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Scenario Analysis in Spreadsheets with Excel's Scenario Tool

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Abstract

"What-if" or sensitivity analysis is one of the most important and valuable concepts in management science (MS). To emphasize its practical relevance in a business environment, we teach students in our introductory MS course to analyze "scenarios" with Excel's built-in Scenario tool. This paper demonstrates the application of the Scenario tool with several examples.

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1. Introduction

The immense popularity of Microsoft Excel throughout the business world today for processing quantitative data and developing analytical solutions is widely acknowledged. As a result, management science (MS) educators have shifted from teaching the detailed steps of algorithms towards spreadsheet-based quantitative analysis (Grossman, 2001; Powell, 2001; Ragsdale, 2001). The new standards for MS recently set by the Association to Advance Collegiate Schools of Business (AACSB) support the view that business graduates need analytical tools and concepts that are important for managerial decision-making, for long-term success in their careers (Horner, 2003). However, it is imperative that MS educators continue to demonstrate the relevance of MS in the business world and to make connections with the other disciplines in business schools.

At our institution, the undergraduate business students are required to take an introductory MS course, with emphasis on end-user modeling and analysis. The course is spreadsheet-based and includes modules on breakeven analysis, linear programming, decision analysis, queuing, simulation, and forecasting. We have increased the emphasis on sensitivity analysis in several of the modules by introducing the use of "sce-

narios" with Excel's built-in Scenario tool. Students learn to take full advantage of the spreadsheet to create and analyze scenarios addressing various what-if questions about the results from a model. Since these skills are applicable to any worksheet with formulas constructed for a particular set of calculations, students can carry their ability to perform sensitivity analysis over to other business classes, such as finance and marketing research, and ultimately, into the workplace.

Scenarios can be defined as descriptions of fundamentally different future states of an organization's environment considering possible developments of relevant interdependent factors (Brauers and Weber, 1988). The use of scenarios as a tool for problem-solving can be seen as early as 1942 in experiments done at Los Alamos in support of the development of an atomic bomb. Since it was not feasible to wait until sufficient quantities of uranium material were available to perform traditional experiments, scientists undertook "let's pretend studies of dummies built up within a framework of theory" (Davis, 1968, p. 166). Following the Second World War, scenario techniques were developed and used by the RAND Corporation for U.S. military strategy planning. These techniques were applied to public policy decisions starting in the 1960s, and eventually began to spread to the business community as long range planning tools (Bradfield et al., 2005). Linneman and Klein (1983) found that fifty

percent of Fortune 1000 companies used scenarios as a business forecasting tool between 1977 and 1981. Since then, increased uncertainty, globalization, and complexity in the business environment have led other companies to incorporate scenario planning into their strategic decision-making process (Schoemaker, 1993). It is by studying scenarios that managers become better prepared to make informed decisions that take possible future developments into account (Bunn and Salo, 1993).

From the MS perspective, scenarios are recognized as one type of sensitivity or "what-if" analysis. The treatment of sensitivity analysis in the new generation of MS textbooks has been greatly expanded beyond the traditional focus on linear programming parametric ranges. Texts now contain numerous examples showing how this important problem-solving concept can be applied to spreadsheet models for a variety of MS methods, using a host of built-in features and add-in tools for Excel. The purpose of this paper is to promote the use of the Excel Scenarios tool in the classroom as an additional mechanism for communicating the vital role of sensitivity analysis in the modeling process. A review of the literature indicates that while some faculty may already be using this tool (Grinde and Kammermeyer, 2003; Powell and Baker, 2004), coverage is generally missing from MS textbooks. In this paper, we demonstrate the tool with several example MS models and highlight the pedagogical benefits of integrating Excel's Scenario tool into an introductory MS course.

