

Excel is a useful tool for solving linear programming problems. In this question we'll solve and analyze our manufacturing problem with Excel. Although this problem can easily be solved graphically or with the Simplex Method, we demonstrate how to use Excel so that you are able to tackle problems where the graphical method or Simplex Method are impossible or not practical.

Let's start by examining an Excel worksheet for the linear programming

$$\text{Maximize } P = 70x + 120y$$

subject to

$$x + y \leq 35$$

$$x + 3y \leq 75$$

$$2x + y \leq 60$$

$$x \geq 0, y \geq 0$$

This worksheet is what we wish to produce for the linear programming problem from Example 1.

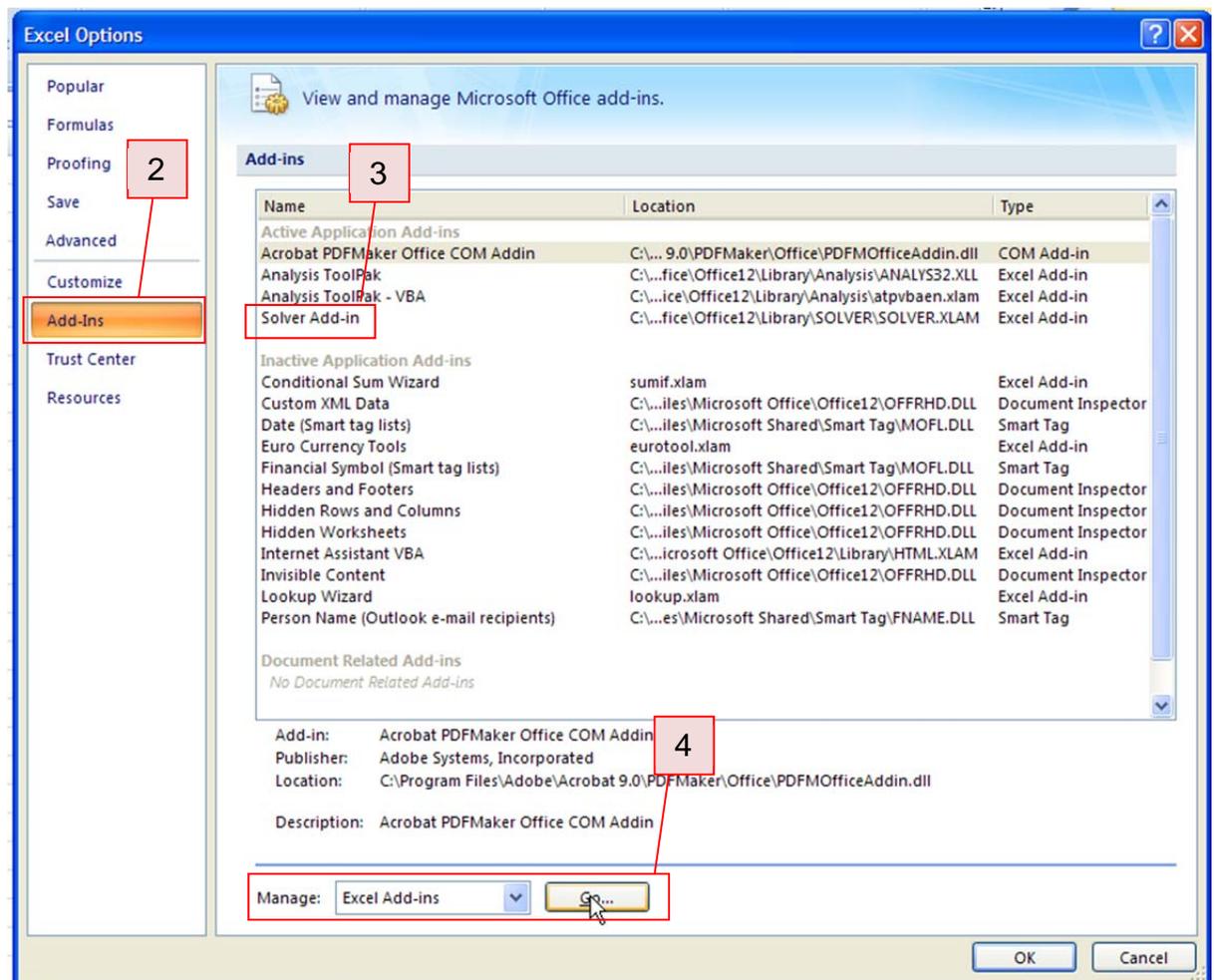
| | A | B | C | D | E | F | G |
|---|--|----------|----------|------------|----|------------|--------------|
| 1 | Frame Bags and Pannier Example | | | | | | |
| 2 | | | | | | | |
| 3 | | x | y | LHS | | RHS | Slack |
| 4 | Profit | 70 | 120 | 3450 | | | |
| 5 | Capacity Constraint | 1 | 1 | 35 | <= | 35 | 0 |
| 6 | Cutting Constraint | 1 | 3 | 75 | <= | 75 | 0 |
| 7 | Assembly & Finishing Constraint | 2 | 1 | 50 | <= | 60 | 10 |
| 8 | | | | | | | |
| 9 | Solution Values | 15 | 20 | | | | |

