

# DECISION-MAKING SYSTEMS, MODELING, AND SUPPORT

## LEARNING OBJECTIVES

- Understand the conceptual foundations of decision-making
- Understand the systems approach
- Understand Simon's four phases of decision-making: intelligence, design, choice, and implementation
- Recognize the concepts of rationality and bounded rationality, and how they relate to decision-making
- Differentiate between the concepts of *making a choice* and *establishing a principle of choice*
- Recognize how decision style, cognition, management style, personality (temperament), and other factors influence decision-making
- Learn how DSS support for decision-making can be provided in practice

The major focus of this book is the computerized support of decision-making. The purpose of this chapter is to describe the conceptual foundations of decision-making and the systems approach, and how support is provided. In addition to the opening vignette, we use the *MMS Running Case* throughout the chapter to illustrate the process of decision-making in industry. This *Running Case* is concluded in Case Application 2.4. This chapter covers

- 2.1 Opening Vignette: Standard Motor Products Shifts Gears into Team-Based Decision-Making
- 2.2 Decision-Making: Introduction and Definitions
- 2.3 Systems
- 2.4 Models
- 2.5 Phases of the Decision-Making Process
- 2.6 Decision-Making: The Intelligence Phase
- 2.7 Decision-Making: The Design Phase
- 2.8 Decision-Making: The Choice Phase
- 2.9 Decision-Making: The Implementation Phase
- 2.10 How Decisions Are Supported
- 2.11 Personality Types, Gender, Human Cognition, and Decision Styles
- 2.12 The Decision-Makers

## 2.1 OPENING VIGNETTE: STANDARD MOTOR PRODUCTS SHIFTS GEARS INTO TEAM- BASED DECISION-MAKING<sup>1</sup>

### INTRODUCTION

**Decision-making** is complex—very complex; and it involves people and information. In most organizations, when you pay people to work, they work—and don't think. But when you pay people to think, they think, and when you empower them to make decisions, they make good ones. The benefits to the bottom line can be huge. You leverage the intellectual assets of your organization in ways that you might not have thought possible. The Standard Motor Products (SMP) plant, in Edwardsville, Kansas, makes and distributes after-market automotive products. Team decision-making by the workers works. A change in work culture and understanding made it possible.

#### A SAMPLE DAY AT SMP

June 11, 6 a.m., a workday: Inside the plant, Brenda Craig pages through the day's order sheets, figuring out what her co-workers should do today. She's not the boss, but the scheduler for her work team this month.

Over the next year, everyone on her 12-member team will rotate through all of the group's tasks. Each will get to determine how many man-hours are needed to load overnight orders onto delivery trucks. The team meets briefly to decide duties. They quickly estimate whether overtime might be needed and whether other work teams need help or can help them.

Everybody on the team is responsible for handling the orders. Everyone understands what needs to be done. The workers are not task-driven. They *think!* They *make decisions!* And everybody is responsible for identifying when members gets off track and helping them get their act together.

### STANDARD MOTOR PRODUCTS' SELF-DIRECTED TEAM CULTURE

The team system thrives in what could be, but is not, a divisive environment. About 55 percent of the workers are union members. There is still a management hierarchy at SMP. But general manager Thom Norbury and the other six members of the plant's core leadership team rarely interfere with work teams' decisions. Usually, team representatives debate options and choose well, Norbury says. The whole process utilizes the *talents* of the employees.

Former plant general manager Joe Forlenza believed that workers could make organization-savvy decisions. When Forlenza was growing up, he saw people managing their own lives under all kinds of circumstances. He says that, "I... saw that anybody with a brain is wasted if they don't use it." Some SMP managers said that empowerment would not work, especially under union contracts. A decade later, the empowered workplace thrives at SMP.

Forlenza examined team-coordinated decision-making and began shifting responsibilities and eliminating midlevel supervisory jobs. Some managers left voluntarily; some were *invited* to do so. After the first year, plant productivity dropped. Since this

<sup>1</sup>Source: Adapted from Diane Stafford, "Team-Based Decision-Making Works at Edwardsville, Kan., Auto Products Plant," *Knight Ridder Tribune Business News*, June 11, 2002, p. 1; and public domain publications.

was expected (Joe had studied how this works in practice), he *remained committed to the change*, and by the end of the second year, productivity was back up and improving. It continues to improve today.

## LEADERSHIP COMMITMENT TO CHANGE

The Edwardsville plant succeeded where other companies failed because of a rare top-down commitment. Joe made a long-term commitment to teach his teams to mature, and to make good decisions for the organization and for themselves. Some of the old management team couldn't conform, but fortunately many did. When the trust level between employer and employee is low, there are problems. Also, some employees have trouble assuming responsibility on the job. Unfortunately, many American businesses have taught their workers that they are not paid to think—so they don't.

In general, about 10 percent of workers cannot function in a team environment. This is sometimes because of personality issues, or because they are top performers or bottom performers who refuse to cooperate with a team. These people must be let go when building a team culture, to eliminate resentment. Norbury says that self-directed work teams require continuous commitment. Otherwise, stress can easily cause managers to revert to old behaviors. Leadership commitment is a *critical factor* in instituting any organizational change.

## TEAM DECISION-MAKING

At SMP, a team knows its schedule, goals, and financial situation. The team has a lot more *information* about the business than workers typically do. Teams know whether they are making good decisions because they have access to financial data that were previously only available to management. They measure productivity and calculate their rewards. The teams strive to be self-managed. Most of the teams in the plant have made it to the highest self-empowerment level. Team members provide *feedback* to one other daily. Feedback recipients accept criticism in a *no excuses* manner. Most of them already know what feedback to expect.

## RESULTS

Since the team approach was instituted, there has been less friction between management and union representatives. They often resolve issues through flexible letters of understanding instead of binding contracts. Such decisions are much easier to negotiate. People are much happier. Workers are responsible for scheduling shipments, determining overtime, scheduling shifts, work assignments, and so on. Team members are responsible for making decisions when production falls off. Most managerial decision-making has moved to the self-directed teams. The workers need little supervision. Overall, empowered workers, when rewarded appropriately, make good decisions.

### • QUESTIONS FOR THE OPENING VIGNETTE

1. Why do you think workers in many organizations are paid to *do*, rather than to *think*? Does this make sense? Why, or why not?
2. Why do you think productivity dropped in the first year of the team-based program? Explain.
3. Why is leadership commitment to change important? Explain.
4. How are decisions handled in the team approach? Consider the following:
  - a. How do teams identify problems?
  - b. How do teams approach problems?

- c. How do teams choose solutions?
- d. How do teams implement solutions?
5. How do teams handle conflicting objectives?
6. What are some of the possible impacts on decision-making if someone who is not a team player is a member of a team? Could this be why many of the midlevel managers were convinced to leave? Explain.
7. Technology is used to access information and data. Describe how information technology can help the teams.
8. What is the impact on decision-making of giving people responsibility for their own work? Why are self-directed team members happier than workers under a traditional hierarchy?

## 2.2 DECISION - MAKING : INTRODUCTION AND DEFINITIONS

The opening vignette demonstrated some aspects of a typical business decision:

- The decision is often made by a group.
- Group members may have biases.
- Empowering a group leads to better decisions.
- Individuals may also be responsible for making a decision.
- There may be many (hundreds or even thousands) of alternatives to consider.
- The results of making a business decision usually materialize in the future. No one is a perfect predictor of the future, especially in the long run.
- Decisions are interrelated. A specific decision may affect many individuals and groups within the organizational system.
- Decision-making involves a process of thinking about the problem leading to the need for data and modeling of the problem (loosely speaking: understanding the relationships among its different aspects). This leads to interpretation and application of knowledge.
- Feedback is an important aspect of decision-making.

Additionally,

- Groupthink (buy-in by group members without any thinking) can lead to bad decisions.
- There can be several, conflicting objectives.
- Many decisions involve risk. Different people have different attitudes toward risk.
- Decision-makers are interested in evaluating what-if scenarios.
- Experimentation with the real system (i.e., develop a schedule, try it, and see how well it works—trial and error) may result in failure.
- Experimentation with the real system is possible only for one set of conditions at a time and can be disastrous.
- Changes in the decision-making environment may occur continuously, leading to invalidating assumptions about the situation (e.g., deliveries around holiday times may increase, requiring a different view of the problem).
- Changes in the decision-making environment may affect decision quality by imposing time pressure on the decision-maker.
- Collecting information and analyzing a problem takes time and can be expensive. It is difficult to determine when to stop and make a decision.

- There may not be sufficient information to make an intelligent decision.
- There may be too much information available (information overload).

Ultimately, we want to help decision-makers make better decisions (see Churchman 1982; Hoch, 2001; Hoch and Kunreuther, 2001; Hoch, Kunreuther with Gunther, 2001; Kleindorfer, 2001; Mora, Forgionne and Gupta, 2002; Power, 2002; Roth and Mullen, 2002; Shim et al., 2002; Shoemaker and Russo, 2001; Simon, 2000; Verma and Churchman, 1998; Vitt, Luckevich, and Misner, 2002). However, making better decisions does not necessarily mean making faster decisions. The fast-changing business environment often requires faster decisions, which may be detrimental to decision quality (see DSS in Focus 2.1). To determine how real decision-makers make decisions, we must first understand the process and the important issues of decision-making. Then we can understand appropriate methodologies for assisting decision-makers and the contribution that information systems can make. Only then can we develop decision support systems to help decision-makers.

This chapter is organized along the three key words that form the term DSS: *decision*, *support*, and *systems*. One does not simply apply information technology tools blindly to decision-making. Rather, support is provided through a rational approach that simplifies reality and provides a relatively quick and inexpensive means of considering various alternative courses of action to arrive at the best (or at least a very good) solution to the problem.

## DECISION-MAKING

Decision-making is a process of choosing among alternative courses of action for the purpose of attaining a goal or goals. According to Simon (1977), *managerial decision-making is synonymous with the whole process of management*. Consider the important managerial function of planning. Planning involves a series of decisions: What should be done? When? Where? Why? How? By whom? Managers set goals, or plan; hence, planning implies decision-making. Other managerial functions, such as organizing and controlling, also involve decision-making.

## DECISION-MAKING AND PROBLEM-SOLVING

A problem occurs when a system does not meet its established goals, does not yield the predicted results, or does not work as planned. Problem-solving may also deal with identifying new opportunities/Differentiating the terms **decision-making** and **problem-**

### DSS IN FOCUS 2.1

#### WHEN DECISION-MAKING IS FAST, THE FAST CAN GET HURT

Fast decision-making requirements may be detrimental to decision quality. Managers were asked which areas suffered most. Here is what they said:

Personnel/HR	27%
Budgeting/finance	24%
Organizational structuring	22%

Quality/productivity	20%
IT selection and installation	17%
Process improvement	17%

Source: Condensed from D.J. Horgan, "Management Briefs: Decision Making: Had We But World Enough and Time," *CIO*, November 15, 2001.

**solving** can be confusing. One way to distinguish between the two is to examine the phases of the decision process. These phases are (1) intelligence, (2) design, (3) choice, and (4) implementation. Some consider the entire process (phases 1-4) as problem-solving, with the **choice phase** as the real decision-making. Others view phases 1-3 as formal decision-making ending with a recommendation, whereas problem-solving additionally includes the actual implementation of the recommendation (phase 4). We use the terms decision-making and problem-solving interchangeably.

## DECISION-MAKING DISCIPLINES

Decision-making is directly influenced by several major disciplines, some behavioral and some scientific in nature. We must be aware of how their philosophies can affect our ability to make decisions and provide support. Behavioral disciplines include

- Anthropology
- Law
- Philosophy
- Political science
- Psychology
- Social psychology
- Sociology.

Scientific disciplines include

- Computer science
- Decision analysis
- Economics
- Engineering
- Hard sciences: biology, chemistry, physics, etc.
- Management science/operations research
- Mathematics
- Statistics.

Each discipline has its own set of assumptions about reality and methods. Each also contributes a unique, valid view of how people make decisions. Finally, there is a lot of variation in what constitutes a successful decision in practice. For example, we provide a sample of the "75 greatest management decisions ever made" in DSS in Action 2.2. All of these were successful for a number of reasons, some serendipitous. Other great decisions, such as building the Great Wall of China, made good sense at the time (it is considered a success; see the list), but actually *failed in practice* because of bad managerial practices. Other decisions failed as well. See DSS in Action 2.2.

## 2.3 SYSTEMS

The acronyms *DSS*, *GSS*, *EIS*, and *ES* all include the term *system*. A **system** is a collection of objects such as people, resources, concepts, and procedures intended to perform an identifiable function or to serve a goal. For example, a university is a system of students, faculty, staff, administrators, buildings, equipment, ideas, and rules with the goal of educating students, producing research, and providing service to the community (another system). A clear definition of the system's goal is a critical consideration

## DSS IN ACTION 2.2

### THE 75 GREATEST MANAGEMENT DECISIONS EVER MADE

*Management Review* asked experts for their nominations of the 75 greatest management decisions ever made. The resulting list is both eclectic and eccentric. All the decisions were *successful* and had *major impact*. Here is a sample:

- Walt Disney listened to his wife, Lillian, and named his cartoon mouse Mickey instead of Mortimer. Entertainment was never the same after Mickey and Minnie debuted in *Steamboat Willie* in 1928.
- As ambassador to France in the 1780s, Benjamin Franklin, spent his time encouraging the emigration of skilled workers to the United States—an early instance of poaching staff.
- Around 59 B.C., Julius Caesar kept people up to date with handwritten sheets that were distributed in Rome and, it is thought, with wall posters. The greatness of leaders has been partly measured ever since by their ability to communicate.
- Ignoring market research, Ted Turner launched the Cable News Network in 1980. No one thought a 24-hour news network would work.
- During World War II, Robert Woodruff, president of Coca-Cola, committed to selling bottles of Coke to members of the armed services for a nickel. Customer loyalty never came cheaper.
- In 1924 Thomas Watson, Sr., changed the name of the Computing-Tabulating-Recording Company to International Business Machines. The company had no international operations, but it was a bold statement of ambitions.
- In 1981 Bill Gates decided to license MS/DOS to IBM, while IBM ceded control of the licenses for all non-IBM PCs. This laid the foundation for Microsoft's huge success and IBM's fall from grace. (IBM's decision here could be listed as one of the 75 worst management decisions ever made.)
- The Chinese Qin Dynasty (221-206 B.C.) produced the Great Wall—a fantastic feat of management and engineering. The Chinese also developed what is reputed to have been the first reliable system of weights and measures, thereby aiding commercial development.
- In the nineteenth century, Andrew Carnegie decided to import British steel and steelmaking processes to America to build railway bridges made of steel instead of wood. The imported skills ignited the U.S. steel industry, and Carnegie became a steel baron.
- Queen Isabella of Spain decided to sponsor Columbus' voyage in 1492. This was a very risky situation that had a high payoff—the discovery of a New World.

*Source: Adapted from Stuart Crainer, The 75 Greatest Management Decisions Ever Made... And 21 of the Worst, MJF Books, New York, 2002. Also see Anonymous, "Top 75: The Greatest Management Decisions Ever Made," Management Review, Vol. 87, No. 10, November, 1998, pp. 20-23; and Stuart Crainer, "The 75 Greatest Management Decisions Ever Made," Management Review, Vol. 87, No. 10, November 1998, pp. 16-19.*

in the design of a management support system (MSS). For example, the purpose of an air defense system is to protect ground targets, and not just to destroy attacking aircraft or missiles.

The notion of levels (i.e., a hierarchy) of systems reflects the fact that all systems are actually subsystems because every system is contained within some larger system. For example, a bank includes such subsystems as a commercial loan department, a consumer loan department, a savings department, and an operations department. The bank itself may also be a branch that is part of a collection of other banks, and these banks may collectively be a subsidiary of a holding corporation, such as the Bank of America, which is a subsystem of the California banking system, which is part of the national banking system, which is part of the national economy, and so on. The interconnections and interactions among the subsystems are called interfaces.

