

## From Refrigerators to Fantasy Football Teams – Using Excel Solver

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### Introduction

The objective of this session is to introduce you to two of the advanced tools found in MS Excel. Most of you know spreadsheet basics but until you have taught an advanced Excel class you may not be aware of two of Excel's most powerful tools - Goal Seek and Solver. This session briefly introduces Goal Seek and concentrates on demonstrating Solver. Solver is used to arrive at a solution of a complicated problem.

Many problems can be solved using trial and error, multiple what-if-analyses, and/or one and two variable data tables. However, some problems are too complex to be solved using these techniques; we have to use stronger, more advanced techniques. Fortunately, Excel provides several tools that will solve complex, multi-variable problems. Today we will look at two built-in tools.

Let's assume that you are the owner of the Sumter Superstore. The appliance manufacturer is having a promotion that we want to take advantage of. We have 39 customer orders that we must fill, we have a budget of \$50,000 and only have 1300 cf of available storage space in our warehouse. Keeping in mind these limitations, we need to figure out how many appliances to order to arrive at our greatest profit.

### Sumter Superstore Orders

	<u>Refrigerators</u>	<u>Stoves</u>	<u>Microwaves</u>	<u>Limits</u>	
<b>Unit Wholesale Cost</b>	\$850	\$420	\$195	Budget	50000
<b>Unit Retail Price</b>	\$1,250	\$595	\$250	Storage Space	1300cf
<b>Profit per Unit</b>	\$400	\$175	\$55	<u>Cust. Orders</u>	
<b>Cubic feet per Unit</b>	25	18	3	6 refrigerators	
				14 stoves	
<b>Customer Orders</b>	6	14	19	19 microwaves	
<b>Quantity to Order</b>	6	14	19		
<b>Total Cost</b>	\$5,100	\$5,880	\$3,705	Find Most Profitable Mix	

## **Finding a Solution Using Goal Seek (GS)**

Usually, trial and error is done by changing input cells and examining the result. GS solves the problem the opposite way; when you use GS, you specify the result you want, and GS changes the value in an input cell to arrive at the result. For example, we could specify the net income we want and tell GS to change one of the inputs until it arrives at that goal. GS is used when you know what answer you want but you do not know the value to place in a cell that is involved in the formula. To invoke GS, from the Tools menu, select Goal Seek. The GS dialog box will then appear. In the Set cell: reference box, enter the address of the result cell we are interested in. In the To Value: box enter the figure you want. In the By Changing cell: box enter the cell address of the input cell you want to change. The limitation of GS is that it only allows you to change one input cell. After clicking OK, GS will report its success in the GS Status box.

One of the problems with GS is caused by the fact that GS does not differentiate between integers and real numbers (we wouldn't want to buy part of a refrigerator, for example). Once GS gives you an answer, you could manually change the answer to a whole number.

## **Finding a Solution Using Solver**

Our problem is to find the best solution – the one that yields the maximum net income. We could do several trials using Goal Seek, and see which one of them is better, but we can't be sure that we have found the best one. The only way to be absolutely sure that you have found the best solution using the trial-and-error method is to create all the solutions and then pick the best one. In the current problem, there are thousands of different combinations, certainly more than we want to run. Fortunately, Excel has an add-in program called Solver, a much more powerful alternative to GS.

### **Installing Solver**

First check the **Tools** menu to see if Solver is installed and activated on your computer. If it is, the word **Solver** will appear on the **Tools** menu. If Solver does not appear, it is either installed and not activated, or not installed. If it is installed, it can be activated by clicking **Add-Ins** on the **Tools** menu. This will bring up a list of the add-in programs available to activate. Solver can be found on the list, and its box checked, and **OK** chosen. If it is installed, this will activate it, and it is available for use. If it is not installed, a dialog box will appear that will walk you through the installation of Solver. The Microsoft Office CD is needed to complete the installation. Once Solver is installed, you will not need to install it again. It will be available on the Tools menu to use any time it is needed.

