An Excel Modeling

Practice Problem

Svelte Glove

With Step-by-Step Instructions

DUKE
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Overview

Svelte Glove is a product mix problem. Build a worksheet to determine what mix of products yields the highest profit. A set of production constraints complicates the model. Build the model so it allows a manual determination of the product mix manually. Then apply Excel's Solver to automate the process.

Features

By completing a Svelte Glove model you'll get practice with:
- building a product-mix model in Excel
- creating formulas
- copying formulas
- using relative and absolute addressing
- using the IF function
- using Excel's Solver

The Svelte Glove Problem

The Svelte Glove Company manufactures and sells two products: work gloves and driving gloves. The company makes a profit of $12 for each pair of work gloves sold and a profit of $4 for each pair of driving gloves sold. The labor-hour requirements for the products in each of the three production departments is shown in the table below:

Labor-Hour Requirements		
Department	**Work Gloves**	**Driving Gloves**
Cutting	1	2
Sewing	1	3
Finishing	2	3

Each product must be processed by *each one* of the three departments before it's complete and ready for sale. Reading the table above, for example, each pair of driving gloves must spend two hours in the Cutting Department, three hours in the Sewing Department, and three hours in the Finishing Department before they're complete.

The supervisors of the three departments have estimated that the following numbers of labor hours will be available during the next month:

Cutting	800 hours
Sewing	1,600 hours
Finishing	2,000 hours

Outputs

Construct a spreadsheet model that:

1) Specifies the number of work gloves and driving gloves to manufacture in the next month.
2) Determines the total number of hours required in each of the three departments to produce these amounts.
3) Allows you to experiment with a variety of product mix scenarios.
4) Finds the product mix that yields maximum total profit while keeping within the constraints.

Approaching the Modeling Task

1. Identify the Purpose of the Model

    The purpose of this model is to maximize Svelte's total profit. We need to determine the most profitable mix of gloves to make.

2. Identify Given Values (Constants) or Relationships (Formulas)

    Known values

    Unit profit:

    Work Gloves - $12
    Driving Gloves - $4

    Labor requirements

    The labor hour requirements for each product in each of the three manufacturing departments are given in the table above.

    Data relationships

    No particular data relationships are stated in this problem.

3. Identify Any Model Constraints

    The hours available in each of the manufacturing departments are limited, as stated in the problem.

    Not stated (but important) is the fact that we can choose to manufacture zero of one product. Of course we can't manufacture less than zero of either product. (This will be significant when we ask Excel's Solver to maximize profit.)

4. Identify Decision Variables to Add to the Model

    Decision variables are the model inputs. The key decision variables here are:

    How many work gloves to make?
    How many driving gloves to make?

5. Consider the Formulas that will be Required
    Item profit:
    Profit/Unit X Number to Make (*for both types of gloves*)

    Total profit:
    Item Profit for work gloves + Item Profit for driving gloves

    Hours required for each product in each dept:
    Dept. Labor Hrs X Number to Make (*for both types of gloves in each of the three manufacturing departments*)

    Total hours required in each dept:
    Department work glove hours + department driving glove hours
        (*calculated for each of the three departments*)

    Constraint check:
    IF (Total Hrs Required <= Hrs Available, OK, NO) (*for each of the three manufacturing departments*)

Determining a Worksheet Layout
    There are a number of different ways to approach the layout of this worksheet. The more information you need to track, the more important it is to give a little thought to devising as simple and clear a layout as possible.

6. Documentation
    Put documentation at the top. Identifying information such as author and worksheet purpose is always useful.

7. Principal Value
    Since the purpose of the worksheet is to maximize Svelte's total profit, locate a label for Total Profit near the top of the worksheet. You can enter the appropriate formula to calculate Total Profit later.

8. Initial Labels and Data Layout
    To model the information about the two products, choose a vertical layout with one product's information appearing in one column, the other product's information appearing in the adjacent column, and labels for constants or formulas appearing at the left. For example, labels at left might include:

    Products   ...for the two product types
    Profit/Unit...for the given profit data: $12 and $4
    # to Make ...for the decision variables we'll enter later
    Item Profit...for the formula that calculates profit for each product

Complete the Formulas & Add Any Other Needed Information

9. Initial Formulas
    For the labels and data we've already entered, complete three crucial
    formulas:

Item Profit for Work Gloves	Number to Make X Profit/Unit
Item Profit for Driving Gloves	Number to Make X Profit/Unit
Total Profit	Work Item Profit + Driving Item Profit

    Enter these formulas even though at this stage of the model construction you
    may not yet have any "real" data entered. With no data, Total Profit will
    display a value of $0.