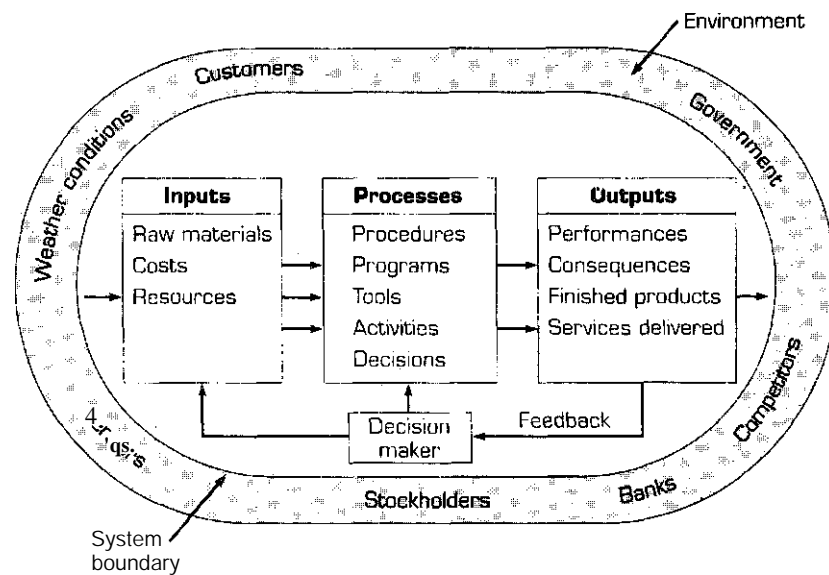


FIGURE 2.1 THE SYSTEM AND ITS ENVIRONMENT

## THE STRUCTURE OF A SYSTEM

Systems (Figure 2.1) are divided into three distinct parts: inputs, processes, and outputs. They are surrounded by an environment and often include a feedback mechanism. In addition, a human decision-maker is considered part of the system.

### INPUTS

**Inputs** are elements that enter the system. Examples of inputs are raw materials entering a chemical plant, students admitted to a university, and data input into a Web page for a database query.

### PROCESSES

Processes are all the elements necessary to convert or transform inputs into outputs. For example, a process in a chemical plant may include heating the materials, using operating procedures, using a material-handling subsystem, and using employees and machines. In a university, a process may include holding classes, doing library work, and Web searching. In a computer, including a Web-based one, a process may include activating commands, executing computations, and storing information.

### OUTPUTS

Outputs are the finished products or the consequences of being in the system. For example, fertilizers are one output of a chemical plant, educated people are one output of a university, and reports may be the outputs of a computer system. A Web server may produce a Web page dynamically, based on its inputs and processes.

### FEEDBACK

There is a flow of information from the output component to the decision-maker concerning the system's output or performance. Based on the outputs, the decision-maker, who acts as a control, may decide to modify the inputs, the processes, or both. This

information flow, appearing as a closed loop (Figure 2.1), is called *feedback*. This is how real systems monitoring occurs. The decision-maker compares the outputs to the expected outputs and adjusts the inputs and possibly the processes to move closer to the output targets.

### THE ENVIRONMENT

The environment of the system is composed of several elements that lie outside it in the sense that they are not inputs, outputs, or processes. However, they affect the system's performance and consequently the attainment of its goals. One way to identify the elements of the environment is by posing two questions (Churchman, 1975; also see Gharajedaghi, 1999):

- Does the element matter relative to the system's goals?
- Is it possible for the decision-maker to significantly manipulate this element?

If and only if the answer to the first question is yes, and the answer to the second is no, is the element in the environment. Environmental elements can be social, political, legal, physical, or economic. Often they consist of other systems. For a chemical plant, suppliers, competitors, and customers are elements of the environment. A state university may be affected by rules and laws passed by the state legislature, but for the most part the legislature is part of the environment, since the university system probably has no direct impact on it. In some cases, they may interact, though, and the environment is redefined. A DSS designed to set tuition rates would not normally interact directly with the state government. For a computer system, the environment is anything that is not part of the system. It can include other systems with which it interacts, users that provide input, and users who examine output.

### THE BOUNDARY

A system is separated from its environment by a *boundary*. The system is inside the boundary, whereas the environment lies outside. A boundary can be physical (e.g., the system is a department with a boundary defined by Building C; in the case of your bodily system, the boundary is your skin), or it can be some nonphysical factor. For example, a system can be bounded by time. In such a case, we can analyze an organization for a period of only 1 year.

The boundary of an information system is usually defined by narrowing the system's scope to simplify its analysis. In other words, the boundary of an information system, especially a decision support system, is by design. Boundaries are related to the concepts of closed and open systems.

### CLOSED AND OPEN SYSTEMS

Because every system is a subsystem of another, it may seem as if the process of system analysis will never end. Therefore, one must confine a system analysis to defined, manageable boundaries. Such confinement is called *closing* the system.

A *closed system* is at one extreme of a continuum that reflects the degree of independence of systems (an *open system* is at the other extreme). A closed system is totally independent, whereas an open system is very dependent on its environment. An open system accepts inputs (information, energy, materials) from the environment and may deliver outputs to the environment.

When determining the impact of decisions on an open system, we must determine its relationship with the environment and with other systems. In a closed system, we need not do this because the system is considered to be isolated. Many computer systems, such as transaction processing systems (TPS), are considered closed systems. Generally, closed systems are fairly simple in nature.

A special type of closed system called a *black box* is one in which inputs and outputs are well defined, but the process itself is not specified. Many managers are not concerned with how a computer works, especially when it is accessed via the Web. Essentially, they prefer to treat computers as black boxes, like a telephone or an elevator. Managers simply use these devices independent of the operational details because they understand the results or consequences of how the devices function. Their tasks do not require them to understand how the devices work. This concept leads to the development of commercially successful expert systems, data mining, and online analytical processing.

Decision-support systems attempt to deal with systems that are fairly open. Such systems are complex, and during when analyzing them one must determine the impacts on and from the environment. Consider the two inventory systems outlined in Table 2.1. We compare a well-known inventory model, the economic order quantity (EOQ) model, for a fairly closed system, with a hypothetical DSS for an inventory system for an open system. The closed system is very restrictive in terms of its assumptions and thus its applicability.

## SYSTEM EFFECTIVENESS AND EFFICIENCY

Systems are evaluated and analyzed in terms of two major performance measures: effectiveness and efficiency.

- **Effectiveness** is the degree to which goals are achieved. It is therefore concerned with the outputs of a system (e.g., total sales or earnings per share).
- **Efficiency** is a measure of the use of inputs (or resources) to achieve outputs (e.g., how much money is used to generate a certain level of sales).

Peter Drucker proposed the following interesting way to distinguish between the two terms:

Effectiveness is doing the right thing.

Efficiency is doing the thing right.

**TABLE 2.1** A Closed Versus an Open Inventory System

<i>Factor</i>	<i>Management Science: EOQ (Closed System)</i>	<i>Inventory DSS (Open System)</i>
<b>Demand</b>	Constant	Variable—influenced by many factors
<b>Unit cost</b>	Constant	May change daily
<b>Lead time</b>	Constant	Variable, difficult to predict
<b>Vendors and users</b>	Excluded from analysis	May be included in analysis
<b>Weather and other environmental factors</b>	Ignored	May <u>influence demand and lead time</u>

### DSS IN ACTION 2.3

#### THE WEB CHANGES THE FACE OF POLITICAL DECISION-MAKING

Getting informed is one of the most difficult things for the public to do during an election campaign. The Web provides new avenues for the dissemination of information about political candidates. For example, the University of Nevada, Reno (UNR), has launched a Web site called Nevada Votes! ([nevadavotes.unr.edu](http://nevadavotes.unr.edu)) to help citizens make informed decisions in upcoming state elections (from the U.S. Congress to municipal offices). The site is a collaborative effort of university libraries, campus IT, and the campus National Public Radio affiliate, KUNR. It includes statewide election

district maps, profiles on more than 350 candidates, photos, streaming audio files with candidate statements, PAC contributions, initiatives, referenda, political parties, and voter registration. In addition to policy views, the profiles include the candidates' responses to questions about their role models, their favorite books, and many other matters.

*Source:* Adapted from Susan DiMattia, "Nevada U. Provides Election Information," *Library Journal*, Vol. 127, No. 16, October 1, 2002, p. 17.

An important characteristic of management support system is their emphasis on the effectiveness, or "goodness," of the decision produced, rather than on the computational efficiency of obtaining it—usually a major concern of a transaction processing system. Most Web-based decision support systems are focused on improving decision effectiveness. Efficiency may be a byproduct.

Measuring the effectiveness and efficiency of many managerial systems is a major problem. This is especially true for systems that deliver human services (education, health, recreation), which often have several qualitative and conflicting goals and are subject to much external influence because of funding and political considerations. For an example of how the Web has influenced political decision-making in a large way, see the example described in DSS in Action 2.3. This is also true for DSS. How does one measure a manager's confidence about making a better decision? Even so, many attempts have been made to quantify DSS effectiveness and efficiency. This is necessary to gain managerial support and the resources to develop them.

### INFORMATION SYSTEMS

An information system collects, processes, stores, analyzes, and disseminates information for a specific purpose. Information systems are at the heart of most organizations. For example, banks and airlines would be unable to function without their information systems. With the advent of electronic businesses (e-businesses), if there is no information system, especially through the Web, there is no business. Information systems accept inputs and process data to provide information to decision-makers and help them communicate the results. Most consumers and decision-makers now expect a World Wide Web presence and activities (see DSS in Action 2.4 for how customers used and evaluated bank Web sites; and Agosto, 2002, who evaluated the role of personal preference in how Web sites are used and evaluated). Information systems and a Web presence for e-commerce have become critical for many organizations that in the past did not rely on them (see DSS in Action 2.5). Dun & Bradstreet's D&B Global DecisionMaker is a Web-based automated credit decision-making service. It offers its customers a simple, fast credit-decision solution. See Anonymous (2002) for

## DSS IN ACTION 2.4

THE WEB RAISES THE BAR FOR CONSUMER  
EXPECTATIONS IN DECISION-MAKING

Information search is the primary reason for most Internet use. Companies must understand consumers' information requirements to ensure Web site effectiveness in aiding consumer decision-making. Kathryn Waite and Tina Harrison performed a study to determine the factors that contribute to customer satisfaction and dissatisfaction with current online information provision by retail banks in Britain. Since the highest Internet use is found in the finance and insurance sectors (over 70 percent of businesses have their own or a third-party Web site), retail banks were studied. An analysis of the most and least important attributes

revealed that those contributing to decision-making convenience are preferred over the technological entertainment value. Certain Web site features and design are most likely to attract and retain customers. Specifically, when it comes to banking, people want to be able to conduct their business and find out what they want to know—not to be entertained.

*Source:* Adapted from K. Waite and T. Harrison, "Consumer Expectations of Online Information Provided by Bank Websites," *Journal of Financial Services Marketing*, Vol. 6, No. 4, June 2002, pp. 309-322.

details. Domaszewicz (2002) describes how health care decisions are supported by Web-based DSS.

## 2.4 MODELS

A major characteristic of a decision support system is the inclusion of at least one model. The basic idea is to perform the DSS analysis on a model of reality rather than on the real system. A model is a simplified representation or abstraction of reality. It is usually simplified because reality is too complex to describe exactly and because much of the complexity is actually irrelevant in solving the specific problem. Models can represent systems or problems with various degrees of abstraction. They are classified, based on their degree of abstraction, as either iconic, analog, or mathematical.

## ICONIC (SCALE) MODELS

An iconic model—the least abstract type of model—is a physical replica of a system, usually on a different scale from the original. An iconic model may be three-dimensional, such as that of an airplane, car, bridge, or production line. Photographs are two-dimensional iconic-scale models.

## ANALOG MODELS

An analog model behaves like the real system but does not look like it. It is more abstract than an iconic model and is a symbolic representation of reality. Models of this type are usually two-dimensional charts or diagrams. They can be physical models, but the shape of the model differs from that of the actual system. Some examples include

## DSS IN ACTION 2.5

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## POLITICAL ADVOCACY VIA THE WEB

What makes an advocacy group's Web site work? How can an advocacy group develop a site to reach its constituency? Heather Sehmel studied these questions and more. To make better decisions, people working in small organizations need to know more about the processes through which they make decisions about the use of Web sites as part of their comprehensive communication effort. Many advocacy Web sites do not exploit the Web to the fullest. Many miss out on the ability to create dialogue or provide personalized information. Heather Sehmel looked into the following questions:

1. How, by whom, and for what reasons are decisions made about how to use the group's Web site?
2. How does the site meet the goals and reflect the values of its developers?
3. How does the site reflect or fail to reflect common goals of environmental advocacy communication?
4. What other documents and communications relate to the advocacy campaign? How, if at all, might these documents interact with or lead individuals to interact with the Web site?
5. Who visits the Web site and why? How do site visitors use the site?

Sehmel's investigation of an Austin-based advocacy group led her to discover that the group encountered many of the common barriers to organizational decision-making. One of the major barriers to the group's making good decisions about how to use its

Web site was the inability of its employees to know the alternatives available to them and/or the consequences of the alternatives. Another major barrier was the lack of feedback about the choices they made, which would have enabled them to become more expert rhetoricians on the Web. The following factors contributed to these problems:

- The group's employees were not trained in Web design, but instead mainly learned about Web communication through their visits to Web sites, an imperfect method,
- The Webmaster perceived herself, and the rest of the staff perceived her, largely as a technical expert, not an expert in Web rhetoric.
- The group had limited knowledge of its Web audience.
- The group had little feedback about the success of its Web communications.
- The group's employees had limited time.
- The group's financial resources were limited.
- The group had to make fast responses to rapidly changing political situations.
- It had to collaborate with other advocacy groups.

*Source: Adapted from Heather Sehmel, "Websites and Advocacy Campaigns: Decision-Making, Implementation, and Audience in an Environmental Advocacy Group's Use of Websites as Part of Its Communication Campaigns," Business Communication Quarterly, June 2002.*

- Organization charts that depict structure, authority, and responsibility relationships
- Maps on which different colors represent objects, such as bodies of water or mountains
- Stock market charts that represent the price movements of stocks
- Blueprints of a machine or a house
- Animations, videos, and movies

## MATHEMATICAL (QUANTITATIVE) MODELS

The complexity of relationships in many organizational systems cannot be represented by icons or analogically because such representations would soon become cumbersome, and using them would be time-consuming. Therefore, more abstract models are described mathematically. Most DSS analyses are performed numerically with mathematical or other quantitative models.

## THE BENEFITS OF MODELS

A management-support system uses models for the following reasons:

- **Model manipulation (changing decision variables or the environment) is much easier than manipulating the real system. Experimentation is easier and does not interfere with the daily operation of the organization.**
- **Models enable the compression of time. Years of operations can be simulated in minutes or seconds of computer time.**
- **The cost of modeling analysis is much less than the cost of a similar experiment conducted on a real system.**
- **The cost of making mistakes during a trial-and-error experiment is much less when models are used rather than real systems.**
- **The business environment involves considerable uncertainty. With modeling, a manager can estimate the risks resulting from specific actions.**
- **Mathematical models enable the analysis of a very large, sometimes infinite, number of possible solutions. Even in simple problems, managers often have a large number of alternatives from which to choose.**
- **Models enhance and reinforce learning and training.**
- **Models and solution methods are readily available over the Web.**
- **There are many Java applets (and other Web programs) that readily solve models.**

Advances in computer graphics, especially through Web interfaces and their associated object-oriented programming languages, have led to an increased tendency to use iconic and analog models to complement MSS mathematical modeling. For example, visual simulation combines all three types of models. Case Application 2.3 contains an interesting description of a multicriteria model that involves both qualitative and quantitative criteria. We provide a preview of the modeling process in a Web Chapter. We defer our detailed discussion on models until Chapter 4.

