15.053

Excel Solver

1

Table of Contents

Note that there is an Excel file that accompanies this tutorial; each worksheet tab in the Excel corresponds to each example problem

2

Introduction to Excel Solver (1 of 2)

- Excel has the capability to solve linear (and often nonlinear) programming problems with the **SOLVER** tool, which:
  - May be used to solve linear and nonlinear optimization problems
  - Allows integer or binary restrictions to be placed on decision variables
  - Can be used to solve problems with up to 200 decision variables

- SOLVER is an Add-In program that you will need to load in Excel
  - **Microsoft users**
    - 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”
      - If “Solver Add-in” is not listed in the “Add-Ins available” box, click “Browse” to locate it
      - If you get prompted that Solver is not currently installed, click Yes to install it
    - 4. After you load Solver, the Solver command is available in the “Analysis group” on the “Data” tab
  - **MAC users**
    - 1. Open Excel for Mac 2011 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. Restart Excel for Mac 2011 (fully quit the program), select the “Data” tab, then select “Solver” to launch

3

Introduction to Excel Solver (2 of 2)

- There are 4 steps on how to use SOLVER to solve an LP
  - The key to solving an LP on a spreadsheet is:
    - Set up a spreadsheet that tracks everything of interest (e.g. costs, profits, resource usage)

    1 Identify the cell that contains the value of your objective function as the ***Target Cell***

    2 Identify the decision variables that can be varied, called ***Changing (Variable) Cells***

    3 Identify the constraints and enter them into the program to tell **SOLVER** how to solve the problem
  - At this point, the optimal solution to our problem will be placed on the spreadsheet, with its value in the target cell

4

Example 1

Diet Problem: Set-Up (1 of 7)

Problem Statement

- Consider the problem of diet optimization based on cost and different nutritional factors
- There are four different types of food: Brownies, Ice Cream, Cola, and Cheese Cake, with nutrition values and cost per unit as follows:

	Brownies	Ice Cream	Cola	Cheese Cake
Calories	400	200	150	500
Chocolate	3	2	0	0
Sugar	2	2	4	4
Fat	2	4	1	5
Cost	$0.50	$0.20	$0.30	$0.80

Task:

- Find a minimum-cost diet that contains
  - at least 500 calories
  - at least 6 grams of chocolate
  - at least 10 grams of sugar
  - at least 8 grams of fat.

5

Example 1

Diet Problem: Set-Up (2 of 7)

- First, we must format our spreadsheet correctly to be entered into SOLVER
- Identify the decision variables (changing cells)
  - To begin we enter heading for each type of food in B2:E2
  - In the range B3:E3, we input random trial values for the amount of each food eaten (any values will work, but at least one should be positive)
  - In the example shown below, we indicate that we are considering eating 3 brownies, 0 scoops of chocolate ice cream, 1 bottle of cola, and 7 pieces of pineapple cheesecake:

	A	B	C	D	E
1	**DECISION VARIABLES**				
2		Brownies	Ice Cream	Cola	Cheese Cake
3	Eaten	3	0	1	7

6

Example 1

Diet Problem: Set-Up (3 of 7)

- Write and enter objective function (target cell)
  - To see if the diet is optimal, we must determine its cost as well as the calories, chocolate, sugar, and fat it provides
  - In the range B7:E7 we reference the number of units, and in B8:E8 we input the per-unit cost for each available food
    - We compute the cost of the diet in cell B10 with the formula
      = B7*B8 + C7*C8 + D7*D8 + E7*E8
      …But it is usually easier to enter the formula
      = SUMPRODUCT (B7:E7, B8:E8)
      …And this is much easier to understand for anyone reading the spreadsheet
  - The ***=SUMPRODUCT*** function requires two ranges as inputs
    - The first cell in range 1 is multiplied by the first cell in range 2, then the second cell in range 1 is multiplied by the second cell in range 2, and so on
    - All of these products are then added
    - Thus, in cell B10 the "=SUMPRODUCT" function computes total cost as
      3*50 + 0*20 + 1*30 + 7*80 = 740 cents.

7

Example 1

Diet Problem: Set-Up (4 of 7)

- Now, the spreadsheet should look like:

	A	B	C	D	E
1	**DECISION VARIABLES**				
2		Brownies	Ice Cream	Cola	Cheese Cake
3	Eaten	3	0	1	7
4					
5	**OBJECTIVE FUNCTION**				
6		Brownies	Ice Cream	Cola	Cheese Cake
7	Eaten	=B3	=C3	=D3	=E3
8	Cost	50	20	30	80
9					
10	Total	740	= SUMPRODUCT (B7:E7, B8:E8)		

8

Example 1

Diet Problem: Set-Up (5 of 7)