2. Excel's Scenario Tool

What-if analysis is a critical part of the problem-solving process and MS textbooks make frequent use of Excel "data tables" to run a model with varying sets of data for input variables in order to study the effects on the output variable(s) (e.g., Ragsdale, 2004; Winston and Albright, 2001). However, sometimes it is more appropriate to consider the effects of a set of input values taken together to represent an alternative option about the future decision-making environment (Powell and Baker, 2004). The Scenario tool in Excel was designed to manage what-if analysis by permanently storing the combinations of input values. It also supports their

retrieval at any time for the automatic generation of a summary report that details each scenario for a side-by-side comparison. We first became interested in this tool after reading an article that appeared in PC Magazine (Bradley, 2001).

Our initial experiments with using scenarios were in the context of breakeven analysis. Breakeven analysis is the first modeling exercise we conduct in the MS course and we found that the Scenarios tool could easily be incorporated at this point (Weida, et al., 2001). Most of our students have been previously exposed to breakeven analysis in other courses such as economics or accounting and are familiar with the concepts of fixed and variable costs, revenues, profit, and breakeven points. While the mathematical aspects of these problems are relatively simple, they provide an opportunity to explain the basic components of a model and present guidelines for building effective spreadsheet implementations. For breakeven analysis, we use scenarios in addition to both data tables and the Goal Seek tool in Excel to demonstrate the benefits of spreadsheet modeling and to discuss the need for what-if analysis in business decision making. This allows us to introduce the concept of sensitivity analysis from the very beginning of the course, before we get to more difficult MS models such as linear programs.

3. Breakeven Example using Scenarios

Consider the example on breakeven analysis at Great Threads (Chapter 2 in Winston and Albright, 2001), a company that sells hand-knit sweaters. The company is planning to print a brochure of its products and undertake a direct mail campaign. The cost of running the printing press for the brochure is \$20,000. There is also a \$0.10 cost per catalog. The cost of mailing each catalog is \$0.15. In addition, the company will include direct reply envelopes in its mailings. It incurs \$0.20 in extra cost for each direct mail envelope that is used by a respondent. The average size of a customer order is \$40, and the company's variable cost per order averages around 80% of the order's value. The company plans to mail 100,000 catalogs and they believe they will have a response rate of 8%. A spreadsheet model for this problem is shown in Figure 1⁽¹⁾.

(1) http://ite.pubs.informs.org/Vol6No2/MarkhamPalocsay/Breakeven_GreatThreads_Scenarios.xls

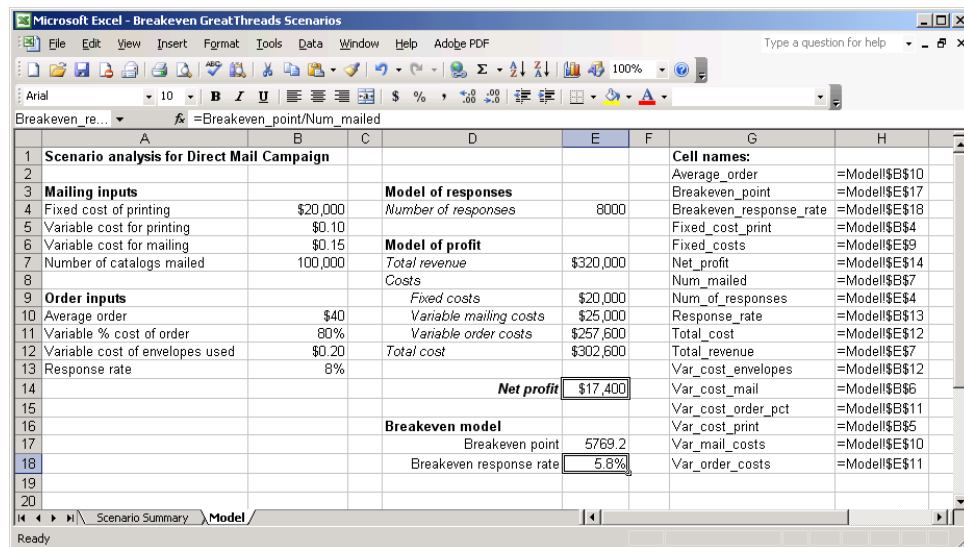


Figure 1: Worksheet for breakeven model.(Breakeven_GreatThreads_Scenarios.xls)