## 2.5 PHASES OF THE DECISION-MAKING PROCESS

It is advisable to follow a systematic decision-making process. Simon (1977) says that this involves three major phases: intelligence, design, and choice. He later added a fourth phase, implementation. Monitoring can be considered a fifth phase—a form of feedback. However, we view monitoring as the **intelligence phase** applied to the **implementation phase**. Simon's model is the most concise and yet complete characterization of rational decision-making. A conceptual picture of the decision-making process is shown in Figure 2.2.

There is a continuous flow of activity from intelligence to design to choice (bold lines), but at any phase there may be a return to a previous phase (feedback). Modeling is an essential part of this process. The seemingly chaotic nature of following a haphazard path from problem discovery to solution by decision-making can be explained by these feedback loops.

The decision-making process starts with the intelligence phase. Reality is examined, and the problem is identified and defined. **Problem ownership** is established as well. In the design phase, a model that represents the system is constructed. This is

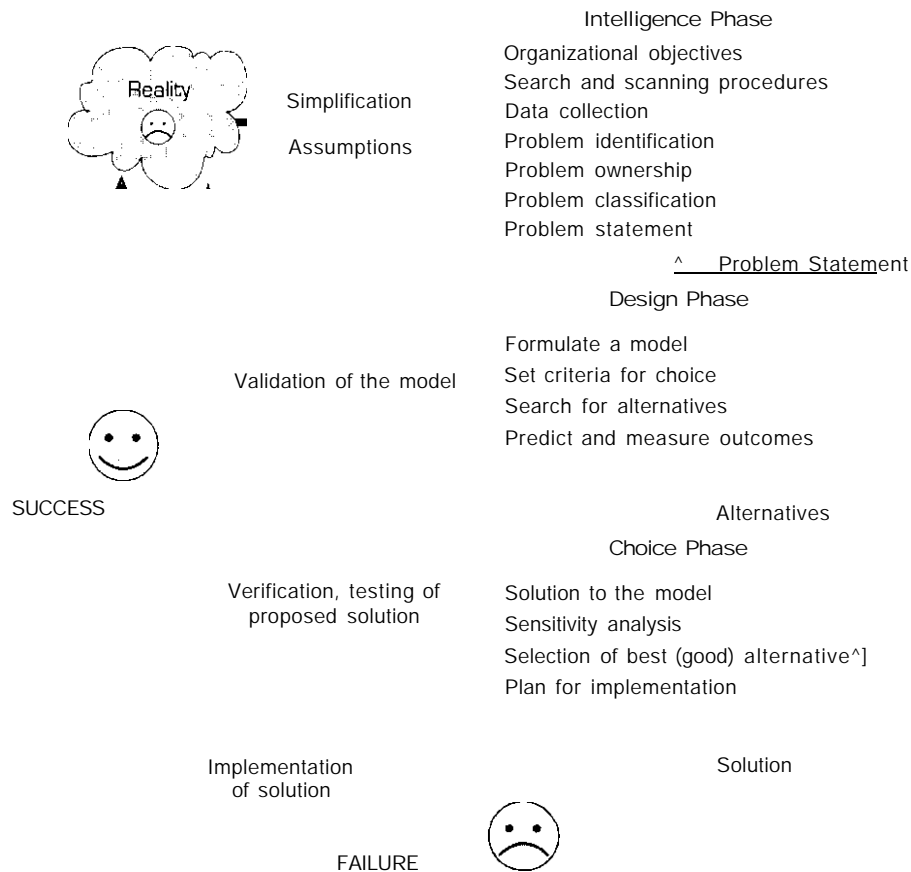


FIGURE 2.2 THE DECISION-MAKING/MODELING PROCESS

done by making assumptions that simplify reality and writing down the relationships among all the variables. The model is then validated, and criteria are determined in a principle of choice for evaluation of the alternative courses of action that are identified. Often the process of model development identifies alternative solutions, and vice versa. The choice phase includes selection of a proposed solution to the model (not necessarily to the problem it represents). This solution is tested to determine its viability. Once the proposed solution seems reasonable, we are ready for the last phase: implementation of the decision (*not necessarily of a system*). Successful implementation results in solving the real problem. Failure leads to a return to an earlier phase of the process. In fact, we can return to an earlier phase during any of the latter three phases. The decision-making situations described in Case Applications 2.1, 2.2, and 2.3 follow Simon's four-phase model, as do almost all decision making situations. We next discuss the decision-making process in detail, illustrated by the *MMS Running Case* in the DSS in Action boxes. Case Application 2.4 contains the summary and conclusion and Case Questions for the *MMS Running Case*.

Note that there are many other decision-making models. Notable among them is the Kepner-Tregoe (1965) method, which has been adopted by many firms because the tools and methods are readily available from Kepner-Tregoe, Inc. (also see Bazerman,

**TABLE 2.2** Simon's Four Phases of Decision-Making and the Web

<i>Phase</i>	<i>Web Impacts</i>	<i>Impacts On The Web</i>
<b>1. Intelligence</b>	<p>Access to information to identify problems and opportunities from internal and external data sources</p> <p>Access to AI methods and other data-mining methods to identify opportunities</p> <p>Collaboration through GSS and KMS</p> <p>Distance learning can provide knowledge to add structure to problems</p>	<p>Identification of opportunities for e-commerce, Web infrastructure, hardware and software tools, etc.</p> <p>Intelligent agents lessen the burden of information overload</p> <p>Smart search engines</p>
<b>2. Design</b>	<p>Access to data, models, and solution methods</p> <p>Use of OLAP, data mining, data warehouses</p> <p>Collaboration through GSS and KMS</p> <p>Similar solutions available from KMS</p>	<p>Brainstorming methods (GSS) to collaborate in Web infrastructure design</p> <p>Models and solutions of Web infrastructure issues</p>
<b>3. Choice</b>	<p>Access to methods to evaluate the impacts of proposed solutions</p>	<p>DSS tools examine and establish criteria from models to determine Web, intranet, and extranet infrastructure</p> <p>DSS tools determine how to route messages</p>
<b>4. Implementation</b>	<p>Web-based collaboration tools (GSS) and KMS can assist in implementing decisions.</p> <p>Tools monitor the performance of e-commerce and other sites, intranet, extranet, and the Internet itself</p>	<p>Decisions were implemented on browser and server design and access: these ultimately determined how to set up the various components that have evolved into the Internet</p>

2001). We have found that these alternative models readily map into the Simon four-phase model. These alternative methods are described in a Web Chapter on the book's Web site ([prenhall.com/turban](http://prenhall.com/turban)). We next turn to a detailed discussion of the four phases. Web impacts on the four phases, and vice versa, are shown in Table 2.2

## 2.6 DECISION - MAKING : THE INTELLIGENCE PHASE

Intelligence in decision-making involves scanning the environment, either intermittently or continuously. It includes several activities aimed at identifying problem situations or opportunities. (It may also include monitoring the results of the implementation phase of a decision-making process.) See DSS in Action 2.6 for the first of the *MMS Running Case* situations.

### PROBLEM (OR OPPORTUNITY) IDENTIFICATION

The intelligence phase begins with the identification of organizational goals and objectives related to an issue of concern (e.g., inventory management, job selection, lack of

## MMS RUNNING CASE: THE INTELLIGENCE PHASE

### INTRODUCTION

MMS Rent-a-Car, based in Atlanta, Georgia, has outlets at major airports and cities throughout North America. Founded by CEO Elena Markum some seven years ago, it has seen fast growth over the last few years, mainly because it offers quality service, fast, at convenient locations. MMS is highly competitive, able to offer cars at slightly lower rates than its competitors, because most of its airport facilities are located near but not at the airport. A keen user of information systems, MMS tracks competitors' prices, stored in a large data warehouse, through its Web-based enterprise information system portal, CLAUDIA (Come Learn About statUs for Deals and Information on Autos). CLAUDIA also tracks sales, fleet status, other internal status information, and external information about the economy and its relevant components. CLAUDIA has been a great success in keeping MMS competitive.

### PROBLEMS

Elena has called a meeting of her vice presidents to discuss a problem that she noticed yesterday while tapping into CLAUDIA. Rentals are off about 10 percent nationally from the MMS projections for last month. Furthermore, CLAUDIA'S forecasts indicate that they will continue to decrease. Elena wants to know why. This morning, the following VPs are present:

- Sharon Goldman, Marketing (CMO)
- Michael Lee, Operations (COO)
- Maria Dana, Fleet Acquisitions (CFAO)
- Tonia van de Stam, Information Systems (CIO)
- Mark Lams, Knowledge Systems (CKO)
- Jelene Thompson, Accounting (CAO)
- Rose.Franklin, Finance (CFO)

### THE FIRST MEETING

Elena calls the meeting to order:

**ELENA:** Thank you all for coming on such short notice. I'm glad that we could schedule this meeting through our new scheduling module of CLAUDIA. I know you have all read my e-mail about our latest problem—sales are off by 10 percent. Basically, this will put us in the red for the year if it

continues for another four months. CLAUDIA'S forecasting system, that links to our revenue management system (RMS), indicates that sales will continue to decrease for the next four months even after we adjust prices. Folks, what's going on? I want to know what has caused this problem, how we can fix it, and how we can prevent it from happening again. Aside from solving the problem, I want to develop some knowledge about it and use it as an opportunity to improve our business.

**MARLA:** Frankly, Elena, I don't understand it! I noticed a slight dip in sales two months ago, but was so busy with our new fleet acquisitions that I planned to go back and look into what happened when I finished replacing the fleet later this week. I should have passed word on to our analysts to have a look back then. Sorry.

**ELENA:** No problem, Maria. I should have noticed it myself. I'm glad you were at least aware and ready to move on it. So, we have evidence of a problem. What else do we have?

**SHARON:** My up-to-date reports from the travel industry indicate that over the last six months there has been a slight increase in business overall. More people are flying for business meetings, conventions, trade shows, and pleasure. And the same proportion of them is renting cars in North America. This is true for all of our primary markets—major cities and airports, but not for our secondary markets in the smaller cities, where most rentals are for business. Overall, business should be up. Vacation business is up quite a bit from the central Florida theme parks advertising specials, and major conventions. Both political party conventions were held in major cities. Data indicate that our rentals did not increase while the total market did. Our earlier forecasts indicated that

- business should have increased, our rental rates reflect this, as does our increased fleet size, by 15 percent. The cars should be moving—but they're not!
- ELENA:** How about the advertising impacts?
- ROSE:** Our financials indicate that we have been spending more on advertising in our primary markets. Yet those are where our sales are dropping fastest.
- JELENE:** I agree. Though our records were about three weeks behind, now they are up date to, and will stay up to date thanks to our upgrade to CLAUDIA. I'm looking at the current data right now on our secure wireless network, and we're definitely down.
- ELENA:** OK. Our advertising expenditures are up. That's because we made that deal with Gold Motors Corporation (GMC). We just finished replacing our entire fleet with GMC cars and vans, right, Maria?
- MARLA:** Absolutely! The cars are much more reliable and cheaper to maintain than the ones that had the transmissions burning out every 45,000 miles [72,000 km.]. These cars and vans are the national best-sellers, have great reputations, and are of high quality. They have the highest safety records in most categories. All of the standard models came in first: subcompacts, compacts, mid-size, full-size, and mini-vans. About six weeks ago we started getting in the hot new GMC Spider 1600 convertible. We have an exclusive deal on this hot little number. It looks like the sporty 1971 Fiat Spider, but is built to new quality standards. It's fun to drive—they let me have one for a year before we got the fleet in! They are expensive, and GMC owns the domestic market. We should be able to rent these out all the time. We have five at each agency across the country, and by year's end we should have ten.
- SHARON:** We got an exclusive with them for the next three years. They only give the fleet discount to us, we feature their cars in our advertising, and they feature us in theirs. And the Spider came to us right off the new assembly line in Pittsburgh.
- ELENA:** I have one of the Spiders, too. So I suspect that they're constantly rented out, aren't they?
- MICHAEL:** Well, no. Only about half of them are rented. The rental rates were supposed to be set pretty high, but our RMS recommends setting it at the same price as a compact. We hedged a little and set the price to about 10 percent higher. Some local agency offices are overriding the system and setting the prices 15 percent less and they still can't move them.
- ELENA:** How about the other classes of cars?
- MICHAEL:** Rentals down about 8 percent nationally on all the other ones.
- ELENA:** So sales are down 8 percent for everything but the Spider, and the Spider, which should be a hot seller, is off by 50 percent. I know from CLAUDIA that our inventory is OK. All the new cars came in on schedule, and we were able to sell the used cars through electronic auction sites and carmax.com. Folks, we definitely have a big problem.
- MICHAEL:** As COO, I see that this is primarily my problem, though all of you here are involved. We've never had this happen before, so I really don't know how to classify the problem. But I think we can get at most of the information we need. This situation is only a symptom of the problem. We need to identify the cause so we can correct the problem. I want some time to get my analysts, and Tonia's, moving on it. I will need some major help from Sharon's people, and probably a bit from everyone. Sharon and I talked before the meeting. We both have a feeling that there is something wrong with how we are marketing the new cars, but we don't have enough information just yet to identify it. I hope that once we solve this problem we'll have a nice piece of strategic knowledge for Mark to put into the KMS. I'll tentatively schedule a meeting through CLAUDIA next week as close to this time as

possible, depending on people's previous commitments. I'll e-mail the major results as we go. I'm sure we'll know something before the next meeting.

**ELENA:** Thanks Michael. OK, folks! We know we have a serious problem. We've 'seen its effects. Michael will assume ownership and move ahead. I also want our IS analysts looking at data even before anyone requests them. That includes any weird economic trends or events, and look at the underlying structure and parameters

of our forecasting models. OK, Tonia? Sharon, you look into the advertising. See if there are any external events or trends or reports on the cars that could affect our rentals. The RMS has been accurate until now. It's been able to balance price, supply, and demand, but something happened. Thank you all and have a great day.

*Source:* This fictional decision-making case is loosely based on several real situations. Thanks to Professor Elena Karahanna at The University of Georgia for inspiring it.

or an incorrect Web presence) and determination of whether they are being met. Problems occur because of dissatisfaction with the status quo. Dissatisfaction is the result of a difference between what we desire (or expect) and what is occurring. In this first phase, one attempts to determine whether a problem exists, identify its symptoms, determine its magnitude, and explicitly define it. Often, what is described as a problem (such as excessive costs) may be only a symptom (measure) of a problem (such as improper inventory levels). Because real-world problems are usually complicated by many interrelated factors, it is sometimes difficult to distinguish between the symptoms and the real problem, as is described in DSS in Action 2.6. New opportunities and problems certainly may be uncovered while investigating the cause of the symptoms.

The existence of a problem can be determined by monitoring and analyzing the organization's productivity level. The measurement of productivity and the construction of a model are based on real data. The collection of data and the estimation of future data are among the most difficult steps in the analysis. Some issues that may arise during data collection and estimation, and thus plague decision-makers, are

- Data are not available. As a result, the model is made with, and relies on, potentially inaccurate estimates.
- Obtaining data may be expensive.
- Data may not be accurate or precise enough.
- Data estimation is often subjective.
- Data may be insecure.
- Important data that influence the results may be qualitative (soft).
- There may be too many data (information overload).
- Outcomes (or results) may occur over an extended period. As a result, revenues, expenses, and profits will be recorded at different points in time. To overcome this difficulty, a present-value approach can be used if the results are quantifiable.
- It is assumed that future data will be similar to historical data. If not, the nature of the change has to be predicted and included in the analysis.

Once the preliminary investigation is completed, it is possible to determine whether a problem really exists, where it is located, and how significant it is. A key issue is whether an information system is reporting a problem or only the symptoms of a

problem. For example, in the *MMS Running Case*, sales are down; there is a problem; but the situation, no doubt, is symptomatic of the problem.

## PROBLEM CLASSIFICATION

*Problem classification* is the conceptualization of a problem in an attempt to place it in a definable category, possibly leading to a standard solution approach. An important approach classifies problems according to the degree of structuredness evident in them.