The worksheet utilizes Excel's Solver Add-In to find the solution to the linear programming problem. Before we can create this worksheet, the Solver Add-In must be installed within Excel. Once that is done, we can construct the worksheet shown above.

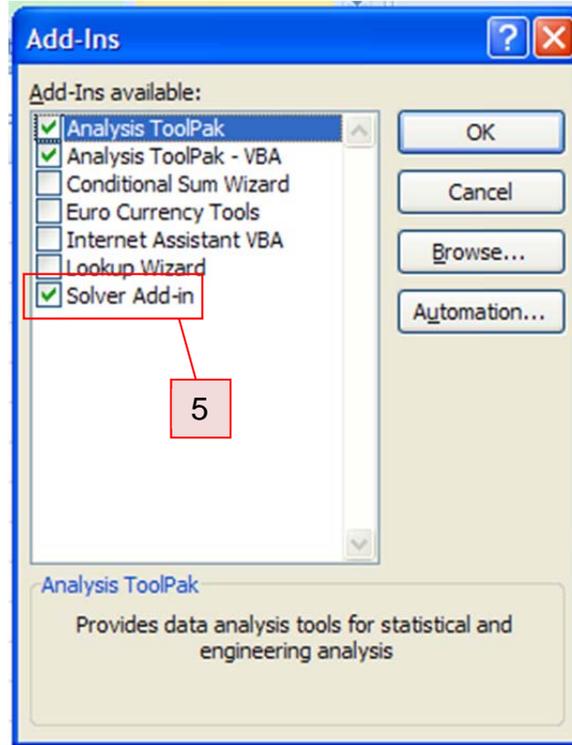
The instructions shown below demonstrate how to load the Solver Add-In for Excel 2007. Other versions of Excel may have a different sequence of steps. For help with

loading the Solver Add-In in those versions, try searching in Excel's Help Utility with the term "solver".

1. To load the Solver Add-In, click on the Office button  in the upper left corner of Excel. Select Excel Options at the bottom of the menu that appears. This will open the Excel options box.
2. From the left side select Add-Ins.



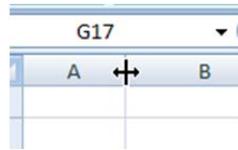
3. If you see the Solver Add-In listed, click on OK at the bottom of the box and skip to step 6. In this case the Solver Add-In is already loaded.
4. To add the Solver Add-In, click in the Manage area and select Excel Add-ins. Press Go.
5. In the Add-Ins box that appears, click in the box next to Solver Add-in to put a check in the box. Click OK. The Solver Add In is now ready to use.



- Now we can begin to make the worksheet that we'll use to solve the linear programming problem. Enter the text show below in the individual cells.

| | A | B | C | D | E | F | G |
|---|--|----------|----------|------------|---|------------|--------------|
| 1 | Frame Bags and Pannier Example | | | | | | |
| 2 | | | | | | | |
| 3 | | x | y | LHS | | RHS | Slack |
| 4 | Profit | | | | | | |
| 5 | Capacity Constraint | | | | | | |
| 6 | Cutting Constraint | | | | | | |
| 7 | Assembly & Finishing Constraint | | | | | | |
| 8 | | | | | | | |
| 9 | Solution Values | | | | | | |

You will need to resize some of the columns. To do this, move the cursor to the top of the column you want to resize. Position the cursor over the border between the columns.



