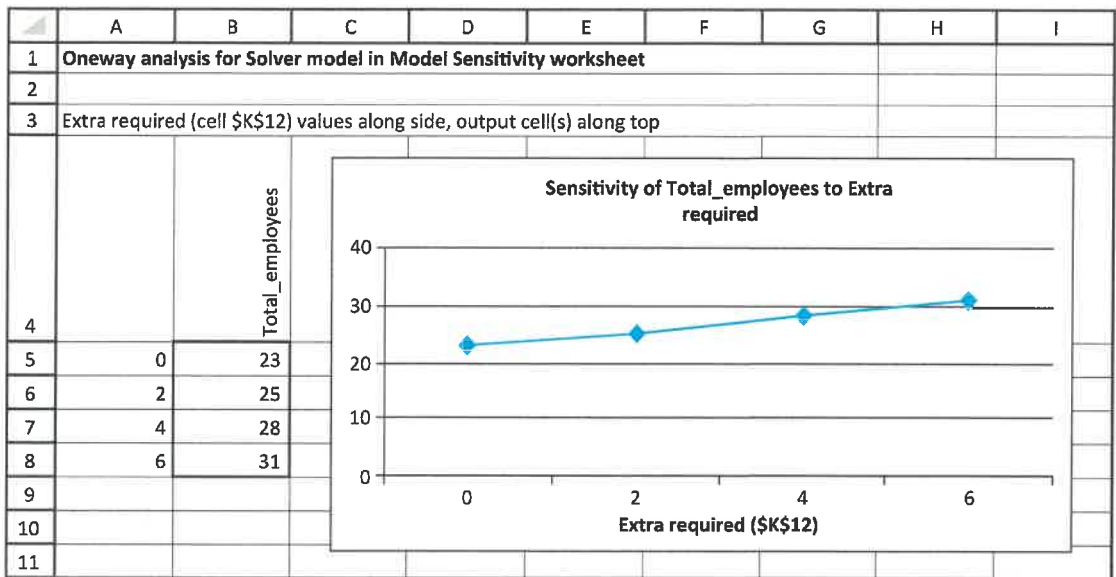


Figure 14.6 Sensitivity to Number of Extra Employees Required per Day



integer constraints are deleted, Solver's sensitivity report does not answer questions about *multiple* input changes, as we have asked here. It is used for questions about one-at-a-time changes to inputs, such as a change to a *specific* day's worker requirement. In this situation, SolverTable is a more flexible tool.

Modeling Issues

- The employee scheduling example is called a *static* scheduling model because we assume that the company faces the same situation each week. In reality, demands change over time, employees take vacations in the summer, and so on, so the company does not face the same situation each week. A *dynamic* scheduling model (not covered here) is necessary for such problems.
- In a weekly scheduling model for a supermarket or a fast-food restaurant, the number of decision variables can grow quickly and optimization software such as Solver have difficulty finding an optimal solution. In such cases, heuristic methods (essentially clever trial-and-error algorithms) have been used to find good solutions to the problem. For example, Love and Hoey (1990) indicate how this was done in a particular staff scheduling problem.
- Our model can easily be expanded to handle part-time employees, the use of overtime, and alternative objectives such as maximizing the number of weekend days off received by employees. You are asked to explore such extensions in the problems. ■

Heuristic solutions are often close to optimal, but they are never guaranteed to be optimal.

PROBLEMS

Note: Student solutions for problems whose numbers appear within a colored box are available for purchase at www.cengagebrain.com.

Level A

1. Modify the employee scheduling model so that employees are paid \$10 per hour on weekdays and \$15 per hour on weekends. Change the objective so that you now minimize the weekly payroll. (You can

assume that each employee works eight hours per day.) Is the previous optimal solution still optimal?

2. How much influence can the employee requirements for one, two, or three days have on the weekly schedule in the employee scheduling example? You are asked to explore this in the following questions.
 - a. Let Monday's requirements change from 17 to 18 in increments of 1. Use SolverTable to see how the total number of employees changes.