## PROGRAMMED VERSUS NONPROGRAMMED PROBLEMS

Simon (1977) distinguished two extremes regarding the structuredness of decision problems. At one end of the spectrum are well-structured problems that are repetitive and routine and for which standard models have been developed. Simon calls these programmed problems. Examples of such problems are weekly scheduling of employees, monthly determination of cash flow, and selection of an inventory level for a specific item under constant demand. At the other end of the spectrum are unstructured problems, also called nonprogrammed problems, which are novel and nonrecurrent. For example, typical unstructured problems include merger and acquisition decisions, undertaking a complex research and development project, evaluating an electronic commerce initiative, determination about what to put on a Web site (see DSS in Action 2.5), and selecting a job. Semistructured problems fall between the two extremes. In the *Running Case*, the problem seems unstructured. With analysis, it should become semistructured. Hopefully, over time, it will become structured. Generally, a structured or semistructured problem tends to gain structure as it is solved (see DSS in Action 2.7).

## PROBLEM DECOMPOSITION

Many complex problems can be divided into subproblems. Solving the simpler subproblems may help in solving the complex problem. Also, seemingly poorly structured problems sometimes have highly structured subproblems. Just as a semistructured problem results when some phases of decision-making are structured while other phases are unstructured, so when some subproblems of a decision-making problem are

### KNOWLEDGE CAN STRUCTURE AN UNSTRUCTURED PROBLEM

A decision-maker must recognize that problems can be unstructured when there is only minimal or even no knowledge and information about them. Developing knowledge about a problem can add structure to unstructured or semistructured problems. This is partly why the prototyping development process for DSS has proven successful in practice (see Chapter 6). This also explains the difference between being an expert and being a novice in a particular field. For example, if you know little about the restaurant business except that

you want to open a restaurant, determining an appropriate location for your restaurant is unstructured. If you seek out expert knowledge and demographic information, you will add structure to the problem through learning. Alternatively, if you are responsible for choosing locations for a large chain of restaurants, determining where to put the 2,000th restaurant is a very structured problem to which known data and models from your organization are applied.

structured with others unstructured, the problem itself is semistructured. As a DSS is developed and the decision-maker and development staff learn more about the problem, it gains structure. Decomposition also facilitates communication among decision-makers. Decomposition is one of the most important aspects of the Analytical Hierarchy Process (AHP) (Forman and Selly, 2001; Saaty, 1999) which helps decision-makers incorporate both qualitative and quantitative factors into their decision-making models. See Case Application 2.3. In the *Running Case*, there are several aspects to be investigated: advertising, sales, new car acquisition, and so on. Each of them is a subproblem that interacts with the others.

## PROBLEM OWNERSHIP

In the intelligence phase, it is important to establish problem ownership. A problem exists in an organization only if someone or some group takes on the responsibility of attacking it and if the organization has the ability to solve it. For example, a manager may feel that he or she has a problem because interest rates are too high. Since interest rate levels are determined at the national and international levels, and most managers can do nothing about them, high interest rates are the problem of the government, not a problem for a specific company to solve. The problem companies actually face is how to operate in a high-interest-rate environment. For an individual company, the interest-rate level should be handled as an uncontrollable (environmental) factor to be predicted.

When problem ownership is not established, either someone is not doing his or her job, or the problem at hand has yet to be identified as belonging to anyone. It is then important for someone to either volunteer to "own" it or assign it to someone. This was done, very clearly, in the *MMS Running Case*.

The intelligence phase ends with a formal problem statement.

## 2.7 DECISION - MAKING : THE DESIGN PHASE

The design phase involves finding or developing and analyzing possible courses of action. These include understanding the problem and testing solutions for feasibility. A model of the decision-making problem is constructed, tested, and validated. See the *MMS Running Case in DSS in Action 2.8*.

Modeling involves conceptualizing the problem and abstracting it to quantitative and/or qualitative form. For a mathematical model, the variables are identified and their mutual relationships are established. Simplifications are made, whenever necessary, through assumptions. For example, a relationship between two variables may be assumed to be linear even though in reality there may be some nonlinear effects. A proper balance between the level of model simplification and the representation of reality must be obtained because of the benefit/cost trade-off. A simpler model leads to lower development costs, easier manipulation, and a faster solution but is less representative of the real problem and can produce inaccurate results. On the other hand, a simpler model generally requires fewer data, or the data are aggregated and easier to obtain.

The process of modeling is a combination of art and science. As a science, there are many standard model classes available, and with practice an analyst can determine

## DSS IN ACTION 2.8

## MMS RUNNING CASE: THE DESIGN PHASE

Later on the day of the first meeting, Michael Lee as his top analyst, Stephanie Elberson, to look into what might have happened. Michael recognized that it was too early to start looking into criteria, solutions, and more (he had studied decision-making in a DSS course in his MBA program). He was still trying to understand the problem and separate the problem that could be analyzed from the symptoms. He wanted to make the connection between the two, but he felt that something was fundamentally wrong and CLAUDIA could not identify it. A good decision-maker relies on judgment and has a good "feel" for what makes sense and what does not. Michael was one of the best.

Stephanie put together a team of analysts and started formulating areas to investigate. One member of the team, Dot Frank, worked closely with Sharon's analyst, Phil Abrams, to establish the accuracy of the forecasting model. Amy Lazbin, on Stephanie's team, looked into databases of operational data available internally and economic data available through subscription services. The latter data focused on the auto rental, automobile, and general economic areas. The analysis team initially set the data-mining tools on automatic to establish relationships in the data. For the most part, Amy was able to verify most of the relationships and assumptions that were already in the forecasting models and the revenue-management system. Nothing new popped up from the artificial neural networks, clustering analysis algorithms, and statistical regression models. The pricing model and the forecasting models were all right, though there were some new fluctuations and the errors were higher when the team looked into how well they had performed over the last two months as this new problem arose. The team noticed that the neural networks outperformed the regression-based systems a bit, so they set up an IS and marketing group to look into how they could improve the regression-based models with neural networks. (This was a new opportunity, which led them to return to the intelligence phase with a new set of issues.)

Stephanie was puzzled. She met with Michael two days later to discuss what she was going to do next. She also invited the marketing team and the IS team to each send someone to the meeting. Phil Abrams and Marina Laksey (from IS) joined the team at this point. The meeting was held in the EMC (electronic meeting center), where they would be able to analyze data and use the group-support system (GSS). Here's how the meeting went:

**STEPHANIE:** Thank you all for coming today. As you know, we are working hard on the problem—or rather the symptoms—to try to get to the heart of the problem. Data-mining tools helped a bit, but there is something fundamentally wrong and we have yet to find it. Any ideas?

**MARINA:** Stephanie, we used the data-mining tools and looked at most, if not all, of the data we normally look at. And we usually look at standard views through our spreadsheet-type interface. I know we have to look "outside the box." First off, the four of us need to fire up our new, powerful OLAP (online analytical processing) software, DOT (Data on Time). It taps into our data warehouse and other data, but it goes beyond data mining by allowing us to poke about in the data. We just got the software in two weeks ago, and I have already gone through the training course. It has many of the features that CLAUDIA has, but allows us to look into multidimensional data from any of our data sources in any "slice" we choose. It also lets us link into other databases and data marts like the one that marketing has. Let me start it up!

**PHIL:** I agree. I learned how to use the OLAP software on my own, and I've developed some interesting views of our marketing data that show relationships we did not believe possible. The graphics are almost automatic. Let's try it!

The team saw the bumps in the data, but had no idea what had caused them. At least they could see them. When they tapped into the advertising plans, they noticed a slight inverse relationship with sales and advertising. When they asked Phil about it, he said:

**PHIL:** Sales dropped two weeks after our new joint-marketing campaign began. We heavily advertised the new cars. Every national and local TV commercial prominently displayed the Spider.

We have data on that in our marketing databases. I know you don't normally look at that. Here, let me bring them up. Hmm! We show how much air time each commercial played where, and what was in them. Let me do a little slicing and aggregating here. Aha! I see. We are mostly advertising the cars nationally. Sales are very weak in primary markets, but also a bit weak in secondary markets. Ah! Ah! Ah! One problem we have is that of distribution. We have over half the cars in the wrong places. We need to move all the Spiders from the secondary markets to the primary markets. But I think we have another problem—the pricing, supply, and demand data that we are using to predict rentals don't make sense. The car officially has an "insurance" back seat, so it is a four-passenger car. But you'd be lucky to get a carry-on suitcase back there. Since we didn't have data on it, someone in our group entered it as a four-seat compact with two doors. The system thinks it is a car ideal for a small family or a single businessperson on a budget. These rent well in the Midwest in the secondary markets, but badly in the convention areas, where there are men who are going through their midlife crises and single women who like to rent sporty cars. We have a lot of analyses to do here on where we are advertising what. I'm not sure who rents what where, but I suspect that we can target our ads better once we determine our market clusters, like males in Nebraska, 45 years old, traveling to San Diego for trade conferences. We have the data, we just need to apply them better.

**MICHAEL:** Hold on. Before I start moving cars around, we need to analyze this a bit more. We've never had a car like the Spider, so we need to investigate its properties and which categories of customers would ideally want it. Part of the solution jumped at us. But what are we trying to do? If I remember correctly, a few years ago we ran a "try before you buy" promotion in conjunction with our previous car supplier. People could rent our excess

stock on our off-days for half the rental rate for up to three days. If they bought the car from a dealer in the area, they got the rental price back. If not, they had fun with the car. It worked well. We noticed that people who liked the car they rented had a tendency to rent them again, especially in our primary markets. We have a lot to look into.

I want to recap what we have. We know that our goal is to maximize net profit. This is clearly our principle of choice. We need to come up with criteria that describe the impact of alternatives and determine how they affect our bottom line. Our revenue management system sets prices so that we can ideally do that. We have some errors in our marketing database, we must rethink how we advertise and how we distribute our stock. OK. I meet with the VP team in a couple of days. I'm going to e-mail them information about what we've uncovered and where to find the data. First I'll talk to Sharon so she can get busy with some ideas on marketing.

AT A MEETING TWO DAYS LATER:  
SAME PLACE, SAME PEOPLE

**STEPHANIE:** Good morning. Those of us in the trenches think we've got it! Here's what's going on. We have several problems, each of which we have developed some alternatives for. We're going to discuss what we think are the best ones for each situation. Some we can implement right away, others will take some time.

Let's start with our objective—to maximize profit. *Our principle of choice is one of profit maximization.* This part of the problem was easy. Our RMS recognizes this and adjusts prices automatically to maximize profit on an annual basis. There are some errors in the price elasticity curve for the Spider, but in general, the real question now is how to manage demand. Our advertising influences demand, as does our inventory. We need for the right product to appeal to the right customers. There are many criteria that we need to

measure, from quality to color to size, and customer service, car availability, etc., in terms of how they affect rentals. We are doing this, but need to do a better job of it in order to track our rentals. We have a team analyzing this right now. In a few weeks, they will have some concrete recommendations for system upgrades to the revenue management system.

Our symptoms indicate the following *real* problems and alternatives, among which we can choose:

**Data accuracy:**

We need to change the profile of the Spider from a compact to a sports car. We need to develop the RMS profile from what little data we've got! Fortunately, we can tap into market data that our faculty consultants at UGA have gathered for us in their research. One of the faculty members drives a Spider as well.

**Inventory Imbalance:**

We have done some analysis to determine what the real demand for the Spider is, and how it affects the demand for other cars, and vice versa. We built an optimization model and solved it. Based on our current advertising, we have determined that by moving about 15 percent of our fleet around (and not too far), we can take care of most of the demand imbalance. We recommend moving all the Spiders from secondary to primary markets right away. We also want to move some of our minivans and full-size cars around. Later, we can adjust advertising to push some secondary market demand.

**Advertising imbalance:**

We advertise where our customers are, but they rent elsewhere, and for different reasons. We need to do a better job of identifying customer homes to determine what to advertise where. Our analysis shows rentals are off partly because we indicate that we have the Spider. Young to middle-aged men and single women want to rent it, but we stock out where they are going. For example, we discovered that middle-aged men and women from the Midwest rent compacts in the secondary Midwest markets, but in the primary markets on the coasts want to rent the Spider. We are still analyzing effects like this, and should be able to complete the work in about a week to determine how to realign our advertising efforts.

**Try before you buy:**

This actually is an opportunity, not a problem. When we saturate Spider demand in primary markets, we should get some additional Spiders in the secondary markets and reestablish the "try before you buy" campaign. This car will be a real boon in this effort. Sharon's group has already established a cooperative agreement with GMC. They're interested, and it should boost our profitability on these cars by 18 percent.

**Discount substitutes:**

We discovered that many customers called or got on our Web site to rent the Spider. When they found out that we didn't have one for them, rather than rent a different car, many were so annoyed that they rented a car from one of our competitors, usually a Toyota MR-2. This happened in almost all of our primary markets. In our secondary markets, people really didn't want the Spider, but instead wanted full-size cars. Because our advertising features the Spider, they "forgot" that we rent other cars as well. Actually, *we forgot to remind them*. Our advertising is backfiring on us. We should immediately discount substitutes for the Spider until we get the Spiders in place next week.

**Florida Theme Park Demand:**

We have a unique opportunity here. Florida theme parks have been advertising heavily in Europe because the euro is strong relative to the dollar. We must increase advertising in Europe either with the theme parks or separately. Phil is confident that we can run a joint campaign. Marketing will look into this, and how we might be able to get customers to pay in advance in euros. To do this we may need to move minivans to Florida from as far away as Tennessee.

What it boils down to is that we want to be more aggressive in balancing our stock to meet demand, and tie this into the RMS and advertising. We also want to refine our advertising model to handle new types of cars like sports cars and update demand data more frequently.

Michael, this is what we want to present to the VPs on Monday. Is that OK?

**MICHAEL:** Perfect! We have identified the real problems and have good alternatives. I really appreciate the *completed staff work* (a la Napoleon). If this all works out, the end-of-the-year bonuses for this team should be excellent. Let's go have lunch! I'm buying!

which one is applicable to a given situation. As an art, a level of creativity and finesse is required when determining what simplifying assumptions can work, how to combine appropriate features of the model classes, and how to integrate models to obtain valid solutions. In the *MMS Running Case*, the problem at hand was very vague.

Decision-makers sometimes develop mental models, especially in time-pressure situations (see DSS in Action 2.9). Mental models help frame the decision-making situation, a topic of cognition theory (see Shoemaker and Russo, 2001). The team investigated the data in order to develop an understanding that was more of a mental model of the situation. Models were indeed used and tested, but not described in the *Running Case*. Data mining, OLAP, and revenue management software have many models embedded in them (see Cross, 1997; Swift, 2001).

#### DSS IN ACTION 2.9

### TO FLY OR NOT TO FLY? THAT IS THE QUESTION: PRESSURE TO FLY FOR THE WRONG REASONS

When pilots find themselves pressured to perform, there is a chance that good judgment and safety will be compromised. How can a pilot determine whether it is safe to fly? Pilots like to think that they have good judgment, and that regardless of the situation, they will always make the right call. They train, practice, and follow the rules. But despite experience and professionalism, flight crews sometimes still get into deep trouble. This may be especially so when the choice to fly or not is framed in the context of a life-and-death situation for a passenger (e.g., if an air-ambulance is needed, the crew might not see dangerous weather as a high risk). Without a doubt, emotions enter the decision-making picture, and they compromise safety (Hoch and Kunreuther, 2001).

The emotional aspects of the mission in air-ambulance operations often create strong pressure to fly, even in marginal conditions. "Whether it's a sick passenger or a bag of rocks, we should be flying the same and making the same decisions," says Ed Phillips, aviation services manager for Life Star Air Ambulance (Hartford, Connecticut). "But if the pilot has a 10-year-old son, and hears that it's a 10-year-old boy who's been injured in the town next to his, [he's going to want] to fly ... no matter what." Phillips explains further, "One way we take the pressure off is to leave out the details of the mission. We give the pilots only the locations, and let them make the go/no-go decision. If they decide to take the mission, we can give them the details once they're in the air." At Air Methods (Jackson County, Georgia), the crew makes a decision about flying before they know the condition of the patient. The pilot does not have any medical training;

so once airborne, he or she ideally flies with the same calm speed on any call. On the corporate side, pressure to fly may come from an executive who needs to be somewhere fast. There are also issues of personal fitness. Alcohol and medications affect judgment. But job and economic pressures can come to bear. There are cases where fatigue and poor weather have unfortunately led to crashes. Time pressure in conjunction with other factors can lead to dangerous conditions.