10. Labor Hour Requirement Data
    Take account in the model of the amount of time it takes to make each
    product (the "labor hour requirements"). Retain the vertical, columnar
    structure already established to add this information. Add the given
    departmental hourly limits, which are the constraints in this problem.

11. Write Formulas to Determine Hours Needed
    The labor hours required is all constant information given in the problem.
    Now add a determination of how many hours are required in each of the
    three departments to produce both glove types. Those numbers will depend
    on two things:
       a. How many of each glove we produce (the mix; our decision variables).
       b. How many hours it takes to produce each glove in each department
          (which is given information).

    Extend the model, again downward in the two glove columns. Write a
    formula for each department and for each product, or a total of six formulas.
    Speed up the process by writing a 'master' formula for each product and then
    copying that formula. It's important to keep in mind any possible
    requirements for absolute addressing in the 'master' formula if it's to be
    copied.

    For example, create the formula for Product 1, Dept. 1 as:

    Hours Required/Unit X Glove-type Number to Make

    The reference in the formula to "number to make" should be absolute. This
    permits the formula to be copied to the two cells beneath it without error,
    completing the formulas for Departments 2 and 3.

    Complete the same steps to complete these formulas for the other glove type.

12. Write Formulas to Manage Constraints

Whatever the product mix turns out to be, we need to make sure that the total hours required to produce our product mix in each of the three manufacturing departments doesn't exceed the stated departmental hourly limits. How do we check this?

You might want to deal with each department separately. Write three formulas, one for each department. Each formula adds together the hours required for both glove types. The formulas use the information we just calculated in the last section: Hours Needed in Each Department.

For example, for Department 1, add together the hours required in Dept. 1 by the two products.

Next, determine whether or not the total hours required in Dept. 1 exceed that department's stated hourly limit of 600. We don't have any 'real' data in our worksheet yet, but that's OK. We know we can just 'eyeball' whatever value ends up here to compare it against the 600-hour limit. But a more elegant way to track the constraint is to build an IF formula to keep track for us. The formula will have this structure:

=IF(hours-required<=hours-avail,"OK","NO")

For example, this formula means that if the total hours required for Dept. 1 don't exceed the 800 hour limit then put "OK" in the cell. If they do exceed the limit, then put "NO" in the cell.

13. Complete the same steps for Departments 2 and 3.

As we manipulate the numbers for the product mix we can just glance at this area of the worksheet to make sure we have "OK"s for each of the three departments. If we have a "NO" we know our product mix must be adjusted.

Use the Model to Determine the Best Product Mix (by Trial & Error)

14. Try Trial & Error

Try using the model. Enter values in the cells for the number of gloves of each type to produce. The mix of values entered determines the Total Profit. It also affects whether "OK" or "NO" appears in the constraints area.

15. Some Values to Try

Try a variety of values for "Number to Make" for both products. You could spend quite a bit of time trying to find the most profitable mix. It's not easy to come up with the best product mix manually.

Use the Model to Determine the Best Product Mix (with Solver)
Excel has a built-in solving tool, called Solver. Use Solver to maximize Total Profit automatically.