The cursor will change to a double headed arrow. If you hold down the left mouse button, you can move the cursor to resize the column like the columns above.

7. Enter the coefficients of the objective function on the line labeled “Profit”.
8. Enter the coefficients of the constraints in the lines labeled “Capacity Constraint”, “Cutting Constraint”, and “Assembly and Finishing Constraint”.
9. Enter the right hand sides for each constraint in the appropriate row in the column labeled “RHS”.

| | A | B | C | D | E | F | G |
|---|--|----|-----|-----|---|-----|-------|
| 1 | Frame Bags and Pannier Example | | | | | | |
| 2 | | | | | | | |
| 3 | | x | y | LHS | | RHS | Slack |
| 4 | Profit | 70 | 120 | | | | |
| 5 | Capacity Constraint | 1 | 1 | | | 35 | |
| 6 | Cutting Constraint | 1 | 3 | | | 75 | |
| 7 | Assembly & Finishing Constraint | 2 | 1 | | | 60 | |
| 8 | | | | | | | |
| 9 | Solution Values | | | | | | |

10. In the row labeled “Solution Values”, enter an initial guess for the solution. These values can be just about any non-negative number. In this worksheet we use the values $(x, y) = (0, 0)$ for simplicity. The cells you place the guesses in, B9 and C9, are called the changing cells. These values are used to evaluate the objective function and left hand side of the constraints.
11. Place the appropriate inequalities in each constraint’s row.

Linear Programming in Excel

| | A | B | C | D | E | F | G |
|---|---------------------------------|----|-----|-----|----|-----|-------|
| 1 | Frame Bags and Pannier Example | | | | | | |
| 2 | | | | | | | |
| 3 | | x | y | LHS | | RHS | Slack |
| 4 | Profit | 70 | 120 | | | | |
| 5 | Capacity Constraint | 1 | 1 | | <= | 35 | |
| 6 | Cutting Constraint | 1 | 3 | | <= | 75 | |
| 7 | Assembly & Finishing Constraint | 2 | 1 | | <= | 60 | |
| 8 | | | | | | | |
| 9 | Solution Values | 10 | 0 | 0 | | 11 | |

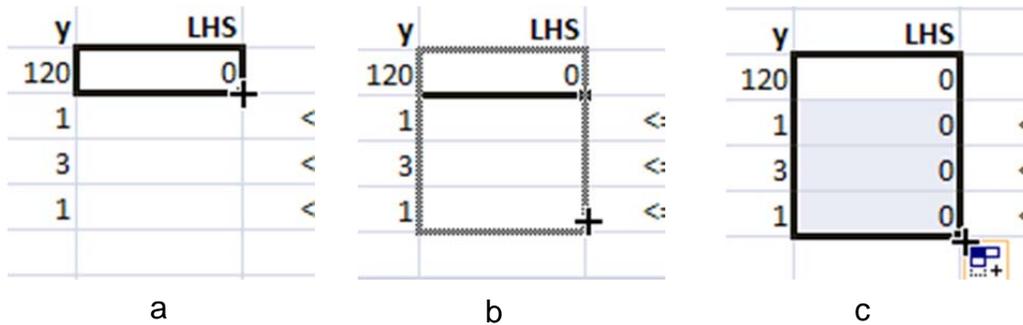
12. In cell D4 we want to calculate the value of the objective at the solution values in cells B9 and C9. This cell is called the target cell. Click your mouse in the target cell.

| D4 | | =SUMPRODUCT(\$B\$9:\$C\$9,B4:C4) | | | | | |
|----|---------------------------------|----------------------------------|-----|-----|----|-----|-------|
| | A | B | C | D | E | F | G |
| 1 | Frame Bags and Pannier Example | | | | | | |
| 2 | | | | | | | |
| 3 | | x | y | LHS | | RHS | Slack |
| 4 | Profit | 70 | 120 | 0 | | | |
| 5 | Capacity Constraint | 1 | 1 | | <= | 35 | |
| 6 | Cutting Constraint | 1 | 3 | | <= | 75 | |
| 7 | Assembly & Finishing Constraint | 2 | 1 | | <= | 60 | |
| 8 | | | | | | | |
| 9 | Solution Values | 0 | 0 | | | | |

In the formula area, type =SUMPRODUCT(\$B\$9:\$C\$9,B4:C4). Press Enter on the keyboard. The SUMPRODUCT function multiplies corresponding cells and adds the results. In this case, the solution values in B9 and C9 are multiplied times the objective function coefficients in B4 and C4. The sum of these products is placed in the target cell.