For a pilot to refocus judgment to alleviate the pressure to fly, the solution is simple. The pilot must try to separate the aviation decision-making from outside influences. Customers must be apprised of the reason that a flight may be delayed or cancelled. Passengers need to be made aware of flight regulations in a clear, written format. *Pilots should not bend the rules.* CRM (crew resource management) can be used to identify customer personalities and show ways to deal with them that deflect the pressure. Ill pilots should not fly. There are self-assessment tools that help pilots determine whether they are fit. Finally, the chief pilot must back a pilot's decision not to fly. This may require a major change in corporate culture.

Pilots tend to be very task-oriented and goal-driven. They tend to put more pressure on themselves than most other people do. But the real job is not transporting people. The most important job of a pilot is decision-making.

*Source: Adapted from Robert N. Rossier, "Pressured to Perform: Flying for the Wrong Reasons," Business & Commercial Aviation, Vol. 90, No. 6, June 2002, 62-69; and Allison Floyd, "Flights Save Time and Lives," Athens Banner-Herald, Vol. 170, No. 3, pp. A1, A5.*

Models have **decision variables** that describe the alternatives a manager must choose among (like how many cars to deliver to an specific rental agency, how to advertise at specific times, or which Web server to buy or lease), a result variable or a set of result variables (like profit, revenue, or sales) that describes the objective or goal of the decision-making problem, and uncontrollable variables or parameters (like economic conditions) that describe the environment. The process of modeling involves determining the (usually mathematical, sometimes symbolic) relationships among the variables. These topics are discussed in depth in Chapter 4.

### SELECTION OF A PRINCIPLE OF CHOICE

A **principle of choice** is a criterion that describes the acceptability of a solution approach. In a model, it is a result variable. Selecting a principle of choice is not part of the choice phase but involves how we establish our decision-making objective(s) and how it is (they are) incorporated into the model(s). Are we willing to assume high risk, or do we prefer a low-risk approach? Are we attempting to optimize or satisfice? It is also important to recognize the difference between a criterion and a constraint (see DSS in Focus 2.10). Among the many principles of choice, *normative* and *descriptive* are of prime importance.

### NORMATIVE MODELS

**Normative models** are those in which the chosen alternative is demonstrably the best of all possible alternatives. To find it, one should examine all the alternatives and prove that the one selected is indeed the best, which is what one would normally want. This process is basically **optimization**. In operational terms, optimization can be achieved in one of three ways:

#### DSS IN FOCUS 2.10

### THE DIFFERENCE BETWEEN A CRITERION AND A CONSTRAINT

Many people new to the formal study of decision-making inadvertently confuse the concepts of criterion and constraint. Often this is because a criterion may imply a constraint, either implicit or explicit, thereby adding to the confusion. For example, in Case Application 2.3, there is a distance criterion, where the decision-maker does not want to travel too far from home. However, there is an implicit constraint that the alternatives from which he selects must be within a certain distance from his home. This constraint effectively says that if the distance from home is greater than a certain amount, then the alternative is not feasible, or rather that the distance to an alternative must be less than or equal to a certain

number (this would be a formal relationship in some models; in the model of the case, it reduces the search, considering fewer alternatives). This is similar to the in-class examples of university selection, where schools beyond a single day's driving distance were not considered by most people, and, in fact, the utility function (criterion value) of distance started out low close to home, peaked at about 70 miles (about 100 km)—the distance between Atlanta and Athens, Georgia—and sharply dropped off thereafter. ( See the Web Chapter "Select a College/University with an Interactive Multiple-Goal DSS.")

- **Get the highest level of goal attainment from a given set of resources. For example, which alternative will yield the maximum profit from an investment of \$10 million?**
- **Find the alternative with the highest ratio of goal attainment to cost (e.g., profit per dollar invested) or maximize productivity.**
- **Find the alternative with the lowest cost (or smallest amount of other resources) that will meet an acceptable level of goals. For example, if your task is to select hardware for an intranet with a minimum bandwidth, which alternative will accomplish this goal at the least cost?**

Normative decision theory is based on the following assumptions of *rational decision-makers*:

- Humans are economic beings whose objective is to maximize the attainment of goals; that is, the decision-maker is rational. (More of a good thing [revenue, fun] is better than less; less of a bad thing [cost, pain] is better than more.)
- For a decision-making situation, all viable alternative courses of action and their consequences, or at least the probability and the values of the consequences, are known.
- Decision-makers have an order or preference that enables them to rank the desirability of all consequences of the analysis (best to worst).

Kontoghiorghes, Rustem, and Siokos (2002) describe the rational approach to decision-making, especially as it relates to using models and computing.

Are decision-makers really rational? See DSS in Focus 2.11; also Schwartz (1998), and Halpern and Stern (1998) for anomalies in rational decision-making. Though there may be major anomalies in the presumed rationality of financial and economic behavior, we take the view that these could be caused by incompetence, lack of knowledge, multiple goals that are framed inadequately, misunderstanding of a decision-maker's true expected utility, and time-pressure impacts. For more on rationality, see Gharajedaghi (1999), Larrson (2002), Ranganathan and Sethi (2002), and Verma and Churchman (1998).

There are other anomalies, often caused by time pressure. For example, Stewart (2002) describes a number of researchers who are working with intuitive decision-making. The idea of "thinking with your gut" is obviously a heuristic approach to decision-making. It works well for firefighters and military personnel on the battle-

## DSS IN FOCUS 2 IT

### ARE DECISION-MAKERS REALLY RATIONAL?

Some researchers question the rationality concept. There are countless cases of individuals and groups behaving irrationally in real-world and experimental decision-making situations. For example, suppose you need to take a bus to work every morning and the bus leaves at 7:00 a.m. Therefore, if it takes you one hour to wake up, prepare for work, and get to the bus stop, you should always awaken at or before 6:00 a.m. However,

sometimes (perhaps many times) you may sleep until 6:30, knowing that you will miss breakfast and not perform well at work. Or you may be late and arrive at the bus stop at 7:05, hoping that the bus will be late. So, why are you late? Multiple objectives and hoped-for goal levels may lead to this situation. Or your true expected utility for being on time might simply indicate that you should go back to bed most mornings!

field. One critical aspect of decision-making in this mode is that many scenarios have been thought through in advance. Even when a situation is new, it can quickly be matched to an existing one on the fly, and a reasonable solution can be obtained. See Stewart (2002) for details. See Luce et al. (2001) for a description of how emotions affect decision-making, and Pauly (2001) for a description of inconsistencies in decision-making. Bonabeau and Meyer (2001) describe a decision-making approach called swarm intelligence. It is based on chaos theory and has its roots in the way an anthill functions successfully. There is a certain rationality underlying its approach. Daniel Kahneman and Amos Tversky received the Nobel Prize in Economics in 2002 for their work on what appears to be irrationality in decision-making. We believe that the irrationality is caused by the factors listed above. For example, Tversky, Slovic, and Kahneman (1990) investigate the causes of preference reversal, which is a known problem in applying the analytical hierarchy process to problems. They conducted experiments to investigate the phenomenon. However, some criterion or preference is generally omitted from the analysis. Ratner, Kahn, and Kahneman (1999) investigated how variety can cause individuals to choose less-preferred options even though they will enjoy them less. In this case, variety clearly has value, is part of a decision-maker's utility, and is a criterion and/or constraint that should be considered in decision-making.

In the *MMS Running Case*, rationality prevailed. Maximizing profit was clearly the principle of choice. However, have a look at the situation faced by the Lafko family described in DSS in Action 2.12. Rationality is present, but it may be preventing the family from obtaining and implementing a viable decision.

## SUBOPTIMIZATION

By definition, optimization requires a decision-maker to consider the impact of each alternative course of action on the entire organization because a decision made in one area may have significant effects (positive or negative) in other areas. Consider a marketing department that implements an e-commerce site. Within hours, orders far exceed production capacity. The production department, which plans its own schedule, cannot meet demand. It may gear up for as high demand as is possible to meet. Ideally and independently, the department should produce only a few products in extremely large quantities to minimize manufacturing costs. However, such a plan may result in large, costly inventories and marketing difficulties caused by the lack of a variety of products, especially if customers start to cancel orders since that were not met in a timely way. This situation illustrates the sequential nature of decision-making (see Borges, Pino, and Valle 2002; Sun and Giles, 2001).

A systems point of view assesses the impact of all decisions on the entire system. Thus, the marketing department should make its plans in conjunction with other departments. However, such an approach may require a complicated, expensive, time-consuming analysis. In practice, the MSS builder may close the system within narrow boundaries, considering only the part of the organization under study (the marketing and/or production department in this case), and incorporate relationships into the model that assume away certain complicated relationships describing interactions with and among the other departments. The other departments can be aggregated into simple model components. Such an approach is called suboptimization.

If a suboptimal decision is made in one part of the organization without considering the details of the rest of the organization, then an optimal solution from the point of view of that part may be inferior for the whole. However, suboptimization may still be a very practical approach to decision-making, and many problems are first approached from this perspective. It is possible to reach tentative conclusions (and

## DSS IN ACTION 2.12

**DECISION-MAKING BETWEEN A ROCK AND A HARD  
PLACE; OR, WHAT CAN YOU DO WHEN THERE ARE  
NO GOOD OR EVEN FEASIBLE ALTERNATIVES?**

Fred J. Lafko, an entrepreneur in Poughkeepsie, New York, had a vision in the early 1980s. He bought the *Alexander Hamilton*, a side-wheeler ship used by the Hudson River Day Line from the early 1900s until the latter part of the twentieth century (you can see image at [farberantiques.com/hudson.html](http://farberantiques.com/hudson.html)). Lafko planned to move the ship from the New York City area to Poughkeepsie and make it into a tourist site. He would build a trendy restaurant, shops, and offices into it and moor it along the banks of the Hudson River. As it happens, the *Alexander Hamilton* was one of the few ships listed as a National Historical Monument. This was because of its unique engine design. It was the last ship of its type that could sail. Lafko arranged to have it moved to Poughkeepsie, but unfortunately the ship ran aground on a sandbar in the river. Experts said he would have to wait until the next major high tide (when the moon was full) to pull it off. He arranged for tugboats to pull the ship off the sandbar. Unfortunately the tugboats were late. A month later, he arranged to have them come a day early, and they successfully pulled the *Alexander Hamilton* off the sandbar. Fred arranged to have the ship tied up at the U.S. Navy's Sulko Pier so that he could assess the damage. Once the ship was made seaworthy, he arranged again to tow it to Poughkeepsie. Before the ship could be moved a hurricane sunk it, just below the water line. Shortly after,

Fred Lafko unfortunately died, and his brother Jack, who handled his estate, did nothing about the ship, much to the consternation of Fred's six grown children and the Navy, which wanted its pier back.

In the summer of 2002 Jack died. Fred's children had to make a decision about the ship. After 20 years underwater, there is probably very little left of it worth salvaging. But since the ship is a National Historical Monument, they cannot simply cut it up and scrap it. They also cannot remove the engine. The conventional way to lift the ship out of the water is to build a water-tight fence around it and pump out the silt. The U.S. Environmental Protection Agency will not allow this, because the silt would pollute the river (even though that is where the silt is now). Other salvage methods are very dangerous or expensive. The Navy will not take ownership of the ship (because then it would have to deal with the problem directly), and it is not clear if the children can donate the ship to anyone else or to another agency interested in preserving the past. No one will buy the ship because of all the complications. There do not appear to be any good or even feasible decisions. What can Fred's family do?

*Source: Dennis Lafko, one of Fred's sons, as told to Jay Aronson on a flight from Atlanta to Colorado Springs, July 2002.*

generally usable results) by analyzing only a portion of a system without getting bogged down in too many details. Once a solution is proposed, its potential effects on the remaining departments of the organization can be tested. If no significant negative effects are found, the solution can be implemented.

Suboptimization may also apply when simplifying assumptions are used in modeling a specific problem. There may be too many details or too many data to incorporate into a specific decision-making situation, and so not all of them are used in the model. If the solution to the model seems reasonable, it may be valid for the problem and thus be adopted. For example, in a production department, parts are often partitioned into A/B/C inventory categories. Generally, A items (large gears, whole assemblies) are expensive (say, \$3,000 or more apiece), built to order in small batches, and inventoried in low quantities; C items (nuts, bolts, screws) are very inexpensive (say, less than \$2) and ordered and used in very large quantities; and B items fall in between. All A items can be handled by a detailed scheduling model and physically monitored closely by management; B items are generally somewhat aggregated, their groupings are scheduled, and management reviews these parts less frequently; and C items are not sched-

uled but are simply acquired or built based on a policy defined by management with a simple EOQ ordering system that assumes constant annual demand. The policy might be reviewed once a year. This situation applies when determining all criteria or modeling the entire problem becomes prohibitively time-consuming or expensive.

Suboptimization may also involve simply bounding the search for an optimum (e.g., by a heuristic) by considering fewer criteria or alternatives or by eliminating large portions of the problem from evaluation. If it takes too long to solve a problem, a good-enough solution found so far may be used and the optimization effort terminated.

## DESCRIPTIVE MODELS

Descriptive models describe things as they are, or as they are believed to be. These models are typically mathematically based. Descriptive models are extremely useful in DSS for investigating the consequences of various alternative courses of action under different configurations of inputs and processes. However, because a descriptive analysis checks the performance of the system for a given set of alternatives (rather than for *all* alternatives), there is no guarantee that an alternative selected with the aid of a descriptive analysis is optimal. In many cases, it is only satisfactory. Simulation is probably the most common descriptive modeling method. Simulation has been applied to many areas of decision-making. Computer and video games are a form of simulation. An artificial reality is created, and the game player lives within it. Virtual reality is also a form of simulation. The environment is simulated, not real. A common use of simulation is in manufacturing. Again, consider the production department of a firm with complications caused by the marketing department. The characteristics of each machine in a job shop along the supply chain can be described mathematically. Relationships can be established based on how each machine physically runs and relates to others. Given a trial schedule of batches of parts, one can measure how batches flow through the system and the utilization statistics of each machine. Alternative schedules may then be tried, and the statistics recorded, until a reasonable schedule is found. Marketing can examine access and purchase patterns on its Web site. Simulation can be used to determine how to structure a Web site for improved performance and to estimate future purchases. Both departments have used primarily experimental modeling methods.

Classes of descriptive models include

- **Complex inventory decisions**
- **Environmental-impact analysis**
- **Financial planning**
- « **Information flow**
- **Markov analysis (predictions)**
- **Scenario analysis**
- **Simulation (alternative types)**
- **Technological forecasting**
- **Waiting line (queuing) management.**

There are a number of nonmathematical descriptive models for decision-making. One is the cognitive map (Eden and Ackermann, 2002; Jenkins, 2002). A cognitive map can help a decision-maker sketch out the important qualitative factors and their causal relationships in a messy decision-making situation. It helps the decision-maker (or decision-making group) focus on what is relevant and what is not, and the map evolves as more is learned about the problem. The map can help the decision-maker under-

stand issues better, focus better, and reach closure. One interesting software tool for cognitive mapping is Decision Explorer (Banxia Software Ltd., Glasgow, Scotland, [banxia.com](http://banxia.com); try the demo).

Another descriptive decision-making model is the use of narratives to describe a decision-making situation. A narrative is a story that, when told, helps a decision-maker uncover the important aspects of the situation and leads to better understanding and framing. It is extremely effective when a group is making a decision and can lead to a more common frame. Juries in court trials typically use narrative-based approaches in reaching verdicts (see Allan, Fairtlough, and Heinzen, 2002; Beach, 1997; Denning, 2000; and the film *12 Angry Men*).

