TUTORIAL D

BUILDING A DECISION SUPPORT SYSTEM USING MICROSOFT EXCEL SOLVER

In Tutorial C, you learned that Decision Support Systems (DSS) are programs used to help managers solve complex business problems. Cases 6 and 7 were DSS models that used Microsoft Excel Scenario Manager to calculate and display financial outcomes given certain inputs, such as economic outlooks and mortgage interest rates. You used the outputs from Scenario Manager to see how different combinations of inputs affected cash flows and income so that you could make the best decision for expanding your business or selecting a technology to develop and market.

Many business situations require models in which the inputs are not limited to two or three choices, but include large ranges of numbers in more than three variables. For such business problems, managers want to know the best or optimal solution to the model. An optimal solution can either maximize an objective variable, such as income or revenues, or minimize the objective variable, such as operating costs. The formula or equation that represents the target income or operating cost is called an objective function. Optimizing the objective function requires the use of constraints (also called constraint equations), which are rules or conditions you must observe when solving the problem. The field of applied mathematics that addresses problem solving with objective functions and constraint equations is called linear programming. Before the advent of digital computers, linear programming required the knowledge of complex mathematical techniques. Fortunately, Excel has a tool called Solver that can compute the answers to optimization problems.

This tutorial has five sections:

1. **Adding Solver to the Ribbon**—Solver is not installed by default with Excel 2010; you must add it to the application. You may need to use Excel Options to add Solver to the Ribbon.
2. **Using Solver**—This section explains how to use Solver. You will start by determining the best mix of vehicles for shipping exercise equipment to stores throughout the country.
3. **Extending the example**—This section tests your knowledge of Solver as you modify the transportation mix to accommodate changes: additional stores to supply and redesign of the product to reduce shipping volume.
4. **Using Solver on a new problem**—In this section, you will use Solver on a new problem: maximizing the profits for a mix of products.
5. **Troubleshooting Solver**—Because Solver is a complex tool, you will sometimes have problems using it. This section explains how to recognize and overcome such problems.

NOTE

If you need a refresher, Tutorial C offers guidance on basic Excel concepts such as formatting cells and using the =IF( ) and AND( ) functions.

ADDING SOLVER TO THE RIBBON

Before you can use Solver, you must determine whether it is installed in Excel. Start Excel and then click the Data tab on the Ribbon. If you see a group on the right side named Analysis that contains Solver, you do not need to install Solver (see Figure D-1).

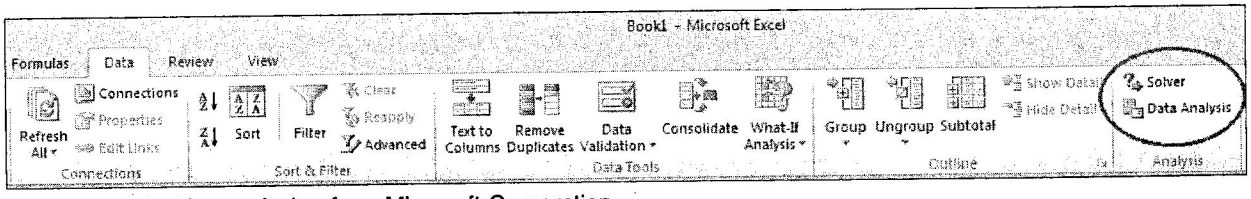

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FIGURE D-1 Analysis group with Solver installed

If the Analysis group or Solver is not shown on the Data tab of the Ribbon, do the following:

1. Click the File tab.
2. Click Options (see Figure D-2).
3. Click Add-Ins (see Figure D-3) to display the available add-ins in the right pane.
4. Click Go at the bottom of the right pane. The window shown in Figure D-4 appears.
5. Click the Solver Add-in box as well as the Analysis ToolPak and Analysis ToolPak-VBA boxes. (You will need the latter options in a subsequent case, so install them now with Solver.)
6. Click OK to close the window and return to the Ribbon. If you click the Data tab again, you should see the Analysis group with Data Analysis and Solver on the right.

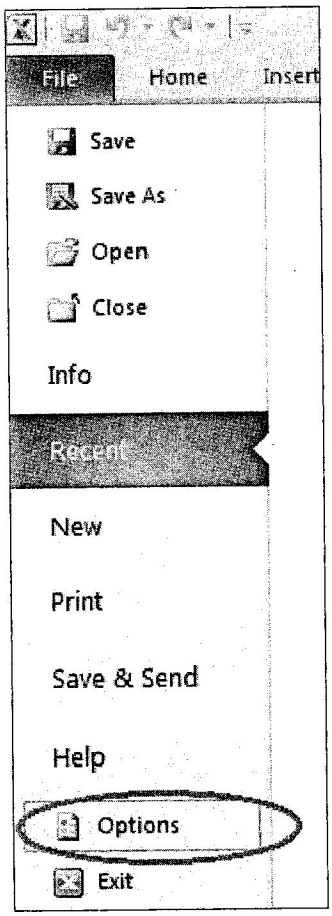

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FIGURE D-2 Excel Options selection

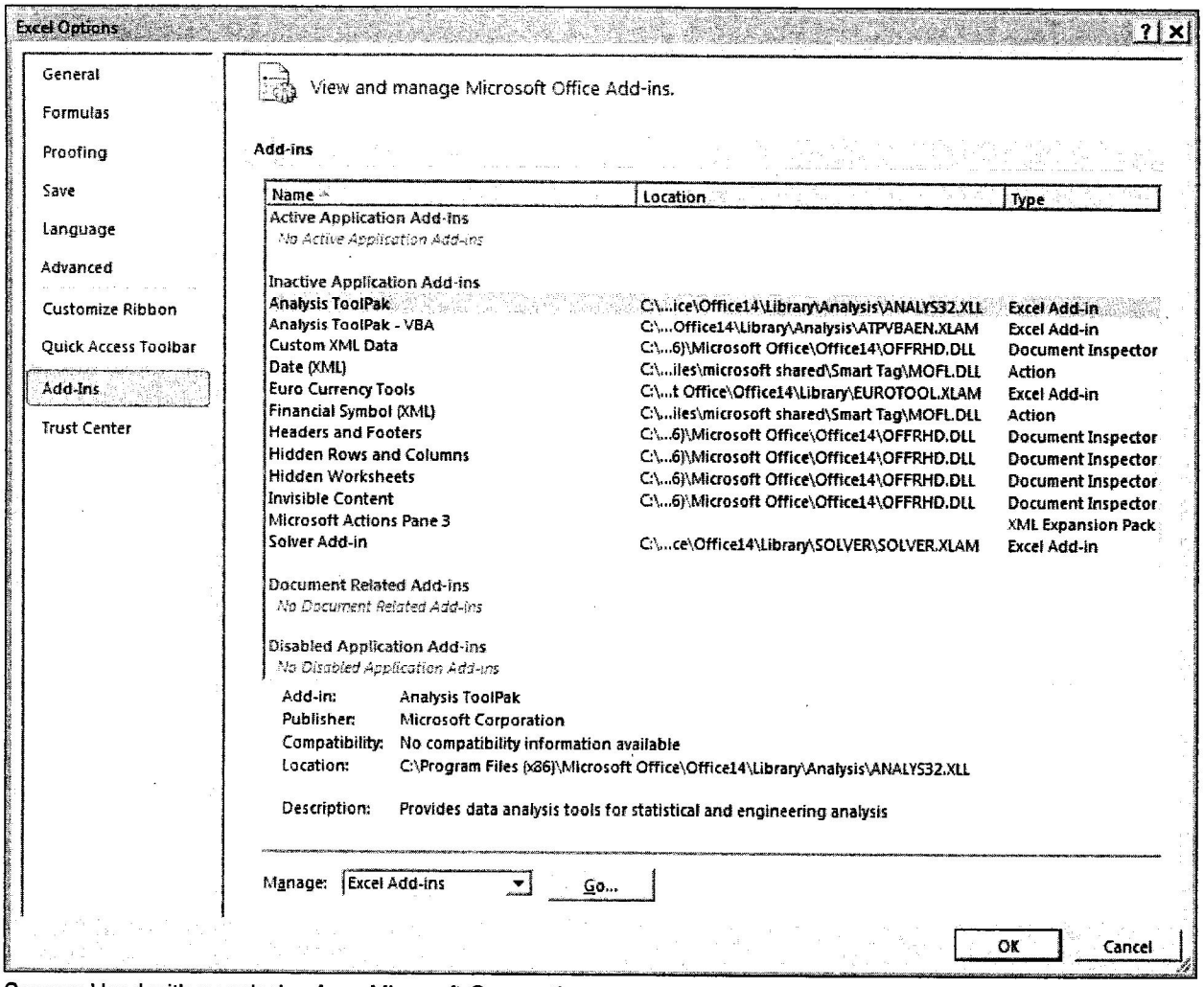

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FIGURE D-3 Add-Ins pane

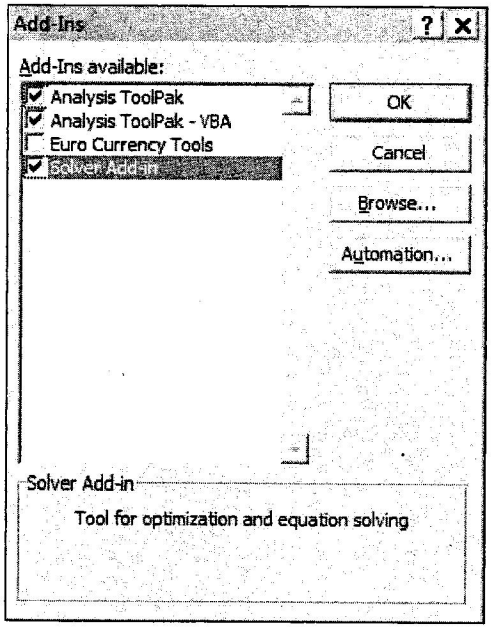

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FIGURE D-4 Add-Ins window with Solver, Analysis ToolPak, and Analysis ToolPak VBA selected

USING SOLVER

A fictional company called CV Fitness builds exercise machines in its plant in Memphis, Tennessee and ships them to its stores across the country. The company has a small fleet of trucks and tractor-trailers to ship its products from the factory to its stores. It costs less money per cubic foot of capacity to ship products with tractor-trailers than with trucks, but the company has a limited number of both types of vehicles and must ship a specified amount of each type of product to each destination. You have been asked to determine the optimal mix of trucks and tractor-trailers to send merchandise to each store. The optimal mix will have the lowest total shipping cost while ensuring that the required quantity of products is shipped to each store.

To use Solver, you must set up a model of the problem, including the factors that can vary (the mix of trucks and tractor-trailers) and the constraints on how much they can vary (the number of each vehicle available). Your goal is to minimize the shipping cost.

Setting Up a Spreadsheet Skeleton

CV Fitness makes three fitness machines: exercise bikes (EB), elliptical cross-trainers (CT), and treadmills (TM). When packaged for shipment, their shipping volumes are 12, 15, and 22 cubic feet, respectively. The finished machines are shipped via ground transportation to five stores in Philadelphia, Atlanta, Miami, Chicago, and Los Angeles. Your vehicle fleet consists of 12 trucks and six tractor-trailers. Each truck has a capacity of 1500 cubic feet, and each tractor-trailer has a capacity of 2350 cubic feet. The spreadsheet includes the road distances from your plant in Memphis to each store, along with each store's demand for the three fitness machines.

What is the best mix of trucks and tractor-trailers to send to each destination? You will learn how to use Solver to determine the answer. The spreadsheet components are discussed in the following sections.

AT THE KEYBOARD

Start by saving your blank spreadsheet. Use a descriptive filename so you can find it easily later—**CV Fitness Trucking Problem.xlsx** should work well. Then enter the skeleton and formulas as directed in the following sections.

Spreadsheet Title

Resize Column A, as illustrated in Figure D-5, to give your spreadsheet a small border on the left side. Enter the spreadsheet title in cell B1. Merge and center cells B1 through F1 using the Merge and Center button in the Alignment group of the Home tab.

Constants Section

Your spreadsheet should have a section for values that will not change. Figure D-5 shows a skeleton of the Constants section and the values you should enter. A discussion of the line items follows the figure.

	A	B	C	D	E	F
1		**CV Fitness, Inc. Truck Load Management Problem**				
2						
3		**Constants Section:**				
4			**Volume Cu. Ft.**	**Operating Cost per mi.**	**Operating Cost per mi-cu. Ft.**	**Available Fleet**
5		**Truck**	**1500**	**$1.00**	**$0.000667**	**12**
6		**Tractor Trailer**	**2350**	**$1.30**	**$0.000553**	**6**
7						
8		**Exercise Bike (EB)**	**12**			
9		**Elliptical Crosstrainer (CT)**	**15**			
10		**Treadmill (TM)**	**22**			

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FIGURE D-5 Spreadsheet title and Constants section

- In column C, enter the Volume Cu. Ft., which is the cubic-foot capacity of the vehicles as well as the shipping volume for each item of exercise equipment.
- In column D, enter the Operating Cost per mi., which is the cost per mile driven for each type of vehicle.
- In column E, enter the Operating Cost per mi.-cu.ft. This value is actually a formula: the operating cost per mile divided by the vehicle volume in cubic feet. Normally you do not put formulas in the Constants section, but in this case it lets you see the relative cost efficiencies of each vehicle. Assuming that both types of vehicles can be filled to capacity, the tractor-trailer is the preferred vehicle for shipping cost efficiency.
- In column F, enter the values for the Available Fleet, which is the number of each type of vehicle your company owns or leases.

You can update the Constants section as the company adds more products to its offerings or adds vehicles to its fleet.

NOTE

The column headings in the Constants section contain two or three lines to keep the columns from becoming too wide. To create a new line in a cell, hold down the Alt key and press Enter.

Now is a good time to save your workbook again. Keep the name you assigned earlier.

Calculations and Results Section

The structure and format of your Calculations and Results section will vary greatly depending on the nature of the problem you need to solve. In some Solver models, you might need to maximize income, which means you might also have an Income Statement section. In other Solver models, you may want to have a separate Changing Cells section that contains cells Solver will manipulate to obtain a solution. In this tutorial, you want to minimize shipping costs while meeting the product demand of your stores. You can accomplish this task by building a single unified table that includes the distances to the stores, the product demand for each store, and the shipping alternatives and costs.

A unified Calculations and Results section makes sense in this model for several reasons. First, it simplifies writing and copying the formulas for the needed shipping volumes, the vehicle capacity totals, and the shipping costs to each destination. Second, a well-organized table allows you to easily identify the changing cells, which Solver will manipulate to optimize the solution, as well as the total cost (or optimization cell). Finally, a unified table allows your management team to visualize both the problem and its solution.

When creating a complex table, it is often a good idea to sketch the table's structure first to see how you want to organize the data. Format the table structure, then enter the data you are given for the problem. Write the cells that contain the formulas last, starting with all the formulas in the first row. If you do a good job structuring your table, you will be able to copy the first-row formulas to the other rows.

Build the blank table shown in Figure D-6. A discussion of the rows and columns follows the figure.

NOTE

Leave rows 11 and 12 blank between the Constants section and the Calculations and Results section. You then will have room to add an extra product to your Constants section later.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
12														
13		Calculations and Results Section:												
14		Distance/Demand Table		Store Demand			Vehicle Loading							Cost
15		Distance Table (from Memphis Plant)	Miles	EB	CT	TM	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16		Philadelphia Store	1010	140	96	86								
17		Atlanta Store	380	76	81	63								
18		Miami Store	1000	56	64	52								
19		Chicago Store	540	115	130	150								
20		Los Angeles Store	1810	150	135	180								
21						Totals:								
22		Fill Legend:		Changing Cells										Total Cost
23				Optimization Cell										

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FIGURE D-6 Blank table for Calculations and Results section

- In row 13, enter "Calculations and Results Section:" as the title of the table.
- In row 14, columns B and C, enter "Distance/Demand Table" as a column heading. Merge and center the heading in the two columns.
- In row 14, columns D, E, and F, enter "Store Demand" as a column heading. Merge and center the heading in the three columns.
- In row 14, columns G through M, enter "Vehicle Loading" as a column heading. Merge and center the heading across the columns.
- In row 14, column N, enter "Cost" as a centered column heading.
- In row 15, column B, enter "Distance Table (from Memphis Plant)" as a centered column heading.
- In row 15, column C, enter "Miles" as a centered column heading.
- In row 15, columns D, E, and F, enter "EB," "CT," and "TM," respectively, as equipment headings.
- In row 15, columns G through N, enter "Volume Required," "Trucks," "Volume for Trucks," "Tractor-Trailers," "Volume for Tractor-Trailers," "Total Vehicle Capacity," "% of Vehicle Capacity Utilized," and "Shipping Cost," respectively, as column headings.
- In rows 16 through 20, column B, enter the destination store locations.
- In rows 16 through 20, column C, enter the number of miles to the destination store locations.
- In rows 16 through 20, columns D through F, enter the number of exercise bikes (EB), cross-trainers (CT), and treadmills (TM) to be shipped to each store location.
- Rows 16 through 20, columns G through N, will contain formulas or "seed values" later. Leave them blank for now, but fill cells H16 through H20 and cells J16 through J20 with a light color to indicate that they are the changing cells for Solver. To fill a cell, use the Fill Color button in the Font group.
- In cell F21, enter "Totals:" to label the following cells in the row.
- Cells G21 through N21 will be used for column totals. Fill cell N21 with a slightly darker shade than you used for the changing cells. Cell N21 is your optimization cell.
- In cell B22, enter "Fill Legend:" as a label.
- Fill cell C22 with the fill color you selected for the changing cells.
- In cells D22 and E22, enter "Changing Cells" as the label for the fill color. Merge and center the label in the cells.
- In cell N22, enter "Total Cost" as the label for the value in cell N21.
- Fill cell C23 with the fill color you selected for the optimization cell.
- In cells D23 and E23, enter "Optimization Cell" as the label for the fill color. Merge and center the label in the cells.