Formulas for the breakeven number of responses and the breakeven response rate are included in the worksheet so that their values can be computed under different assumptions for model inputs. Students often have difficulty developing a formula for the breakeven point when there are multiple sources of fixed or variable costs, although they can readily solve for its value algebraically in a specific instance. Creating this formula in Excel requires a clear understanding of the order of mathematical operations and, therefore, is a challenging initial exercise in spreadsheet modeling for students.

Before developing the scenarios, the spreadsheet cells representing both model inputs and outputs are named so that the summary report will be readable. Appropriate descriptive labels can be assigned to individual cells using Insert/Name/Define from the main Excel menu or entered directly into the Name Box at the left of the formula toolbar. Without these cell range names, the scenario summary report will only show the alphanumeric cell addresses for model parameters and variables. A list of names can then be provided on the model sheet for ease of reference, as shown in Figure 1, using Insert/Name/Paste. The Scenario Manager is available from the Tools menu with a dialog box as shown in Figure 2.

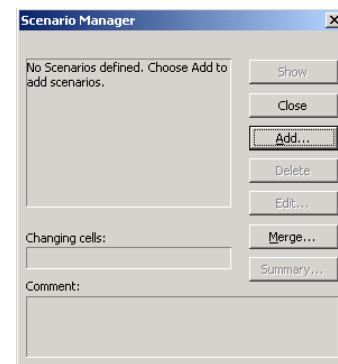


Figure 2: Scenario Manager.

With the current data values in the worksheet serving as a base case, a scenario is "added" by providing a descriptive name and identifying the cells that represent model inputs as "changing cells". (Note the common use of this term in the Goal Seek and Solver tools as well.) We instruct students to select all model inputs as changing cells, even when some of the values are not changing, to give a complete description of the assumptions being made for each scenario. For our example, an optimistic scenario where the average order is \$45, the fixed cost of printing is \$18,000, the variable order cost percentage is 75%, and the response rate is 9% is created, as illustrated in Figures 3 and 4. A pessimistic scenario, with average order at \$35, a fixed printing cost of \$22,000, a variable order cost percentage of 85%, and a response rate of 7%, is also added. All other inputs are held at the base rate for this example.

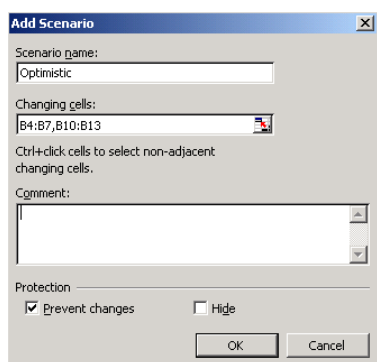


Figure 3: Creation of a scenario.

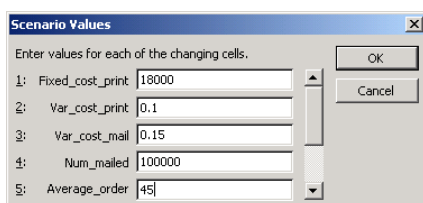


Figure 4: Entering scenario input values.

Once all of the scenarios have been entered, model inputs and outputs can be summarized in a report created by the Scenario Manager in a new worksheet. When "Summary" is selected in Figure 2, we specify the type of report and identify the "results cells" (i.e., model outputs) in the dialog box in Figure 5. We introduce the Scenario tool during the first week of class, immediately after developing and solving a breakeven analysis problem with Goal Seek. Yet we have discovered that some students will still be confused about which cells in the spreadsheet model should be changing cells and which should be results cells, indicating that a review of the basic components of a model is worthwhile at this point.