### GOOD ENOUGH OR SATISFICING

According to Simon (1977), most human decision-making, whether organizational or individual, involves a willingness to settle for a satisfactory solution, "something less than the best." When satisficing, the decision-maker sets up an aspiration, goal, or desired level of performance and then searches the alternatives until one is found that achieves this level. The usual reasons for satisficing are time pressure (decisions may lose value over time), the ability to achieve optimization (solving some models could take longer than until when the sun is supposed to become a supernova), as well as recognition that the marginal benefit of a better solution is not worth the marginal cost to obtain it. (This is like searching the Web. You can look at only so many Web sites before you run out of time and energy.) In this situation, the decision-maker is behaving rationally, though in reality he or she is satisficing. Essentially, *satisficing is a form of suboptimization*. There may be a best solution, an optimum, but it is difficult, if not impossible, to attain. With a normative model, too much computation may be involved; with a descriptive model, it may not be possible to evaluate all the sets of alternatives.

Related to satisficing is Simon's idea of *bounded rationality*. Humans have a limited capacity for rational thinking; they generally construct and analyze a simplified model of a real situation by considering fewer alternatives, criteria, and/or constraints. Their behavior with respect to the simplified model may be rational. However, the rational solution for the simplified model may not be rational for the real-world problem. Rationality is bounded not only by limitations on human processing capacities but also by individual differences, such as age, education, knowledge, and attitudes. Bounded rationality is also why many models are descriptive rather than normative. This may also explain why so many good managers rely on intuition, an important aspect of good decision-making (see Stewart, 2002; Pauly, 2001). Agosto (2002) investigated bounded rationality and satisficing in "young people's" Web-based decision-making. Agosto was interested in how adolescents handle time constraints, information overload, and personal preferences, all factors that lead to satisficing. The research study indicates that reduction (filtering out information) and termination (early stopping) are two major satisficing behaviors. And personal preference plays a major role in Web site evaluation, especially in graphic/multimedia and subject-content preferences. Mingers and Rosenhead (2000) describe moving away from mathematical models and toward a facilitated, "enriched" decision-making process that involves group processes. This may make the decision-makers feel good about the process, but it ignores the fact that many models embedded in DSS are available just for the taking. Organizations that do not use the models may feel good, but firms that utilize the models (even in a facilitated environment) will definitely make more effective decisions. When tools are available and are effective, they should be used for competitive advantage.

## DEVELOPING (GENERATING) ALTERNATIVES

A significant part of the process of model building is generating alternatives. In optimization models (such as linear programming), the alternatives may be generated automatically by the model. In most MSS situations, however, it is necessary to generate alternatives manually. This can be a lengthy process that involves searching and creativity. It takes time and costs money. Issues such as when to stop generating alternatives can be very important. Too many alternatives can be detrimental to the process of decision-making. A decision-maker may suffer from information overload. See DSS in Action 2.13. Cross (2001) describes a new initiative for administrators in higher-education institutions to handle *information overload*. The National Learning Infrastructure Initiative (NLII) Institute Readiness Program (READY) provides a way to organize and communicate information about the incorporation of technology into higher education. The Web-based READY portal filters through large amounts of information to select only relevant items for alternative selection. Generating alternatives is heavily dependent on the availability and cost of information and requires expertise in the problem area. This is the least formal aspect of problem-solving. Alternatives can be generated and evaluated with heuristics. The generation of alternatives from either individuals or groups can be supported by electronic brainstorming software in a Web-based GSS.

Note that the search for alternatives usually comes after the criteria for evaluating the alternatives are determined. This sequence can reduce the search for alternatives and the effort involved in evaluating them, but identifying potential alternatives can sometimes aid in identifying criteria. Identifying criteria and alternatives proved difficult in the *MMS Running Case*. The analysts first had to identify the many *problems*. Once the problems were identified, years of experience and access to information through the CLAUDIA portal made it easy for the team to develop obvious solutions and establish their value to the bottom line.

The outcome of every proposed alternative must be established. Depending upon whether the decision-making problem is classified as one of certainty, risk, or uncer-

### DSS IN ACTION 2.13

## TOO MANY ALTERNATIVES SPOILS THE BROTH

The following decision-making situation was overheard on a bus ride at a national meeting:

A major university was in the process of moving its distance learning activities to the Web. A professor was assigned the task of looking into the possible alternatives. He created a list of 23 companies in a report. He included detailed descriptions of the alternatives and what the university needed. There was extensive documentation. He wanted to be thorough, even though not all of the alternatives were appropriate for the university (constraints clearly would have cut the list down). He felt it was a good report.

The day before the decision was to be made, a salesman for such products stopped by the president's office. The president picked this company's product. As

was overheard on the bus: "Studies on decision-making show that when you give someone too many options to choose from, plus a deadline, he or she usually freezes and is likely to choose the last one mentioned."

Three to five alternatives seem to be about right. An executive summary would have been a good idea. After all, they were trying to solve a problem, not survey the marketplace. Even using a software tool to compare these few valid alternatives would have been a good idea. Perhaps Expert Choice could have been used. See Case Application 2.3.

*Source:* Modified and condensed from S.M. Johnstone, "Decision Support for Distance Learning Solutions: Help is Online," *Syllabus*, October 2001.

## HOW DO PEOPLE REALLY VIEW RISK?

Professor Adam Goodie at The University of Georgia has empirically demonstrated how people view risk in decision-making. "When people are called to gamble on a random event, where there's a very large probability of something small but good happening and a very low probability of something big and bad happening, they don't want to do it," Goodie says. "If it's something they have control over, like their own knowledge of the world, *then they insist on doing it. That has significance for all sorts of decisions we make in our lives.*" The most obvious example is the debate over airline travel since the events of September 11, Goodie says. "People aren't afraid of driving, but they're afraid of flying, even though air travel is statistically much safer per mile traveled," he says. "But

people feel safer if they're driving because they have control over the sources of risk and uncertainty."

A sense of control is a key factor in determining whether people take risks or avoid them. People are more willing to take risks when they feel they can control the outcome of a situation—even if they have overestimated their likelihood of success. People are often overconfident about their knowledge. This may explain why slot machines require the player to pull a lever. It may give the player a feeling of control.

*Source:* For more information, see A. Mann, "Risky Business," *Columns* (UGA Faculty Newsletter), February 11, 2002, p. 3; Goodie (2001).

tainty, different modeling approaches may be used (see Drummond, 2002; Koller, 2000). These are discussed in Chapter 4. See DSS in Focus 2.14 for a description of how people really view risk.

## MEASURING OUTCOMES

The value of an alternative is evaluated in terms of goal attainment. Sometimes an outcome is expressed directly in terms of a goal. For example, profit is an outcome, profit maximization is a goal, and both are expressed in dollar terms. An outcome such as customer satisfaction may be measured by the number of complaints, by the level of loyalty to a product, or by ratings found by surveys. Ideally, one would want to deal with a single goal, but in practice it is not unusual to have multiple goals (see Barba-Romero, 2001; Koksalan and Zions, 2001). When groups make decisions, each group participant may have a different agenda. For example, executives may want to maximize profit, marketing may want to maximize market penetration, operations may want to minimize costs, while stockholders may want to maximize the bottom line. Typically these goals conflict, so special multiple-criteria methodologies have been developed to handle this. One such method is the analytic hierarchy process, outlined in Case Application 2.3 and the Web Chapter on college/university selection.

## SCENARIOS

A scenario is a statement of assumptions about the operating environment of a particular system at a given time; that is, a narrative description of the decision-situation setting. A scenario describes the decision and uncontrollable variables and parameters for a specific modeling situation. It also may provide the procedures and constraints for the modeling.

Scenarios originated in the theater. The term was borrowed for war gaming and large-scale simulations. Scenario planning and analysis is a DSS tool that can capture a whole range of possibilities. A manager can construct a series of scenarios (what-if cases), perform computerized analyses, and learn more about the system and decision-

making problem while analyzing it. Ideally, the manager can identify an excellent, possibly optimal, solution to the model of the problem.

A scenario is especially helpful in simulations and what-if analysis. In both cases, we change scenarios and examine the results. For example, one can change the anticipated demand for hospitalization (an input variable for planning), thus creating a new scenario. Then one can measure the anticipated cash flow of the hospital for each scenario.

Scenarios play an important role in MSS because they

- Help identify opportunities and problem areas
- Provide flexibility in planning
- Identify the leading edges of changes that management should monitor
- Help validate major modeling assumptions
- Allow the decision-maker to explore the behavior of a system through a model
- Help to check the sensitivities of proposed solutions to changes in the environment as described by the scenario

## POSSIBLE SCENARIOS

There may be thousands of possible scenarios for every decision situation. However, the following are especially useful in practice:

- The worst possible scenario
- The best possible scenario
- The most likely scenario
- The average scenario

The scenario determines the context of the analysis to be performed. Scenarios were used in the *MMS Running Case* in establishing the value of each alternative.

## ERRORS IN DECISION-MAKING

The model is the critical component in the decision-making process, but one may make a number of errors in its development and use. Validating the model before it is used is critical. Gathering the right amount of information, with the right level of precision and accuracy, to incorporate into the decision-making process is also critical. Sawyer (1999) describes "the seven deadly sins of decision-making," most of which are behavior- or information-related. We summarize these "sins" in DSS in Focus 2.15.

## 2.8 DECISION - MAKING : THE CHOICE PHASE

Choice is the *critical act* of decision-making. The choice phase is the one in which the actual decision is made and where the commitment to follow a certain course of action is made. The boundary between the design and choice phases is often unclear because certain activities can be performed during both of them and because one can return frequently from choice activities to design activities. For example, one can generate new alternatives while performing an evaluation of existing ones. The choice phase includes the search, evaluation, and recommendation of an *appropriate* solution to the model. A solution to a model is a specific set of values for the decision variables in a selected alternative. In the *MMS Running Case* (see DSS in Action 2.16), choices were evaluated as to their viability and profitability. A choice was made to correct data errors and to move a specific number of cars from one set of locations to another. The

## THE SEVEN DEADLY SINS OF DECISION-MAKING

Sawyer (1999) describes what she calls "the seven deadly sins of decision-making." These are common pitfalls of decision-making that decision-makers often unwittingly encounter. They are all interrelated. The seven deadly sins are:

1. Believing that you already have all the answers (no attempt is made to seek outside information or expertise)
2. Asking the wrong questions (you need the right information to make an informed decision)
3. The old demon ego (a decision-maker feels he or she is right and refuses to back down from a bad policy or decision)
4. Flying-by-the-seat-of-your-pants saves money—doesn't it? (by not seeking out information, an organization saves money—and makes bad decisions)
5. All aboard the bandwagon: if it works for them, it'll work for us (copying someone else's ideas

really involves understanding why and how they work)

6. Hear no evil (discourage and ignore negative advice—kill the messenger with the bad news)
7. Hurry up and wait: making no decision can be the same as making a bad decision (procrastination is not necessarily a good managerial technique).

Of course, all of these lead to bad decisions that lead to unnecessary and high costs for firms and individuals (including getting fired). Many of these "sins" clearly involve behavioral issues and lack of information and expertise that leads to less objectivity in the decision-making process. These "sins" often appear in the press and on the Web as ways *not* to make decisions.

*Source: Based on D.C. Sawyer, Getting It Right: Avoiding the High Cost of Wrong Decisions, Boca Raton, FL: St. Lucie Press, 1999.*

advertising plan was modified, and new data and features were to be added to the firm's DSS.

*Note: Solving the model is not the same as solving the problem the model represents. The solution to the model yields a recommended solution to the problem. The problem is considered solved only if the recommended solution is successfully implemented.*

Solving a decision-making model involves searching for an appropriate course of action. These search approaches include analytical techniques (solving a formula), algorithms (step-by-step procedures), heuristics (rules of thumb), and blind search (shooting in the dark, ideally in a logical way). These are covered in Chapter 4.

Each alternative must be evaluated. If an alternative has multiple goals, these must all be examined and balanced off against the others. Sensitivity analysis is used to determine the robustness of any given alternative (slight changes in the parameters should ideally lead to slight or no changes in the alternative chosen). What-if analysis is used to explore major changes in the parameters. Goal seeking helps the manager determine values of the decision variables to meet a specific objective. All of this is covered in Chapter 4.

## 2.9 DECISION - MAKING : THE IMPLEMENTATION PHASE

In *The Prince*, Machiavelli astutely noted some 500 years ago that there was "nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things." The implementation of a proposed solution to a problem is, in effect, the initiation of a new order of things, or the introduction-of

## DSS IN ACTION 2.16

**MMS** RUNNING CASE: THE CHOICE PHASE

**Monday's Meeting: With All Vice Presidents, Stephanie, and Her Team**

**ELENA:** Thank you again for coming. Stephanie, Michael tells me you're on to something. Let's hear what you have to say.

**STEPHANIE:** Well, we think we've discovered what to do. But first let me outline what the *real* problems are, and some suggested solutions and why these are appropriate solutions.

Next Stephanie essentially outlines the details from the meeting described in DSS in Action 2.8. There is a little discussion to clarify a few points.

**ELENA:** Amazing. I'm glad Mark recommended acquiring DOT three months ago. Though expensive, it's already paid off. Can you get me specifics on the bottom line for each alternative?

**STEPHANIE:** Not accurate ones for each just yet. Some will take up to a couple of weeks. We do have estimates on all of them. Here are the results in my PowerPoint presentation.

**ELENA:** HMMM. OK. I want those data on the Spider updated immediately, and some of them moved to where they'll rent.

**MARI A:** It's already done. I took steps right away once Michael told me what happened. After all, it's my responsibility. I already gave some updated data to IS. They've adjusted the revenue management system. Preliminary data indicate that they have improved our profitability already. In a couple of markets where it was relatively inexpensive, I have moved some cars around based on the DSS model's recommendation. It worked! I think we should make the major changes recommended by the solution to the model. My estimates, just from these few markets, are that it will work just as the model predicts.

**SHARON:** We're looking into how to modify our marketing and tie it into the revenue-management system. We're also running models on how European marketing should work. We'll know in a week what to do.

**ELENA:** Excellent! Here's where we stand. We're going to adjust the profile data of the Spider and all models frequently, move cars around, and discount substitutes until we can get the imbalance fixed. We'll decide on what to do about the other issues after the rest of the analysis is completed.

change. And change must be managed. User expectations must be managed as part of change management.

The definition of implementation is somewhat complicated because implementation is a long, involved process with vague boundaries. Simplistically, implementation means putting a recommended solution to work, *not necessarily the implementation of a computer system*. Many generic implementation issues, such as resistance to change, degree of support of top management, and user training, are important in dealing with management support systems. In the *MMS Running Case* (DSS in Action 2.17), implementation was a little fuzzy. Some decisions were pilot-tested by the people responsible for that aspect of decision-making before the decision was implemented nationally. Essentially for MMS, implementation involved updating computer systems, testing models and scenarios for impacts, and physically moving the cars from some locations to others. THE computer system updates ideally should involve some kind of formal information system development approach, while the actual implementation of the decision may not. Implementation is covered in detail in Chapter 6. The decision-

DSS IN ACTION 2.17

MMS RUNNING CASE: THE IMPLEMENTATION PHASE

The implementation of the first couple of decisions was relatively easy. Transport vehicles were rented and cars were moved. Discounts were easy to establish for substitute cars, because this could be done as routinely as when there was a normal stockout. A customer would first be offered the opportunity to upgrade. If the customer turned it down, the upgrade would be offered free. This work 95 percent of the time, even in the case of the Spider. Sales were up, and the company was projected to be profitable with these small changes.

Elena got the results of the additional analyses. They all made sense. She decided, with the advice of her

VPs and the analysts, to go ahead with all the recommendations, but held back on European marketing until a presence in Europe could be established in major markets. The "try before you buy" campaign would be started once there were 15 Spiders in most major markets and three in each secondary market. She also approved adding new data and features to CLAUDIA.