Figure D-7 illustrates a magnified section of the Distance/Demand table in case the numbers in Figure D-6 are difficult to read.

	A	B	C	D	E	F
12						
13	Calculations and Results Section:					
14	Distance/Demand Table		Store Demand			
15	Distance Table (from Memphis Plant)	Miles	EB	CT	TM	
16	Philadelphia Store	1010	140	96	86	
17	Atlanta Store	380	76	81	63	
18	Miami Store	1000	56	64	52	
19	Chicago Store	540	115	130	150	
20	Los Angeles Store	1810	150	135	180	
21					Totals:	
22	Fill Legend:		Changing Cells			
23			Optimization Cell			

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FIGURE D-7 Magnified view of the Distance/Demand table

Use the Borders menu in the Font group to select and place appropriate borders around parts of the Calculations and Results section (see Figure D-8). The All Borders and Outside Borders selections are the most useful borders for your table.

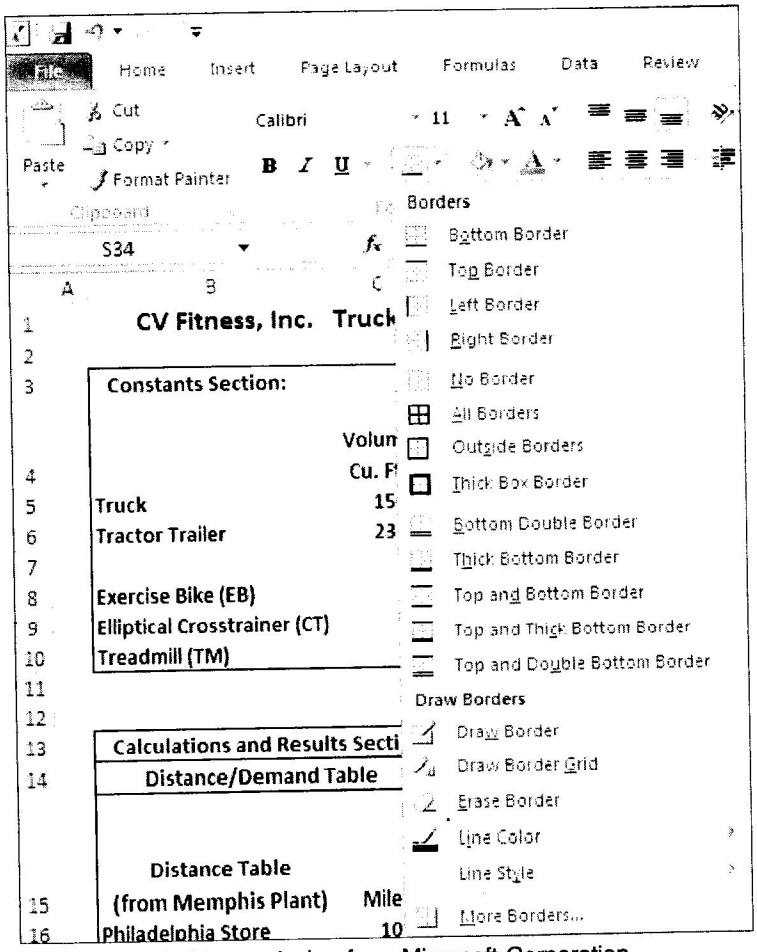

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FIGURE D-8 Borders menu

Next, you write the formulas for the volume and cost calculations. Figure D-9 shows a magnified view of the Vehicle Loading and Cost sections. A discussion of the formulas required for the cells follows the figure.

	G	H	I	J	K	L	M	N
13								
14	Vehicle Loading							Cost
15	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16								
17								
18								
19								
20								
21								
22								Total Cost

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FIGURE D-9 Vehicle Loading and Cost sections

For illustration purposes, the cell numbers in the following list refer to values for the Philadelphia store.

- Volume Required—Cell G16 contains the total shipping volume of the three types of equipment shipped to the Philadelphia store. The formula for this cell is =D16*$C$8+E16*$C$9+F16*$C$10. Cells D16, E16, and F16 are the quantities of each item to be shipped, and cells $C$8, $C$9, and $C$10 are the shipping volumes for the exercise bike, cross-trainer, and treadmill, respectively. When taking values from the Constants section to calculate formulas, you almost always should use absolute cell references ($) because you will copy the formulas down the columns.
- Trucks—Cell H16 contains the number of trucks selected to ship the merchandise. Cell H16 is a changing cell, which means Solver will determine the best number of trucks to use and place the number in this cell. For now, you should "seed" the cell with a value of 1.
- Volume for Trucks—Cell I16 contains the number of trucks selected, multiplied by the capacity of a truck. The capacity value is taken from the Constants section. The formula for this cell is =H16*$C$5. Cell H16 is the number of trucks selected, and cell $C$5 is the volume capacity of the truck in cubic feet.
- Tractor-Trailers—Cell J16 contains the number of tractor-trailers selected to ship the merchandise. Cell J16 is a changing cell, which means Solver will determine the best number of tractor-trailers to use and place the number in this cell. For now, you should "seed" the cell with a value of 1.
- Volume for Tractor-Trailers—Cell K16 contains the number of tractor-trailers selected, multiplied by the capacity of a tractor-trailer. The capacity value is taken from the Constants section. The formula for this cell is =J16*$C$6. Cell J16 is the number of tractor-trailers selected, and cell $C$6 is the cubic feet capacity of the tractor-trailer.
- Total Vehicle Capacity—Cell L16 contains the sum of the Volume for Trucks and the Volume for Tractor-Trailers. The formula for this cell is =I16+K16. You need to know the Total Vehicle Capacity to make sure that you have enough capacity to ship the Volume Required. This value will be one of your constraints in Solver.
- % of Vehicle Capacity Utilized—Cell M16 contains the Volume Required divided by the Total Vehicle Capacity. The formula for this cell is =G16/L16; after entering the formula, format it as a percentage using the % button in the Number group. Although this information is not required to minimize shipping costs, it is useful for managers to know how much space was filled in the selected vehicles. Alternatively, you could run Solver to determine the highest space utilization on the vehicles rather than the lowest cost. Note that you cannot use more than 100% of the available space on the vehicles.

- Shipping Cost—Cell N16 contains the following calculation:
  Mileage to destination store × Number of trucks selected × Cost per mile for trucks + Mileage to destination store × Number of tractor-trailers selected × Cost per mile for tractor-trailers
  The formula for this cell is =H16*C16*$D$5+J16*C16*$D$6. Note that absolute cell references for the cost-per-mile values are taken from the Constants section.

If you entered the formulas correctly in row 16, your table should look like Figure D-10.

	G	H	I	J	K	L	M	N
14	Vehicle Loading							Cost
15	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16	5012	1	1500	1	2350	3850	130%	$2,323.00
17								
18								
19								
20								
21								
22								Total Cost

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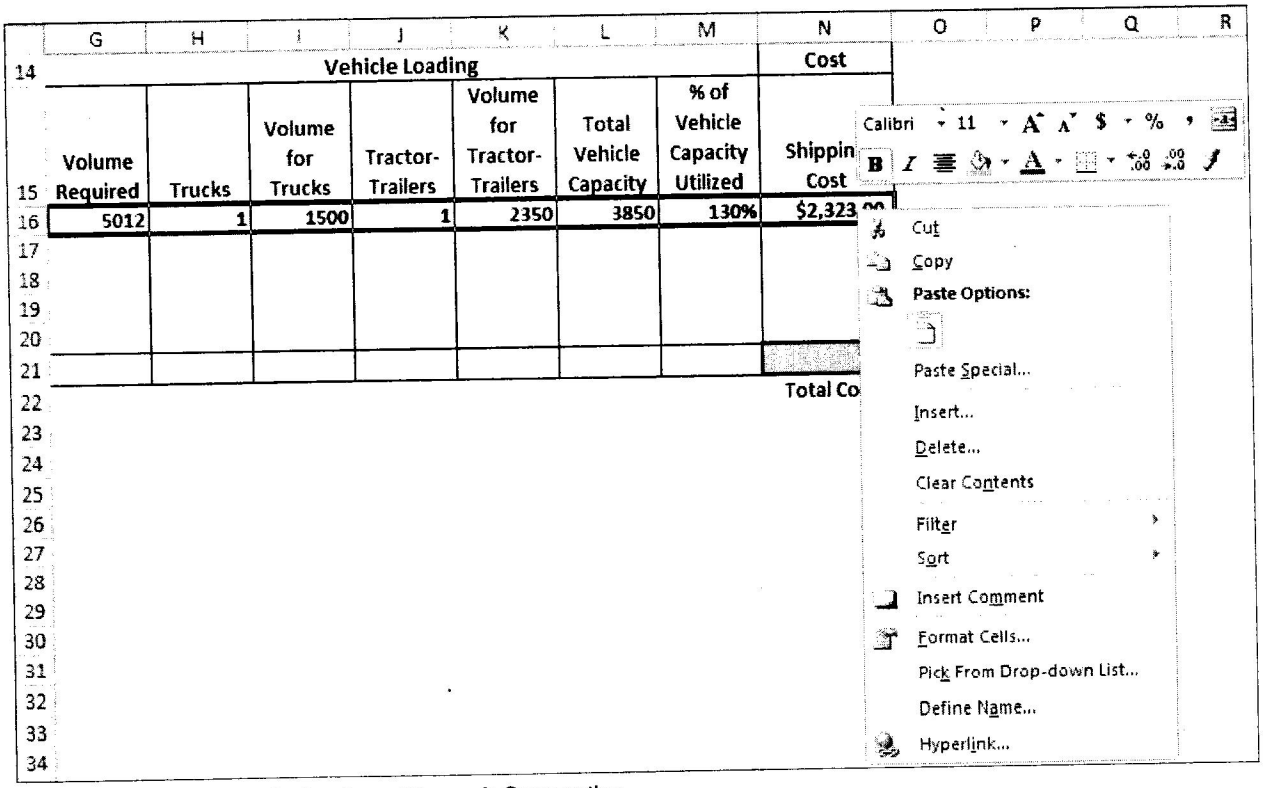
FIGURE D-10 Vehicle Loading and Cost sections with formulas entered in the first row

To complete the empty cells in rows 17 through 20, you can copy the formulas from cells G16 through N16 to the rest of the rows. Click and drag to select cells G16 through N16, then right-click and select Copy from the menu (see Figure D-11).



Source: Used with permission from Microsoft Corporation

FIGURE D-11 Copying formulas

Next, select cells G17 through N20, which are in the four rows beneath row 16. Either press Enter or click Paste in the Clipboard group. The formulas from row 16 should be copied to the rest of the destination cities (see Figure D-12).

	G	H	I	J	K	L	M	N
14	Vehicle Loading							Cost
15	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16	5012	1	1500	1	2350	3850	130%	$2,323.00
17	3513	1	1500	1	2350	3850	91%	$874.00
18	2776	1	1500	1	2350	3850	72%	$2,300.00
19	6630	1	1500	1	2350	3850	172%	$1,242.00
20	7785	1	1500	1	2350	3850	202%	$4,163.00
21								
22								Total Cost

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FIGURE D-12 Formulas from row 16 successfully copied to rows 17 through 20

You have one row of formulas to complete: the Totals row. You will use the AutoSum function to sum up one column, and then copy the formula to the rest of the columns *except* cell M21. This cell is not actually a total, but an overall capacity utilization rate.

To enter the sum of cells G16 through G20 in cell G21, select cells G16 through G21, then click AutoSum in the Editing group on the Home tab of the Ribbon (see Figure D-13).

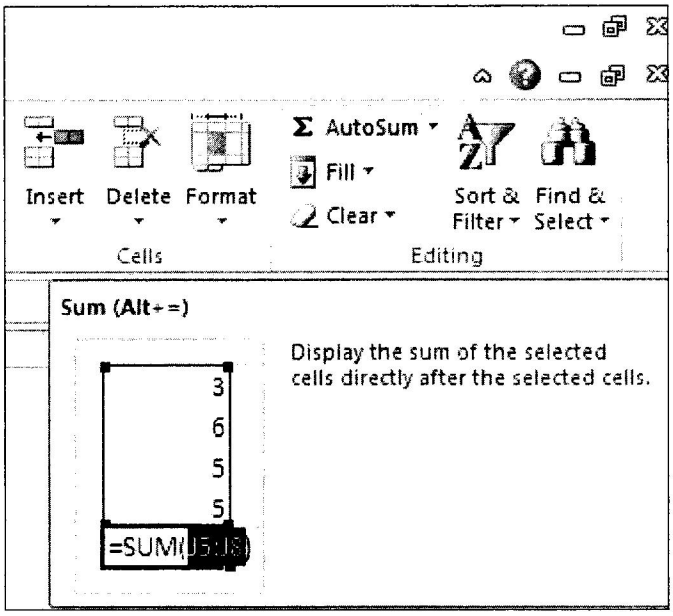

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FIGURE D-13 AutoSum button in the Editing group

Cell G21 should now contain the formula =SUM(G16:G20), and the displayed answer should be 25716. Now you can copy cell G21 to cells H21, I21, J21, K21, L21, and N21. When you have completed this section of the table, it should have the values shown in Figure D-14.

	G	H	I	J	K	L	M	N
14	Vehicle Loading							Cost
15	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16	5012	1	1500	1	2350	3850	130%	$2,323.00
17	3513	1	1500	1	2350	3850	91%	$874.00
18	2776	1	1500	1	2350	3850	72%	$2,300.00
19	6630	1	1500	1	2350	3850	172%	$1,242.00
20	7785	1	1500	1	2350	3850	202%	$4,163.00
21	25716	5	7500	5	11750	19250		$10,902.00
22								Total Cost

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FIGURE D-14 Totals cells completed

The last formula to enter is for cell M21. This is not a total, but an overall percentage of Vehicle Capacity Utilized for all the vehicles used. This calculation uses the same formula as the cell above it, so you can simply copy cell M20 to cell M21. The formula for this cell is =G21/L21, which is Volume Required divided by Total Vehicle Capacity, expressed as a percentage. Your completed spreadsheet should look like Figure D-15.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
14		Distance/Demand Table		Store Demand			Vehicle Loading							Cost
15		Distance Table (from Memphis Plant)	Miles	EB	CT	TM	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16		Philadelphia Store	1010	140	96	86	5012	1	1500	1	2350	3850	130%	$2,323.00
17		Atlanta Store	380	76	81	63	3513	1	1500	1	2350	3850	91%	$874.00
18		Miami Store	1000	56	64	52	2776	1	1500	1	2350	3850	72%	$2,300.00
19		Chicago Store	540	115	130	150	6630	1	1500	1	2350	3850	172%	$1,242.00
20		Los Angeles Store	1810	150	135	180	7785	1	1500	1	2350	3850	202%	$4,163.00
21						Totals:	25716	5	7500	5	11750	19250	134%	$10,902.00
22		Fill Legend:			Changing Cells									Total Cost
23					Optimization Cell									

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FIGURE D-15 Completed Calculations and Results section

Working the Model Manually

Now that you have a working model, you could manipulate the number of trucks and tractor-trailers manually to obtain a solution to the shipping problem. You would need to observe the following rules (or constraints):

1. Assign enough Total Vehicle Capacity to meet the Volume Required for each destination. (In other words, you cannot exceed 100% of Vehicle Capacity Utilized.)
2. The total number of trucks and tractor-trailers you assign cannot exceed the number available in your fleet.