- Finally, we must set up the given problem constraints (for calories, chocolate, sugar, and fat)
  - To begin, we recreate the table in Excel that defines how many calories and units of chocolate, sugar, and fat are in each type of dessert
    - We can use this information to calculate total amounts based on the quantities of different decision variables
  - Next, take the =SUMPRODUCT of the number of items with the calories in each to calculate total calories in our dessert selection
    = SUMPRODUCT (B7:E7, B14:E14)
  - Finally, indicate the limitations highlighted in the problem
    - Add a >= or <= to identify maximum versus minimum constraints in Column G, and use Column H to indicate those limits:

9

Example 1

Diet Problem: Set-Up (6 of 7)

- The formulas will look like:

	A	B	C	D	E	F	G	H
13		Brownies	Ice Cream	Cola	Cheese Cake	Totals		Required
14	Calories	400	200	150	500	=SUMPRODUCT($B$7:$E$7,B14:E14)	>=	500
15	Chocolate	3	2	0	0	=SUMPRODUCT($B$7:$E$7,B15:E15)	>=	6
16	Sugar	2	2	4	4	=SUMPRODUCT($B$7:$E$7,B16:E16)	>=	10
17	Fat	2	4	1	5	=SUMPRODUCT($B$7:$E$7,B17:E17)	>=	8

- The constraint values that will show up on your screen look like:

	A	B	C	D	E	F	G	H
13		Brownies	Ice Cream	Cola	Cheese Cake	Totals		Required
14	Calories	400	200	150	500	4850	>=	500
15	Chocolate	3	2	0	0	9	>=	6
16	Sugar	2	2	4	4	38	>=	10
17	Fat	2	4	1	5	42	>=	8

10

Example 1

Diet Problem: Set-Up (7 of 7)

- The complete LP to be entered into SOLVER now looks like:

	A	B	C	D	E	F	G	H
1	**DECISION VARIABLES**							
2		Brownies	Ice Cream	Cola	Cheese Cake			
3	Eaten	3	0	1	7			
4								
5	**OBJECTIVE FUNCTION**							
6		Brownies	Ice Cream	Cola	Cheese Cake			
7	Eaten	3	0	1	7			
8	Cost	50	20	30	80			
9								
10	Total	740						
11								
12	**CONSTRAINTS**							
13		Brownies	Ice Cream	Cola	Cheese Cake	Totals		Required
14	Calories	400	200	150	500	4850	>=	500
15	Chocolate	3	2	0	0	9	>=	6
16	Sugar	2	2	4	4	38	>=	10
17	Fat	2	4	1	5	42	>=	8

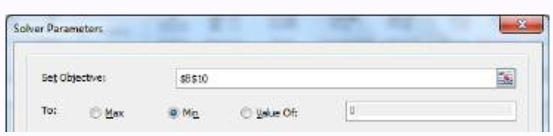
11

Example 1

Diet Problem: Dialog Box (1 of 6)

- Now, we need to enter the LP into SOLVER (click on "Data" > "Solver" to get this box)
- We need to fill in each of the components of the Parameters Dialog Box

1. Identify the cell that contains the value of your objective function as the ***Target Cell***
   - Fill in the **"**Set Objective" box by clicking on the cell in our spreadsheet that calculates our objective function (in this case, B10)
   - Use the buttons to identify the type of problem we are solving; a "Max" or "Min" (here we want to minimize total cost, so select "Min")



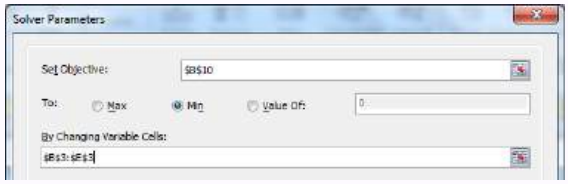
12

Example 1

Diet Problem: Dialog Box (2 of 6)

2 Identify the decision variables that can be varied, called “Changing Cells” or “Variable Cells”

- Click into the “By Changing Variable Cells” box
- Select the decision variable cells of our LP (which are B3:E3)



- SOLVER now knows that it can change the number of brownies, scoops of ice cream, sodas, and pieces of cheese cake to reach an optimal solution

13

Example 1

Diet Problem: Dialog Box (3 of 6)

3 Identify the constraints and enter them into the program

- Click on the “Add a constraint” button, and a box will appear that allows us to add our constraints
- We can use the “Cell Reference” box to input the totals for each constraint that we calculated
  - Using Calories as an example, we would click on Cell F14, which computed the total calories from all our desserts
- There are several options for constraint type: <=, >=, =, int (integer), bin (binary), or dif (all different)
  - After adjusting the constraint type to be greater than or equal to (>=), click on the cell referencing the minimum quantity permitted (Cell H14)
  - *Note:* Instead of a reference, we can also enter a specific number
  - The complete constraint looks as follows:

14

Example 1

Diet Problem: Dialog Box (4 of 6)

- The “Add” button will allow us to include all the other constraints to SOLVER.
  - Instead of entering each constraint individually, you can add them all at once
  - In the “Cell Reference” box and “Constraint” box, you can also specify an array of cell references; if both the Cell Reference and Constraint are specified using an array of cell references, the length of the arrays must match and Solver treats this constraint as *n* individual constraints, where *n* is the length of each array
- We have now created four constraints
  - SOLVER will ensure that the changing cells are chosen so F14>=H14, F15>=H15, F16>=H16, and F17>=H17
- The “Change” button allows you to modify a constraint already entered and “Delete” allows you to delete a previously entered constraint

