Chapter 9:
Model-Based Decision Making: Optimization and Multi-Criteria Systems

Learning Objectives for Chapter 9

1. Understand the basic concepts of analytical decision modeling
2. Describe how prescriptive models interact with data and the user
3. Understand some different, well-known model classes
4. Understand how to structure decision making with a few alternatives
5. Describe how spreadsheets can be used for analytical modeling and solution
6. Explain the basic concepts of optimization and when to use them
7. Describe how to structure a linear programming model
8. Describe how to handle multiple goals
9. Explain what is meant by sensitivity analysis, what-if analysis, and goal seeking
10. Describe the key issues of multi-criteria decision making

CHAPTER OVERVIEW

In this chapter, we describe selected techniques employed in prescriptive analytics. We present this material with a note of caution: Modeling can be a very difficult topic and is as much an art as a science. The purpose of this chapter is not necessarily for you to master the topics of modeling and analysis. Rather, the material is geared toward gaining familiarity with the important concepts as they relate to DSS and their use in decision making. It is important to recognize that the modeling we discuss here is only cursorily related to the concepts of data modeling. You should not confuse the two. We walk through some basic concepts and definitions of modeling before introducing the influence diagrams, which can aid a decision maker in sketching a model of a situation and even solving it. We next introduce the idea of modeling directly in spreadsheets. We then discuss the structure and application of some successful time-proven models and methodologies: optimization, decision analysis, decision trees, and analytic hierarchy process. This chapter includes the following sections:

CHAPTER OUTLINE

9.1 OPENING VIGNETTE: MIDWEST ISO SAVES BILLIONS BY BETTER PLANNING OF POWER PLANT OPERATIONS AND CAPACITY PLANNING

Questions for the Opening Vignette
A. WHAT WE CAN LEARN FROM THIS VIGNETTE

9.2 DECISION SUPPORT SYSTEMS MODELING
   ♦ Application Case 9.1: Optimal Transport for ExxonMobil Downstream Through a DSS
A. CURRENT MODELING ISSUES
   1. Identification of the Problem and Environmental Analysis
   2. Variable Identification
   3. Forecasting (Predictive Analytics)
      ♦ Application Case 9.2: Forecasting/Predictive Analytics Proves to Be a Good Gamble for Harrah’s Cherokee Casino and Hotel
   4. Model Categories
   5. Model Management
   6. Knowledge-Based Modeling
   7. Current Trends in Modeling
      ‣ Section 9.2 Review Questions

9.3 STRUCTURE OF MATHEMATICAL MODELS FOR DECISION SUPPORT
A. THE COMPONENTS OF DECISION SUPPORT MATHEMATICAL MODELS
   1. Result (Outcome) Variables
   2. Decision Variables
   3. Uncontrollable Variables, or Parameters
   4. Intermediate Result Variables
B. THE STRUCTURE OF MATHEMATICAL MODELS
   ‣ Section 9.3 Review Questions

9.4 CERTAINTY, UNCERTAINTY, AND RISK
A. DECISION MAKING UNDER CERTAINTY
B. DECISION MAKING UNDER UNCERTAINTY
C. DECISION MAKING UNDER RISK (RISK ANALYSIS)
   ♦ Application Case 9.3: American Airlines Uses Should-Cost Modeling to Assess the Uncertainty of Bids for Shipment Routes
   ‣ Section 9.4 Review Questions

9.5 DECISION MODELING WITH SPREADSHEETS
   ♦ Application Case 9.4: Showcase Scheduling at Fred Astaire East Side Dance Studio
   ‣ Section 9.5 Review Questions

9.6 MATHEMATICAL PROGRAMMING OPTIMIZATION
   ♦ Application Case 9.5: Spreadsheet Model Helps Assign Medical Residents
A. MATHEMATICAL PROGRAMMING
B. LINEAR PROGRAMMING
C. MODELING IN LP: AN EXAMPLE
   ♦ Technology Insights 9.1: Linear Programming
D. IMPLEMENTATION
   ‣ Section 9.6 Review Questions