Try to assign your trucks and tractor-trailers to meet your shipping requirements, and note the total shipping costs—you may get lucky and come up with an optimal solution. The tractor-trailers are more cost efficient than the trucks, but the problem is complicated by the fact that you want to achieve the best capacity utilization as well. In some instances, the trucks may be a better fit. Figure D-16 shows a sample solution determined from working the problem manually.

CV Fitness, Inc. Truck Load Management Problem

Constants Section:

	Volume Cu. Ft.	Operating Cost per mi.	Operating Cost per mi-cu. Ft.	Available Fleet
Truck	1500	$1.00	$0.000667	12
Tractor Trailer	2350	$1.30	$0.000553	6

Exercise Bike (EB)	12
Elliptical Crosstrainer (CT)	15
Treadmill (TM)	22

Manual attempt at a solution to the shipping problem, maximizing Vehicle capacity utilized

Calculations and Results Section:

Distance/Demand Table		Store Demand			Vehicle Loading								Cost
Distance Table (from Memphis Plant)	Miles	EB	CT	TM	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
Philadelphia Store	1010	140	96	86	5012	2	3000	1	2350	5350	94%	$3,333.00
Atlanta Store	380	76	81	63	3513	1	1500	1	2350	3850	91%	$874.00
Miami Store	1000	56	64	52	2776	2	3000	0	0	3000	93%	$2,000.00
Chicago Store	540	115	130	150	6630	3	4500	1	2350	6850	97%	$2,322.00
Los Angeles Store	1810	150	135	180	7785	4	6000	1	2350	8350	93%	$9,593.00
				Totals:	25716	12	18000	4	9400	27400	94%	$18,122.00

Fill Legend: Changing Cells; Optimization Cell

Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-16 Manual attempt to solve the vehicle loading problem optimally

This probably looks like a good solution—after all, you have not violated any of your constraints, and you have a 94% average vehicle capacity utilization. But is it the most cost-effective solution for your company? This is where Solver comes in.

Setting Up Solver Using the Solver Parameters Window

To access the Solver pane, click the Data tab on the Ribbon, then click Solver in the Analysis group on the far right side of the Ribbon. The Solver Parameters window appears (see Figure D-17).

NOTE

Solver in Excel 2010 has changed significantly from earlier versions of Excel. It allows three different calculation methods, and it allows you to specify an amount of time and number of iterations to perform before Excel ends the calculation. Refer to Microsoft Help for more information.

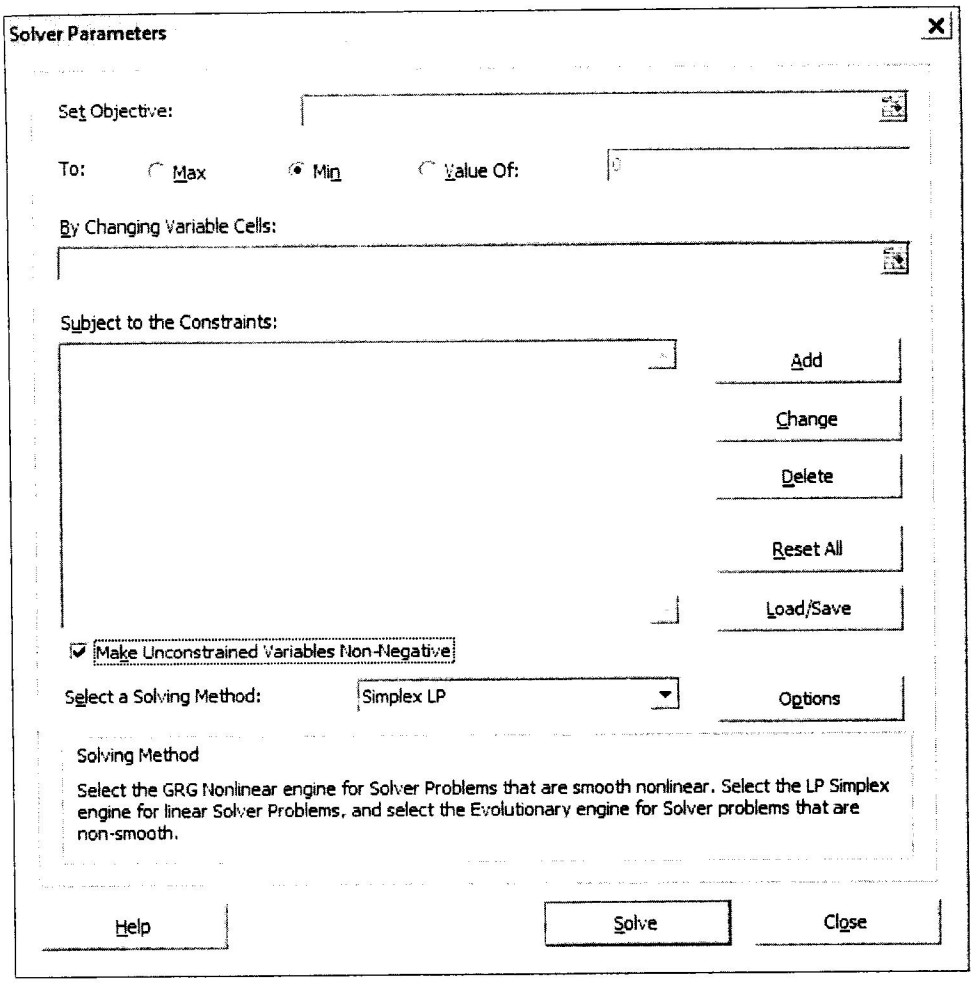

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FIGURE D-17 Solver Parameters window

The Solver Parameters window in Excel 2010 looks intimidating at first. However, to solve linear optimization problems, you have to satisfy only three sets of conditions by filling in the following fields:

- Set Objective—Specify the optimization cell.
- By Changing Variable Cells—Specify the changing cells in your worksheet.
- Subject to the Constraints—Define all of the conditions and limitations that must be met when seeking the optimal solution.

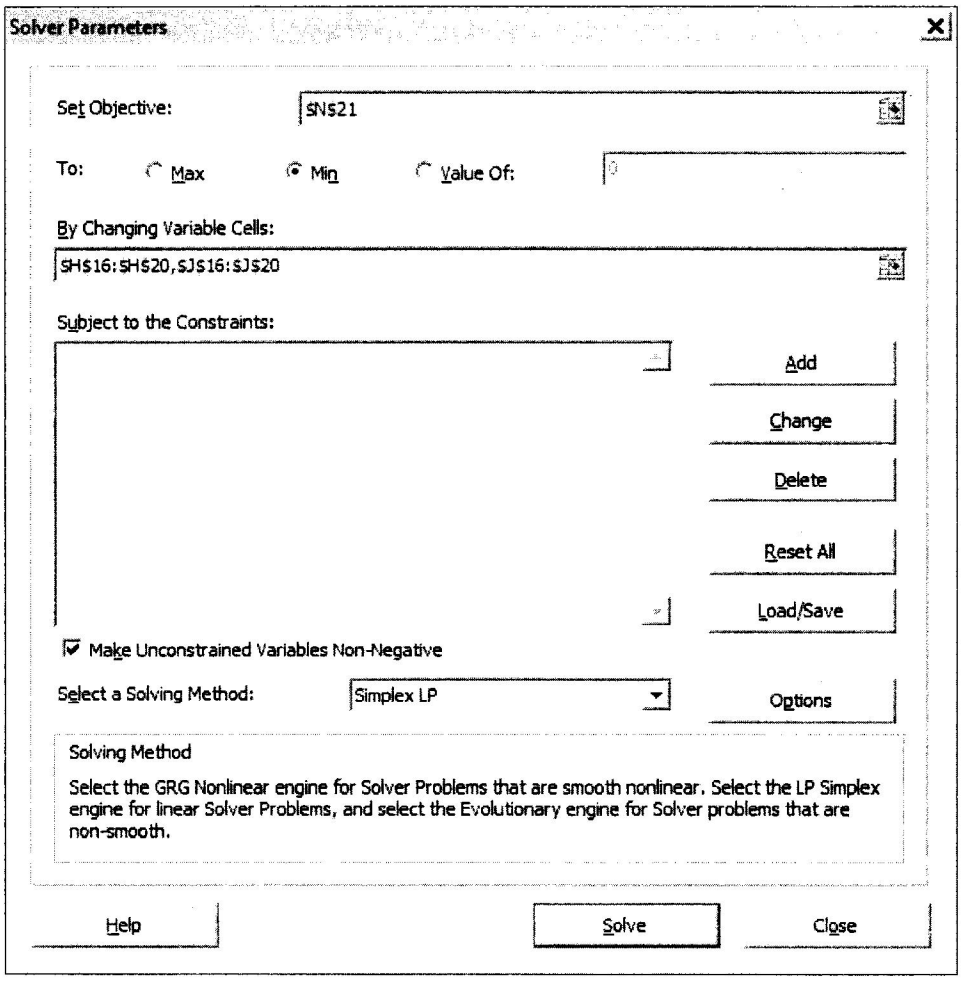
The following sections explain these fields in detail. You may also need to click the Options button and select one or more options for solving the problem. Most of the cases in this book are linear problems, so you can set the solving method to Simplex LP, as shown in Figure D-17. If this method does not work in later cases, you can select the GRG Nonlinear or Evolutionary method to try to solve the problem. Note that the GRG Nonlinear and Evolutionary solving methods are available only in Excel 2010.

Optimization Cell and Changing Cells

To use Solver successfully, you must first specify the cell you want to optimize—in this case, the total shipping cost, or cell N21. To fill the Set Objective field, click the button at the right edge of the field, and then click cell N21 in the spreadsheet. You could also type the cell address in the window, but selecting the cell in the spreadsheet reduces your chance of entering the wrong cell address. Next, specify whether you want Solver to seek the maximum or minimum value for cell N21. Because you want to minimize the total shipping cost, click the radio button next to Min.

Next, tell Solver which cell values it will change to determine the optimal solution. Use the By Changing Variable Cells field to specify the range of cells that you want Solver to manipulate. Again, click the button at the right edge of the field, select the cells that contain the numbers of trucks (H16 to H20), and then hold down the

Ctrl key and select the cells that contain the numbers of tractor-trailers (J16 to J20). If you used a fill color for the changing cells, they will be easy to find and select. The Solver Parameters window should look like Figure D-18.



Source: Used with permission from Microsoft Corporation

FIGURE D-18 Solver Parameters window with the objective cell and changing cells entered

Note that Solver has added absolute cell references (the $ signs before the column and row designators) for the cells you have specified. Solver will also add these references to the constraints you define. Solver adds the references to preserve the links to the cells in case you revise the worksheet in the future. In fact, you will make changes to the worksheet later in the tutorial.

Defining and Entering Constraints

For Solver to successfully determine the optimum solution for the shipping problem, you need to specify what constraints or rules it must observe to calculate the solution. Without constraints, Solver theoretically might calculate that the best solution is not to ship anything, resulting in a cost of zero. Furthermore, if you failed to define variables as positive numbers, Solver would select "negative trucks" to maximize "negative costs." Finally, the vehicles are indivisible units—you cannot assign a fraction of a vehicle for a fraction of the cost, so you must define your changing cells as integers to satisfy this constraint.

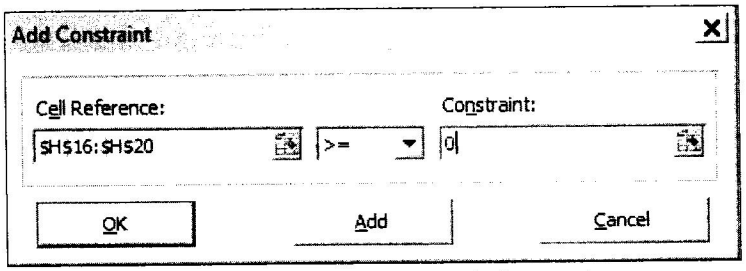
Aside from the preceding logical constraints, you have operational constraints as well. You cannot assign more vehicles than you have in your fleet, and the vehicles you assign must have at least as much total capacity as your shipping volume.

Before entering the constraints in the Solver Parameters window, it is a good idea to write them down in regular language. You must enter the following constraints for this model:

- All trucks and tractor-trailers in the changing cells must be integers greater than or equal to zero.
- The sums of trucks and tractor-trailers assigned (cells H21 and J21) must be less than or equal to the available trucks and tractor-trailers (cells F5 and F6, respectively).

- The Total Vehicle Capacity for the vehicles assigned to each store (cells L16 to L20) must be greater than or equal to the Volume Required to be shipped to each store (cells G16 to G20, respectively).

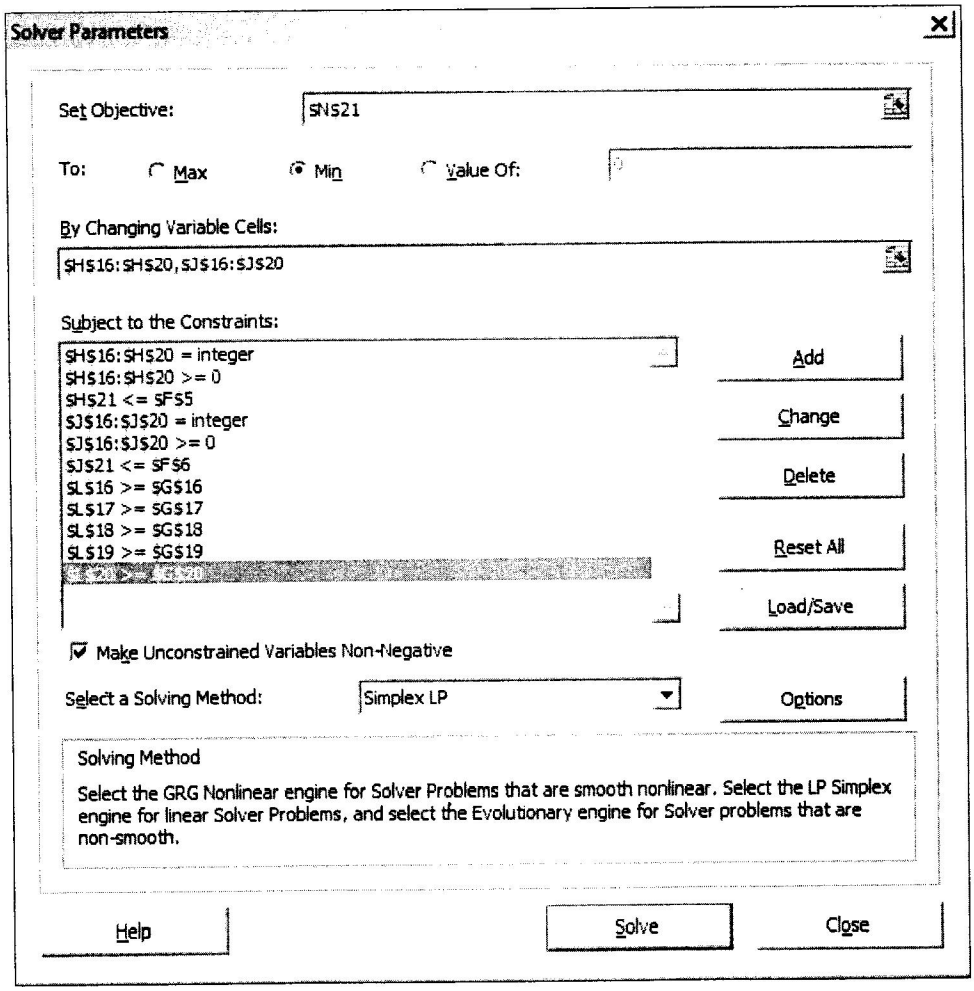
You are ready to enter the constraints as equations or inequalities in the Add Constraint window. To begin, click the Add button in the Solver Parameters window. In the window that appears (see Figure D-19), click the button at the right edge of the Cell Reference box, select cells H16 to H20, and then click the button again. Next, click the drop-down menu in the middle field and select > =. Then go to the Constraint field and type 0. Finally, click Add; otherwise, the constraint you defined will not be added to the list defined in the Solver Parameters window.



Source: Used with permission from Microsoft Corporation

FIGURE D-19 Add Constraint window

You can continue to add constraints in the Add Constraint window. For this example, enter the constraints shown in the completed Solver Parameters window in Figure D-20. When you finish, click Add to save the last constraint, then click Cancel in the Add Constraint window to return to the Solver Parameters window.