16. Setting up Solver
> To use the Solver with this problem:
> a. Make the Total Profit cell the current cell.
>
> b. Click *Tools, Solver* to open the *Solver Parameters* dialog box.
>
>> - The *Set Cell* here is Total Profit. In the dialog box we indicate to Solver that we want to *max*imize this value.
>> - The *By Changing Cells* area references our decision variables, or how many of Product 1 and 2 to make.
>> - Complete in the *Constraints* area of the dialog box to reflect departmental hourly limits *and* to tell Solver not to attempt to make a negative number of either product.
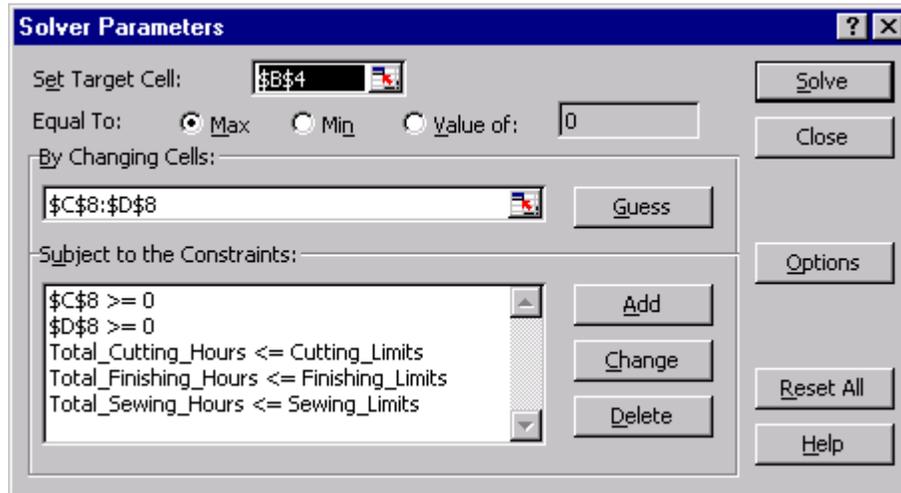
> c. Leave other Solver defaults as they are. (If you know this is a linear programming type of problem, you can click the *Options* button and on the dialog box that appears select *Assume Linear Model.*)
>
> d. Click the *Solve* button to start Solver. Solver returns with an information box like this one:
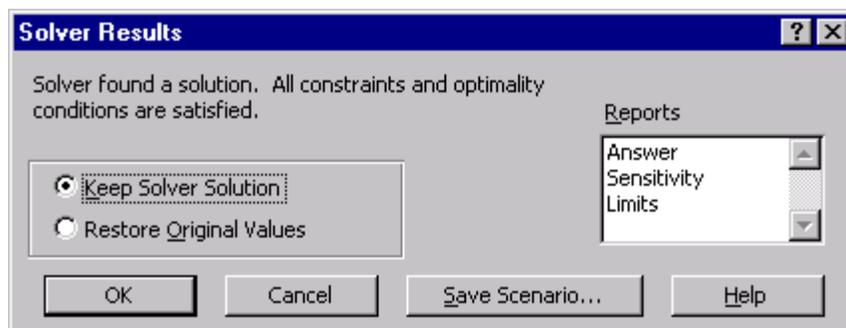
e. Click *OK* to keep the solution Solver found.

Solver Notes:

a) If after running the Solver there's a "NO" displayed in the model constraint area for a department it may be that Solver has found a product mix that results in a value *very* fractionally above the departmental hourly limits for that department. See below for a fix.

b) Solver displays results to seven decimal places. If this amount of precision isn't useful for a problem, reformat the affected cells to display no decimal places.

c) Once you start using Solver, the constraints area we originally built into the model is no longer very important. But to clean things up, you might want to rewrite the constraint area IF statements to include rounding. For the Department 1 IF statement, for example, substitute this formula:

=IF(ROUND(hours-used,0)<=hours-avail,"OK","NO")

The new version of the formula results in an "OK" display in the cell.

An Sample Svelte Worksheet Layout and (suboptimal) Solution

This initial model allows you to specify how many work gloves and driving gloves to manufacture. In this initial version you need not be concerned about optimizing the product mix for greatest profit. Just plug in some test numbers to make sure your model is working. Include *IF* statements to keep track of the problem's labor hour constraints.

This version of the model shows:

a. The number of hours that would be required in each of the three departments to produce whatever product mix is specified in the section with the label *Hours Required/Type*. The numbers in this section are derived from calculations.

b. The total profit that would result from a specified product mix in a cell with the label *Total Profit*. This cell's formula sums the calculated *Item Profits* for both types of gloves.

c. Logical formulas that display at a glance whether or not the total hours required to produce a specified product mix are within the stated departmental hourly limits. The model has a *Within Limits?* section with IF statements. For example, the IF statement for the Cutting Department looks like this:

**=if(Cutting_Hrs_Required<Cutting_Hrs_Avail,"OK","NO")**

That is, based on the production amounts specified for the model, if the hours required for the Cutting Department don't exceed the hours available then write "OK" in the cell, otherwise write "NO". Experiment with the product mix to see when "NO" messages appear.

The Worksheet with Formulas Displayed
Use Tools, Options, View and click Formulas to see formulas displayed.