9.7 MULTIPLE GOALS, SENSITIVITY ANALYSIS, WHAT-IF ANALYSIS, AND GOAL SEEKING
A. MULTIPLE GOALS
B. SENSITIVITY ANALYSIS
   1. Automatic Sensitivity Analysis
   2. Trial-and-Error Sensitivity Analysis
C. WHAT-IF ANALYSIS
D. GOAL SEEKING
   1. Computing a Break-Even Point by Using Goal Seeking
      ‣ Section 9.7 Review Questions

9.8 DECISION ANALYSIS WITH DECISION TABLES AND DECISION TREES
A. DECISION TABLES
   1. Treating Uncertainty
   2. Treating Risk
B. DECISION TREES
   ‣ Section 9.8 Review Questions

9.9 MULTICRITERIA DECISION MAKING WITH PAIRWISE COMPARISONS
A. THE ANALYTIC HIERARCHY PROCESS
   ♦ Application Case 9.6: U.S. HUD Saves the House by Using AHP for Selecting IT Projects
B. TUTORIAL ON APPLYING ANALYTIC HIERARCHY PROCESS USING WEB-HIPRE
   ‣ Section 9.9 Review Questions

Chapter Highlights
Key Terms
Questions for Discussion
Exercises
   Teradata UNIVERSITY NETWORK (TUN) and Other Hands-on Exercises
   ♦ End of Chapter Application Case: Pre-Positioning of Emergency Items for CARE International
      ‣ Questions for the Case
References
The purpose of this chapter is to teach the concepts of prescriptive mathematical modeling so students will begin to understand how models can be used to evaluate decision alternatives and find optimal solutions. It does so by going through a wide variety of model types, from the familiar (most DSS students will have encountered at least one financial model on a spreadsheet) through some that may have been seen in other courses (linear programming is often taught in operations management courses) to many that students will not have seen before. This can be a daunting amount of information to cover in the time you can allocate to a single chapter.

For this reason, you may want to select parts of this chapter to go into more deeply than others. Your choice of topics to stress will depend on your own perspective as to what is important, what isn’t. It’s still a good idea to at least touch on all the sections, though. Each one discusses a method that has been used in some DSS and that students may therefore encounter on the job. Your professional experience may tell you that some are less important than others, but that doesn’t mean any are totally unimportant.

Modeling is an applied discipline, best learned by reinforcement, through exercises and problems. Encourage the students to understand it through trial-and-error. The chapter mentions several software tools. You may wish to download, install, and use some of them. You can also work through a simple what-if analysis by hand, or do a goal seek problem using Excel’s Solver and what-if analysis features in class. Students should do practical work using some of the available tools for simple but realistic and relevant business problems. Many of these can be found by doing a Google search. Because so much of the material in this chapter can be done with Excel, you should take advantage of this to give plenty of exercises to your students.

Another good in-class exercise would be to give a description of a problem and have groups of students try come up with a conceptual decision model by identifying the decision, uncontrollable results, and intermediate results variable of the system. Students can go further by postulating potential mathematical functions of their model. Even if this is not ultimately implemented in Excel or some other software, it will give students experience in coming up with a conceptual model design.

ANSWERS TO END OF SECTION REVIEW QUESTIONS

Section 9.1 Review Questions

1. In what ways were the individual companies in Midwest ISO better off being part of MISO as opposed to operating independently?

Individually, the companies had to make extra investments to manage risk. Their mode of operation resulted in inefficient use of transmission lines. MISO also ensures that all members of the organization have equal access to high-voltage power lines. Individually, the companies had to make extra investments to
manage risk. As part of MISO, risk is managed collectively for the members by keeping a contingency reserve.

2. The dispatch problem was solved with a linear programming method. Explain the need of such method in light of the problem discussed in the case.