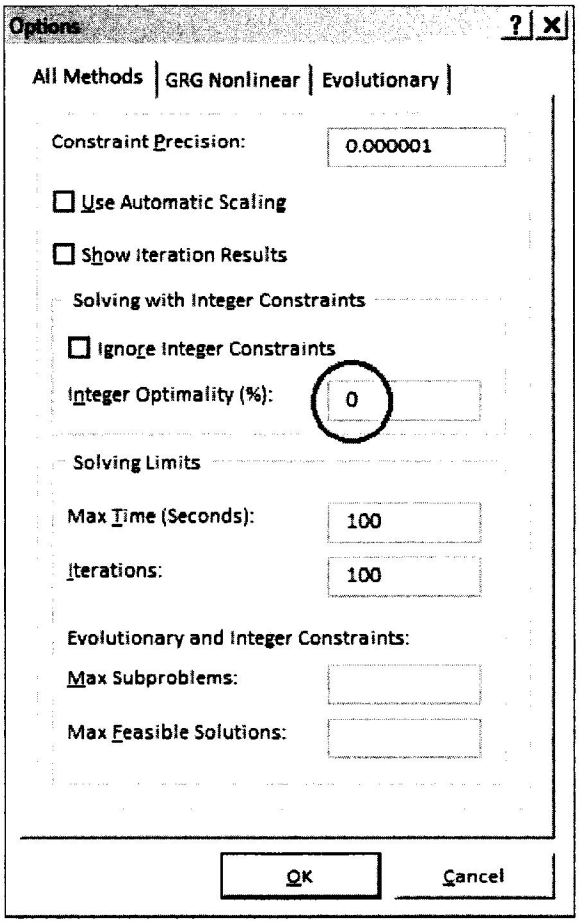
Source: Used with permission from Microsoft Corporation

FIGURE D-20 Completed Solver Parameters window

If you have difficulty reading the constraints listed in Figure D-20, use the following list instead:

- $H$16:$H$20 = integer
- $H$16:$H$20 >= 0
- $H$21 <= $F$5
- $J$16:$J$20 = integer
- $J$16:$J$20 >= 0
- $J$21 <= $F$6
- $L$16 >= $G$16
- $L$17 >= $G$17
- $L$18 >= $G$18
- $L$19 >= $G$19
- $L$20 >= $G$20

You should also click the Options button in the Solver Parameters window and check the Options window shown in Figure D-21. You can use this window to set the maximum amount of time and iterations you want Solver to run before stopping. Leave both options at 100 for now, but remember that Solver may need more time and iterations for more complex problems. To get the best solution, you should set the Integer Optimality (%) to zero. Click OK to close the window.

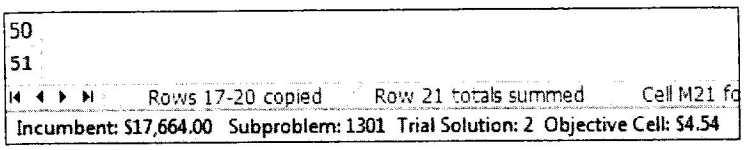


Source: Used with permission from Microsoft Corporation

FIGURE D-21 Solver Options window with Integer Optimality set to zero

You are ready to run Solver to find the optimal solution. Click Solve at the bottom of the Solver Parameters window. Solver might require only a few seconds or more than a minute to run all the possible

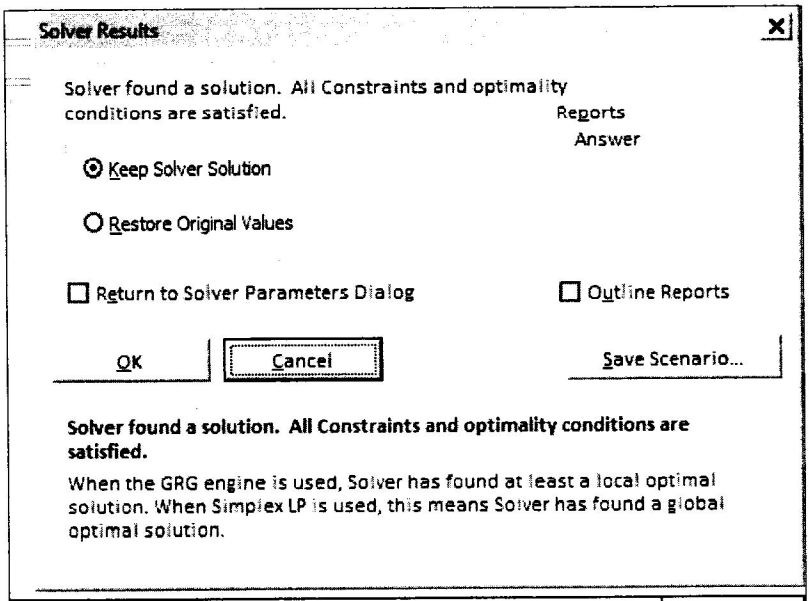
iterations—the status bar at the bottom of the Excel window displays iterations and possible solutions continuously until Solver finds an optimal solution or runs out of time (see Figure D-22).



Source: Used with permission from Microsoft Corporation

FIGURE D-22 Excel status bar showing Solver running through possible solutions

A new window will appear eventually, indicating that Solver has found an optimal solution to the problem (see Figure D-23). The portion of the spreadsheet that displays the assigned vehicles and shipping cost should be visible below the Solver Results window. Solver has assigned nine of the 12 trucks and all six tractor-trailers, for a total shipping cost of $17,398. The earlier manual attempt to solve the problem (see Figure D-16) assigned all 12 trucks and four tractor-trailers, for a total shipping cost of $18,122. Using Solver in this situation saved your company $724.



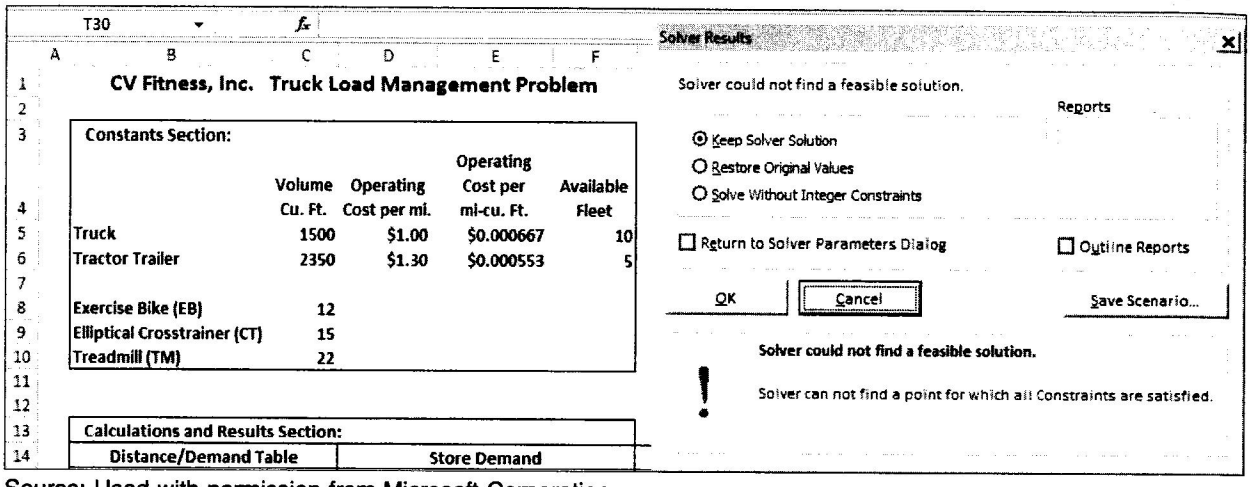
Vehicle Loading						Cost
Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
2	3000	1	2350	5350	94%	$3,333.00
1	1500	1	2350	3850	91%	$874.00
2	3000	0	0	3000	93%	$2,000.00
3	4500	1	2350	6850	97%	$2,322.00
1	1500	3	7050	8550	91%	$8,869.00
9	13500	6	14100	27600	93%	$17,398.00
						Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-23 Solver Results window

If the Solver Results window does not report an optimal solution to the problem, it will report that the problem could not be solved given the changing cells and constraints you specified. For instance, if you had not had enough vehicles in your fleet to carry the required shipping volume to all the destinations, the

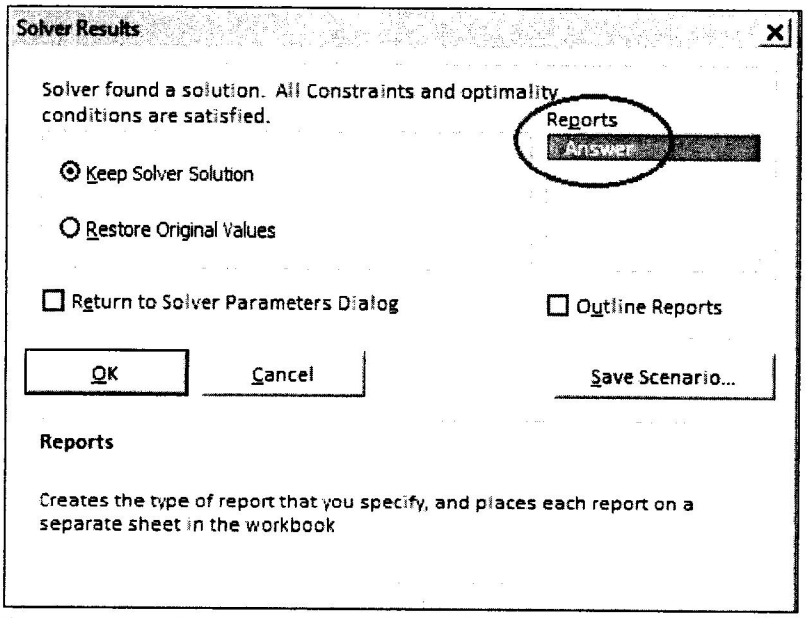
Solver Results window might have looked like Figure D-24. In the figure, your vehicle fleet was reduced to 10 trucks and five tractor-trailers, so Solver could not find a solution that satisfied the shipping volume constraints.



Source: Used with permission from Microsoft Corporation

FIGURE D-24 Solver could not find a feasible solution with a reduced vehicle fleet

Fortunately, Solver did find an optimal solution. To update the spreadsheet with the new optimal values for the changing cells and optimization cell, click OK in the Solver Results window. You can also create an Answer Report by clicking the Answer option in the Solver Results window (see Figure D-25) and then clicking OK.



Source: Used with permission from Microsoft Corporation

FIGURE D-25 Creating an Answer Report

Excel will create a report in a separate sheet called Answer Report 1. The Answer Report is shown in Figures D-26 and D-27.

Microsoft Excel 14.0 Answer Report
Worksheet: [CV Fitness Trucking Problem.xlsx]Truck Loading Problem--Solver
Report Created: 6/18/2012 11:42:14 AM
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Engine: Simplex LP
Solution Time: 2.964 Seconds.
Iterations: 3 Subproblems: 1416
Solver Options
Max Time 100 sec, Iterations 100, Precision 0.000001
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 0%

Objective Cell (Min)

Cell	Name	Original Value	Final Value
$N$21	Totals: Shipping Cost	$18,122.00	$17,398.00

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$H$16	Philadelphia Store Trucks	2	2	Integer
$H$17	Atlanta Store Trucks	1	1	Integer
$H$18	Miami Store Trucks	2	2	Integer
$H$19	Chicago Store Trucks	3	3	Integer
$H$20	Los Angeles Store Trucks	4	1	Integer
$J$16	Philadelphia Store Tractor-Trailers	1	1	Integer
$J$17	Atlanta Store Tractor-Trailers	1	1	Integer
$J$18	Miami Store Tractor-Trailers	0	0	Integer
$J$19	Chicago Store Tractor-Trailers	1	1	Integer
$J$20	Los Angeles Store Tractor-Trailers	1	3	Integer

Source: Used with permission from Microsoft Corporation

FIGURE D-26 Top portion of the Answer Report

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$L$19	Chicago Store Total Vehicle Capacity	6850	$L$19>=$G$19	Not Binding	220
$L$18	Miami Store Total Vehicle Capacity	3000	$L$18>=$G$18	Not Binding	224
$L$20	Los Angeles Store Total Vehicle Capacity	8550	$L$20>=$G$20	Not Binding	765
$L$16	Philadelphia Store Total Vehicle Capacity	5350	$L$16>=$G$16	Not Binding	338
$L$17	Atlanta Store Total Vehicle Capacity	3850	$L$17>=$G$17	Not Binding	337
$H$21	Totals: Trucks	9	$H$21<=$F$5	Not Binding	3
$J$21	Totals: Tractor-	6	$J$21<=$F$6	Binding	0
$H$16	Philadelphia Store Trucks	2	$H$16>=0	Binding	0
$H$17	Atlanta Store Trucks	1	$H$17>=0	Binding	0
$H$18	Miami Store Trucks	2	$H$18>=0	Binding	0
$H$19	Chicago Store Trucks	3	$H$19>=0	Binding	0
$H$20	Los Angeles Store Trucks	1	$H$20>=0	Binding	0
$J$16	Philadelphia Store Tractor-Trailers	1	$J$16>=0	Binding	0
$J$17	Atlanta Store Tractor-Trailers	1	$J$17>=0	Binding	0
$J$18	Miami Store Tractor-Trailers	0	$J$18>=0	Binding	0
$J$19	Chicago Store Tractor-Trailers	1	$J$19>=0	Binding	0
$J$20	Los Angeles Store Tractor-Trailers	3	$J$20>=0	Binding	0
$H$16:$H$20=Integer					
$J$16:$J$20=Integer					

Source: Used with permission from Microsoft Corporation

FIGURE D-27 Bottom portion of the Answer Report—note the new tab created by Solver

The Answer Report gives you a wealth of information about the solution. The top portion displays the original and final values of the Objective cell. The second part of the report displays the original and final values of the changing cells. The last part of the report lists the constraints. Binding constraints are those that reached their maximum or minimum value; nonbinding constraints did not.

Perhaps a savings of $724 does not seem significant—however, this problem does not have a specified time frame. The example probably represents one week of shipments for CV Fitness. The store demands will change from week to week, but you could use Solver each time to optimize the truck assignments. In a 50-week business year, the savings that Solver helps you find in shipping costs could be well over $30,000!

Go to the File tab to print the worksheets you created. Save the Excel file as **CV Fitness Trucking Problem.xlsx**, then select the Save As command in the File tab to create a new file called **CV Fitness Trucking Problem 2.xlsx**. You will use the new file in the next section.

EXTENDING THE EXAMPLE

Like all successful companies, CV Fitness looks for ways to grow its business and optimize its costs. Your management team is considering two changes:

- Opening two new stores and expanding the vehicle fleet if necessary
- Improving product design and packaging to reduce the shipping volume of the treadmill from 22 cubic feet to 17 cubic feet

You have been asked to modify your model to see the new requirements for each change separately. The two new stores would be in Denver and Phoenix, and they are 1,040 and 1,470 miles from the Memphis plant, respectively. If necessary, open the CV Fitness Trucking Problem 2.xlsx file, then right-click row 21 at the left worksheet border. Click Insert to enter a new row between rows 20 and 21. Repeat the steps to insert a second new row. Your spreadsheet should look like Figure D-28. Do not worry about the borders for now—you can fix them later.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
13		Calculations and Results Section:												
14		Distance/Demand Table		Store Demand			Vehicle Loading							Cost
15		Distance Table (from Memphis Plant)	Miles	EB	CT	TM	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16		Philadelphia Store	1010	140	96	86	5012	2	3000	1	2350	5350	94%	$3,333.00
17		Atlanta Store	380	76	81	63	3513	1	1500	1	2350	3850	91%	$874.00
18		Miami Store	1000	56	64	52	2776	2	3000	0	0	3000	93%	$2,000.00
19		Chicago Store	540	115	130	150	6630	3	4500	1	2350	6850	97%	$2,322.00
20		Los Angeles Store	1810	150	135	180	7785	1	1500	3	7050	8550	91%	$8,869.00
21														
22														
23						Totals:	25716	9	13500	6	14100	27600	93%	$17,398.00
24		Fill Legend:		Changing Cells										Total Cost
25				Optimization Cell										

Source: Used with permission from Microsoft Corporation

FIGURE D-28 Distance/Demand table with two blank rows inserted for the new stores

Enter the two new stores in cells B21 and B22, enter their distances in cells C21 and C22, and enter the Store Demands in cells D21 through F22, as shown in Figure D-29. When you complete this part of the table, fix the borders to include the two new stores. Select the area in the table you want to fix, click the No Borders button to clear the old borders, highlight the area to which you want to add the border, and then click the Outside Borders button.

	A	B	C	D	E	F
13		Calculations and Results Section:				
14		Distance/Demand Table			Store Demand	
15		Distance Table (from Memphis Plant)	Miles		EB	CT	TM
16		Philadelphia Store	1010		140	96	86
17		Atlanta Store	380		76	81	63
18		Miami Store	1000		56	64	52
19		Chicago Store	540		115	130	150
20		Los Angeles Store	1810		150	135	180
21		Denver Store	1040		74	67	43
22		Phoenix Store	1470		41	28	37
23						Totals:	
24		Fill Legend:			Changing Cells		
25					Optimization Cell		

Source: Used with permission from Microsoft Corporation

FIGURE D-29 Distance/Demand table with new store locations and demands entered

Next, copy the formulas from cells G20 to N20 to the two new rows in the Vehicle Loading and Cost sections of the table. Select cells G20 to N20, right-click, and click Copy on the menu. Then select cells G21 to N22 and click Paste in the Clipboard group. Your table should look like Figure D-30.