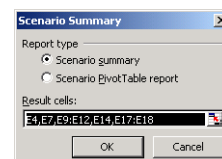


Figure 5: Summarizing scenarios.

Scenario Summary			
	Current Values:	Optimistic	Pessimistic
Changing Cells:			
Fixed_cost_print	\$20,000	\$18,000	\$22,000
Var_cost_print	\$0.10	\$0.10	\$0.10
Var_cost_mail	\$0.15	\$0.15	\$0.15
Num_mailed	100,000	100,000	100,000
Average_order	\$40	\$45	\$35
Var_cost_order_pct	80%	75%	85%
Var_cost_envelopes	\$0.20	\$0.20	\$0.20
Response rate	8%	9%	7%
Result Cells:			
Num_of_responses	8000	9000	7000
Total_revenue	\$320,000	\$405,000	\$245,000
Fixed_costs	\$20,000	\$18,000	\$22,000
Var_mail_costs	\$25,000	\$25,000	\$25,000
Var_order_costs	\$257,600	\$305,550	\$209,650
Total_cost	\$302,600	\$348,550	\$256,650
Net_profit	\$17,400	\$56,450	-\$11,650
Breakeven_point	5769.2	3891.4	9306.9
Breakeven_response_rate	5.8%	3.9%	9.3%

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

Figure 6: Scenario summary for breakeven model.

The report is automatically generated and placed in a sheet named "Scenario Summary", formatted as shown above in Figure 6. It provides a basis for discussing the effects of various changes in model inputs on net profit and the response rate required to break even. Some students will recommend that company management "choose" the optimistic scenario, which affords an opportunity to stress the distinction between 'alter-

natives' and 'uncertainties' in decision making and to point out the need for probability assessments of the likelihoods of future scenarios. Using scenarios at the beginning of the MS course gives students an initial exposure to the MS problem-solving methodology and sets the stage for learning about more sophisticated MS modeling techniques such as optimization and simulation. Another benefit is that it gives them prac-

tical, hands-on spreadsheet experience with built-in Excel tools in the first two weeks, consequently increasing the perceived value of MS and generating more interest in the course.

4. Queuing Example using Scenarios

In order to reinforce the scenario analysis approach and assure that the students become comfortable using the Scenario tool, we apply it again in a later module of the course on queuing theory. Consider the case of the Bullseye Department store (Chapter 13 in Ragsdale, 2004), a discount retailer with over 50 stores that is concerned with the truck loading operation at its warehouse. The company is considering three alternatives to the current situation of eight loading docks with one worker at each dock. One alternative is to hire an extra worker at each of the loading docks; a second alternative is to use a single worker at each dock but lease new forklifts to replace the existing

ones; and a third alternative is to build two new loading docks and hire two new workers.

The spreadsheet model in Figure 7⁽²⁾ is developed by modifying the queuing template Q.xls file provided in Ragsdale (2004) to permit entering of the average service time (rather than the rate) and to add formulas for computing service, waiting, and total cost as a function of the queuing configuration and the hourly costs.

Then a scenario is defined for current operations and for each of the three alternatives by specifying the appropriate input values for the average service time, number of docks (servers), and number of additional workers, forklifts, and docks over current levels. The resulting scenario summary is shown in Figure 8, and clearly shows that only one of the alternatives, upgrading the forklift equipment, would lower the average total cost.