In terms of MISO’s DSS, the dispatch problem was to decide how much output should be produced by each power plant, and determine the price of energy based on the location of the power plant. The linear programming method fits well with this type of problem. Constraints include limits on frequency deviation (60 hertz) and power-loss time (10 minutes). The objective function involves expending the least possible total power to meet the electrical needs, and the decision variables are the power plant’s output.

3. What were the two main optimization algorithms used? Briefly explain the use of each algorithm.

For the commitment problem, which determined when power plants should be turned on or off, a Lagrangian relaxation method was used. For the dispatch problem, which determined the amount of output from a plant, a linear programming approach was used. In addition, a mixed integer programming model was used for the ancillary service market commitment problem.

Section 9.2 Review Questions

1. List three lessons learned from modeling.

This question refers to lessons found in the examples in this section, not to lessons learned from modeling in general. Many examples could be cited, among them these three: PillowTex learned how a simulation model can lead to lean manufacturing and save millions of dollars. IBM was able to use a combination of weather and sensor data to build a river system simulation application that could simulate thousands of river branches at a time for flood prediction and irrigation management. TurboRouter, a DSS for ship routing and scheduling, claims that over the course of just a three-week period, a company used this model to better utilize its fleet, generating additional profit of $1–2 million.

2. List and describe the major issues in modeling.

Major modeling issues include:
  • problem identification and environmental analysis: scanning the environment to figure out what problems exist and can be solved via a model
  • variable identification: identifying the critical factors in a model and their relationships
• forecasting: predicting the future
• model categories: selecting the right type of model for the problem or sub-problem
• model management: coordinating a firm’s models and their use
• knowledge-based modeling: how to take advantage of human knowledge in modeling

3. What are the major types of models used in DSS?

The major types from Table 9.1 follow.
• Optimization with few alternatives
• Optimization via an algorithm
• Optimization via an analytical formula
• Simulation
• Heuristics (“rules of thumb”)
• Predictive models
• Other models

4. Why are models not used in industry as frequently as they should or could be?

There are several reasons. The most important is that useful models are often complex, requiring major investments of time and money as well as scarce, expensive expertise.

5. What are the current trends in modeling?

One recent trend is the development of model libraries and solution technique libraries. Another is an increasing emphasis toward developing and using Web tools and software to access and even run software to perform modeling, optimization, and simulation. There is a continuing trend toward making analytics models completely transparent to the decision maker. There is also a trend to build a model of a model to help in its analysis. Influence diagram help in this respect.

Section 9.3 Review Questions

1. What is a decision variable?

A decision variable is a data element controlled by the decision maker, whose possible values describe alternative courses of action.
2. List and briefly discuss the three major components of linear programming.

Of the four components of any decision support mathematical model, linear programming uses result (outcome) variables, decision variables, and uncontrollable variables (parameters). Linear programming models do not use the fourth component, intermediate result variables.

There are other possible answers that do not tie in to the concepts of this section. For example, one could say that the three major components of a linear programming problem are its objective function, its decision variables, and its constraints. You might wish to connect this question to Section 4.8.

3. Explain the role of intermediate result variables.

An intermediate result variable reflects an intermediate result of the mathematical model. It is a result variable, and therefore is influenced by decision and uncontrollable variables in the mathematical model. An intermediate variable also influences other result variables in the mathematical model. For example, in a human resources system, employee salaries (decision variable) affect employee satisfaction (intermediate result variable), which further affects productivity (result variable).

Section 9.4 Review Questions

1. Define what it means to perform decision making under assumed certainty, risk, and uncertainty.
   - Decision making under assumed certainty: the values of all variables affecting the decision, including future values, are known or can be assumed to be known.
   - Decision making under risk: the exact value of decision variables is not known, but their statistical probability distributions are known (or can be assumed to be).
   - Decision making under uncertainty: even these distributions are not known.