	G	H		J	K	L	M	N
13								
14	Vehicle Loading							Cost
15	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16	5012	2	3000	1	2350	5350	94%	$3,333.00
17	3513	1	1500	1	2350	3850	91%	$874.00
18	2776	2	3000	0	0	3000	93%	$2,000.00
19	6630	3	4500	1	2350	6850	97%	$2,322.00
20	7785	1	1500	3	7050	8550	91%	$8,869.00
21	2839	1	1500	3	7050	8550	33%	$5,096.00
22	1726	1	1500	3	7050	8550	20%	$7,203.00
23	30281	9	13500	6	14100	27600	110%	$17,398.00
24								Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-30 Formulas from row 20 copied into rows 21 and 22

Note that most cells in the Totals row have not changed—their formulas need to be updated to include the values in rows 21 and 22. To quickly check which cells you need to update, display the formulas in the Totals row. Hold down the Ctrl key and press the ~ key (on most keyboards, this key is next to the "1" key). The Vehicle Loading and Cost sections now display formulas in the cells (see Figure D-31).

	G	H	I	J	K	L	M	N
13								
14	Vehicle Loading							Cost
15	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16	=D16*$C$8+E16*$C$9+F16*$C$10	2	=H16*$C$5	1	=J16*$C$6	=I16+K16	=G16/L16	=H16*C16*$D$5+J16*C16*$D$6
17	=D17*$C$8+E17*$C$9+F17*$C$10	1	=H17*$C$5	1	=J17*$C$6	=I17+K17	=G17/L17	=H17*C17*$D$5+J17*C17*$D$6
18	=D18*$C$8+E18*$C$9+F18*$C$10	2	=H18*$C$5	0	=J18*$C$6	=I18+K18	=G18/L18	=H18*C18*$D$5+J18*C18*$D$6
19	=D19*$C$8+E19*$C$9+F19*$C$10	3	=H19*$C$5	1	=J19*$C$6	=I19+K19	=G19/L19	=H19*C19*$D$5+J19*C19*$D$6
20	=D20*$C$8+E20*$C$9+F20*$C$10	1	=H20*$C$5	3	=J20*$C$6	=I20+K20	=G20/L20	=H20*C20*$D$5+J20*C20*$D$6
21	=D21*$C$8+E21*$C$9+F21*$C$10	1	=H21*$C$5	3	=J21*$C$6	=I21+K21	=G21/L21	=H21*C21*$D$5+J21*C21*$D$6
22	=D22*$C$8+E22*$C$9+F22*$C$10	1	=H22*$C$5	3	=J22*$C$6	=I22+K22	=G22/L22	=H22*C22*$D$5+J22*C22*$D$6
23	=SUM(G16:G22)	=SUM(H16:H20)	=SUM(I16:I20)	=SUM(J16:J20)	=SUM(K16:K20)	=SUM(L16:L20)	=G23/L23	=SUM(N16:N20)
24								Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-31 Vehicle Loading and Cost sections with formulas displayed in the cells

You must update any Totals cells that do not include the contents of rows 21 and 22. For example, you need to update the Totals cells H23 through L23 and cell N23. Cell M23 is not really a total; it is a cumulative ratio formula, so you do not need to update the cell. Use the following formulas to revise the Totals cells:

- Cell H23: =SUM(H16:H22)
- Cell I23: =SUM(I16:I22)
- Cell J23: =SUM(J16:J22)
- Cell K23: =SUM(K16:K22)
- Cell L23: =SUM(L16:L22)
- Cell N23: =SUM(N16:N22)

The updated sections should look like Figure D-32.

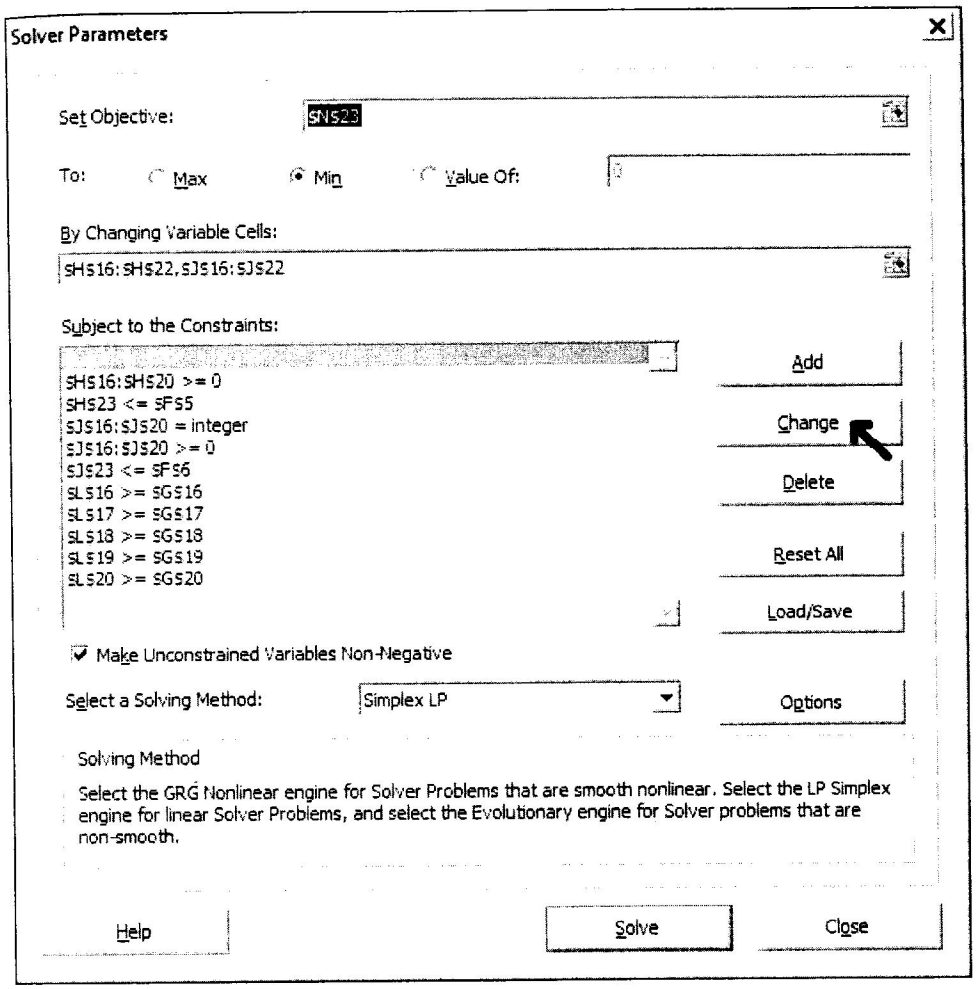
	G	H	I	J	K	L	M	N
14	Vehicle Loading							Cost
15	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
16	5012	2	3000	1	2350	5350	94%	$3,333.00
17	3513	1	1500	1	2350	3850	91%	$874.00
18	2776	2	3000	0	0	3000	93%	$2,000.00
19	6630	3	4500	1	2350	6850	97%	$2,322.00
20	7785	1	1500	3	7050	8550	91%	$8,869.00
21	2839	1	1500	3	7050	8550	33%	$5,096.00
22	1726	1	1500	3	7050	8550	20%	$7,203.00
23	30281	11	16500	12	28200	44700	68%	$29,697.00
24								Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-32 Vehicle Loading and Cost sections with the formulas updated

You are ready to use Solver to determine the optimal vehicle assignment. Click Solver in the Analysis group of the Data tab. You should notice immediately that you must revise the changing cells to include the two new stores; you must also change some of the constraints and add others. Solver has already updated the Objective cell from $N$21 to $N$23 and has updated the $H$23<=$F$5 and $J$23<=$F$6 constraints for vehicle fleet size. To update the changing cells, click the button to the right of the By Changing Variable Cells field and select the cells again, or edit the formula in the window by changing cell address $H$20 to $H$22 and cell address $J$20 to $J$22.

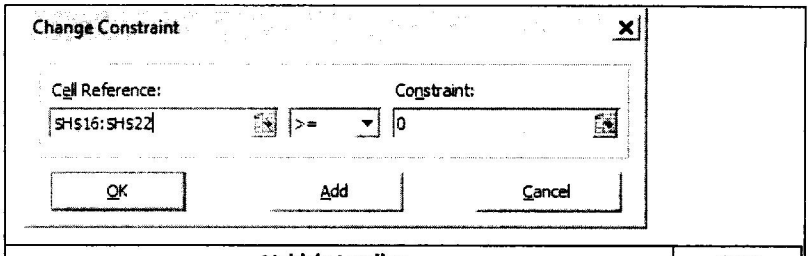
To change a constraint, select the one you want to change, and then click Change (see Figure D-33).



Source: Used with permission from Microsoft Corporation

FIGURE D-33 Selecting a constraint to change

When you click Change, the Change Constraint window appears. Click the Cell Reference button; the selected cells will appear on the spreadsheet with a moving marquee around them (see Figure D-34). Highlight the new group of cells; when the new range appears in the Cell Reference field, click OK. The Solver Parameters window appears with the constraint changed.



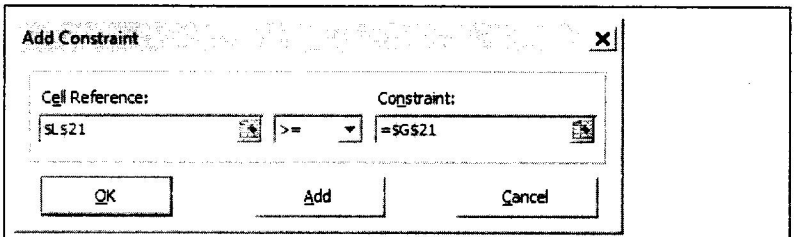
Vehicle Loading							Cost
Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
5012	2	3000	1	2350	5350	94%	$3,333.00
3513	1	1500	1	2350	3850	91%	$874.00
2776	2	3000	0	0	3000	93%	$2,000.00
6630	3	4500	1	2350	6850	97%	$2,322.00
7785	1	1500	3	7050	8550	91%	$8,869.00
2839	1	1500	3	7050	8550	33%	$5,096.00
1726	1	1500	3	7050	8550	20%	$7,203.00
30281	11	16500	12	28200	44700	68%	$29,697.00
							Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-34 Adding cells H21 and H22 to the Trucks constraint cell range

You also need to update or add the following constraints:

- Update $J$16:$J$20 >=0 to $J$16:$J$22 >=0.
- Update $H$16:$H$20 = integer to $H$16:$H$22 = integer. When changing integer constraints, you must click "int" in the middle field of the Change Constraint window; otherwise, you will receive an error message.
- Update $J$16:$J$20 = integer to $J$16:$J$22 = integer.
- Add constraint $L$21 >= $G$21 (see Figure D-35).
- Add constraint $L$22 >= $G$22.

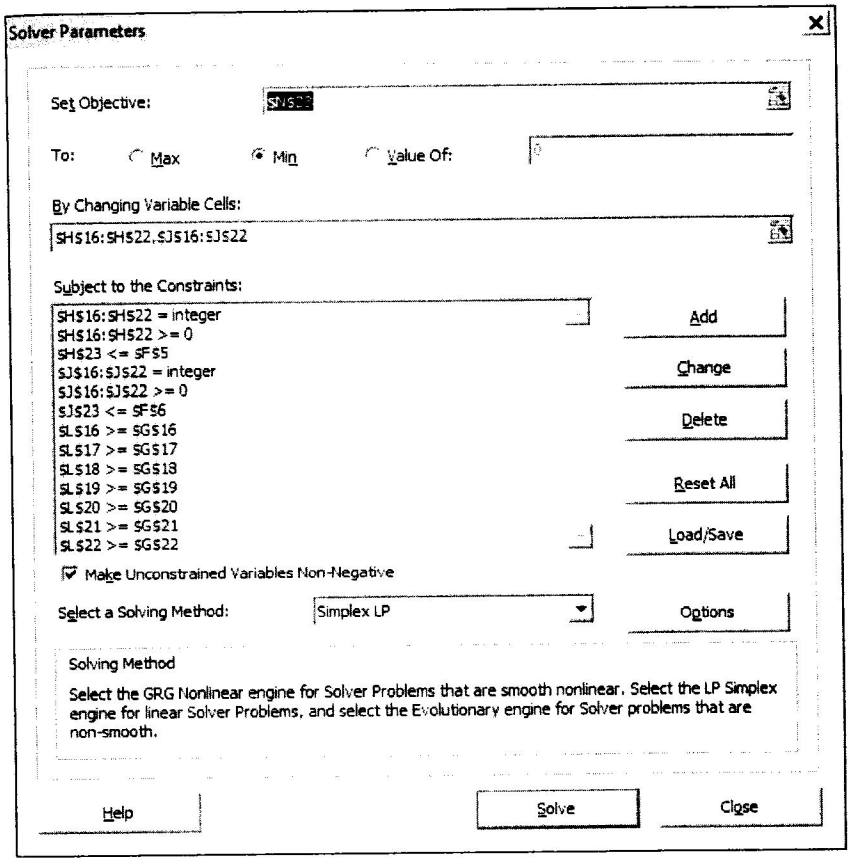


Vehicle Loading							Cost
Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
5012	2	3000	1	2350	5350	94%	$3,333.00
3513	1	1500	1	2350	3850	91%	$874.00
2776	2	3000	0	0	3000	93%	$2,000.00
6630	3	4500	1	2350	6850	97%	$2,322.00
7785	1	1500	3	7050	8550	91%	$8,869.00
2839	1	1500	3	7050	8550	33%	$5,096.00
1726	1	1500	3	7050	8550	20%	$7,203.00
30281	11	16500	12	28200	44700	68%	$29,697.00
							Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-35 Adding a constraint using the Add Constraint window

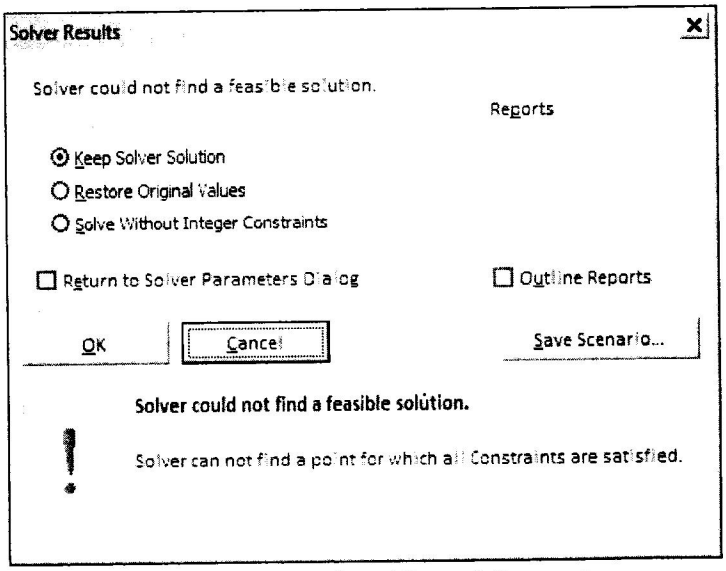
You are ready to solve the shipping problem to include the new stores in Denver and Phoenix. Figure D-36 shows the updated Solver Parameters window.