13. The dollars signs used in step 13 are called absolute references. Absolute references are useful when fills are used to create entries in cells. Click on cell D4 again. Notice the darker box in the lower right hand corner of the cell. This

box is called the fill handle. Move your cursor over this box and you'll see that it changes to a black cross (see a below). Left mouse click and hold the mouse button down while dragging the cursor to cell D7 (see b below). Release the mouse button (see c below).



This fills the cells D5 through D7 with entries based on the formula in D4. If we click on cells D4 through D7 and examine the formula bar, we see a pattern.

- Cell D4: `=SUMPRODUCT(B9:C9,B4:C4)`
- Cell D5: `=SUMPRODUCT(B9:C9,B5:C5)`
- Cell D6: `=SUMPRODUCT(B9:C9,B6:C6)`
- Cell D7: `=SUMPRODUCT(B9:C9,B7:C7)`

In each of the cells, one factor in the product always comes from the solution values in cells B9 and C9. The other factor in the product comes from the cells in the B and C column on the same line. Cells that are fixed in a certain location are called absolute references and utilize the dollar sign. Cells that are located with respect to another cell are called relative references.

When cells are entered using a fill, relative references are filled with values according to their location. For this worksheet, the second part of each product

comes from the cells immediately to the left and on the same row. The other part of the product is fixed by absolute references in B9 and C9.

- Now we'll utilize a fill to put the entries under the "Slack" label. The slack is the difference between the right hand side and the left hand side of a constraint. Left mouse click on cell G5. In the formula bar, type =F5-D5.

| NORMDIST | | | | | | | |
|----------|---------------------------------|----|-----|---|----|-----|--------|
| | A | B | C | D | E | F | G |
| 1 | Frame Bags and Pannier Example | | | | | | |
| 2 | | | | | | | |
| 3 | | x | y | | | RHS | Slack |
| 4 | Profit | 70 | 120 | | | | |
| 5 | Capacity Constraint | 1 | 1 | 0 | <= | 35 | =F5-D5 |
| 6 | Cutting Constraint | 1 | 3 | 0 | <= | 75 | |
| 7 | Assembly & Finishing Constraint | 2 | 1 | 0 | <= | 60 | |
| 8 | | | | | | | |
| 9 | Solution Values | 0 | 0 | | | | |
| 10 | | | | | | | |

- Press Enter to calculate the slack for the capacity constraint. This value is the difference between the left hand side and the right hand side of the capacity constraint.
- Left mouse click in cell G5 again. Use the fill handle to fill the cells in G6 and G7.

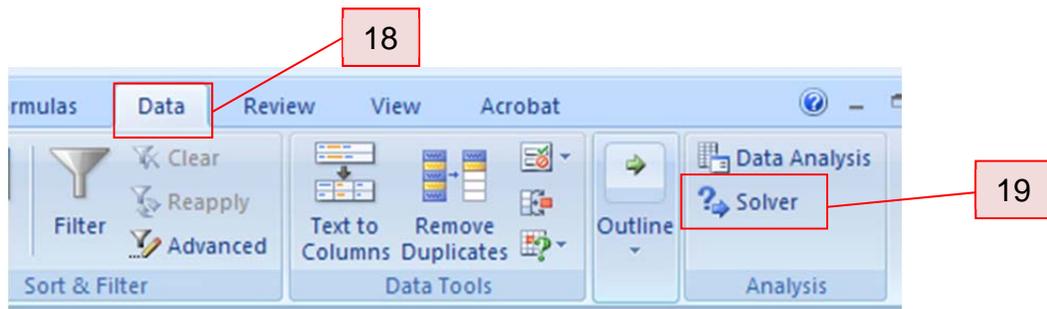
| | A | B | C | D | E | F | G |
|----|---------------------------------|----|-----|-----|----|-----|-------|
| 1 | Frame Bags and Pannier Example | | | | | | |
| 2 | | | | | | | |
| 3 | | x | y | LHS | | RHS | Slack |
| 4 | Profit | 70 | 120 | 0 | | | |
| 5 | Capacity Constraint | 1 | 1 | 0 | <= | 35 | 35 |
| 6 | Cutting Constraint | 1 | 3 | 0 | <= | 75 | 75 |
| 7 | Assembly & Finishing Constraint | 2 | 1 | 0 | <= | 60 | 60 |
| 8 | | | | | | | |
| 9 | Solution Values | 0 | 0 | | | | |
| 10 | | | | | | | |

17. To test whether the cell entries are correct, let's try some different values in the changing cells B9 and C9. Change both of these values to 1 and observe the values in the target cell D4, the left hand side values of the constraints in cells D5 through D7, and slack in G5 through G7. The values in those cells should match those shown below.