2. How can decision-making problems under assumed certainty be handled?
Decision-making problems under assumed certainty can be handled by mathematical models that will yield an optimum solution.

3. How can decision-making problems under assumed uncertainty be handled?
Decision-making problems under uncertainty can be handled, first, by trying to get more information. If this is not possible or if the uncertainty remains after this has been done, it is necessary to evaluate the outcomes of many possible values of
the decision variables. The choice then depends on the decision maker’s attitude toward risk. For example, one solution may have a higher expected value than another, but also a higher likelihood of a negative outcome. A manager with an inclination to gamble might choose that solution, whereas a more conservative and risk-averse manager would choose a solution that offers a lower probable return but also minimizes the likelihood of loss.

4. How can decision-making problems under assumed risk be handled?

Decision-making problems under assumed risk can be handled by taking the probability distributions of the decision variables and working through the model with those distributions. The result will be a distribution of outcomes.

Note that the mean of the distribution of outcomes is often not the outcome that would be obtained under assumed certainty if each variable had its mean value. This is because, in a complex model, decision variables interact in complex ways and effect is not always immediately obvious.

Another approach to problems under assumed risk is to select a random value from each decision variable’s probability distribution and to run the model, under assumed certainty, with those values. This is repeated until a statistical distribution of results is obtained. This approach is used when a model is too complex to work through with statistical distributions directly.

Section 9.5 Review Questions

1. What is a spreadsheet?

This section does not define the concept, relying on student’s experience to tell them what a spreadsheet is. Given the audience of this book, that should normally be appropriate. Instructors who assign this question with no further explanation should expect some students to search for definitions (finding one or more like the above two) whereas others come up with their own and still others use descriptive phrases from the text. If a specific approach is wanted, that should be stated in advance.

2. What is a spreadsheet add-in? How can add-ins help in DSS creation and use?

Spreadsheet add-ins are small programs designed to extend the capabilities of a spreadsheet package. They help in DSS creation and use because many add-ins are designed specifically for that purpose, often by structuring and solving specific types of models.
3. Explain why a spreadsheet is so conducive to the development of DSS.

A spreadsheet is conducive to DSS development because it provides an easily understood metaphor for the computation and typically incorporates many powerful modeling functions.

Section 9.6 Review Questions

1. List and explain the assumptions involved in LP.

The LP approach involves both economic and technical assumptions. Economic assumptions are:
- Returns from different allocations can be measured by a common unit (e.g., dollars, utility).
- The return from any allocation is independent of other allocations.
- The total return is the sum of the returns yielded by the different activities.
- All data are known with certainty.
- Resources are to be used in the most economical manner.

Technical assumptions are:
- The objective function (that is to be maximized) is a linear combination of the outputs.
- Each output (decision variable) uses a linear combination of the inputs.
- Constraints on inputs are linear (or constant, which is a special case of linear) inequalities.

The requested explanations should show that the student understands each of the concepts, and is not simply parroting items from a list.

2. List and explain the characteristics of LP.

Linear programming is an optimization method used to solve problems in which the objective function and the constraints are all linear. It rests on the assumptions listed in the previous answer. LP problems can be solved by a wide variety of software for all popular computers.

3. Describe an allocation problem.

An allocation problem is a linear programming problem in which limited resources can be allocated among several possible uses, each of which yields a known return per unit and are subject to constraints.


The product-mix problem is a linear programming problem in which a variety of different products are made from common resources. Each product requires a
known resource mix and has a known profitability. Some resources are limited. Total profitability is to be maximized.

A product-mix problem can be viewed as an allocation problem. The difference is that a person formulating the problem as a product-mix problem is typically interested in the quantities of each product to be produced, while a person formulating the same problem as an allocation problem is usually interested in the quantities of each resource to be used. The solutions are identical, and each approach can produce both answers.

5. Define the blending problem.

The *blending problem* is a linear programming problem in which resources can be used in different ways to create a desired end product. The ways in which the resources combine to create the characteristics of the end product are known. Total cost of the end product is to be minimized.

