

Excel Solver Function



- ◆ What is the Excel Solver good for?
- ◆ What must I do to use a solver?
- ◆ How do I define a model?
- ◆ What kind of solution can I expect?
- ◆ What makes a model hard to solve?
- ◆ Can you show me step by step?

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What is the Excel Solver good for?

- ◆ Solvers, or optimizers, are software tools that help users find the best way to allocate scarce resources.
- ◆ The resources may be raw materials, machine time or people time, money, or anything else in limited supply.
- ◆ The "best" or optimal solution may mean maximizing profits, minimizing costs, or achieving the best possible quality.

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What must I do to use a solver?

- ◆ To use a solver, you must build a model that specifies:
 - ◆ The resources to be used, using **decision variables**
 - ◆ The limits on resource usage, called **constraints**, and
 - ◆ The measure to optimize, called the **objective**.
- ◆ The solver will find values for the decision variables that satisfy the constraints while optimizing (maximizing or minimizing) the objective.

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What must I do to use a solver?

- ◆ Spreadsheets such as Excel provide a convenient way to build a model
- ◆ Anyone who has used a spreadsheet is already familiar with the process:
 - ◆ Cells on a worksheet can hold numbers, labels, or formulas that calculate new values -- such as the **objective** of an optimization
 - ◆ **Constraints** are simply limits (specified with $\leq$, $=$ or $\geq$ relations) on formula cells
 - ◆ And the **decision variables** are simply input cells containing numbers

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How do I define a model? **Decision Variables**

- ◆ A solver deals with numbers, so you'll need to quantify the various elements of your model: **decision variables**, **constraints**, and the **objective** -- and their relationships
- ◆ **Decision variables** usually measure the amounts of resources, such as time and money, to be allocated to some purpose, or the level of some activity
- ◆ For example, the number of products to be manufactured, the number of pounds or gallons of a chemical required for some process, etc.

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How do I define a model? **Decision Variables**

- ◆ For example, if you are shipping goods from 3 different plants to 5 different warehouses, there are $3 \times 5 = 15$ different routes along which products could be shipped
- ◆ So, you might have 15 variables, each one measuring the number of products shipped along that route

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How do I define a model? **Decision Variables**

- ◆ In addition, you might also have 4 different product types, and you might want to plan shipments in each of the next 6 months
- ◆ So this might lead to $15 \times 4 \times 6 = 360$ variables
- ◆ This illustrates how a model can become large rather quickly!
- ◆ Part of the art of modeling is deciding how much detail is really required

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How do I define a model? **Objective**

- ◆ Once you've defined the **decision variables**, the next step is to define the **objective**, which is a function that depends on the variables
- ◆ For example, suppose you were planning how many units to manufacture of three products:

TV sets, stereos, and speaker

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How do I define a model? **Objective**

- ◆ Your objective might be to maximize profit
- ◆ Assume that: each TV set yields a profit of \$75, each stereo \$50, and each speaker \$35
- ◆ Then your objective function might be:

$$75 \times \text{TV sets} + 50 \times \text{stereos} + 35 \times \text{speakers}$$

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How do I define a model? **Objective**

- ◆ On a spreadsheet where the number of TV sets, stereos and speakers are in cells D9, E9 and F9 respectively, the formula would be:

$$= 75 \times D9 + 50 \times E9 + 35 \times F9$$

- ◆ You'd be finished at this point, if the model did not require any **constraints**

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How do I define a model? **Constraints**

- ◆ In most models **constraints** play a key role in determining what values can be assumed by the decision variables
- ◆ **Constraints** reflect real-world limits on variables
- ◆ To define a **constraint**, you first compute a value based on the decision variables
- ◆ Then you place a limit ($\leq$, $=$ or $\geq$) on this computed value

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How do I define a model? **Constraints**

General Constraints

- ◆ For example, the cell range A1:A5 contains the percentage of funds to be used to purchase 5 different types of material
- ◆ You could use cell B1 to calculate $=\text{SUM}(A1:A5)$
- ◆ Then define a **constraint** of $B1 = 1$ so that the percentages allocated must sum up to 100%.

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How do I define a model? **Constraints**

Bounds on Variables

- ◆ Of course, you can also place a limit directly on a decision variable, such as $A1 \leq 100$
- ◆ Upper and lower bounds on the variables are efficiently handled by most optimizers and are very useful in many problems.

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How do I define a model? **Constraints**

Physical Constraints

- ◆ Many **constraints** are determined by the physical nature of the problem.
- ◆ For example, if your **decision variables** measure the physical dimensions of an object, negative values for these variables would make no sense.

