Excel Solver Function

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.

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.

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 <=, = or >= relations) on formula cells
  - And the decision variables are simply input cells containing numbers

How do I define a model?
- 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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**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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**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 speakers

**Objective**
- Your objective might be to maximize profit.
- Assume that:
  - Each TV set yields a profit of $75$
  - Each stereo $50$
  - Each speaker $35$
- Then your objective function might be:
  $$75 \times \text{TV sets} + 50 \times \text{stereos} + 35 \times \text{speakers}$$

**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.

**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 <= 100.
- Upper and lower bounds on the variables are efficiently handled by most optimizers and are very useful in many problems.

**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.
- This type of non-negativity constraint is very common.
- Constraints such as A1 >= 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?** Constraints**

- 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.
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, picture tubes, 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.

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.

The parts you have on hand are 450 chassis, 250 picture tubes, 800 speaker cones, 450 power supplies and 600 sets of electronics.

To assemble a TV set, you need 1 chassis, 1 picture tube, 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 picture tubes, 800 speaker cones, 450 power supplies and 600 sets of electronics.

Before we implement this problem statement in either Excel, let’s write out formulas corresponding to the verbal description above.

- 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:

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

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.
The objective function is:

\[ 75x + 50y + 35z \]

The Excel formula is:

\[ =E4*E14+F4*F14+G4*G14 \]

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 picture tubes used is:

\[ =E8*$E$4+F8*$F$4+G8*$G$4 \]

The constraints are:

- Number of used parts must be less than inventory, or

\[ D7:D11 \leq C7:C11 \]

- Number of TV sets, stereos, and speakers must be non-negative, or

\[ E4:G4 \geq 0 \]

To run Solver click on the Tools menu and select Solver and the Solver dialog box will appear

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?

- Choose the "Set 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?

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

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Can you show me step by step?

- Set the inventory constraint: D7:D11 <= C7:C11

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Can you show me step by step?

- Set the non-negative constraint: E4:G4 >= 0

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Can you show me step by step?

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

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Can you show me step by step?

- When you click on Solve the following window appears
- You can select an Answer Report and Excel inserts a new sheet into the workbook
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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?