6. List several common optimization models.

Several common optimization models are listed at the end of the section. These include the assignment problem, dynamic programming, goal programming, investment, linear and integer programming, network models for planning and scheduling, nonlinear programming, replacement (capital budgeting), simple inventory models (e.g., economic order quantity) and transportation (minimizing cost of shipments). A motivated student will be able to find others through a Web search.

**Section 9.7 Review Questions**

1. List some difficulties that may arise when analyzing multiple goals.

   - It is usually difficult to obtain an explicit statement of the organization’s goals.
   - The importance of specific goals may change over time or in different situations.
   - Goals and subgoals are viewed and weighted differently by different people and in different parts of the organization.
   - Goals change in response to changes in the organization and its environment.
   - The relationship between alternatives and their role in determining goals may be difficult to quantify.
   - Participants assess the importance (priorities) of the various goals differently.
2. List the reasons for performing sensitivity analysis.

Sensitivity analysis attempts to assess the impact of a change in input data or parameters on the result variable(s). Reasons for using it listed in this section include:
- Revising models to eliminate too-large sensitivities
- Adding details about sensitive variables or scenarios
- Obtaining better estimates of sensitive external variables
- Altering a real-world system to reduce actual sensitivities
- Accepting and using the sensitive (and hence vulnerable) real world, leading to the continuous and close monitoring of actual results

Another reason for using sensitivity analysis is to understand the sensitivity of different decision choices to variations in external conditions. One alternative may promise excellent results under nominal conditions but performs poorly if conditions vary from the nominal. Another may not turn out quite as well if all goes according to plan but will perform better if conditions vary from it. For example, one possible supplier may offer low prices for deliveries according to a pre-planned schedule but impose large penalties if the schedule is changed; another might have a higher base price but lower penalties for changing the delivery schedule.

3. Explain why a manager might perform what-if analysis.

A manager might perform what-if analysis to find out what will happen if a particular action is taken. A manager might also perform what-if analysis to try out several alternatives, choosing the one that works out best.

4. Explain why a manager might use goal seeking.

A manager might use goal seeking to find values of decision variables that enable him or her to meet a predetermined criterion. For example, a manager may need to find an advertising budget that will reach X households at a cost of not over $Y.

Section 9.8 Review Questions

1. What is a decision table?

A decision table is a way to organize information in a systematic way to prepare it for analysis. Typically, decisions are shown along one axis, states of nature on the other. The range of outcomes that can result from any decision, given the possible states of nature, can then be easily seen in one column (or row).
2. What is a decision tree?

A decision tree is an alternative representation of a decision situation, in which choices and states of nature are shown as alternating nodes along the branches of a tree. The range of outcomes that can result from any decision, given the possible states of nature, can then be easily seen by following all branches from that decision to their ends.

3. How can a decision tree be used in decision making?

By showing the decision maker the possible outcomes that could result from a given choice, the tree gives the decision maker information by which to compare choices.

4. Describe what it means to have multiple goals.

Having multiple goals means that a decision maker hopes to obtain the best possible combination of several factors, all of which depend on the decision to be made. For example, a student may want to find an instructor who is entertaining, has a good reputation for teaching, grades easily, assigns little homework, and whose section meets at convenient times. It will be difficult, if not impossible, to achieve all these at the same time. Multiple goals require willingness to compromise.

(You may want to defer this question until students have read Section 9.9, or to refer them forward to it at this point.)

Section 9.9 Review Questions

1. What is analytic hierarchy process?

The analytic hierarchy process (AHP) is an excellent modeling structure for representing multicriteria (multiple goals, multiple objectives) problems—with sets of criteria and alternatives (choices)—commonly found in business environments.

2. What steps are needed in applying AHP?

The decision maker uses AHP to decompose a decision-making problem into relevant criteria and alternatives. The AHP separates the analysis of the criteria from the alternatives, which helps the decision maker to focus on small, manageable portions of the problem.
3. What software can be used for AHP?