PROBLEMS

Level A

13. In the original Grand Prix example, the total capacity of the three plants is 1550, well above the total customer demand. Would it help to have 100 more units of capacity at plant 1? What is the most Grand Prix would be willing to pay for this extra capacity? Answer the same questions for plant 2 and for plant 3. Explain why extra capacity can be valuable even though the company already has more total capacity than it requires.
14. The optimal solution to the original Grand Prix problem indicates that with a unit shipping cost of \$132, the route from plant 3 to region 2 is evidently too expensive—no autos are shipped along this route. Use SolverTable to see how much this unit shipping cost would have to be reduced before some autos would be shipped along this route.
15. In the RedBrand example, suppose the plants cannot ship to each other and the customers cannot ship to each other. Modify the model appropriately, and rerun Solver. How much does the total cost increase because of these disallowed routes?
16. Modify the RedBrand example so that all flows must be from plants to warehouses and from warehouses to customers. Disallow all other arcs. How much does this restriction cost RedBrand, relative to the original optimal shipping cost?
17. In the RedBrand example, the costs for shipping from plants or warehouses to customer 2 were purposely made high so that it would be optimal to ship to customer 1 and then let customer 1 ship to customer 2. Use SolverTable appropriately to do the following. Decrease the unit shipping costs from plants and warehouses to customer 1, all by the same amount, until it is no longer optimal for customer 1 to ship to customer 2. Describe what happens to the optimal shipping plan at this point.
18. In the RedBrand example the arc capacity is the same for all allowable arcs. Modify the model so that each arc has its own arc capacity. You can make up the arc capacities.
19. Continuing the previous problem, make the problem even more general by allowing upper bounds (arc capacities) and lower bounds for the flows on the allowable arcs. Some of the upper bounds can be very large numbers, effectively indicating that there is no arc capacity for these arcs, and the lower bounds can be zero or positive. If they are positive, they indicate that some

positive flow must occur on these arcs. Modify the model appropriately to handle these upper and lower bounds. You can make up the upper and lower bounds.

20. Suppose in the original Grand Prix example that the routes from plant 2 to region 1 and from plant 3 to region 3 are not allowed. (Perhaps there are no railroad lines for these routes.) How would you modify the original model (Figure 14.14) to rule out these routes? How would you modify the alternative model (Figure 14.19) to do so? Discuss the pros and cons of these two approaches.
21. The RedBrand model in the file [RedBrand Logistics Multiple Product Finished.xlsx](#) assumes that the unit shipping costs are the same for both products. Modify the model so that each product has its own unit shipping costs. You can assume that the original unit shipping costs apply to product 1, and you can make up new unit shipping costs for product 2.

Level B

22. Here is a problem to challenge your intuition. In the original Grand Prix example, reduce the capacity of plant 2 to 300. Then the total capacity is equal to the total demand. Rerun Solver on the modified model. You should find that the optimal solution uses all capacity and exactly meets all demands with a total cost of \$176,050. Now increase the capacity of plant 1 and the demand at region 2 by one automobile each, and optimize again. What happens to the optimal total cost? How can you explain this “more for less” paradox?
23. Continuing the previous problem (with capacity 300 at plant 2), suppose you want to see how much extra capacity and extra demand you can add to plant 1 and region 2 (the same amount to each) before the total shipping cost stops decreasing and starts increasing. Use SolverTable appropriately to find out. (You will probably need to use some trial and error on the range of input values.) Can you explain intuitively what causes the total cost to stop decreasing and start increasing?
24. Modify the original Grand Prix example by increasing the demand at each region by 200, so that total demand is well above total plant capacity. However, now interpret these “demands” as “maximum sales,” the most each region can accommodate, and change the “demand” constraints to become “ $\leq$ ” constraints, not “ $\geq$ ” constraints. How does the optimal solution change? Does it make realistic sense? If not, how

(without the integer constraints). They indicate that as the interest rate increases, James gets by with fewer bonds of types 1 and 2, and he can allocate less money for the problem reason is that he is making more interest on excess cash. ■