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How do I define a model? **Constraints**

Physical Constraints

- ◆ This type of non-negativity constraint is very common
- ◆ **Constraints** such as $A1 \geq 0$ must be stated explicitly, because the solver has no other way to know that negative values are disallowed

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How do I define a model? **Constraints**

Integer Constraints

- ◆ Advanced optimization software also allows you to specify **constraints** that require **decision variables** to assume only integer (whole number) values at the solution
- ◆ If you are scheduling a fleet of trucks, for example, a solution that called for a fraction of a truck to travel a certain route would not be useful.
- ◆ Integer **constraints** normally can be applied only to **decision variables**, not to quantities calculated from them.

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What kind of solution can I expect?

- ◆ A solution (set of values for the **decision variables**) for which all of the **constraints** in the Solver model are satisfied is called a **feasible solution**
- ◆ Most solution algorithms first try to find a feasible solution, and then try to improve it by finding another feasible solution that increases the value of the objective function (when maximizing, or decreases it when minimizing)
- ◆ An **optimal solution** is a feasible solution where the objective function reaches a maximum (or minimum) value

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What kind of solution can I expect?

- ◆ A **globally optimal solution** is one where there are no other feasible solutions with better objective function values
- ◆ A **locally optimal solution** is one where there are no other feasible solutions "in the vicinity" with better objective function values
- ◆ The Solver is designed to find **optimal solutions** -- ideally the global optimum -- but this is not always possible

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What makes a model hard to solve?

- ◆ Three major factors interact to determine how difficult it will be to find an optimal solution to a solver model:
 - ◆ The mathematical relationships between the **objective** and **constraints**, and the **decision variables**
 - ◆ The size of the model (number of **decision variables** and **constraints**)
 - ◆ The use of integer variables - memory and solution time may rise exponentially as you add more integer variables

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Can you show me step by step?

Consider the following problem:

- ◆ Imagine that you are managing a factory that is building three products: TV sets, stereos and speakers
- ◆ Each product is assembled from parts in inventory, and there are five types of parts: chassis, displays, speaker cones, power supplies and electronics units
- ◆ Your goal is to produce the mix of products which will maximize profits, given the inventory of products on hand

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Can you show me step by step?

- ◆ From this description, we can see that:
 - ◆ The **decision variables** are the number of products to build
 - ◆ The **objective function** will be (gross) profit
- ◆ Assume that you can sell TV sets for a gross profit of \$75 each, stereos for a profit of \$50 each, and speaker cones for \$35 each

$$75 \times \text{TV sets} + 50 \times \text{stereos} + 35 \times \text{speakers}$$

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Can you show me step by step?

- ◆ To assemble a TV set, you need 1 chassis, 1 display, 2 speaker cones, 1 power supply and 2 sets of electronics
- ◆ To make a stereo, you need 1 chassis, 2 speaker cones, 1 power supply and 1 set of electronics
- ◆ To build a speaker, all you need is 1 speaker cone and 1 set of electronics
- ◆ The parts you have on hand are 450 chassis, 250 displays, 800 speaker cones, 450 power supplies and 600 sets of electronics

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Can you show me step by step?

- ◆ Before we implement this problem statement in either Excel, let's write out formulas corresponding to the verbal description above.
- ◆ If we temporarily use the symbols:
 - ◆ x for the number of TV sets assembled,
 - ◆ y for the number of stereos, and
 - ◆ z for the number of speakers,
- ◆ The total profit is:

$$\text{Maximize } 75x + 50y + 35z \text{ (Profit)}$$

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Can you show me step by step?

- ◆ Building each product requires a certain number of parts of each type.
- ◆ The number of parts used depends on the mix of products built (constraint left hand side), and the number of parts of each type on hand (constraint right hand side):

$$\begin{aligned} 1x + 1y + 0z &\leq 450 \text{ (Chassis)} \\ 1x + 0y + 0z &\leq 250 \text{ (Displays)} \\ 2x + 2y + 1z &\leq 800 \text{ (Speaker cones)} \\ 1x + 1y + 0z &\leq 450 \text{ (Power supplies)} \\ 2x + 1y + 1z &\leq 600 \text{ (Electronics)} \end{aligned}$$

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Can you show me step by step?