Source: Used with permission from Microsoft Corporation

FIGURE D-36 Solver parameters updated for shipping to seven stores

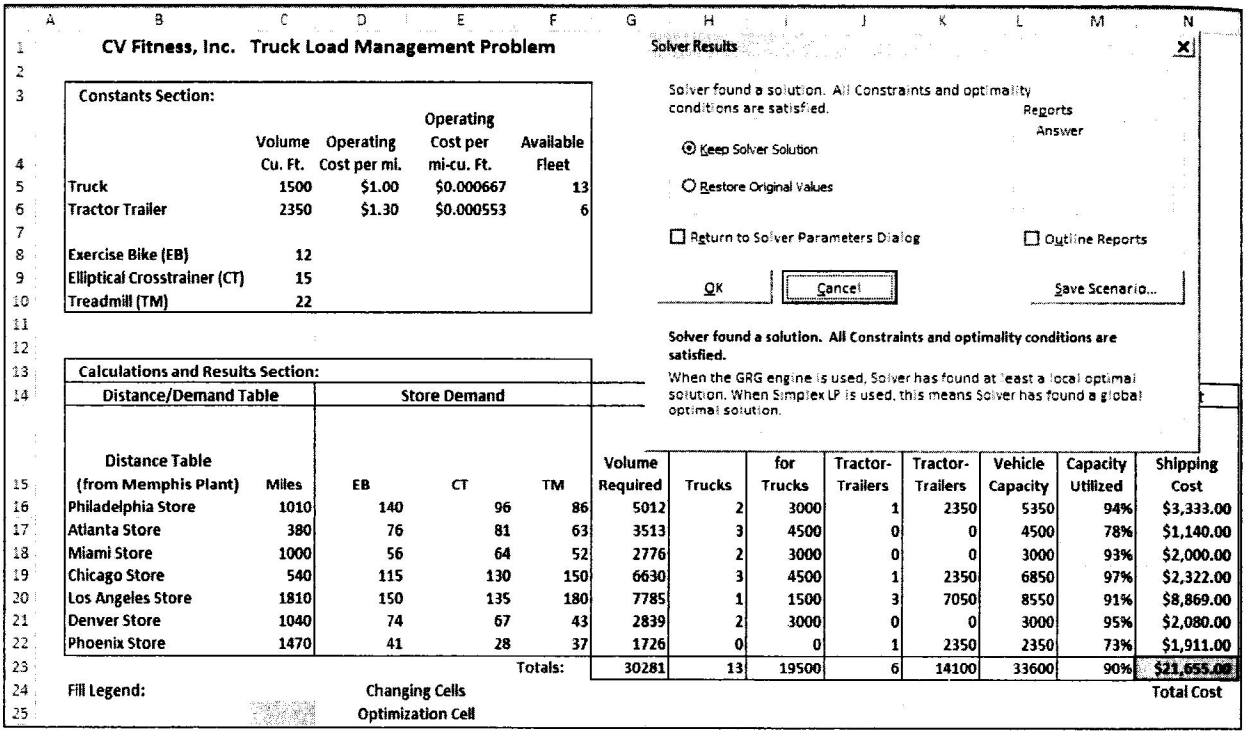
Before you run Solver again, you might want to attempt to assign the vehicles manually, because your fleet may not be large enough to handle two more stores. In this case, you will quickly realize that the vehicle fleet is at least one truck or tractor-trailer short of the minimum required to ship the needed volume. You can confirm this by running Solver (see Figure D-37).



Source: Used with permission from Microsoft Corporation

FIGURE D-37 Vehicle fleet does not meet minimum requirements

The Solver Results window confirms that your truck fleet is too small, so change the value in cell F5 from 12 to 13 to add another truck to your fleet, and then run Solver again. As you add more stores and vehicles to make the problem more complex, Solver will take longer to run, especially on older computers. You may have to wait a minute or more for Solver to finish its iterations and find an answer (see Figure D-38). In this example, Solver recommends that you use 13 trucks and six tractor-trailers.



CV Fitness, Inc. Truck Load Management Problem

Constants Section:

	Volume Cu. Ft.	Operating Cost per mi.	Operating Cost per mi-cu. Ft.	Available Fleet
Truck	1500	$1.00	$0.000667	13
Tractor Trailer	2350	$1.30	$0.000553	6
Exercise Bike (EB)	12			
Elliptical Crosstrainer (CT)	15			
Treadmill (TM)	22			

Solver Results

Solver found a solution. All Constraints and optimality conditions are satisfied.

Reports: Answer

Keep Solver Solution

Restore Original Values

Return to Solver Parameters Dialog

Outline Reports

OK | Cancel | Save Scenario...

Solver found a solution. All Constraints and optimality conditions are satisfied.

When the GRG engine is used, Solver has found at least a local optimal solution. When Simplex LP is used, this means Solver has found a global optimal solution.

Calculations and Results Section:

Distance Table (from Memphis Plant)	Miles	Store Demand EB	CT	TM	Volume Required	Trucks	for Trucks	Tractor-Trailers	Tractor-Trailers	Vehicle Capacity	Capacity Utilized	Shipping Cost
Philadelphia Store	1010	140	96	86	5012	2	3000	1	2350	5350	94%	$3,333.00
Atlanta Store	380	76	81	63	3513	3	4500	0	0	4500	78%	$1,140.00
Miami Store	1000	56	64	52	2776	2	3000	0	0	3000	93%	$2,000.00
Chicago Store	540	115	130	150	6630	3	4500	1	2350	6850	97%	$2,322.00
Los Angeles Store	1810	150	135	180	7785	1	1500	3	7050	8550	91%	$8,869.00
Denver Store	1040	74	67	43	2839	2	3000	0	0	3000	95%	$2,080.00
Phoenix Store	1470	41	28	37	1726	0	0	1	2350	2350	73%	$1,911.00
				Totals:	30281	13	19500	6	14100	33600	90%	$21,655.00

Fill Legend: Changing Cells; Optimization Cell

Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-38 Solver's solution

Select Answer in the Reports list to add an Answer Report to the workbook, and then click OK. You can keep or delete the old Answer Report 1 tab from the earlier workbook. The new Answer Report is in a new worksheet named Answer Report 2.

You can meet the shipping requirements by adding one more truck, but is it really the most cost-effective solution? What if you add a tractor-trailer instead? Set the number of trucks back to 12, and add a tractor-trailer by entering 7 instead of 6 in cell F6. Run Solver again.

This time Solver finds a less expensive solution, as shown in Figures D-39 and D-40. At first it does not make sense—how can adding a more expensive vehicle (a tractor-trailer) reduce the overall expense? In fact, the additional tractor-trailer has replaced two trucks. With seven tractor-trailers, you only need 11 trucks instead of the original 13.

Microsoft Excel 14.0 Answer Report
Worksheet: [CV Fitness Trucking Problem 2.xlsx]Truck Loading Problem--DEN-PHX
Report Created: 6/18/2012 11:57:22 AM
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Engine: Simplex LP
Solution Time: 38.673 Seconds.
Iterations: 6 Subproblems: 15498
Solver Options
Max Time 100 sec, Iterations 100, Precision 0.000001
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 0%

Objective Cell (Min)

Cell	Name	Original Value	Final Value
$N$23	Totals: Shipping Cost	$21,655.00	$21,389.00

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$H$16	Philadelphia Store Trucks	2	2	Integer
$H$17	Atlanta Store Trucks	3	1	Integer
$H$18	Miami Store Trucks	2	2	Integer
$H$19	Chicago Store Trucks	3	3	Integer
$H$20	Los Angeles Store Trucks	1	1	Integer
$H$21	Denver Store Trucks	2	2	Integer
$H$22	Phoenix Store Trucks	0	0	Integer
$J$16	Philadelphia Store Tractor-Trailers	1	1	Integer
$J$17	Atlanta Store Tractor-Trailers	0	1	Integer
$J$18	Miami Store Tractor-Trailers	0	0	Integer
$J$19	Chicago Store Tractor-Trailers	1	1	Integer
$J$20	Los Angeles Store Tractor-Trailers	3	3	Integer
$J$21	Denver Store Tractor-Trailers	0	0	Integer
$J$22	Phoenix Store Tractor-Trailers	1	1	Integer

Source: Used with permission from Microsoft Corporation

FIGURE D-39 Answer Report 3 displays a more cost-effective solution

	Vehicle Loading							Cost
	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
	5012	2	3000	1	2350	5350	94%	$3,333.00
	3513	1	1500	1	2350	3850	91%	$874.00
	2776	2	3000	0	0	3000	93%	$2,000.00
	6630	3	4500	1	2350	6850	97%	$2,322.00
	7785	1	1500	3	7050	8550	91%	$8,869.00
	2839	2	3000	0	0	3000	95%	$2,080.00
	1726	0	0	1	2350	2350	73%	$1,911.00
	30281	11	16500	7	16450	32950	92%	$21,389.00
								Total Cost

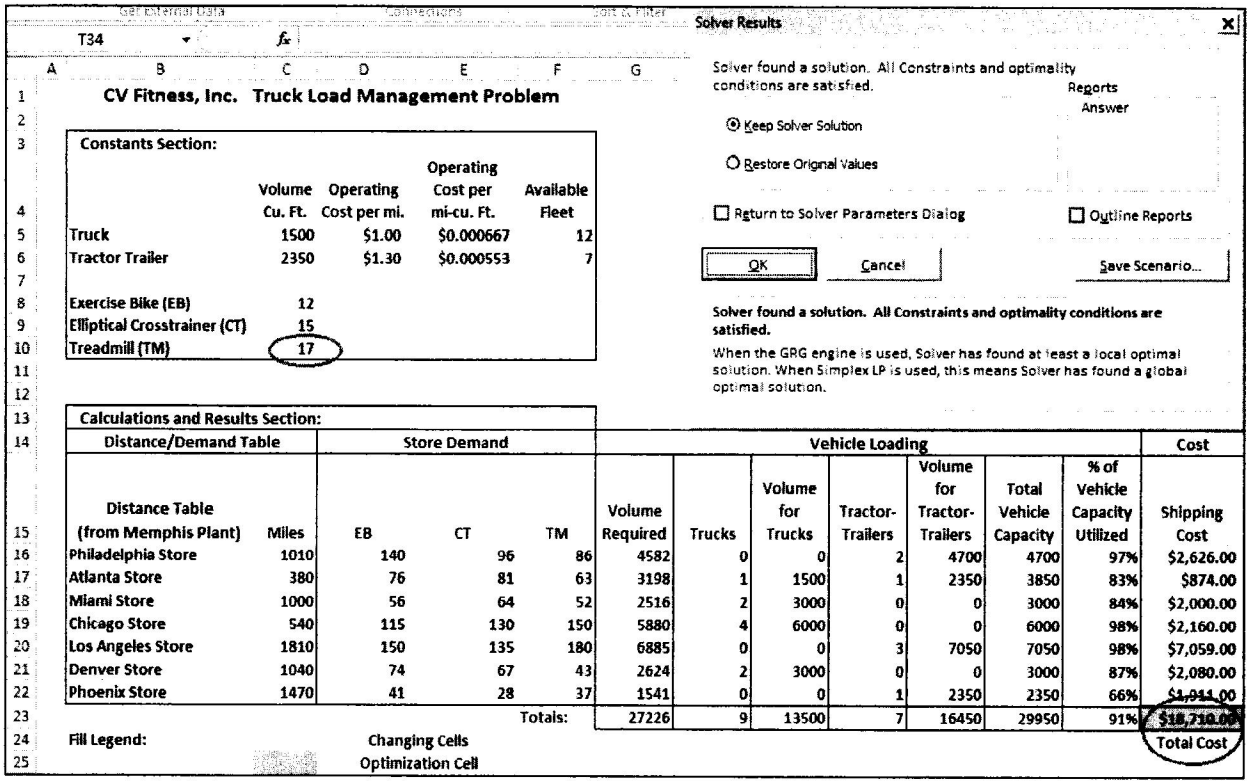
Source: Used with permission from Microsoft Corporation

FIGURE D-40 Seven tractor-trailers and 11 trucks are the optimal mix

You have a solution for the expansion to seven stores. Save your workbook, and then create a new workbook using the Save As command. Name the new workbook **CV Fitness Trucking Problem 3.xlsx.**

Next, evaluate the potential cost savings if the company redesigns its treadmill product and packaging to reduce the shipping volume from 22 cubic feet to 17 cubic feet. Your engineers report that the redesign will cost approximately $10,000. If you can save at least $500 per shipment, the project will pay for itself in less than six months (20 weekly shipments).

Go to cell C10 on the worksheet, replace 22 with 17, and run Solver again. When Solver finds the solution, select Answer to create another Answer Report, and then click OK. See Figure D-41.



Solver Results

Solver found a solution. All Constraints and optimality conditions are satisfied.

Reports: Answer

Keep Solver Solution

Restore Original Values

Return to Solver Parameters Dialog

Outline Reports

OK | Cancel | Save Scenario...

Solver found a solution. All Constraints and optimality conditions are satisfied.

When the GRG engine is used, Solver has found at least a local optimal solution. When Simplex LP is used, this means Solver has found a global optimal solution.

CV Fitness, Inc. Truck Load Management Problem

Constants Section:

	Volume Cu. Ft.	Operating Cost per mi.	Operating Cost per mi-cu. Ft.	Available Fleet
Truck	1500	$1.00	$0.000667	12
Tractor Trailer	2350	$1.30	$0.000553	7
Exercise Bike (EB)	12			
Elliptical Crosstrainer (CT)	15			
Treadmill (TM)	17			

Calculations and Results Section:

Distance/Demand Table		Store Demand			Vehicle Loading							Cost
Distance Table (from Memphis Plant)	Miles	EB	CT	TM	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
Philadelphia Store	1010	140	96	86	4582	0	0	2	4700	4700	97%	$2,626.00
Atlanta Store	380	76	81	63	3198	1	1500	1	2350	3850	83%	$874.00
Miami Store	1000	56	64	52	2516	2	3000	0	0	3000	84%	$2,000.00
Chicago Store	540	115	130	150	5880	4	6000	0	0	6000	98%	$2,160.00
Los Angeles Store	1810	150	135	180	6885	0	0	3	7050	7050	98%	$7,059.00
Denver Store	1040	74	67	43	2624	2	3000	0	0	3000	87%	$2,080.00
Phoenix Store	1470	41	28	37	1541	0	0	1	2350	2350	66%	$1,911.00
				Totals:	27226	9	13500	7	16450	29950	91%	$18,710.00

Total Cost

Fill Legend: Changing Cells; Optimization Cell

Source: Used with permission from Microsoft Corporation

FIGURE D-41 Solver solution with redesigned treadmill and packaging

Check the Answer Report to see the cost difference between shipping the old treadmills and the redesigned models (see Figure D-42). The cost savings for one shipment is $2,679, which is more than five times the minimum savings you needed. You should go ahead with the project.

Worksheet: [CV Fitness Trucking Problem 3.xlsx]Truck Loading Problem--TM cu-ft
Report Created: 6/18/2012 12:02:09 PM
Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine
Engine: Simplex LP
Solution Time: 25.21 Seconds.
Iterations: 8 Subproblems: 10238
Solver Options
Max Time 100 sec, Iterations 100, Precision 0.000001
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 0%

Objective Cell (Min)

Cell	Name	Original Value	Final Value
$N$23	Totals: Shipping Cost	$21,389.00	$18,710.00

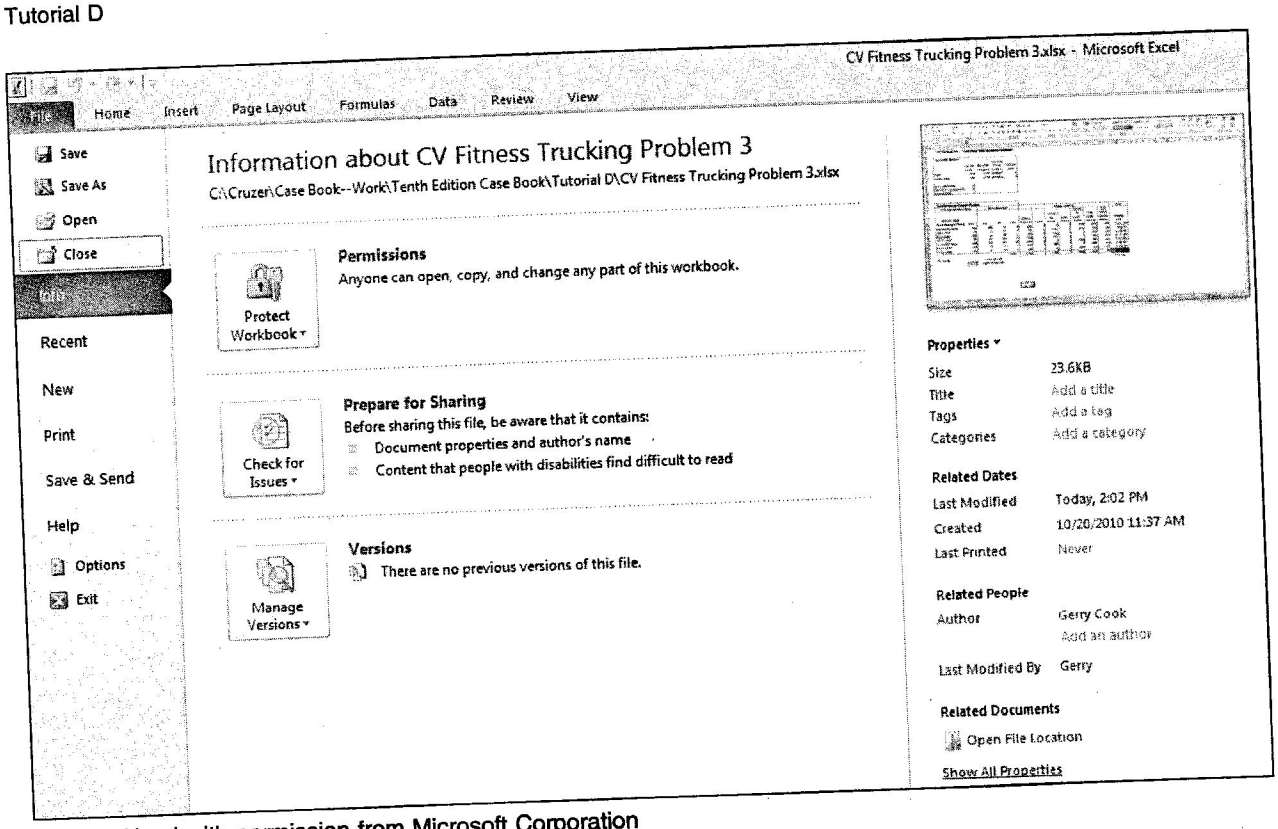
Variable Cells

Cell	Name	Original Value	Final Value	Integer
$H$16	Philadelphia Store Trucks	2	0	Integer
$H$17	Atlanta Store Trucks	1	1	Integer
$H$18	Miami Store Trucks	2	2	Integer
$H$19	Chicago Store Trucks	3	4	Integer
$H$20	Los Angeles Store Trucks	1	0	Integer
$H$21	Denver Store Trucks	2	2	Integer
$H$22	Phoenix Store Trucks	0	0	Integer
$J$16	Philadelphia Store Tractor-Trailers	1	2	Integer
$J$17	Atlanta Store Tractor-Trailers	1	1	Integer
$J$18	Miami Store Tractor-Trailers	0	0	Integer
$J$19	Chicago Store Tractor-Trailers	1	0	Integer
$J$20	Los Angeles Store Tractor-Trailers	3	3	Integer
$J$21	Denver Store Tractor-Trailers	0	0	Integer
$J$22	Phoenix Store Tractor-Trailers	1	1	Integer

Source: Used with permission from Microsoft Corporation

FIGURE D-42 Answer Report for the treadmill redesign

When you finish examining the Answer Report, save your file and then close it. To close the workbook, click the File tab and then click Close (see Figure D-43).