PROBLEMS

Level A

37. Modify the Barney-Jones investment problem so that there is a minimum amount that must be put into any investment, although this minimum can vary by investment. For example, the minimum amount for investment A might be \$0, whereas the minimum amount for investment D might be \$50,000. These minimum amounts should be inputs; you can make up any values you like. Run Solver on your modified model.
38. In the Barney-Jones investment problem, increase the maximum amount allowed in any investment to \$150,000. Then run a one-way sensitivity analysis to the money market rate on cash. Capture one output variable: the maximum amount of cash ever put in the money market account. You can choose any reasonable range for varying the money market rate.
39. We claimed that our model for Barney-Jones is generalizable. Try generalizing it to the case where there are two more potential investments, F and G. Investment F requires a cash outlay in year 2 and returns \$0.50 in each of the next four years. Investment G requires a cash outlay in year 3 and returns \$0.75 in each of years 5, 6, and 7. Modify the model as necessary, making the objective the final cash after year 7.
40. In our Barney-Jones spreadsheet model, we ran investments across columns and years down rows. Many financial analysts prefer the opposite. Modify the spreadsheet model so that years go across columns and investments go down rows. Run Solver to ensure that your modified model is correct. (We suggest three possible ways to do this, and you can experiment to see which you prefer. First, you could start over on a blank worksheet. Second, you could use Copy and then Paste Special with the Transpose option. Third, you could use Excel's TRANSPOSE function.)
41. In the pension fund problem, suppose there is a fourth bond, bond 4. Its unit cost in year 1 is \$1020, it returns coupons of \$70 in years 2 through 7 and a payment of \$1070 in year 8. Modify the model to incorporate this extra bond, and reoptimize. Does the solution change—that is, should James purchase any of bond 4?
42. In the pension fund problem, suppose there is an upper limit of 60 on the number of bonds of any particular type that can be purchased. Modify the model to incorporate this extra constraint and then optimize. How much more money does James need to allocate initially?
43. In the pension fund problem, suppose James has been asked to see how the optimal solution will

change if the required payments in years 8 through 15 all increase by the same percentage, where this percentage could be anywhere from 5% to 25%. Use an appropriate one-way SolverTable to help him and write a memo describing the results.

44. Our pension fund model is streamlined, perhaps too much. It does all of the calculations concerning cash flows in row 20. James decides he would like to break these out into several rows of calculations: Beginning cash (for year 1, this is the amount allocated; for other years, it is the unused cash, plus interest, from the previous year), Amount spent on bonds (positive for year 1 only), Amount received from bonds (positive for years 2 through 15 only), Cash available for making pension fund payments, and, below the Pension payment row, Cash left over (amount invested in the fixed interest). Modify the model by inserting these rows, enter the appropriate formulas, and run Solver. You should obtain the same result, but you get more detailed information.

Level B

45. Suppose the investments in the Barney-Jones problem sometimes require cash outlays in more than one year. For example, a \$1 investment in investment B might require \$0.25 to be spent in year 1 and \$0.75 to be spent in year 2. Does the current model easily accommodate such investments? Try it with some cash outlay data and make up, run Solver, and interpret your results.
46. In the pension fund problem, you know that if the amount of money allocated initially is *less* than the amount found by Solver, James will not be able to meet all of the pension fund payments. Use the current model to demonstrate that this is true. To do so, enter a value less than the optimal value in cell B16. Then run Solver, but remove the Cash_allocated cell as a decision variable cell and as the objective cell. (If there is no objective cell, Solver simply tries to find a solution that satisfies all of the constraints.) What do you find?
47. Continuing the previous problem in a slightly different direction, continue to use the Cash_allocated cell as a decision variable cell, but add a constraint that it must be less than or equal to any value, such as \$195,000, that is *less* than its current optimal value. With this constraint, James will again not be able to meet all of the pension fund payments. Create a new objective cell to minimize the total amount of payments not met. The easiest way to do this is with IF functions. Unfortunately, this makes the model nonsmooth, and Solver might have trouble finding the optimal solution. Try it and see.