraints												LHS	RHS	
9		Plant 1	1	1									=SUMPRODUCT(C9:L9,\$C\$5:\$L\$5)	≤	100
10		Plant 2			1	1							=SUMPRODUCT(C10:L10,\$C\$5:\$L\$5)	≤	125
11															
12	Demand Constraints														
13		Region 1					1			1			=SUMPRODUCT(C13:L13,\$C\$5:\$L\$5)	≥	25
14		Region 2						1			1		=SUMPRODUCT(C14:L14,\$C\$5:\$L\$5)	≥	95
15		Region 3							1			1	=SUMPRODUCT(C15:L15,\$C\$5:\$L\$5)	≥	80
16															
17	Conservation of Flow Constraints														
18		Center A	1		1		-1	-1	-1				=SUMPRODUCT(C18:L18,\$C\$5:\$L\$5)	=	0
19		Center B		1		1				-1	-1	-1	=SUMPRODUCT(C19:L19,\$C\$5:\$L\$5)	=	0

This will help us spot if there are errors in your SUMPRODUCT formulas or other formulas you use. To get this view in Excel (as well as LibreOffice), you simply press **Ctrl+`** --> that is, **hold the control key down, and then also press the "back-tick" key**. You can use the same key combination to toggle between the formula and the value view in Excel and LibreOffice. Note that you may have to resize your cells for the full formula to be visible.

If you are unable to locate the "back-tick" key, the following link may be useful:

<https://superuser.com/questions/254076/how-do-i-type-the-tick-and-backtick-characters-on-windows>

If you have generated these 4 screenshots, please study them in detail. There is a good chance that you can spot the problem on your own. For example, you may have the wrong formula in one of the cells (using SUM instead of SUMPRODUCT); or you may have setup the constraints incorrectly; or you may have selected the wrong solver /parameter. If you've not resolved the problem yourself after studying these screenshots, please continue reading further...

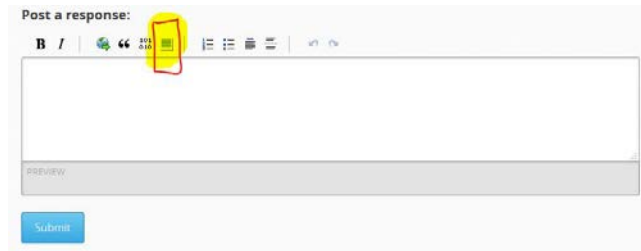
Step 3 Rather than us ask for these screenshots one at a time, **providing all 4 of them at one go will help save all of us time.**

Step 4 If you don't know how to create screenshots easily:

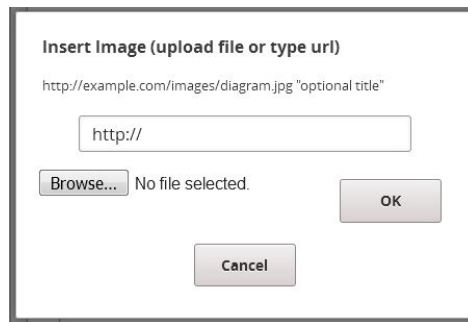
- **On Windows: Snipping Tool** -- <http://windows.microsoft.com/en-in/windows/use-snipping-tool-capture-screen-shots#1TC=windows-vista>
- **Linux:** Several options; **Gimp** is a good choice -- <http://www.thegeekstuff.com/2012/08/screenshot-ubuntu/>
- **Mac:** <https://support.apple.com/en-in/HT201361>

Step 5 If you have trouble uploading the image to the discussion forum post, follow the instructions below:

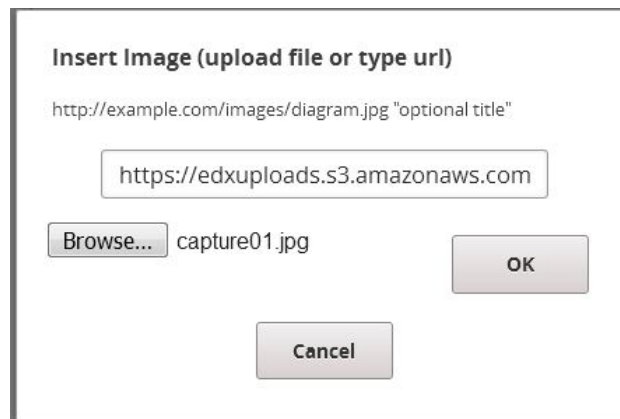
(a) Click on the following icon to start uploading your screenshot image file:



(b) You will be presented with a pop-up window like the one below (note that the URL field is empty):



(c) You will need to upload your screenshot image file by clicking on the "Browse" button and locating your local file. When you click on "Browse" to upload the screenshot image file, ***please wait until the URL is populated; only then click on the OK button - otherwise, the upload will not have completed and the image will not show up in your post.*** Here is how the URL field would look like after the upload is complete:



(d) Please be patient. The upload process sometimes takes several seconds depending on the load on the servers as well your Internet connection speed etc.

(6) Provide us with the details of:

- Your operating system and version (for example, Windows 7, Windows 8.1, Debian 7, Ubuntu 14.04 etc..)
- Your spreadsheet software and version (for example, Excel 2007, Excel 2010, Excel 2013, LibreOffice 4.4.5 etc...)