Source: Used with permission from Microsoft Corporation

FIGURE D-43 Closing the Excel workbook

USING SOLVER ON A NEW PROBLEM

A common problem in manufacturing businesses is deciding on a product mix for different items in the same product family. Sensuous Scents Inc. makes a premium collection of perfume, cologne, and body spray for sale in large department stores and boutiques. The primary ingredient is ambergris, a valuable digestive excretion from whales that is harvested without harming the animals. Ambergris costs more than $9,000 per pound and is very difficult to obtain in large quantities; Sensuous Scents can obtain only about 20 pounds of ambergris each year. The other ingredients—deionized water, ethanol, and various additives—are available in unlimited quantities for a reasonable cost.

You have been asked to create a spreadsheet model for Solver to determine the optimal product mix that maximizes Sensuous Scents' net income after taxes.

Setting up the Spreadsheet

The sections in this spreadsheet are different from those in the preceding trucking problem. You will create a Constants section, a Bill of Materials section for the three products, a Quantity Manufactured section that contains the changing cells, a Calculations section (to calculate ambergris usage, manufacturing costs, and sales revenue per product line), and an Income Statement section to determine the net income after taxes, which will be the optimization cell.

AT THE KEYBOARD

Start a new file called **Sensuous Scents Inc.xlsx** and set up the spreadsheet.

Spreadsheet Title and Constants Section

Your spreadsheet title and Constants section should look like Figure D-44. A discussion of the section entries follows the figure.

	A	B	C	D	E	F
1		Sensuous Scents Inc. Product Mix				
2						
3		Constants:		Body Spray	Cologne	Perfume
4		Sales Price per bottle		$11.95	$21.00	$53.00
5		Conversion Cost per Unit (Direct Labor plus Manufacturing Overhead)		$2.60	$6.50	$13.00
6		Minimum Sales Demand		60000	25000	12000
7		Income Tax Rate	0.32			
8		Sales, General and Administrative Expenses per Dollar Revenue	0.30			
9		Available Ambergris (lbs)	20			
10		Cost per lb, Deionized Water	$0.50			
11		Cost per lb, Ethanol	$1.00			
12		Cost per lb, other Additives	$182.00			
13		Cost per lb, Ambergris	$9,072.00			

Source: Used with permission from Microsoft Corporation

FIGURE D-44 Spreadsheet title and Constants section for Sensuous Scents Inc.

- Sales Price per bottle—These values are the sales prices for each of the three products.
- Conversion Cost per Unit—These values are the direct labor costs plus the manufacturing overhead costs budgeted per unit manufactured. A conversion cost is often used in industries that manufacture liquid products.
- Minimum Sales Demand—These values reflect the forecast minimum sales demand that you must supply to your customers. These values will be used later as constraints.
- Income Tax Rate—The rate is 32% of your pretax income. No taxes are paid on losses.
- Sales, General and Administrative Expenses per Dollar Revenue—This value is an estimate of the non-manufacturing costs that Sensuous Scents will incur per dollar of sales revenue. These expenses are subtracted from the Gross Profit value in the Income Statement section to obtain Net Income before taxes.
- Available Ambergris (lbs.)—This value is the amount of ambergris that Sensuous Scents obtained this year for production.
- Cost per lb., Deionized Water—This value is the current cost per pound of deionized water.
- Cost per lb., Ethanol—This value is the current cost per pound of ethanol.
- Cost per lb., other Additives—Scent products contain other additives and fixatives to enhance or preserve the fragrance. This value is the cost per pound of the other additives.
- Cost per lb., Ambergris—This value is the current market price per pound of naturally harvested ambergris. Again, no whales are harmed to obtain the ambergris.

The rest of the cells are filled with a gray background to indicate that you will not use their values or formulas. The section is arranged this way to maintain one column per product all the way down the spreadsheet, which will simplify writing the formulas later.

Bill of Materials Section

Your spreadsheet should contain a Bill of Materials section, as shown in Figure D-45. The section entries are explained after the figure. A bill of materials is a list of raw materials and ingredients required to make one unit of a product.

	A	B	C	D	E	F
14						
15		Bill of Materials:		Body Spray	Cologne	Perfume
16		Deionized Water (lb)		0.4	0.1	0.05
17		Ethanol (lb)		0.1	0.02	0.01
18		Other Additives (lb)		0.01	0.001	0.0001
19		Ambergris (lb)		0.0001	0.00018	0.00055

Source: Used with permission from Microsoft Corporation

FIGURE D-45 Bill of Materials section

- Deionized Water (lb.)—The amount of deionized water required to make one unit of each product
- Ethanol (lb.)—The amount of ethanol required to make one unit of each product
- Other Additives (lb.)—The amount of other additives required to make one unit of each product
- Ambergris (lb.)—The amount of ambergris required to make one unit of each product

Extremely small quantities of ambergris and other additives are required to make one bottle of each product. Also, each product requires a different amount of ambergris. Check the values to make sure you entered the correct number of decimal places.

Quantity Manufactured (Changing Cells) Section

This model contains a separate Changing Cells section called Quantity Manufactured, as shown in Figure D-46. This section contains the cells that you want Solver to manipulate to achieve the highest net income after taxes.

	A	B	C	D	E	F
20						
21		**Quantity Manufactured (Changing Cells)**		**Body Spray**	**Cologne**	**Perfume**
22		**Units Produced**		**60000**	**25000**	**12000**

Source: Used with permission from Microsoft Corporation

FIGURE D-46 Quantity Manufactured (changing cells) section

Cells D22, E22, and F22 are yellow to indicate that Solver will change them to reach an optimal solution. To begin, enter the minimum sales demand in these cells, which will remind you to specify the minimum demand constraints from the Constants section in the Solver Parameters window.

Calculations Section

Your model should contain the Calculations section shown in Figure D-47.

	A	B	C	D	E	F	G
23							
24		**Calculations:**		**Body Spray**	**Cologne**	**Perfume**	**Totals**
25		**Lbs of Ambergris Used**					
26		**Manufacturing Cost per Unit (Materials Costs plus Conversion Cost)**					
27		**Total Manufacturing Costs per Product Line**					
28		**Sales Revenues per Product Line**					

Source: Used with permission from Microsoft Corporation

FIGURE D-47 Calculations section

The section contains the following calculations:

- Lbs. of Ambergris Used—This value is the pounds of ambergris per unit from the Bill of Materials section, multiplied by Units Produced from the Quantity Manufactured section for each of the three products. The Totals cell (G25) is the sum of cells D25, E25, and F25. Use the value in this cell to specify the constraint that you have only 20 pounds of ambergris available to use for raw materials (Constants section, cell C9).
- Manufacturing Cost per Unit (Materials Costs plus Conversion Cost)—To get this value, write a formula that multiplies the unit cost for each of the four product ingredients by the amount per unit specified in the bill of materials, multiplied by Units Produced. The total materials costs for the four ingredients are added together, and then the Conversion Cost per Unit is added from the Constants section to obtain the Manufacturing Cost per Unit. Enter the following formula for the Body Spray Manufacturing Cost per Unit in cell D26:

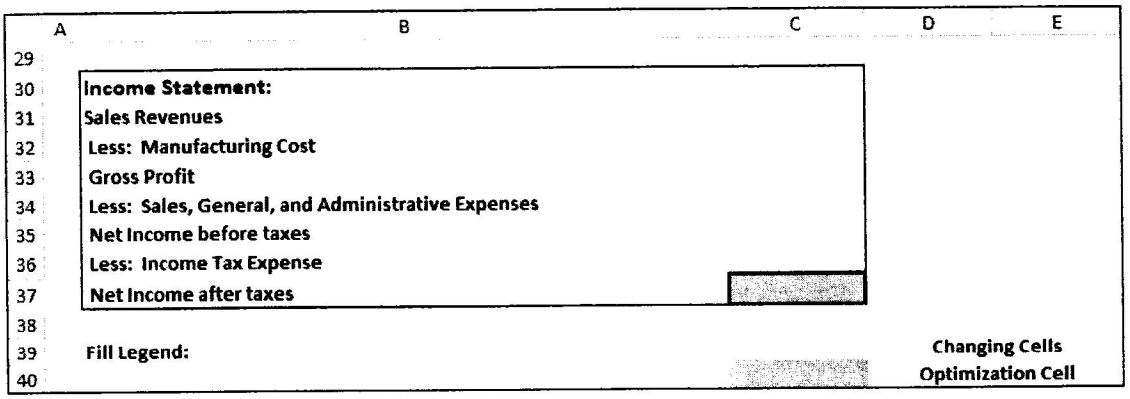
  =$C$10*D16+$C$11*D17+$C$12*D18+$C$13*D19+D5

  Use absolute cell references for the cells that hold values for costs per pound ($C$10, $C$11, $C$12, and $C$13). By doing so, you can copy the body spray formula to the Manufacturing Cost per Unit cells for the cologne and perfume values (cells E26 and F26). The Totals cell (G26) is not used in this row—you can fill the cell in gray to indicate that it is not used.
- Total Manufacturing Costs per Product Line—This value is the Manufacturing Cost per Unit multiplied by Units Produced from the Quantity Manufactured section. The Totals cell (G27) is the sum of cells D27, E27, and F27. You will use the value in the Totals cell in the Income Statement section.

- Sales Revenues per Product Line—This value is the Sales Price per bottle from the Constants section multiplied by Units Produced from the Quantity Manufactured section. The Totals cell (G28) is the sum of cells D28, E28, and F28. You will use the value in this cell in the Income Statement section.

Income Statement Section

The last section you need to construct is the Income Statement, as shown in Figure D-48. An explanation of the needed formulas follows the figure.



Source: Used with permission from Microsoft Corporation

FIGURE D-48 Income Statement section with fill legend

- Sales Revenues—This value is the total sales revenues from the Calculations section (cell G28).
- Less: Manufacturing Cost—This value is the total manufacturing costs from the Calculations section (cell G27).
- Gross Profit—This value is the Sales Revenues minus the Manufacturing Cost.
- Less: Sales, General, and Administrative Expenses—This value is the Sales Revenues multiplied by the Sales, General, and Administrative Expenses per Dollar Revenue from the Constants section (cell C8).
- Net Income before taxes—This value is the Gross Profit minus the Sales, General, and Administrative Expenses.
- Less: Income Tax Expense—If the Net Income before taxes is greater than zero, this value is the Net Income before taxes multiplied by the Income Tax Rate in the Constants section. If Net Income before taxes is zero or less, the Income Tax Expense is zero.
- Net Income after taxes—This value is the Net Income before taxes minus the Income Tax Expense. You will use this value as your optimization cell because you want to maximize Net Income after taxes.

Setting up Solver

You need to satisfy the following conditions when running Solver:

- Your objective is to maximize Net Income after taxes (cell C37).
- Your changing cells are the Units Produced (cells D22, E22, and F22).
- Observe the following constraints:
  - You must produce at least the Minimum Sales Demand for each product (cells D6, E6, and F6).
  - Your total Lbs. of Ambergris Used (cell G25) cannot exceed the Available Ambergris (cell C9).
  - You cannot produce negative units of any product (enter constraints for the changing cells to be greater than or equal to zero).
  - You can produce only whole units of any product (enter constraints for the changing cells to be integers).

Run Solver and create an Answer Report when Solver finds the solution. When you complete the program, print your spreadsheet with the Solver solution, and print the Answer Report. Save your work and close Excel.

TROUBLESHOOTING SOLVER

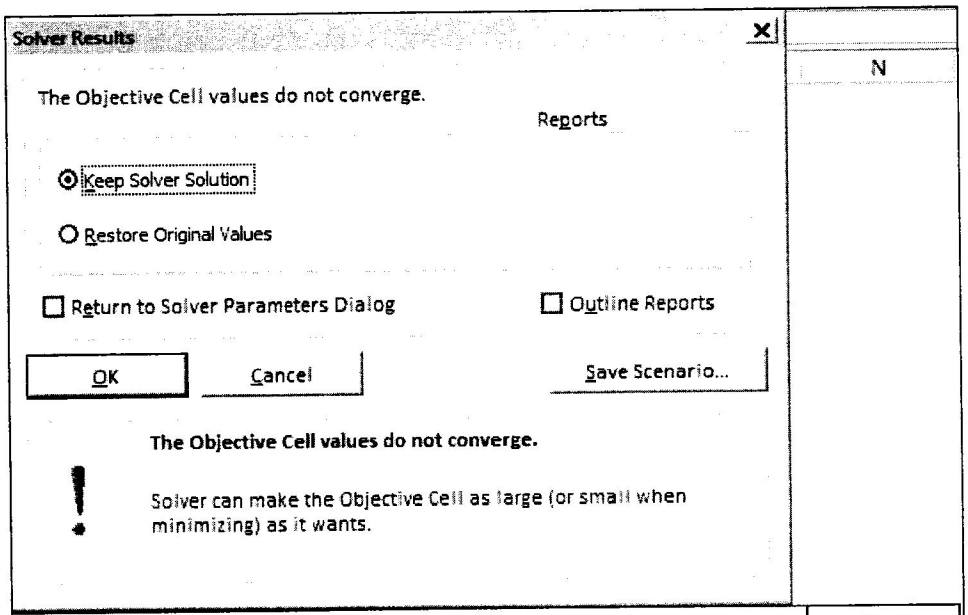
Solver is a fairly complex software program. This section helps you address common problems you may encounter when attempting to run Solver.

Using Whole Numbers in Changing Cells

Before you run your first Solver model or rerun a previous model, always enter a positive whole number in each of the changing cells. If you have not already defined maximum and minimum constraints for the values in the changing cells, enter 1 in each cell before running Solver.

Getting Negative or Fractional Answers

If you receive negative or fractional answers when running Solver, you may have neglected to specify one or more of the changing cells as non-negative integers. Alternatively, if you are working on a cost minimization problem and you fail to specify the optimization cell as non-negative, you may receive a negative answer for the cost. Sometimes Solver will also warn you that you have one or more unbounded constraints (see Figure D-49).