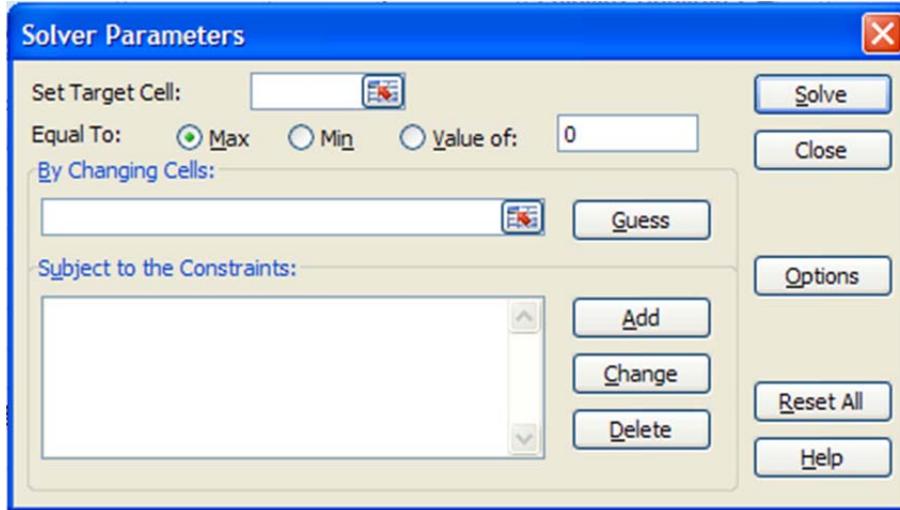
| | A | B | C | D | E | F | G |
|----|--|----------|----------|------------|----|------------|--------------|
| 1 | Frame Bags and Pannier Example | | | | | | |
| 2 | | | | | | | |
| 3 | | x | y | LHS | | RHS | Slack |
| 4 | Profit | 70 | 120 | 190 | | | |
| 5 | Capacity Constraint | 1 | 1 | 2 | <= | 35 | 33 |
| 6 | Cutting Constraint | 1 | 3 | 4 | <= | 75 | 71 |
| 7 | Assembly & Finishing Constraint | 2 | 1 | 3 | <= | 60 | 57 |
| 8 | | | | | | | |
| 9 | Solution Values | 1 | 1 | | | 17 | |
| 10 | | | | | | | |

If any of the cells do not show the correct values, examine the contents of that cell and make changes to correct the entry or formula in the cell. Once the worksheet is calculating the proper values when the changing cells are varied, we can use the Solver Add-In to solve the linear programming problem.

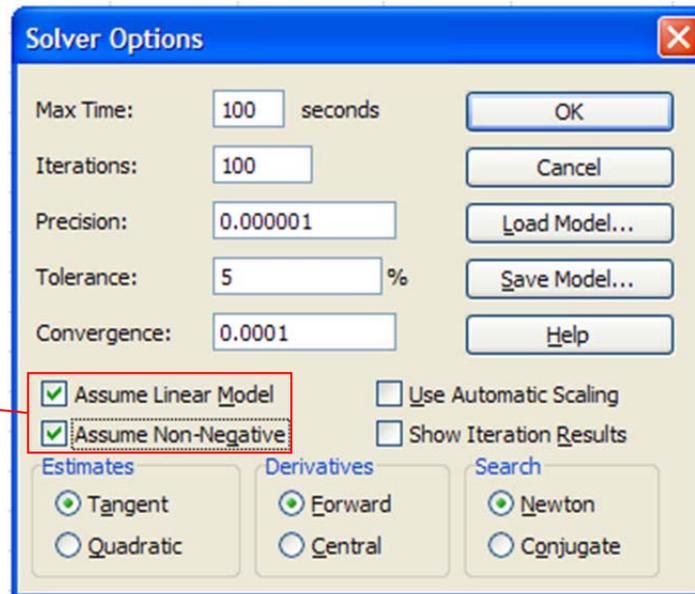
18. Click on the Data tab along the top of the Excel window.
 19. In the Analysis panel, click in the Solver button.