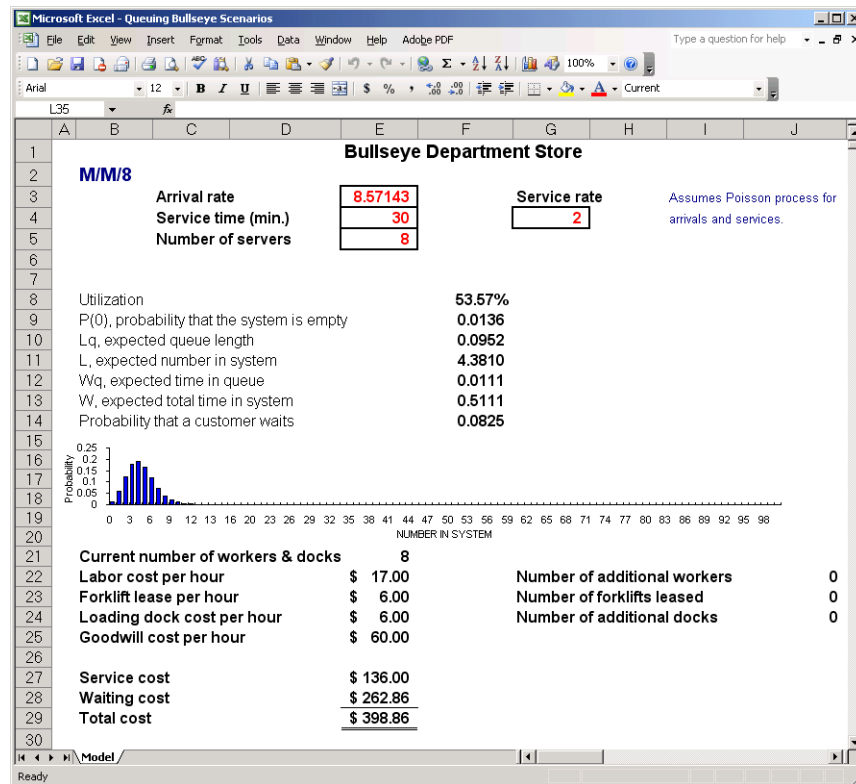


Figure 7: Worksheet for queuing model.(Queuing_Bullseye_Scenarios.xls)

(2) http://ite.pubs.informs.org/Vol6No2/MarkhamPalocsay/Queuing_Bullseye_Scenarios.xls

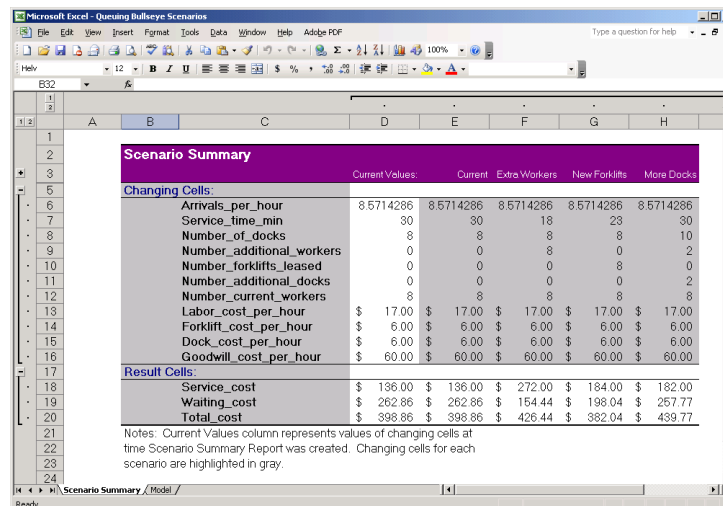


Figure 8: Scenario summary for queuing model.

addition to the summary report, Excel will also a pivot table showing the scenario results as in 9. This interactive table permits alternative of the information, and can be used to generate corresponding pivot chart. Figure 10 presents the cost for each scenario in a graphical format that the relative portions of cost attributed to pro-

viding service versus waiting time. The various scenarios can also be viewed on the model worksheet at any time using the Show button in the Scenario Manager dialog box (Figure 2) or by adding a drop-down list box to the toolbar (available in the Tools category on the Command tab when customizing a toolbar) as shown in the upper left of Figure 7.