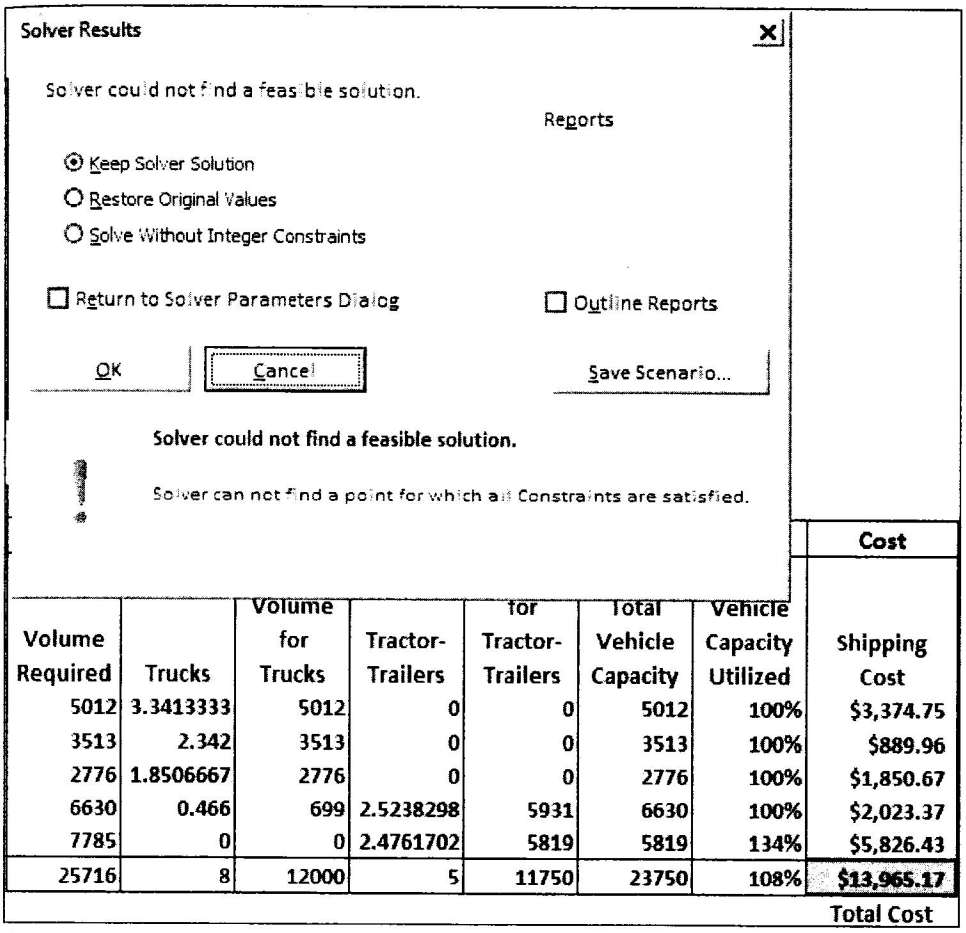
Vehicle Loading							Cost
Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity	% of Vehicle Capacity Utilized	Shipping Cost
5012	-1.802667	-2704	3.2834043	7716	5012	100%	$2,490.42
3513	2.342	3513	0	0	3513	100%	$889.96
2776	1.8506667	2776	0	0	2776	100%	$1,850.67
6630	4.42	6630	0	0	6630	100%	$2,386.80
7785	5.19	7785	0	0	7785	100%	$9,393.90
25716	12	18000	3.2834043	7716	25716	100%	$17,011.74
							Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-49 Solver has an "unbounded" objective function because you did not specify non-negative integer constraints

Creating Overconstrained Models

If Solver cannot find a solution because it cannot meet the constraints you defined, you will receive an error message. When this happens, Solver may even violate the integer constraints you defined in an attempt to find an answer, as shown in Figure D-50.



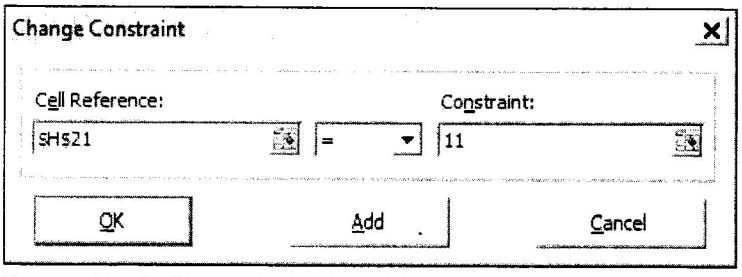
							Cost
Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	for Tractor-Trailers	Total Vehicle Capacity	Vehicle Capacity Utilized	Shipping Cost
5012	3.3413333	5012	0	0	5012	100%	$3,374.75
3513	2.342	3513	0	0	3513	100%	$889.96
2776	1.8506667	2776	0	0	2776	100%	$1,850.67
6630	0.466	699	2.5238298	5931	6630	100%	$2,023.37
7785	0	0	2.4761702	5819	5819	134%	$5,826.43
25716	8	12000	5	11750	23750	108%	$13,965.17
							Total Cost

Source: Used with permission from Microsoft Corporation

FIGURE D-50 Solver could not find a feasible solution because not enough vehicles were available

Setting a Constraint to a Single Amount

Sometimes you may want to enter an exact amount into a constraint, as opposed to a number in a range. For example, if you wanted to assign exactly 11 trucks in the CV Fitness problem instead of a maximum of 12, you would select the equals (=) operator in the Change Constraint window, as shown in Figure D-51.



Source: Used with permission from Microsoft Corporation

FIGURE D-51 Constraining a value to a specific amount

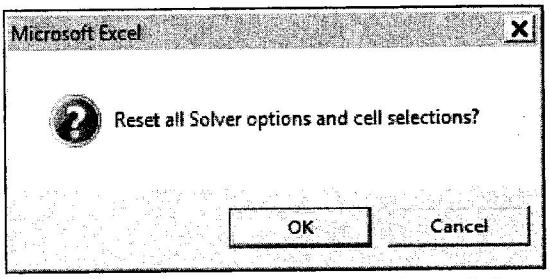
Setting Changing Cells to Integers

Throughout the tutorial, you were directed to set the changing cells to integers in the Solver constraints. In many business situations, there is a logical reason for demanding integer solutions, but this approach does

have disadvantages. Forcing integers can sometimes increase the amount of time Solver needs to find a feasible solution. In addition, Solver sometimes can find a solution using real numbers in the changing cells instead of integers. If Solver cannot find a feasible solution or reports that it has reached its calculation time limit, consider removing the integer constraints from the changing cells and rerunning Solver to see if it finds an optimal solution that makes sense.

Restarting Solver with New Constraints

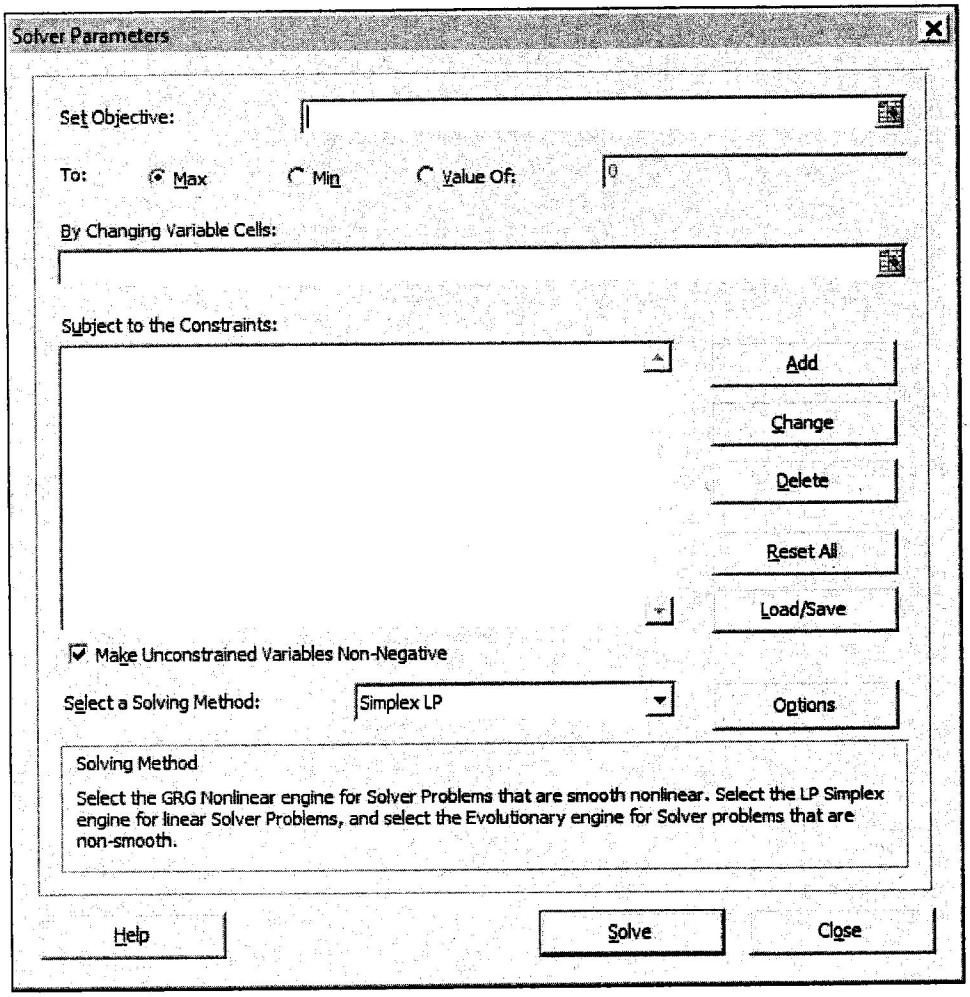
Suppose you want to start over with a completely new set of constraints. In the Solver Parameters window, click Reset All. You will be asked to confirm that you want to reset all the Solver options and cell selections (see Figure D-52).



Source: Used with permission from Microsoft Corporation

FIGURE D-52 Reset options warning

If you want to clear all the Solver settings, click OK. An empty Solver Parameters window appears with all the former entries deleted, as shown in Figure D-53. You can then set up a new model.



Source: Used with permission from Microsoft Corporation

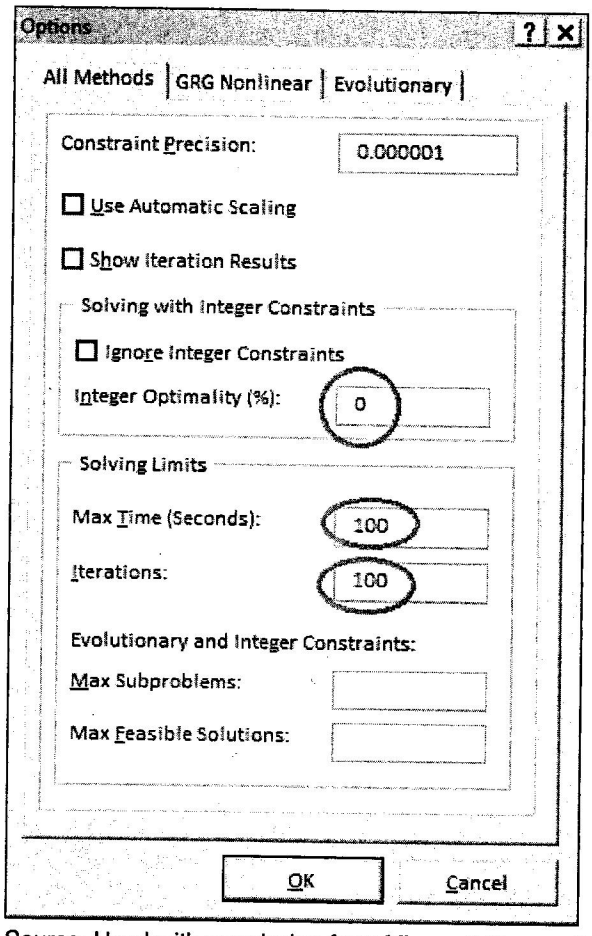
FIGURE D-53 Solver Parameters window after selecting Reset All

NOTE

Be certain that you want to select the Reset All option before you use it. If you only want to edit, delete, or add a constraint, use the Add, Delete, or Change button for that constraint.

Using the Solver Options Window

Solver has several internal settings that govern its search for an optimal answer. Click the Options button in the Solver Parameters window to see the default selections for these settings, as shown in Figure D-54.

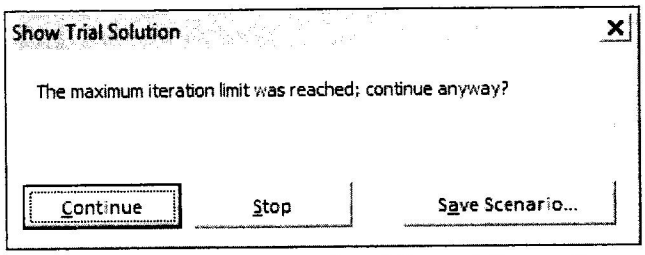


Source: Used with permission from Microsoft Corporation

FIGURE D-54 Solver Options window

You should not need to change the settings in the Options window except for the default value of 5% for Integer Optimality. When it is set at 5%, Solver will get within 5% of the optimal answer, but this setting might not give you the lowest cost or highest income. Change the setting to 0 and click OK.

In more complex problems that have a dozen or more constraints, Solver may not find the optimal solution within the default 100 seconds or 100 iterations. If so, a window will prompt you to continue or stop (see Figure D-55). If you have time, click Continue and let Solver keep working toward the best possible solution. If Solver works for several minutes and still does not find the optimal solution, you can stop by pressing the Ctrl and Break keys together. Click Stop in the resulting window.



Source: Used with permission from Microsoft Corporation

FIGURE D-55 Prompt that appears when Solver reaches its maximum iteration limit

If you think that Solver needs more time and iterations to reach an optimal solution, you can increase the Max Time and Iterations, but you should probably keep both values under 32,000.

Printing Cell Formulas in Excel

Earlier in the tutorial, you learned how to display cell formulas in your spreadsheet cells. Hold down the Ctrl key and then press the ~ key (on most keyboards, this key is next to the "1" key). You can change the cell widths to see the entire formula by clicking and dragging the column by the dividing lines between the column letters. See Figure D-56.

R27 — Width: 14.14 (208 pixels)

	G	H	I	J	K	L
13						
14		Vehicle Loading				
15	Volume Required	Trucks	Volume for Trucks	Tractor-Trailers	Volume for Tractor-Trailers	Total Vehicle Capacity
16	=D16*$C$8+E16*$C$9+F16*$C$10	2	=H16*$C$5	1	=J16*$C$6	=I16+K16
17	=D17*$C$8+E17*$C$9+F17*$C$10	1	=H17*$C$5	1	=J17*$C$6	=I17+K17
18	=D18*$C$8+E18*$C$9+F18*$C$10	2	=H18*$C$5	0	=J18*$C$6	=I18+K18
19	=D19*$C$8+E19*$C$9+F19*$C$10	3	=H19*$C$5	1	=J19*$C$6	=I19+K19
20	=D20*$C$8+E20*$C$9+F20*$C$10	4	=H20*$C$5	1	=J20*$C$6	=I20+K20
21	=SUM(G16:G20)	=SUM(H16:H20)	=SUM(I16:I20)	=SUM(J16:J20)	=SUM(K16:K20)	=SUM(L16:L20)

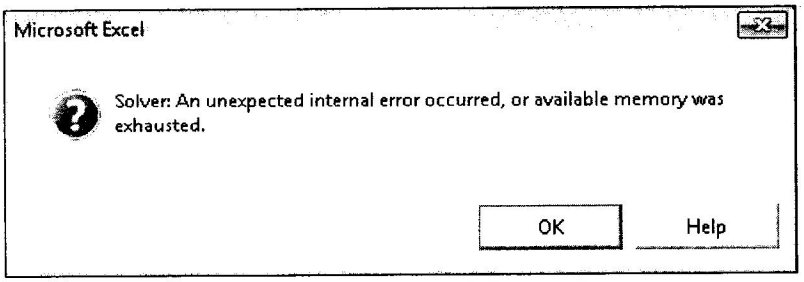
Source: Used with permission from Microsoft Corporation

FIGURE D-56 Spreadsheet with formulas displayed in the cells

To print the formulas, click the File tab and select Print. To restore the screen to its normal appearance and display values instead of formulas, press Ctrl+~ again; the key combination is actually a toggle switch. If you changed the column widths in the formula view, you might have to resize the columns after you change back.

"Fatal" Errors in Solver

When you run Solver, you might sometimes receive a message like the one shown in Figure D-57.



Source: Used with permission from Microsoft Corporation

FIGURE D-57 Fatal error in Solver

Solver usually attempts to find a solution or reports why it cannot. When Solver reports a fatal error, the root cause is difficult to troubleshoot. Possible causes include merged cells on the spreadsheet or printing

multiple Answer Reports after running Solver multiple times. A common solution to this error has been to remove the Solver add-in, close Excel, reopen it, and then reinstall Solver. If you encounter a fatal error when using this book, check with your instructor.

Sometimes Solver will generate strange results. Even when your cell formulas and constraints match the ones your instructor has created, Solver's answers might not match the "book" answers. You might have entered your constraints into Solver in a different order, you may have changed some of the options in Solver, or you may have specified real numbers instead of integers for the constraints (or vice versa). Also, the solving method you selected and the amount of time you gave Solver to work can affect the final answer. If your solution is close to the one posted by your instructor, but not exactly the same, show the instructor your setup in the Solver Parameters window. Solver is a powerful tool, but it is not infallible—ask your instructor for guidance if necessary.