- The next step is to create a worksheet where the formulas for the **objective function** and the **constraints** are calculated
- In the worksheet on the next slide, we have reserved cells E4, F4, and G4 to hold our decision variables x, y and z: the number of TV sets, stereos and speakers to build

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Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	200	1	1	0
Displays	250	100	1	0	0
Speaker cone	800	500	2	2	1
Power supply	450	200	1	1	0
Electronics	600	400	2	1	1

Profits by product: \$ 75 \$ 60 \$ 35

Total Profit: \$ 15,000

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Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	200	1	1	0
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Power supply	450	200	1	1	0
Electronics	600	400	2	1	1

Profits by product: \$ 75 \$ 60 \$ 35

Total Profit: \$ 15,000

- The objective function is:
 $75x + 50y + 35z$
- The Excel formula is:
 $=E4*E14+F4*F14+G4*G14$

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Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	200	1	1	0
Displays	250	100	1	0	0
Speaker cone	800	500	2	2	1
Power supply	450	200	1	1	0
Electronics	600	400	2	1	1

Profits by product: \$ 75 \$ 60 \$ 35

Total Profit: \$ 15,000

- The Excel formula for the number of chassis used is:
 $=E7*E\$4+F7*F\$4+G7*G\$4$
- The Excel formula for the number of displays used is:
 $=E8*E\$4+F8*F\$4+G8*G\$4$
- The remaining "# Used" values are computed in similar ways

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Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	200	1	1	0
Displays	250	100	1	0	0
Speaker cone	800	500	2	2	1
Power supply	450	200	1	1	0
Electronics	600	400	2	1	1

Profits by product: \$ 75 \$ 60 \$ 35

Total Profit: \$ 15,000

- The constraints are:
- Number of TV sets, stereos, and speakers must be non-negative, or
 $E4:G4 \geq 0$
- Number of used parts must be less than inventory, or
 $D7:D11 \leq C7:C11$

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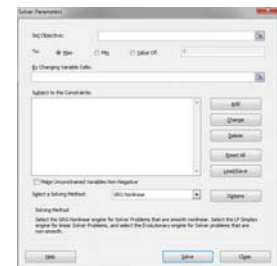
Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
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Speaker cone	800	500	2	2	1
Power supply	450	200	1	1	0
Electronics	600	400	2	1	1

Profits by product: \$ 75 \$ 60 \$ 35

Total Profit: \$ 15,000

- To run Solver, click on the **Data** tab, in the **Analysis** group, click **Solver**.



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Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	1	1	0	0
Displays	250	1	0	0	0
Speaker cone	800	2	2	1	0
Power supply	450	1	1	0	0
Electronics	600	2	1	1	1

Profits by product: \$ 75 \$ 55 \$ 35

Total Profit: \$ 10,500

- Set the target cell, or the value of the **objective function**, in this case, the Total Profit, cell E16

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Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	1	1	0	0
Displays	250	1	0	0	0
Speaker cone	800	2	2	1	0
Power supply	450	1	1	0	0
Electronics	600	2	1	1	1

Profits by product: \$ 75 \$ 55 \$ 35

Total Profit: \$ 10,500

- Set the "By Changing Variable Cells" or the value of the **decision variables**, in this case, the number of TVs, stereos, and speakers: E4:G4

Excel Solver Function



Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	1	1	0	0
Displays	250	1	0	0	0
Speaker cone	800	2	2	1	0
Power supply	450	1	1	0	0
Electronics	600	2	1	1	1

Profits by product: \$ 75 \$ 55 \$ 35

Total Profit: \$ 10,500

- Set the inventory constraint:
 $D7:D11 \leq C7:C11$

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Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	1	1	0	0
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Power supply	450	1	1	0	0
Electronics	600	2	1	1	1

Profits by product: \$ 75 \$ 55 \$ 35

Total Profit: \$ 10,500

- Set the inventory constraint:
 $D7:D11 \leq C7:C11$

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Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	1	1	0	0
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Power supply	450	1	1	0	0
Electronics	600	2	1	1	1

Profits by product: \$ 75 \$ 55 \$ 35

Total Profit: \$ 10,500

- Set the non-negative constraint:
 $E4:G4 \geq 0$

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Can you show me step by step?

Part Name	Inventory	# Used	TV sets	Stereo	Speakers
Chassis	450	1	1	0	0
Displays	250	1	0	0	0
Speaker cone	800	2	2	1	0
Power supply	450	1	1	0	0
Electronics	600	2	1	1	1

Profits by product: \$ 75 \$ 55 \$ 35

Total Profit: \$ 10,500

- Excel Solver is ready to run.
- Just click on **Solve**

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Can you show me step by step?

- You can select an Answer Report and Excel inserts a new sheet into the workbook

- When you click on **Solve** the results appear in the spreadsheet.



Excel Solver Function



Can you show me step by step?

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How do I define a model?

- See if you can use Solver to:

Maximize the Cost-Adjusted SWR for the reinforced concrete beam project

- What are the **decision variables**?
- What is the **objective function**?
- What are the **constraints**?

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Questions?