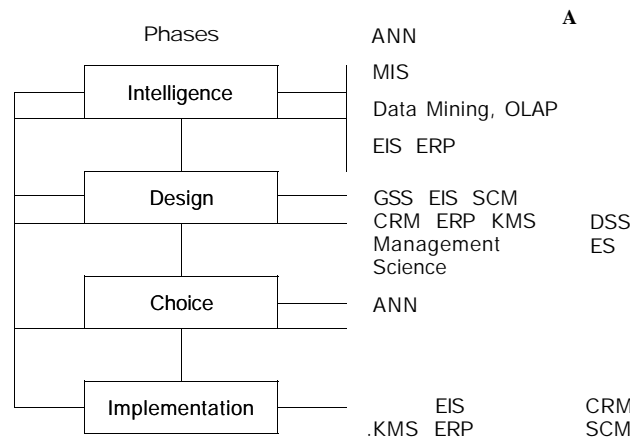
Once the advertising effort was refined and tied into the revenue management system, profits soared. Every member of Stephanie's team and all the VPs involved got a generous end-of-year bonus, an extra week's vacation, and a gift of a free GMC Spider.

making process, though conducted by people, can be improved with computer support, the subject of the next section.

2.10 HOW DECISIONS ARE SUPPORTED

In Chapter 1 we discussed the need for computerized decision support and briefly described some decision aids. Here we relate specific management support system technologies to the decision-making process (Figure 2.3).

FIGURE 2.3 DSS SUPPORT



Source: Based on Sprague, R. H., Jr., "A Framework for the Development of DSS." *MIS Quarterly*, Dec. 1980, Fig. 5, p. 13.

## SUPPORT FOR **THE** INTELLIGENCE PHASE

The primary requirement of decision support for the intelligence phase is the ability to scan external and internal information sources for opportunities and problems and to interpret what the scanning discovers. Web tools and sources are *extremely* useful for environmental scanning. Web browsers provide useful front ends for a variety of tools, from OLAP to data mining and data warehouses. Data sources may be internal and external. Internal sources may be accessed via a corporate intranet. External sources are many and varied. For a list of many Web sites with global macroeconomic and business data, see Hansen (2002).

Decision support technologies can be very helpful. For example, an enterprise information system can support the intelligence phase by continuously monitoring both internal and external information, looking for early signs of problems and opportunities through a Web-based enterprise information portal, as in the *MMS Running Case* (also see DSS in Action 2.18 for an example in the pharmaceutical industry). Similarly, (automatic) data mining (which may include expert systems, CRM, and neural networks) and (manual) online analytic processing (OLAP) also support the intelligence phase by identifying relationships among activities and other factors. These relationships can be exploited for competitive advantage (e.g., CRM identifies classes of customers to approach with specific products and services; see Sparacino and O'Reilly, 2000). A knowledge management system can be used to identify similar past situations and how they were handled. Group support systems can be used to share information and for brainstorming. Artificial neural networks can be used to identify the best takeover targets, as was demonstrated for banks by Shawver and Aronson

### DSS IN ACTION 2.18

#### PHARMACEUTICAL FIRMS ANALYZE AND VISUALIZE WITH WEB PORTALS INTO DATA

Infinity Pharmaceuticals, Inc. (Boston) speeds drug development by facilitating the process of evaluating new chemicals through real-time Web analytics. Researchers need to generate statistical models of how compounds will behave in a given chemical assay. With so many different models, the more real-time and interactive a researcher is, the more effective he or she will be. Data integration of chemical models databases with outside sources, such as databases of chemical compounds, and a consistent interface are critical. Infinity's IT staff solved the problem by building a real-time system using Web services as its application model. XML interfaces are coded into every program. The design also includes a standardized metadata model, to which Infinity maps its data dictionaries. Data integration is done upfront. The Spotfire.net (Spotfire Inc., Cambridge, Massachusetts) decision-analytics portal uses Web connectivity to provide scientific decision-making communities with a unified workspace to access large amounts

of complex chemical-structure or gene-expression data, visually explore and analyze these data, and share results. Spotfire.net automatically generates interactive query devices for rapid identification of trends, anomalies, outliers, and patterns. Researchers can view and maneuver data in 3-D by selecting different visualization types or displaying multiple variables on the same screen. Spotfire.net provides algorithms for data mining and basic statistical analysis via the Web to the user's desktop. These include decision tree analysis, principal components analysis, K-means clustering, hierarchical clustering, and other statistical calculations, such as box-plots. Millions of compounds can be analyzed and visualized in seconds.

*Sources:* Adapted from Mark Hall, "Web Analytics: Get Real," *ComputerWorld*, Vol. 36, No. 14, April 1, 2002, 42-43; Julia Boguslavsky, "Visualize Large Data Sets Online," *Research & Development*, Vol. 42, No. 9, September 2000, p. 59.

(2003). The Web provides consistent, familiar interface tools via portals and access to critical, often fuzzy information necessary to identify problems and opportunities.

Expert systems, on the other hand, can render advice regarding the nature of the problem, its classification, its seriousness, and the like. ES can advise on the suitability of a solution approach and the likelihood of successfully solving the problem. One of the primary areas of ES success is interpreting information and diagnosing problems. This capability can be exploited in the intelligence phase. Even intelligent agents can be used to identify opportunities (see Desouza, 2001).

Another area of support is reporting. Both routine and ad hoc reports can aid in the intelligence phase. For example, regular reports can be designed to assist in the problem-finding activity by comparing expectations with current and projected performance. Web-based OLAP tools are excellent at this task (see DSS in Action 2.18). So are electronic document management systems.

Much of the information used in seeking new opportunities is qualitative or soft. This indicates a high level of unstructuredness in the problems, thus making DSS quite useful in the intelligence phase. For example, see DSS in Action 2.19, where Union Pacific seeks out opportunities in the avalanche of data that it *must* collect by law.

The Web and advanced database technologies have created a glut of data and information available to decision-makers—so much that it can detract from the quality and speed of decision-making. Fortunately, intelligent agents and other artificial intelligence tools can lessen the burden. In DSS in Focus 2.20, we describe the issues that managers are grappling with in the digital age of decision-making.

## SUPPORT FOR THE DESIGN PHASE

The design phase involves generating alternative courses of action, discussing the criteria for choice and their relative importance, and forecasting the future consequences of using various alternatives. Several of these activities can use standard models provided by a decision support system (such as financial and forecasting models, available as applets). Alternatives for structured problems can be generated through the use of either standard or special models. However, the generation of alternatives for complex problems requires expertise that can only be provided by a human, brainstorming software, or an expert system. OLAP and data mining software are quite useful in identifying relationships that can be used in models (see the *MMS Running Case*). Most DSS

### DSS IN ACTION 2.19

#### UNION PACIFIC RAILROAD: IF YOU'RE COLLECTING DATA, YOU SHOULD USE IT PROFITABLY!

Union Pacific is required by law to collect dozens of gigabytes of data every month about rail conditions, but a competitive spirit is why the company *leverages* those data, stored in several incompatible formats in various relational and mainframe systems, for its business intelligence initiative. Using reporting, analysis, and query applications, decision-makers can find the

needed and appropriate information from existing systems and derive answers from composite, incompatible data—without waiting for daily or monthly batch loads into a centralized data warehouse.

Source: Modified from Anonymous, "Smarter, Faster, More Profitable: 20 Organizations That Get It," *IntelligentEnterprise*, Oct. 4, 2001, pp. 18-19.

## DECISION-MAKING IN THE DIGITAL AGE

Kepner-Tregoe, Inc. (Princeton, New Jersey) surveyed managers and workers across the United States to determine how they are coping with the need for faster decision-making and how companies are balancing the requirement for speed with the concomitant need for quality.

Decision-makers are under pressure to keep up but in the process are too often sacrificing the quality of decision-making. *Digital age* decision-makers are not making the most of what is available. Decision-makers are often unable to gather sufficient information, they're doing a poor job of sharing that information, and they're failing to involve the right people in the decision process. Here are the key findings:

- \* **More decisions are being made in less time.**  
Both managers and workers must make more decisions in the same or less time. Sixty-five percent of workers and 77 percent of managers say that they must make more decisions every day. At the same time, most also agree that the amount of time they have to make these decisions has either decreased or stayed the same.
- \* **Respondents are missing opportunities.**  
Despite the pressure to make speedy decisions, nearly three-quarters of workers and four-fifths of managers say they miss opportunities because they don't make decisions quickly enough. Most agree that decisions are frequently not implemented in a timely manner.
- **Many feel as if they are losing the race.**  
When asked to compare the speed of their organization's decision-making to that of rivals, only one-quarter of workers and less than one-third of managers said they are moving faster than their competition.
- **Many barriers to speed are human.**  
Workers and managers closely agreed that the need for multiple approvals is the most frequently

encountered barrier. Other common roadblocks are organizational politics, changing priorities, and getting people to agree up front on what they want the decision to accomplish.

- **Information technology clearly has a widespread influence.**  
When asked specifically where IT has become the most important source of information for decision-making, both workers and managers listed budgeting/finance, purchasing and customer service, followed closely by daily product management, quality/productivity, personnel/human resources, and process improvement.
- **Sources of information are constantly changing.**  
When asked where they get the information upon which they base their decisions today (compared to three years earlier), both workers and managers described a major shift from real to virtual sources. The most dramatic change has been in the increased use of e-mail. Most also agree not only that the quantity of information has increased, but that the quality of the information has increased as well.
- **Decision-making amnesia is rampant.**  
Organizations are *not very effective* at preserving their decision-making experiences. Of those who said that their organizations have a system in place to house decision criteria, 77 percent of workers and 82 percent of managers said they couldn't assess the utility of their database.

Decision-leading firms have figured out ways to counter these deficiencies. See the source for details.

Source: Modified from D.K. Wessel, "Decision Making in the Digital Age," *DM Review 2002 Resource Guide*, *DM Review*, December 2001.

have quantitative analysis capabilities, and an internal ES can assist with qualitative methods as well as with the expertise required in selecting quantitative analysis and forecasting models. A knowledge management system should certainly be consulted to determine whether such a problem has been encountered before, or whether there are experts on hand who can provide quick understanding and answers. Customer relationship management systems, revenue management systems (as in the *MMS Running Case*), enterprise resource planning, and supply chain management systems software

are useful in that they provide models of business processes that can test assumptions and scenarios. If the problem requires brainstorming to help identify important issues and options, a group support system may prove helpful. Tools that provide cognitive mapping can also help. All of these tools may be accessed via the Web. Cohen, Kelly, and Medaglia (2001) describe several Web-based tools that provide decision support, mainly in the design phase, by providing models and reporting of alternative results. Each of their cases has saved millions of dollars annually by utilizing these tools. Web-based DSS are helping engineers in product design as well as decision-makers solving business problems. See DSS in Action 2.21.

### SUPPORT FOR THE CHOICE PHASE

In addition to providing models that rapidly identify a best or good enough alternative, a decision support system can support the choice phase through the what-if and goal-seeking analyses. Different scenarios can be tested for the selected option to reinforce the final decision. Again, a knowledge management system helps identify similar past experiences; CRM, ERP, and SCM systems are used to test the impacts of the decisions in establishing their value leading to an intelligent choice. An expert system can be used to assess the desirability of certain solutions as well as to recommend an appropriate solution. If a group makes the decision, a group support system can provide support to lead to consensus.

### SUPPORT FOR THE IMPLEMENTATION PHASE: MAKING THE DECISION HAPPEN

The DSS benefits provided during implementation may be as important as or even more important than those in the earlier phases. DSS can be used in implementation activities such as decision communication, explanation, and justification.

Implementation phase DSS benefits are partly due to the vividness and detail of analyses and reports. For example, one chief executive officer (CEO) gives employees and external parties not only the aggregate financial goals and cash needs for the near

#### DSS IN ACTION 2.21

### WEB-BASED DSS ASSIST ENGINEERS IN PRODUCT DESIGN

Though not a business decision-making situation, engineering organizations must solve product and service *design* problems. 3Ga Corp. has developed 3G.web.decisions, an Internet technology that accelerates the product-design process. 3G.web.decisions was developed on the Java, XML, and Microsoft.NET platforms. It lets project engineers use their Web browsers to access and reuse parametric CAD and engineering data to support design change recommendations. Any member of a product-design team can simulate the impact of parametric

engineering changes on the fit, form, and functional behavior of a design. Hundreds of design alternatives can be evaluated in real time. Team members collectively determine which configuration is the most cost-effective, highest quality, and easiest to produce. The software supports models from several standard data package formats.

*Source: Adapted from Anonymous, "Validating Design Decisions On-Line," Computer-Aided Engineering, Vol. 20, No. 4, April, 2000, p. 24.*

term but also the calculations, intermediate results, and statistics used in determining the aggregate figures. In addition to communicating the financial goals unambiguously, the CEO signals other messages. Employees know that the CEO has thought through the assumptions behind the financial goals and is serious about their importance and attainability. Bankers and directors are shown that the CEO was personally involved in analyzing cash needs and is aware of and responsible for the implications of the financing requests prepared by the finance department. Each of these messages improves decision implementation in some way. In the Opening Vignette, team members had access to information in order to make decisions, and information about the results of the decisions. The same is true in the *MMS Running Case*. KMS, EIS, ERP, CRM, and SCM are all useful in tracking how well the implementation is working. GSS is useful for a team to collaborate in establishing implementation effectiveness. For example, a decision might be made to get rid of unprofitable customers. An effective CRM can identify classes of customers to get rid of, identify the impact, and then verify that it really worked that way (see Murphy, 2002; Swift, 2001).

All phases of the decision-making process can be supported by improved communication by collaborative computing through GSS and KMS. Computerized systems can facilitate communication by helping people explain and justify their suggestions and opinions. Quantitative support can also be quickly provided for analyzing various possible scenarios while a meeting is in session (either in person or virtually).

Decision implementation can also be supported by expert systems. An ES can be used as an advisory system regarding implementation problems (such as handling resistance to change). Finally, an ES can provide training that may smooth the course of implementation.

Impacts along the value chain, though reported by an enterprise information system through a Web-based enterprise information portal, are typically identified by SCM and ERP systems. CRM systems report and update internal records based on the impacts of the implementation. And then these inputs are used to identify new problems and opportunities—a return to the intelligence phase.

## NEW TECHNOLOGY SUPPORT FOR DECISION-MAKING

Web-based systems clearly have influenced how decision-making is supported. With the development of m-commerce (mobile commerce), more and more personal devices (personal digital assistants, cell phones, tablet computers, laptop computers) can access information sources, and users can respond to systems with information updates, collaboration efforts, and decisions. This is especially important for salespeople, who can be more effective if they can access their CRM while on the road and then enter orders. Constant access to corporate data, inventory and otherwise, can only help them in their work. Overall, wireless devices are taking on greater importance in the enterprise, generally by accessing specialized Web servers that provide data and communication directly to the m-commerce device. East Bay Restaurant Supply (Oakland, California) reports that though it has not evaluated the effectiveness of providing instantaneous information to all its sales reps, it has saved \$45,000 by providing each of its 15 reps with a Palm Pilot instead of a notebook computer. (For details on how East Bay Restaurant Supply and other firms have initiated m-commerce efforts, see McVicker, 2001.) Finally, advanced artificial intelligence technologies can be utilized in decision-making. Camacho et al. (2001) describe how travel planning in e-tourism can be handled by intelligent agents; Desouza (2001) surveys applications of intelligent agents for competitive intelligence.

The Web provides a vehicle to disseminate knowledge and information about decision-making and DSS. We list some of the many sources for decision-making support and theory in Table 2.3.

## 2.11 PERSONALITY TYPES, GENDER, HUMAN COGNITION, AND DECISION STYLES

### PERSONALITY (TEMPERAMENT) TYPES

Many studies indicate that there is a strong relationship between personality and decision-making. Personality type influences general orientation toward goal attainment, selection of alternatives, treatment of risk, and reactions under stress. It affects a decision-maker's ability to process large quantities of information, time pressure, and reframing. It also influences the rules and communication patterns of an individual decision-maker. For example, see Harrison (1999).