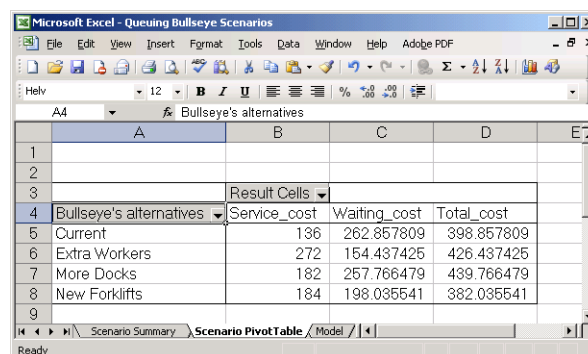


Figure 9: PivotTable report for queuing model.

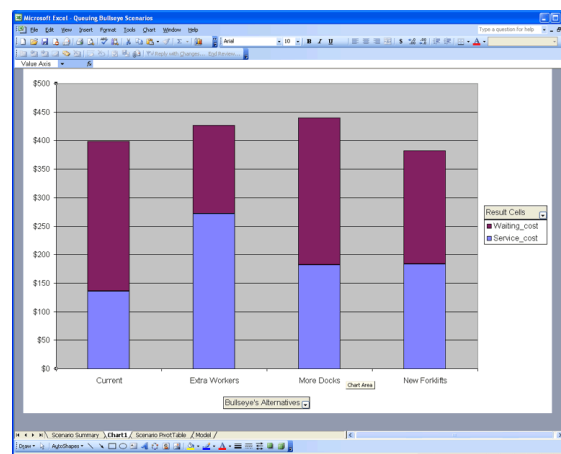


Figure 10: PivotChart for queuing model.

5. Decision Analysis Example using Scenarios

It is also possible to incorporate scenarios in a module on decision analysis. The Dumond International case study in Chapter 5 of Clemen and Reilly (2001) provides an excellent framework for scenario analysis. In this problem, the company's board of directors must decide whether to proceed with the development of a new pesticide product to replace an old one or continue to rely on the current product which has been very successful. Uncertainty about the current product is due to the possibility that it could be banned because there is some evidence it may create serious health risks. Furthermore, the new product may fail to meet the due date if development issues cannot be resolved in time, and its future acceptance in the pesticide market is unknown.

The decision tree showing the alternatives and uncertain issues in this situation was developed with the TreePlan add-in for Excel (written by Mike Middleton, University of San Francisco) and is shown in Figure 11⁽³⁾.

A formula was added below the decision tree to translate the branch number associated with the optimal decision into meaningful text. Based on initial estimates of probabilities and payoffs, the expected profit for the new product is higher than that of the current product and the recommendation is to go ahead with the new product. However, four of the board members have raised questions about some of the probabilities and final outcome values.

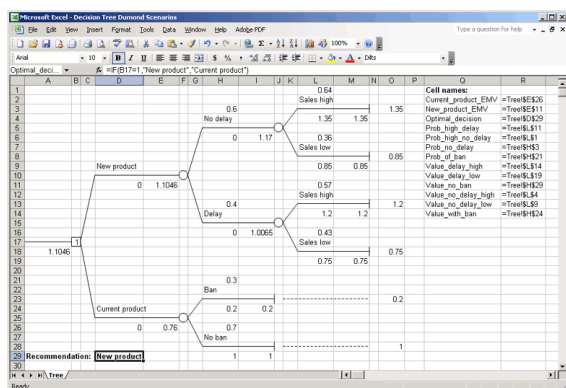


Figure 11: Worksheet for decision tree model. (Decision_Tree_Dumond_Scenarios.xls)

We create a scenario for each member's suggested changes to the model and for some combinations of changes as indicated by their discussion in the case. Figure 12 presents the scenario summary, which should convince the board members that the new product is the preferred choice since it has the maximum expected profit under each scenario. This result is counter-intuitive to most students, giving them an example where the optimal decision strategy is not sensitive to proposed changes in the model assumptions. It is difficult for many students to understand that making simultaneous changes in multiple model values may not always affect the decision. This case provides an excellent opportunity to demonstrate the potential role of sensitivity analysis in settling disagreements among decision makers in a group decision.