### **Introduction to Solver**

Solver's ability to maximize or minimize the results of a formula makes it a powerful tool. Complex business scenarios can be set up in a worksheet enabling you to use Solver to determine the optimal set of decisions to meet an objective, such as maximizing profits or minimizing expenses. Because Solver can answer very complex questions, it is an excellent tool for determining the best way to allocate resources, such as money, materials, or people.

Choosing **Solver** on the **Tools** menu brings up the Solver Parameters dialog box. Solver needs four types of information:

- (1) It needs the address of the target cell that you want to maximize, minimize, or set to a specific value.
- (2) It needs to know what you want to do with the target cell. (You have three choices – you can ask Solver to set the target cell's value to the greatest possible value, to the least possible value, or to a certain value which you enter.)
- (3) Which cells it can change to arrive at the desired result.
- (4) Constraints that limit how to solve the problem.

You will enter these values in the Solver Parameter dialog box. In our example, the target cell is the cell where the net income is, and we want Solver to find the maximum possible value. Changing cells (also called adjustable cells) are those cells that will be modified by Solver to solve the problem. The cells that Solver can change to solve the problem are the cells containing the count of each kind of appliance. The next step is to enter the requirements, or constraints. A constraint is sometimes (as in our problem) a limiting factor. Constraints are requirements that have been placed on certain values. The first requirement is that we order at least the number of appliances that customers already have ordered. We also are limited to a maximum order of \$50,000 and all the appliances cannot take up more than 1300 cubic feet in our warehouse. Using these parameters I will walk you through solving the problem. We will type the constraints in the Add Constraint dialog box like this: First, click on **Add** in the **Constraints** section of the Solver Parameters dialog box. This brings up the Add Constraint dialog box, which has three boxes to enter values in. The first box asks for references to the cells in question. The second box lets you choose from several comparison options. The third box asks you for the address of the constraining cells.

Once all the constraints are set up, the **Solve** button in the Solver Parameters dialog box can be clicked. In the status bar, Solver can be seen trying several different solutions. When Solver finds the optimal solution, it displays a Solver Results box, saying that it has found a solution.

### Creating a Solver Answer Report

Now that we have examined the optimal solution created by Solver, we can create a report that captures the important facts about the solution. Solver allows the capability to create an answer report. You create the answer report from the Solver Results window. Run Solver again. Click the **Solve** button and wait for the Solver Results window to appear. Check the Keep Solver Solution check box, and click on **Answer** in the Reports box. (Besides the Answer report, Solver also offers a Sensitivity report and a Limits report. Since these last two reports do not apply to problems where some cells are constrained to integer, we cannot create them for this problem.) Click **OK**. Solver creates the answer report and stores it in a separate worksheet called “Answer Report 1”. If you run Solver again, and create another answer report, it will be stored on a worksheet called “Answer Report 2”, and so on, for as many answer reports as you wish to create.

The answer report has four sections. Section one is the title section, containing identifying information. Section two is the Target Cell section. It shows the optimization goal (in this case, “Max”), the cell's address, the cell's name, the cell's value at the beginning of the Solver run, and the cell's value at the end of the run. The third section is the Adjustable Cells section, containing the same information (address, name, start value, ending value) about all of the changing cells.

The fourth section is the Constraints section. In addition to the cell address, name, and ending value for each of the constrained cells, there are three other columns. You include information about the constraining formula, the current status of the cell relative to the constraining formula, and the cell's slack. Each cell's status is either "Binding", which means it is at the constraint limit, or "Not Binding", which means the cell did not limit the solution. The slack (which is zero for all cells with binding status) shows the difference between the current value of the cell and the value at the constraint limit.