A Graphical View of a Proposed Product Mix
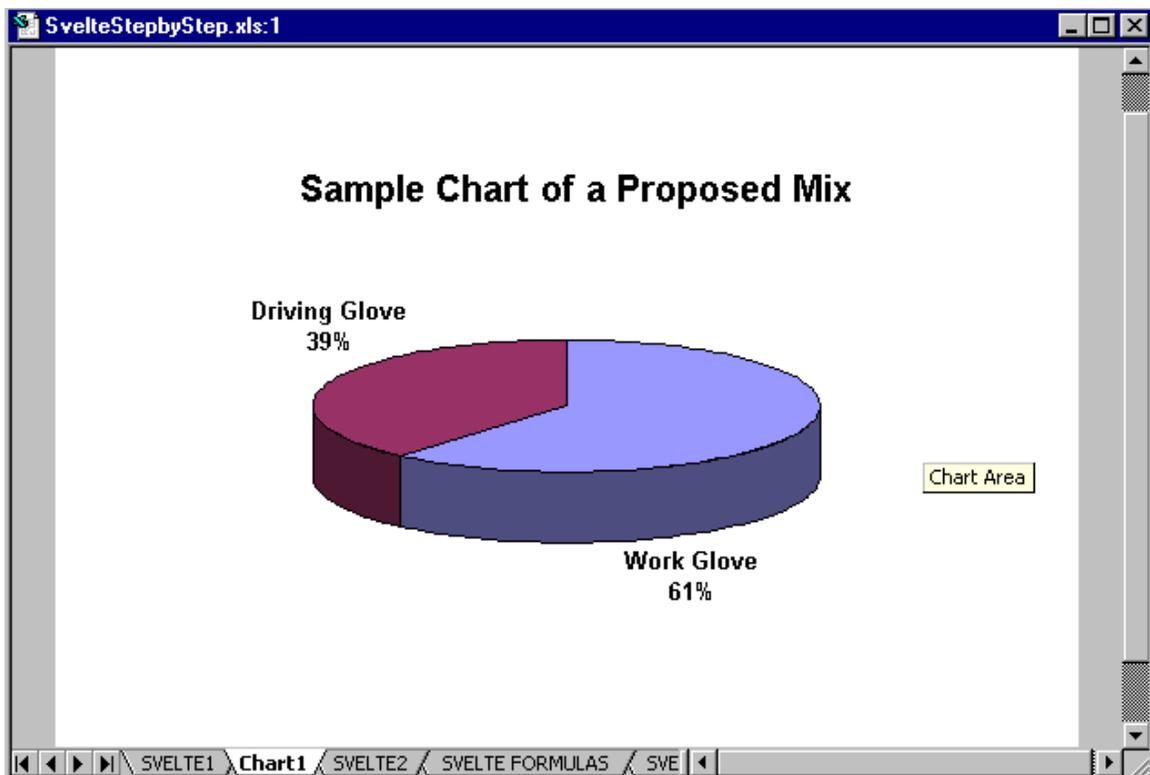
An Example of Excel's Scenario Manager Report

Choose *Tools, Scenarios* to open the Scenario Manager. The illustration below shows the Scenario Summary Report, with three different scenarios: "Lots of Work Gloves", "Lots of Driving Gloves", "Equal of Each".

Using the Scenario Manager's summary it's easy to compare the profit generated by each scenario's numbers. See Excel's online help for information about how to use the Scenario Manager.

		Current Values:	Lots of Work Gloves	Lots of Driving Gloves	Equal of Each
Scenario Summary					
Changing Cells:					
	C8	800	800	5	400
	D8	0	0	795	400
Result Cells:					
	B4	$9,600	$9,600	$3,240	$6,400

Notes: Current Values column represents values of changing cells at time Scenario Summary Report was created. Changing cells for each scenario are highlighted in gray.

SVELTE1 / Chart1 / SVELTE2 / SVELTE FORMULAS / **Scenar**

Solver's Solution to the Problem

This worksheet shows the optimum product mix, derived by using Excel's Solver. I left Solver's options at their defaults. Solver should find a product mix that results in a total profit of **$9,600.**

	A	B	C	D	E	F
	SvelteStepbyStep.xls:1					
1	Svelte Glove Company Model					
2	Worksheet with Solver's Solution					
3						
4	Total Profit:	$9,600				
5						
6		Products:	Work Glove	Driving Glove		
7		Profit/Unit:	$12	$4		
8		Qty to Make:	800	0		
9		Item Profit:	$9,600	$0		
10						
11	Department:	Limits (Hours)	Labor Hours Per Unit			
12	1	800	1	2		
13	2	1600	1	2		
14	3	2000	2	3		
15						
16		Department	Hours Required/Type		Total Hours Required	Within Limits?
17		1	800	0	800	OK
18		2	800	0	800	OK
19		3	1600	0	1600	OK
20						

SVELTE2 / SVELTE FORMULAS \ SVELTE&SOLVER / Scenario Si

Tip: To specify parameters in the Solver, click in the *Subject to Constraints* box and then click *Add...* A small *Add Constraint* dialog box appears that let's you add a constraint. Add constraints in this way one at a time. When you've specified all constraints click *OK* to return to the main Solver dialog box. For this problem be sure to include as constraints the fact that you can't make less than zero of either work gloves or driving gloves.

End of Sample Worksheet Printouts

c:\data\ba318\handouts\Excel Review\SvelteStepByStep.doc