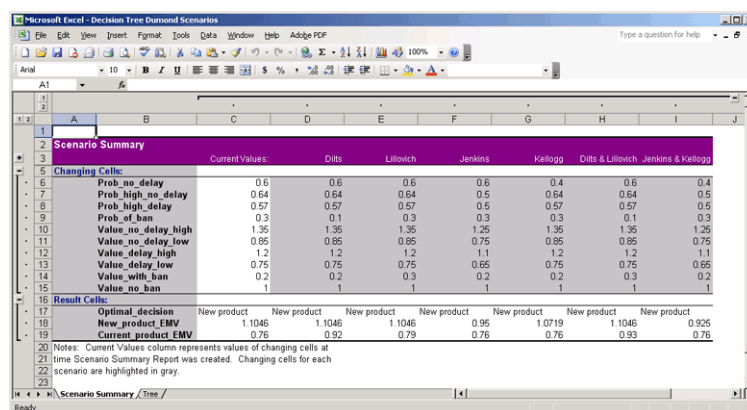


Figure 12: Scenario summary for decision tree model.

6. Limitations of Scenario Analysis and the Scenario Tool

The most serious criticism of scenario analysis is that it does not explicitly consider the probability of occurrence of different scenarios. This can potentially lead to scenarios with low likelihoods being assigned too much weight in the decision-making process. Pointing out this limitation in the classroom provides a basis for introducing expected value and/or simulation analysis, where probability distributions are assigned to key model parameters. For example, to illustrate the stochastic nature of breakeven analysis, we can specify probabilities for possible values of inputs that are not under the control of the business and perform a simulation of the required number of units to breakeven (Doane, 2004).

(3) http://ite.pubs.informs.org/Vol6No2/MarkhamPalocsay/Decision_Tree_Dumond_Scenarios.xls

There is also a practical limitation in the implementation of Excel's Scenario Manager that is worth noting – values must be typed into the dialog box for scenario inputs (see Figure 4) and cannot be entered as cell references. As a result, we are forced to embed numerical data in the tool, violating a basic principle of good spreadsheet design. In addition to permitting cell references, the capabilities of the Scenario tool could be further enhanced from an MS perspective by allowing the user to enter discrete probability distributions for cells corresponding to input variables in linear models and then automatically calculating the expected value of each output variable.

Another concern with the Scenario tool is its use of the term "changing cells." In Solver and Goal Seek the term is used for a cell that represents an unknown value to be determined by the tool whereas in Scenario Manager it represents a cell for which the user supplies a value (i.e., a model parameter). While in both usages the term is intuitive in the sense that a changing cell is one whose value can be modified, there is a clear difference between them. This distinction is obvious to us but it may cause some students in an introductory MS course to confuse the two concepts. Nevertheless, this common terminology supports a direct link between the Solver and the Scenario tools. In the Solver Result box, the user can select "Save Scenario" to save the optimal decision variable values as the changing cells of a particular scenario. In a typical product-mix linear program, this option automatically designates the cells for total profit (objective function) and the quantities of resources used (constraint left-hand-sides) as the scenario's result cells. If a model is solved repeatedly with different parameter values, the optimal results can be saved for a series of scenarios and summarized later in a report generated by the Scenario tool.

7. Summary

We have been extremely pleased with the outcomes from teaching the use of the Scenario tool in an introductory MS course. Students generally find scenario analysis easy to understand but at the same time it challenges them to specify assumptions, identify model inputs and outputs, and think carefully about their spreadsheet layout to design a single worksheet that can be used to model multiple scenarios. Discussion of scenarios for what-if analysis leads naturally to other modeling techniques, such as optimization

and simulation, and conceptually links MS modeling to the managerial decision making process. We recommend adding Excel's Scenario Manager to students' toolbox for analyzing business problems.

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