The Solver Tool will open.



20. Before we can enter any values into the Solver Parameters box, we need to set some options. Click on the Options button.



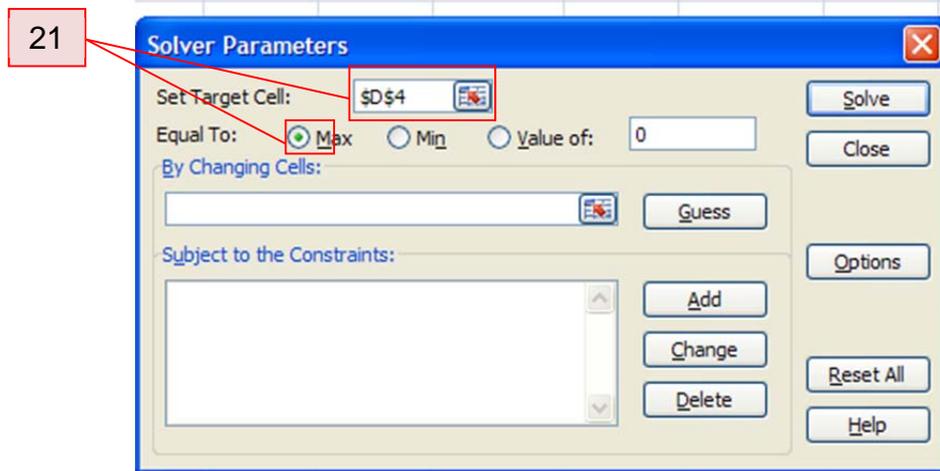
20

Use the cursor to check the boxes, “Assume Linear Model” and “Assume Non-Negative”. Click OK to return to the Solver Parameters box.

21. Make sure the cursor is positioned in the box next to the “Set Target Cell:”. Now click your mouse in cell D4. The absolute reference \$D\$4 will be placed in the box. This cell contains the value of the objective function evaluated at the

solution values. Make sure Max is checked since we are maximizing the objective function.

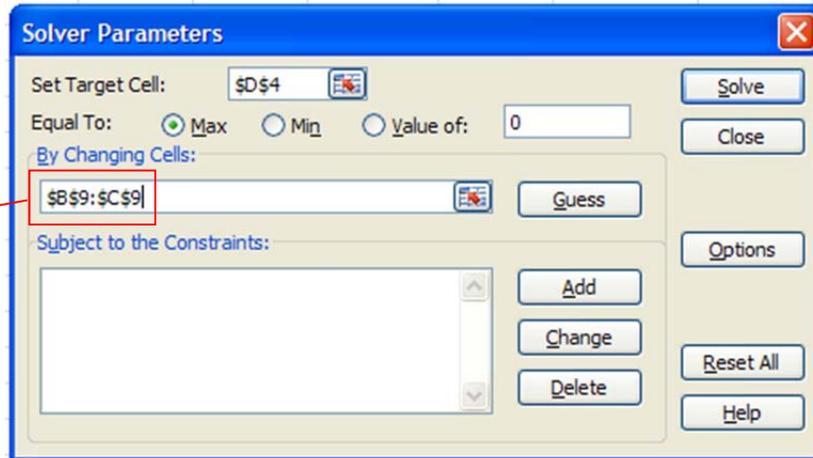
| | B | C | D | E | F | G |
|------------|----|-----|-----|----|-----|-------|
| Example | | | | | | |
| | x | y | LHS | | RHS | Slack |
| | 70 | 120 | 190 | | | |
| | 1 | 1 | 2 | <= | 35 | 33 |
| | 1 | 3 | 4 | <= | 75 | 71 |
| Constraint | 2 | 1 | 3 | <= | 60 | 57 |
| | 1 | 1 | | | | |



- Position the cursor in the box below "By Changing Cells:". Click and hold the left mouse button in cell B9. Drag the cursor to cell C9. This selects the two cells containing the guess for the solution values. The absolute references for the cells are placed into the Changing Cells box.

