

# Using Excel to solve linear programming problems

Technology can be used to solve a system of equations once the constraints and objective function have been defined. Excel has an add-in called the Solver which can be used to solve systems of equations or inequalities.

Consider this problem:

**Example:** A corporation plans on building a maximum of 11 new stores in a large city. They will build these stores in one of three sizes for each location – a convenience store (open 24 hours), standard store, and an expanded-services store. The convenience store requires \$4.125 million to build and 30 employees to operate. The standard store requires \$8.25 million to build and 15 employees to operate. The expanded-services store requires \$12.375 million to build and 45 employees to operate. The corporation can dedicate \$82.5 million in construction capital, and 300 employees to staff the stores. On the average, the convenience store nets \$1.2 million annually, the standard store nets \$2 million annually, and the expanded-services store nets \$2.6 million annually. How many of each should they build to maximize revenue?

Assign the variables:

$x_1$  = number of convenience stores

$x_2$  = number of standard stores

$x_3$  = number of expanded services stores

Write the constraints:

a.  $x_1 + x_2 + x_3 \leq 11$

b.  $4.125x_1 + 8.25x_2 + 12.375x_3 \leq 82.5$

c.  $30x_1 + 15x_2 + 45x_3 \leq 300$

$x_1 \geq 0, x_2 \geq 0, \text{ and } x_3 \geq 0$

Write the objective function:  $N(x_1, x_2, x_3) = 1.2x_1 + 2x_2 + 2.6x_3$   
(in millions)

We first need to open Excel and enter the data.

There are two methods – one uses tables within the worksheet while the other uses only the constraints. **The second method is preferred when we know the constraints since it is much faster!!!**

## Method One: Using Tables

Type in variable assignments at the top of the spreadsheet.

Assign decision variable cells.

Decision variable cells:  
D6, F6, and H6

Construct table from data in problem. How you set up the table is a matter of personal preference.

Not in table: the constraint which shows the sum is less than or equal to eleven.

	A	B	C	D	E	F	G	H	I
1									
2				x1 = no. convenience stores					
3				x2 = no. standard stores					
4				x3 = no. expanded-services stores					
5									
6				x1 =		x2 =		x3 =	
7									
8			Conven.	Stand.	Exp-Serv.		Limit		
9		Construct.	4.125	8.25	12.375		82.5		
10		Staffing	30	15	45		300		
11									
12		Revenue	1.2	2	2.6				
13									
14		Constraints							
15					0 <=		11		
16					0 <=		82.5		
17					0 <=		300		
18									
19		Maximize			0				
20									

Formulas in cells:

	Cell	Formula
constraint a	D15	= D6 + F6 + H6
constraint b	D16	= 4.125*D6 + 8.25*F6 + 12.375*H6
constraint c	D17	=30* D6 + 15*F6 + 45*H6
Maximize	D19	=1.2* D6 + 2*F6 + 2.6*H6

Now that the table is set up, we can access the solver. Click on Tools. If you do not see Solver then click on Add-Ins and select Solver. Now click on Tools again and select Solver.

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L
1												
2				x1 = no. convenience stores								
3				x2 = no. standard stores								
4				x3 = no. expanded-services stores								
5												
6				x1 =		x2 =		x3 =				
7												
8				Conven.	Stand.	Exp-Serv.		Limit				
9		Construct.	4.125	8.25	12.375			82.5				
10		Staffing	30	15	45			300				
11												
12		Revenue	1.2	2	2.6							
13												
14		Constraints										
15						0 <=		11				
16						0 <=		82.5				
17						0 <=		300				
18												
19		Maximize										
20												
21												

The Solver Parameters dialog box is open, showing:

- Set Target Cell: \$D\$19
- Equal To:  Max  Min  Value of: 0
- By Changing Variable Cells: \$D\$6:\$F\$6
- Subject to the Constraints:
  - \$D\$15 <= 11
  - \$D\$16 <= 82.5
  - \$D\$17 <= 300

**Target cell:** Maximize cell. To enter it, just click on that cell.

**Equal to Max**

**Changing Cells:** Decision variable cells D6, F6, H6.

**Subject to the constraints:** Click on Add. Click on Cell Reference and then click in D15, then click on Constraint and then click in F15. Be sure the test listed between them is <=.

Now click on **Options**

Make sure **Assume Linear Model** and **Assume Non-Negative** boxes are checked, then click OK.

Back at the Solver, click **Solve**. It should yield the solution. Click on Keep solution.

The Solver Options dialog box shows the following settings:

- Max Time: 100 seconds
- Iterations: 100
- Precision: 0.000001
- Tolerance: 5 %
- Convergence: 0.0001
- Assume Linear Model
- Use Automatic Scaling
- Assume Non-Negative
- Show Iteration Results
- Estimates:  Tangent  Quadratic
- Derivatives:  Forward  Central
- Search:  Newton  Conjugate

The solutions are as shown:  
 two convenience stores  
 nine standard stores,  
 and  
 no expanded-services  
 stores.

	A	B	C	D	E	F	G	H
1								
2			x1 = no. convenience stores					
3			x2 = no. standard stores					
4			x3 = no. expanded-services stores					
5								
6			x1 =	2	x2 =	9	x3 =	0
7								
8			Conven.	Stand.	Exp-Serv.		Limit	
9		Construct.	4.125	8.25	12.375		82.5	
10		Staffing	30	15	45		300	
11								
12		Revenue	1.2	2	2.6			
13								
14		Constraints						
15					11 <=		11	
16					82.5 <=		82.5	
17					195 <=		300	
18								
19		Maximize		20.4				
20								

Method Two: Using Constraints

Using a table to set up the problem makes the organization of data organized, but it has one problem. All of this is time consuming! We can get the same results by just typing in the constraints! The alternate format looks like this...

	A	B	C	D	E	F	G	H	I
1									
2			x1 = no. convenience stores						
3			x2 = no. standard stores						
4			x3 = no. expanded-services stores						
5									
6			x1 =		x2 =		x3 =		
7									
8			Constraints:						
9			x1 + x2 + x3 <=	11		0 <=		11	
10			4.125*x1 + 8.25*x2 + 12.375*x3 <=	82.5		0 <=		82.5	
11			30*x1 + 15*x2 + 45*x3 <=	300		0 <=		300	
12									
13			Maximize:	1.2*x1 + 2*x2 + 2.6*x3		0			
14									
15									
16									
17									
18									
19									
20									
21									

The first of the spreadsheet is done the same – typing in the variable assignments and assigning decision variable cells. Next, we type the constraints which will be used as a guide to type in the formulas in F9, F10, F11. They are the same formulas as in the earlier spreadsheet – with different cell references. Finally, we type in the maximize formula for reference and its formula in F13. We are now ready to access the Solver like we did before. We should get the same results...