Expert Choice (expertchoice.com; a demo is available directly on its Web site) is an excellent commercial implementation of AHP. Another product is Web-HIPRE (hipre.aalto.fi), an adaptation of AHP and several other weighting schemes, which enables a decision maker to create a decision model, enter pairwise preferences, and analyze the optimal choice.

ANSWERS TO APPLICATION CASE QUESTIONS FOR DISCUSSION

Application Case 9.1: Optimal Transport for ExxonMobil Downstream Through a DSS

1. List three ways in which manual scheduling of ships could result in more operational cost as compared to the tool developed.

Without the optimization model, there is likely to be greater shipping cost and more demurrage expenses. This is because the manual process is unable to maximize the effective utilization of ships and design the best routing schedules. In addition, the manual process is cumbersome and time consuming, involving several parties.

2. In what other ways can ExxonMobil leverage the decision support tool developed to expand and optimize their other business operations?

(Answers will vary.) Since this DSS is geared to shipping transportation concerns, ExxonMobil could potentially market it as a product for other shipping companies. Also, the methodology used and lessons learned from this project could be applied to other areas at ExxonMobil, such as oil drilling.

3. What are some strategic decisions that could be made by decision makers using the tool developed?

Ship selection and route design are two immediate benefits. Also, the DSS could help ExxonMobil balance their own managed vessels and third-party vessels. This tool can also affect investment decisions in their shipping infrastructure as well as in future DSS projects.

Application Case 9.2: Forecasting/Predictive Analytics Proves to Be a Good Gamble for Harrah’s Cherokee Casino and Hotel

(This application case has no discussion questions.)
Application Case 9.3: American Airlines Uses Should-Cost Modeling to Assess the Uncertainty of Bids for Shipment Routes

1. Besides reducing the risk of overpaying or underpaying suppliers, what are some other benefits AA would derive from its “should be” model?

As a model for evaluating bids, the DSS could be used to streamline and standardize AA’s RFQ process. It also helps to give users a better understanding and quicker analysis of different bids, and potentially leads to better relations with suppliers.

2. Can you think of other domains besides air transportation where such a model could be used?

Since this is a model for determining fair payment to suppliers, it can apply to most supplier relationships involving product inventory. Any industry involving a supply chain could benefit from models like AA’s should-cost model.

3. Discuss other possible methods with which AA could have solved its bid overpayment and underpayment problem.

AA could use other BI-related approaches besides decision analysis via DPL. For example, this problem may have been formulated using a linear programming approach, multi-criteria decision model, or some other optimization approach. Even text analytics could be useful; by searching past RFQ bids from suppliers, AA could get a better idea of the bid process.

Application Case 9.4: Showcase Scheduling at Fred Astaire East Side Dance Studio

(This application case has no discussion questions.)

Application Case 9.5: Spreadsheet Model Helps Assign Medical Residents

(This application case has no discussion questions.)

Application Case 9.6: U.S. HUD Saves the House by Using AHP for Selecting IT Projects

(This application case has no discussion questions.)
1. What is the relationship between environmental analysis and problem identification?

Environmental analysis is the monitoring, scanning, and interpretation of collected information. Its purpose is to detect problem situations, after which they can be identified more precisely.

2. Explain the differences between static and dynamic models. How can one evolve into the other?

A static model describes relationships among parts of a system at a point in time. A dynamic model describes relationships among parts of a system as it moves through time, with its state at one instant influencing (together with its inputs) its state at the next.

The relationships that hold in a static model at a point in time must also hold in a dynamic model of the same system at every time. To modify a static model into a dynamic model, it is necessary to add relationships between time periods so that the static model in one time period depends, in an appropriate way, on the values of system variables in the prior time period rather than standing on its own. This may increase the model’s complexity dramatically and make it harder, if not impossible, to solve.