### **Saving and Loading Solver Models**

There may be times when you will want to save the parameters of a Solver model. To do so, return to the original worksheet. Solver will save the parameters in some cells on this worksheet. From the **Tools** menu, choose **Solver**. From the Solver Parameters dialog box, click the **Options** button, which will bring up the Solver Options dialog box. Click the **Save Model** button. In the Save Model dialog box, you will see the suggested addresses of the cells where Solver will save the parameters. Change these addresses (it is only necessary to give Solver the starting address) so that Solver will not write the parameters over sections of the worksheet that have data in them, and click **OK**. It is a good idea to label this model. Now you may go back to Solver and change the parameters (perhaps to minimize the inventory, or maximize the count of one particular model), and run Solver again. You can reload the saved parameters at any time, by clicking **Tools, Solver, Options, and Load Model**, then entering the address of the cells where the parameters are saved. Then, click **OK** as many times as necessary to return to the Solver Parameters dialog box. The Solver Parameters dialog box will display the saved parameters.

### **Understanding Solver**

Solver is designed to use an iterative process. That is, it starts with an initial solution, and then does the problem over and over, using different values in the changing variables. When a change to a variable results in a better solution, Solver makes another change to the same variable in the same direction. When a change results in a worse solution, Solver does not make any more changes to that variable in that direction. Solver continues to make changes and re-run the problem, until it arrives at a solution that is not significantly better than the previous one. At that point, Solver reports success. Solver uses a technique called linear programming to solve problems. (Linear programming is a complex mathematical process used to solve problems that include multiple variables and the minimizing or maximizing result values).

The Solver Options dialog box has the following choice boxes, where you can control the way Solver runs: (1) Max Time – Solver will stop when it has been looking for a solution for this much time. If it has not yet found a solution, it will give you the option of stopping without an optimal solution or continuing for another time set. (2) Iterations – Solver will stop when it has done the problem this many times, even though it may not have arrived at a solution. Again, it will give you the option to stop or continue. (3) Precision – Solver continues to work until the constraints are satisfied within this precision. (4) Tolerance – similar to Precision, but for integer constraints. Solver stops when the answer is within this per cent of the constraint value. (5) Convergence – Solver uses this to determine when a solution is "significantly better" than the previous one. If the change in the two solutions is less than or equal to this value, Solver will stop and declare that it has found a solution. (6) Assume Linear Model – if you know your problem can be solved with linear functions, you can speed up Solver by checking this box. A linear

function is a function that can be written as the sum of a series of variables, where each variable is multiplied by some constant. A non-linear function involves using some mathematical operation other than summation. Solver sometimes has problems arriving at a solution to non-linear problems, simply because in a non-linear problem, there may be many avenues that Solver could travel to find solutions, and it is not always possible to determine which of these directions is best. The rest of the choice boxes in the Solver Options dialog box have to do with helping Solver solve non-linear problems. These options are for the advanced user.

Knowing about these options sometimes allows us to reduce the time and effort Solver uses to solve a problem. For example, as was previously stated, checking the Assume Linear Model box will greatly speed up Solver. You can also reduce the time and iteration count, and raise the precision, tolerance and convergence levels. You can do any or all of these things to help Solver arrive at a solution, thus fitting Solver to the data of your problem, thereby making it more efficient. Most problems are solved without these advanced settings.

I plan to conclude the demonstration by using solver to pick your winning fantasy football team. This will enable to win the office pool. Isn't ASCUE wonderful?

## Summary

GS allows you to change only one cell while trial and error requires too much time to solve complex problems. Because GS is limited to one input and one output, you learned how to use Solver to manage multiple inputs to maximize the value in a target cell (goal). Solver allows you to solve complex problems where a number of variables can be changed in a worksheet in order to meet a goal in a particular cell. Because Solver changes the values in up to 200 cells to arrive at the desired value in the target cell, it is an indispensable tool for optimization problems in which you must determine the best way to arrive at a goal.

Solver is a very useful tool. Like anything complex, practice is the key.

## References

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