| | B | C | D | E | F | G |
|------------|----|-----|-----|----|-----|-------|
| Example | | | | | | |
| | x | y | LHS | | RHS | Slack |
| | 70 | 120 | 190 | | | |
| | 1 | 1 | 2 | <= | 35 | 33 |
| | 1 | 3 | 4 | <= | 75 | 71 |
| Constraint | 2 | 1 | 3 | <= | 60 | 57 |
| | 1 | 1 | | | | |

22



23. To enter the constraints into the Solver, click on the Add button under the “Subject to the Constraints” heading. The Add Constraint box will open and allow you to enter the left hand side, inequality, and right hand of the first constraint.

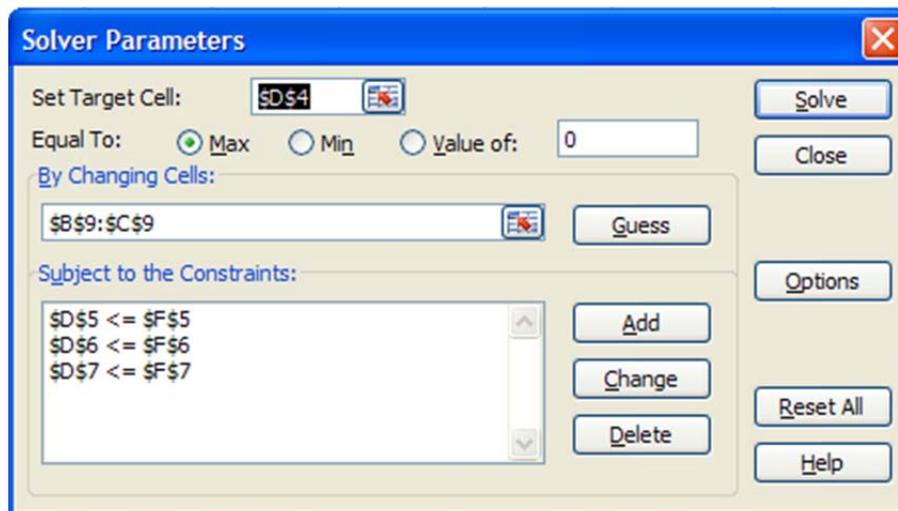


24. Position the cursor in the box under “Cell Reference”. Click on the cell containing the left hand side of the capacity constraint, D5. Next position the cursor in the box under “Constraints”. Click on the cell containing the right hand side of the capacity constraint, F5.



Click the Add button.

- Repeat step 24 for the other two constraints and the corresponding cells for the left and right hand sides. It is not necessary to enter the nonnegativity constraints. Once the constraints have been entered, click on the OK button in the Add Constraints box. You'll return to the Solve Parameters box seen below.



At this point the linear programming problem has been entered into the Solver, and we are ready for Excel to solve it.

26. Click on the Solve button. The values in the cell are changed to correspond to the solution of the linear programming problem. According to Excel, the solution is $(x, y) = (15, 20)$. Notice that in the first two constraints, the left and right hand sides appear to be equal. But the slack is not equal to zero as it should. This is a rounding issue due to the nature of the algorithm used to solve the problem and is nothing to be concerned about. If we were to start with a different initial guess like $(0, 0)$, the slack for each of the first two constraints would be 0.

| | x | y | LHS | | RHS | Slack |
|----|---------------------------------|----|-----|------|-----|-------------|
| 3 | | | | | | |
| 4 | Profit | 70 | 120 | 3450 | | |
| 5 | Capacity Constraint | 1 | 1 | 35 | <= | 35 -7.7E-11 |
| 6 | Cutting Constraint | 1 | 3 | 75 | <= | 75 3.28E-12 |
| 7 | Assembly & Finishing Constraint | 2 | 1 | 50 | <= | 60 10 |
| 8 | | | | | | |
| 9 | Solution Values | 15 | 20 | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| 13 | | | | | | |
| 14 | | | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |
| 18 | | | | | | |
| 19 | | | | | | |

27. Highlight the Answer and Sensitivity Reports, and click on the OK button. Two new sheets will be created in your Excel workspace, Answer Report, and Sensitivity Report. You can click on the tab for either of these reports at the bottom of the Excel window to view them.