3. What is the difference between an optimistic approach and a pessimistic approach to decision making under assumed uncertainty?

An optimist makes the choice that has the best best-case outcome, even if it gives worse results under other conditions. The pessimist makes the choice as the best worst-case outcome, even if it gives worse results under other conditions.

For example: Suppose one choice has equally probable results of +$80 and +$30. Another has equally probable results of +$120 and –$10. (The expected value of both is +$55, so a rational decision maker with a linear utility function would call it a tie.) An optimist will choose the second because, in the best case, it will yield +$120: better than the best-case result of +$80 for the other option. A pessimist will choose the first because, at worst, it will yield +$30: better than the worst-case result of –$10 for the other choice.

4. Explain why solving problems under uncertainty sometimes involves assuming that the problem is to be solved under conditions of risk.

Solving problems under uncertainty means the decision maker has no idea of likelihood of one outcome or another. However, decision makers usually have some idea of the relative probability of certain influencing factors. By assuming approximate probabilities (changing the situation to one of risk even if the probabilities are not really known), the decision maker can predict the results to be expected from a course of action. Sensitivity analysis can then be used, if
desired, to determine how much the prediction depends on the accuracy of the estimates.

5. Excel is probably the most popular spreadsheet software for PCs. Why? What can we do with this package that makes it so attractive for modeling efforts?

The reasons why Excel is the most popular spreadsheet program for PCs have more to do with industry dynamics and Lotus’s slowness in porting 1-2-3 to Windows than with its technical merits. Although undoubtedly a good program, it achieved dominance in the mid-1990s when it was not markedly superior to competitors. Its superiority over most competing products today is due to the limited development resources available for products with far smaller market shares and came about only after its dominance was already well established. A full discussion of how and why Excel became the most popular PC spreadsheet program is beyond the scope of a DSS book or course.

Once a program such as Excel achieves a dominant market share, factors such as size and inertia of its user community, the infrastructure that builds up around it (add-ins, books, etc.) and (in its case) bundling into Microsoft Office combine to help it maintain that position.

Excel’s attractiveness for modeling efforts is due to five factors: the intuitiveness of the spreadsheet metaphor, its ubiquity (which makes Excel models easy to share), user familiarity with it, its flexibility, and its power. You can do many things with Excel. Its ease of use facilitates creating ad-hoc DSS. Macros allow complex procedures to be automated, with VBA available when macros fall short. Built-in goal-seeking and scenario analysis capabilities enable a model, once developed, to become part of a larger problem-solving process.

In short: (nearly) everyone has Excel, and Excel has what (nearly) everyone needs.

6. Explain how decision trees work. How can a complex problem be solved by using a decision tree?

A decision tree is an alternative representation of a decision situation, in which choices and states of nature are shown as alternating nodes along the branches of a tree. The range of outcomes that can result from any decision, given the possible states of nature, can then be easily seen by following all branches from that decision to their ends. By showing the decision maker the possible outcomes that could result from a given choice, the tree gives the decision maker information by which to compare choices. (This question is essentially the same as Review Questions 2 and 3 of Section 9.8, combined.)
7. Explain how LP can solve allocation problems.

LP solves allocation problems by using mathematical relationships (inputs required per unit of output) under known constraints (resource availability, etc.) to find the allocation of finite resources that produces the greatest value (highest value of the objective function).

8. What are the advantages of using a spreadsheet package to create and solve LP models? What are the disadvantages?

*Advantages:* The spreadsheet framework is well understood by many modern managers, linear programming models fit well into the tabular format, solutions can be stored directly in the spreadsheet, and it is possible to explain linear programming using what-if analysis directly in a spreadsheet for small problems. Spreadsheet models are not bound by the theoretical limitations of the linear programming approach, so they can (for example) work with nonlinear constraints.

*Disadvantages:* Large problems are difficult to create, debug, modify, and interpret. The fact that spreadsheets are a general-purpose tool, not a specialized one, makes them slower than LP software, and special structures, such as for network optimization problems, cannot be exploited for efficient solution.