15

Example 1

Diet Problem: Dialog Box (5 of 6)

- The final SOLVER Parameters Dialog Box:
  - *Note:* the checked box titled “Make Unconstrained Variables Non-Negative” allows us to capture non-negativity constraints (all variables will be constrained to be >= 0)
  - Additionally, you should change the “Select a Solving Method” to “SIMPLEX LP” when you are solving a linear program
- Finally, click “Solve” for your solution
  - The Parameters Dialog Box will close and decision variables will change to the optimal solution:

	A	B	C	D	E	F	G	H
1	DECISION VARIABLES							
2		Brownies	Ice Cream	Cola	Cheese Cake			
3	Eaten	0	3	1	0			
4								
5	OBJECTIVE FUNCTION							
6		Brownies	Ice Cream	Cola	Cheese Cake			
7	Eaten	0	3	1	0			
8	Cost	50	20	30	80			
9								
10	Total	90						
11								
12	CONSTRAINTS							
13		Brownies	Ice Cream	Cola	Cheese Cake	Totals		Required
14	Calories	400	200	150	500	750	>=	500
15	Chocolate	3	2	0	0	6	>=	6
16	Sugar	2	2	4	4	10	>=	10
17	Fat	2	4	1	5	13	>=	8

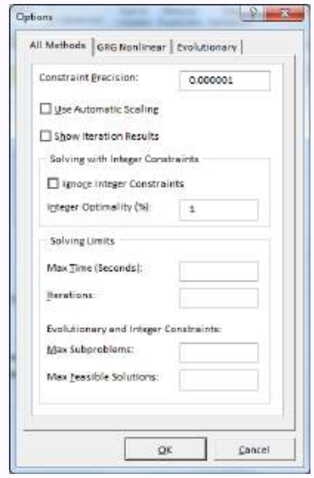
Note: because we referenced these cells in all our calculations, the objective function and constraints will also change

16

Example 1

Diet Problem: Dialog Box (6 of 6)

- The Parameters Dialog Box also has a number of options on how to calculate solutions
  - ***Constraint Precision*** is the degree of accuracy of the Solver algorithm (for example, how close does the value of the LHS of a constraint have to be before it is considered equal to the RHS)
  - ***Max Time*** allows you to set the number of seconds before Solver will stop
  - ***Iterations***, similar to Max Time, allows you to specify the maximum number of steps of the Solver algorithm takes before stopping
  - If you want to learn about other options in SOLVER, please reference the SOLVER website:
    - **www.solver.com**



17

Example 2

Food Start-Up Problem (1 of 2)

Problem Statement:

- You create a start-up company that caters food directly to customers. You want to allocate production capabilities to devise a feasible daily production plan that maximizes your profit
  - There are three kinds of food that you order at this early stage of the company: Hummus (H), a Moussaka (M), and a Tabouleh (T). Each meal has to be cooked, packaged and delivered; you estimate that total available cooking hours is 4, packaging hours 2, and delivery hours 2
  - **Hummus** for 10 portions requires 1 hour of time, packaging is done at the rate of 20 portions per hour, and delivery at the rate of 30 per hour; Ingredients for 1 portion cost $1, and each packaged portion can be sold for $7
  - In 1 hour, the food cooking team can prepare 5 portions of **Moussaka**, packaging is done at the rate of 15 per hour, and 15 portions can be delivered in 1 hour; Ingredients for 1 portion cost $2, and it can be sold for $12
  - Finally, **Tabouleh** can be prepared at the rate of 15 portions per hour, packaged at 25 portions per hour, and delivered at 30 per hour; one portion only costs $0.5 in raw ingredients, and can be sold for $5
  - Customers expressed interest in having the following products delivered every day: 20 Hummus meals, 10 Moussaka meals, and 30 Tabouleh meals

Task:

- Solve this in Excel on your own!

18

Example 2

Food Start-Up Problem (2 of 2)

- The solution to this problem is:

	A	B	C	D	F	G	H
1	**DECISION VARIABLES**						
2		Hummus	Moussaka	Tabouleh			
3	Orders	8	6	30			
4							
5	**COST AND/OR PROFIT DATA**						
6		Hummus	Moussaka	Tabouleh			
7	Orders	8	6	30			
8	Profit	6	10	4.5			
9	OBJECTIVE	FUNCTION					
10	Total	243					
11							
12	**CONSTRAINTS**						
13		Hummus	Moussaka	Tabouleh	Totals		Maximum
14	Cooking	0.100	0.200	0.067	4.000	<=	4
15	Packaging	0.050	0.067	0.040	2.000	<=	2
16	Delivery	0.033	0.067	0.033	1.667	<=	2
17	Demand H				8	<=	20
18	Demand M				6	<=	10
19	Demand T				30	<=	30

19