9. What are the advantages of using an LP package to create and solve LP models? What are the disadvantages?

*Advantages:* The software was designed to do that one thing, it can be quite fast, the best packages can interface with large-scale databases, and some systems even feature modeling languages to enter problems.

*Disadvantages:* The output can be cryptic, it may require an analyst to operate and even develop the model, the software can be cumbersome to operate, and limitations of a particular package can make it difficult to solve large problems.

10. What is the difference between decision analysis with a single goal and decision analysis with multiple goals (i.e., criteria)? Explain in detail the difficulties that may arise when analyzing multiple goals.

In a single goal we compare only one result (e.g., profit). In multiple goals we compare several results. Since in the latter case we rarely find an alternative that is superior along all the criteria, it is necessary to prioritize goals, weight them, or combine them in some other way in order to make a choice.

11. Explain how multiple goals can arise in practice.

It is rare to have only one objective in making a business or personal decision. In choosing a flight, for example, people consider schedule, price, airline preference,
and more. When multiple stakeholders are involved, which is common in business decisions, there are even more goals to compromise among. (Consider, for example, three business travelers trying to pick a single flight. They might agree on cost, but have different schedule preferences and want frequent flyer credit on different airlines.)

12. Compare and contrast what-if analysis and goal seeking.

What-if analysis begins with conditions and determines their result. Goal seeking begins with a desired result and determines the conditions that will produce it. That often calls for using what-if analysis in an iterative process: assume some conditions, examine the result, on that basis choose other conditions, examine their result, and continue (using an intelligent search process that considers how prior condition changes affected the result) until the desired result is reached.

13. Does Simon’s four-phase decision-making model fit into most of the modeling methodologies described? Explain.

Yes. They have a problem identification phase, followed by design and choice phases and then an implementation phase. This is only to be expected, since Simon’s model is a general description of how decisions are made. The modeling methodologies described, as specific approaches to specific decisions, of necessity fall within the general framework.

ANSWERS TO END OF CHAPTER APPLICATION CASE QUESTIONS

1. What were the main challenges encountered by CARE International before they created their warehouse pre-positioning model?

CARE International faced challenges in offering the needed help to affected areas in the event of natural disasters. The previous mode of transportation, where third-party vendors fly into affected areas and CARE distributes by ground, was unreliable and slow. CARE wanted the ability to gather supplies and relief items from both local and international suppliers in an agile manner so they could better serve people affected by disasters. Once the supplies are mobilized, they wanted to be able to effectively distribute them in the most timely and cost-efficient manner to affected regions.

2. How does the objective function relate to the organization’s need to improve relief services to affected areas?

The objective function of the model calculates the total response time in moving items to affected areas. The goal of the linear programming model is to minimize this value. Thus, the objective function is directly related to the main problem for CARE International, especially in response to natural disasters.
3. Conduct online research and suggest at least three other applications or types of software that could handle the magnitude of variables and constraints CARE International used in their MIP model.

(Answers will vary by student.)

An Internet search finds many documented applications that involve the magnitude of variables and constraints of CARE International. Domain areas include large-scale farming econometrics (http://econpapers.repec.org/paper/wpawuwpem/0112002.htm), airline crew scheduling (http://www.cc.gatech.edu/projects/ihpcl/people/projects/lso.html), and supply chain (http://www.ima.umn.edu/optimization/abstracts/9-9abs.html).

Software products for large scale linear programming problems include AMPL, Gurobi, and SAS.

4. Elaborate on some benefits CARE International stands to gain from implementing their pre-positioning model on a large scale in the future.

The main benefit is their ability to provide relief services more rapidly, especially in times of crisis. In addition, the pre-positioning model promises to save money, labor, and time by increasing the efficiency of their operations. Most importantly, CARE will save more lives and help people get back onto their feet more effectively over time.