People are *not* alike. In the 1920s, Carl Jung (1923) described how people are fundamentally different, though they all have the same set of instincts that drive them internally. Actually, personality (temperament) types were described in ancient Greece by Hippocrates (Keirse, 1998; Montgomery, 2002), and were surely known long before that. In the 1950s, Myers and Briggs revived Jung's research and developed the well-known Myers-Briggs Type Indicator (Quenk, 1999), along with an interpretation of each type (Berens et al., 2002; Montgomery, 2002; Myers and Myers, 1999). The Myers-Briggs temperament types are described briefly in DSS in Focus 2.22.

There is a long, detailed Myers-Briggs test that can be administered only by a professional counselor (contact the Center for Applications of Psychological Type, [capt.org](http://capt.org)); however, Keirse and Bates (1984) have published a shorter, readily available questionnaire to determine one's type, along with a detailed description of the types and how they are motivated, act, and interact.

Birkman (1995) developed a personality typing called "True Colors" (be aware that there are several different "colors" types in books and on the Web). His personality typing follows the basic Jungian structure, but the establishment of one's personality type requires answering 16 simple, true/false questions. One author has used this personality typing in his classes since 1998, and of the more than 1,000 students who have been typed, few have claimed that the types did not match their own sense of their personalities. The color types can be quickly established, discussed, and used to build teams in classes and, more important, in decision-making environments. Birkman's True Colors typing is briefly described in DSS in Focus 2.23.

Temperament helps describe how one can best attack decision-making problems because certain activities are better handled by each type. It also indicates how each type relates to each of the other types, describing positive communication patterns, work patterns, and so on. This information can be helpful in determining the best way to interact with your significant other. The most important issue to understand in identifying and using temperament types is that there is no right or wrong, or good or bad type. People simply have different personality types. People of different types act and react differently in different situations (e.g., under stress, under normal conditions), have different motivational needs and values, conceptualize differently, and readily adopt certain roles in the decision-making process. Each type has preferred ways of learning and explaining (important for college careers and training). People of each type are communicated with in different "best" ways, and thus there are differences in

TABLE 2.3 Web Smirei\*; inr Divi-inn Makim<sup>1</sup>. Suppnil Sampler

<i>Web Site</i>	<i>Content Sample</i>	<i>Organization</i>
<a href="http://www.ubmail.ubalt.edu/~harsham/">www.ubmail.ubalt.edu/~harsham/</a>	An extensive bibliography on decision-making tools: "Applied Management Science: Making Good Strategic Decisions" ( <a href="http://www.ubmail.ubalt.edu/~harsham/opre640/opre640.htm">www.ubmail.ubalt.edu/~harsham/opre640/opre640.htm</a> ); "Decision Science Resources" ( <a href="http://www.ubmail.ubalt.edu/~harsham/refop/Refop.htm">www.ubmail.ubalt.edu/~harsham/refop/Refop.htm</a> ); "Compendium of Decision-making Web Site Reviews" ( <a href="http://www.ubmail.ubalt.edu/~harsham/opre640a/part1.htm">www.ubmail.ubalt.edu/~harsham/opre640a/part1.htm</a> )	Hossein Arsham, University of Baltimore
<a href="http://www.mindtools.com">www.mindtools.com</a>	Information about decision-making, decision trees, decision analysis, and creativity	Mind Tools Community
<a href="http://faculty.fuqua.duke.edu/daweb/">faculty.fuqua.duke.edu/daweb/</a>	Contact point for decision analysis research. "Lexicon of Decision-making," by Tom Spradlin	Decision Analysis Society Home Page
<a href="http://psych.fullerton.edu/mbirnbaum/dec.html">psych.fullerton.edu/mbirnbaum/dec.html</a>	Applied research site. Contains online Decision Research Center experiments	Decision Research Center
<a href="http://www.sjdm.org">www.sjdm.org</a>	Society for Judgment and Decision-Making References and meetings on judgment and decision-making	Psychology Department, California State University, Fullerton
<a href="http://www.smdm.org">www.smdm.org</a>	Contact point for promoting rational and systematic approaches to decision-making that will improve the health and clinical care of individuals and assist in health policy formation	Society for Medical Decision Making
<a href="http://www.cdm.lcs.mit.edu">www.cdm.lcs.mit.edu</a>	Description of projects and references on providing better health care through applied artificial intelligence	The Clinical Decision-making Group at the Laboratory for Computer Science at MIT
<a href="http://dieoff.com/page163.htm">dieoff.com/page163.htm</a>	"Decision-making and Problem Solving" by Herbert A. Simon and Associates	Brain Food, Jay Hanson
<a href="http://www.aol.com/progresssite/">www.aol.com/progresssite/</a>	Building a collection of cases on decision-making	Progress Research Project with Brunei University
<a href="http://www.ncedr.org">www.ncedr.org</a>	Produces and disseminates scientific and operational advances of direct use to subnational environmental decision-makers.	National Center for Environmental Decision-Making Research
<a href="http://www.iiasa.ac.at/Research/DAS/research/res98/node5.html">www.iiasa.ac.at/Research/DAS/research/res98/node5.html</a>	Project on the development, testing, and use of Web-based systems for decision-making and negotiations	International Institute for Applied Systems Analysis (HASA)
<a href="http://www.ethics.ubc.ca/resources/dec-mkg/">www.ethics.ubc.ca/resources/dec-mkg/</a>	Applied Ethics Resources on WWW References and software for ethical decision-making A Framework for Ethical Decision-Making software-	Centre for Applied Ethics
<a href="http://www.scu.edu/ethics/practicing/decision/">www.scu.edu/ethics/practicing/decision/</a>	Articles on ethical decision-making	Markkula Center for Applied Ethics at Santa Clara University
<a href="http://www.banxia.com">www.banxia.com</a>	Cognitive map bibliography and software	Banxia
<a href="http://www.terry.uga.edu/mcdm/">www.terry.uga.edu/mcdm/</a>	Contact organization for researchers	International Society on Multiple Criteria Decision Making
Various	Good source of Web sites with global macroeconomic and business data	Hansen (2002)

## DSS IN FOCUS 2.22

## MYERS-BRIGGS TEMPERAMENT TYPES

The Myers-Briggs temperament types are characterized along four dimensions, four pairs of so-called preferences:

- Extraversion (E) to Introversion (I)
- Sensation (S) to Intuition (N)
- Thinking (T) to Feeling (F)
- Perceiving (P) to Judging (J).

There are 16 main types (combinations) and an additional 32 mixed types. Types change over time and depend a bit on mood and situation. Some simple words that describe people of each type are

- Extraversion: sociable
- Introversion: territorial
- Sensation: practical
- Intuition: innovative
- Thinking: impersonal
- Feeling: personal

- Perceiving: open
- Judging: closure.

If one examines the entire population, the types are distributed approximately as shown below:

- Extraversion (75 percent) to Introversion (25 percent)
- Sensation (75 percent) to Intuition (25 percent)
- Thinking (50 percent) to Feeling (50 percent)
- Perceiving (50 percent) to Judging (50 percent).

According to Jung, one need not be one or the other of each pair but can exhibit traits of both. Through learning, it is possible for an introvert to behave like an extrovert (as do many college faculty), and for an extrovert to behave like an introvert (as do some college students).

*Source:* Based partly on Berens (2000), Berens et al. (2002), Myers (1998), Keirsey (1998), Keirsey and Bates (1984), Montgomery (2002).

## DSS IN FOCUS 2.23

sSli

## TRUE COLORS TEMPERAMENT TYPES

The True Colors temperament types are Red, Green, Yellow, and Blue. The colors have *no formal meaning* but are simply used to differentiate the types. The colors appear on the following grid:

Red	Green
Yellow	Blue

Some traits are shared up and down the columns (Red and Yellow, Green, and Blue), whereas others are shared across the rows (Red and Green, Yellow and Blue). Diagonal colors have little in common in their makeup. Green types like to communicate directly and work with people. They like to work in groups and to get people excited about what they are doing. Marketing specialists have a tendency to be Green. Red types also like to communicate directly but stay focused

on the task at hand, as do Yellow types. Red types tend to volunteer to be group leaders and stay excited about and focused on getting a job done. Yellow types are most comfortable with indirect communication and like to deal with details (they make great accountants and programmers). Blue types also prefer indirect communication and are innovative, introspective, and creative but are easily distracted and may need people nearby to keep them focused. Blue types make great researchers but often have to be reminded to stay on track with their projects. When a team is formed with members of all the different color types, the team tends to be very creative and productive. One author always has his students take the True Colors test and uses the results to help establish class teams.

*Source:* Based partly on Birkman (1995).

the way they work in teams, in the way they lead teams, in how they frame problems, and also in their cognitive and decision styles. Since each type can be best reached differently, it is important in developing *shared frames* to use an appropriate approach for each type. Finally, it is important to have a balanced team made up of various types to best get the work done. Some types are better thinkers, others are better doers, and so on. Each type can contribute actively to teamwork. Personality type clearly influences one's cognitive style and decision style. See DSS in Action 2.24 and Pearman (1998). For more information on the Myers-Briggs Type Indicator, see Keirsey (1998); Keirsey and Bates (1984); and keirsey.com; for more information on True Colors typing, see Birkman (1995) and birkman.com.

## GENDER

Psychological empirical testing sometimes indicates that there are (slight) gender differences and gender similarities in decision-making, including such factors as boldness, quality, ability, risk-taking attitudes, and communication patterns. Powell and Johnson (1995) observe that decision-support systems are designed on the assumption of no gender differences, but people of each gender may take decisions in different ways and have different information style preferences. Their extensive review of the recent literature suggests that gender differences are associated with abilities and motivation, risk attitude and confidence, as well as decision style. Men are more inclined to take risks than women in a variety of situations, a difference which does not stem from differences in the perceived probability of success (Smith, 1999). Where gender differences exist (i.e., have statistical significance) they are very small (Smith, 1999). The results are essentially inconclusive, and so it is unwise to attempt to characterize either males or females as better or worse decision-makers.

## COGNITION THEORY

Cognition is the set of activities by which a person resolves differences between an internalized view of the environment and what actually exists in the environment. In other words, it is the ability to perceive and understand information. Cognitive models are attempts to explain or understand human cognitive processes. Such models explain, for instance, how people revise formerly held opinions to conform with the

### DSS IN ACTION 2.24

#### TEMPERAMENT DOES INFLUENCE DECISION STYLE

The influence of a manager's decision style in strategic decision-making was examined in an experimental setting. Simulated decisions were used for 79 executive-level hospital managers and 89 hospital middle managers. They first took a Myers-Briggs type-indicator test to determine their decision styles. Then the managers were asked to evaluate a set of projects keyed to their individual styles. Decision style influenced their views of adoption and risk. The decisions of top executives were more style-dependent than those of middle managers. The *judicial* top executive was found to be *action-*

*oriented*, and the *systematic* top executive was found to be *action-averse*. The *speculative* and *heuristic* top executives took nearly identical *neutral* positions. Top executives with a *sensate* style were similar to top executives with a *pure systematic* style, and top executives with a *feeling* style were similar to top executives with a *pure judicial* style.

Source: Modified from P.C. Nutt, "Strategic Decisions Made by Top Executives and Middle Managers with Data and Process Dominant Styles? *Journal of Management Studies*, Vol. 27, No. 2, March 1990, pp. 173-194.

choices they have made. Elkins (2000) discusses how we can observe and learn better for improved problem-framing and, ultimately, decision-making.

### COGNITIVE STYLE

Cognitive style is the subjective process through which people perceive, organize, and change information during the decision-making process. Cognitive style, sometimes called *management style*, is important because in many cases it determines a person's preference for the human-machine interface. For example, should data be raw or aggregate, or should they be tabulated or presented as graphs? Should data be presented as auditory, visual, or action-oriented (Markova, 1996; Wallington, 2001).

*There is no one best style.* Each has its own unique strengths and weaknesses. A good manager can utilize more than one style. Flexibility is a definite advantage because your preferred style may not mesh well with the needs of other people (Wallington, 2001). But meshing the strengths of complementary styles can lead to more effective collaboration.

Furthermore, cognitive styles affect preferences for qualitative versus quantitative analysis as well as for decision-making aids. In this way, cognitive style affects the way an individual frames a decision-making situation so as to understand it better. Simply put, a frame "provides the context within which information is used, and different frames put the focus on different kinds of information" (Beach, 1997; also see Shoemaker and Russo, 2001). In other words, a frame is the decision-maker's interpretation of the situation. A frame provides a mental model for the decision-maker. As a problem is analyzed, it can be reframed in light of new information. When a group is involved in decision-making, it is desirable to have shared frames that involve some level of common organizational culture. If frames are not shared sufficiently, the group will have trouble developing a consensus. Are there cultural differences that vary by country and affect management styles? See DSS in Focus 2.25.

Research on cognitive styles is directly relevant to the design of management information systems. MIS and transaction processing systems tend to be designed by people who perceive the decision-making process as systematic. Systematic managers are generally willing to use such systems; they are typically looking for a standard technique and view the system designer as an expert with a catalog of methods. However, such systems do not conform to the natural style of a heuristic decision-maker. For such an individual, a system should allow for exploration of a wide range of alternatives, permit changes in priorities or in processing, allow the user to shift easily between

#### DSS IN FOCUS 2.25

### MANAGEMENT STYLES AROUND THE WORLD

There are substantive cultural differences in the way decisions are made in different countries. In effect, *countries have management styles*. Albaum and Herche (1999) tested dimensions of management style, including cautious autonomy, quantitative planning, market listening, lone planning, and lone implementation. Four of these five dimensions (all but cautious autonomy) distinguish unique characteristics of the management style of

marketing managers in the nations studied (Spain, Netherlands, Denmark, Finland, and France). For example, French managers clearly showed a distinctive style in that they paid more attention to quantitative information, listened to markets, were driven by data, and placed a lower priority on individual implementation.

*Source:* Adapted from Albaum and Herche (1999).

TABLE 2.4 Cognitive style Decision Approach<sup>a</sup>

<i>Problem-solving Dimension</i>	<i>Heuristic</i>	<i>Analytic</i>
Approach to learning	Learns more by acting than by analyzing the situation and places more emphasis on feedback	Employs a planned sequential approach to problem solving; learns more by analyzing the situation than by acting and places less emphasis on feedback
Search	Uses trial and error and spontaneous action	Uses formal rational analysis
Approach to analysis	Uses common sense, intuition, and feelings	Develops explicit, often quantitative, models of the situation
Scope of analysis	Views the totality of the situation as an organic whole rather than as a structure constructed from specific parts	Reduces the problem situation to a set of underlying causal functions
Basis for inferences	Looks for highly visible situational differences that vary with time	Locates similarities or commonalities by comparing objects

levels of detail, and permit some user control over the output form (visual, verbal, graphic, etc.). This is precisely what a decision support system attempts to do (Table 2.4).

Although cognitive style is a useful concept, it may be overemphasized in the MIS literature. It is difficult to take cognitive style into consideration for information systems and decision-making. For one thing, cognitive style is not distinct; it varies along a continuum. Many people are not completely heuristic or analytic but are somewhere in between. Related to cognitive style are the concepts of personality (temperament) type and decision style.

Research on cognitive and management styles states an obvious fact: in general, when a decision support system (or any information system) matches a manager's cognitive style, the DSS is more effective (see Lu, Yu, and Lu, 2001). Furthermore, when the DSS matches a manager's problem-solving mode (a cognitive model that characterizes the problem-solving process of a manager; this includes reasoning, analogizing, creating, optimizing), the DSS is more successful (see Van Bruggen and Wierenga, 2001). Clearly, the task at hand indicates what mode is needed. This is critical when deploying Web-based DSS and especially for appealing to e-commerce customers (see DSS in Action 2.4). In keeping with the idea of problem-solving mode, Hoenig (2001) describes six essential skills of problem-solving, each related to a specific *problem-solving personality*. These are described in DSS in Focus 2.26.

## DECISION STYLE

Decision style is the manner in which decision-makers think and react to problems. This includes the way they perceive, their cognitive response, and how values and beliefs vary from individual to individual and from situation to situation. As a result, people make decisions differently. Although there is a general process of decision-making, it is far from linear. People do not follow the same steps of the process in the same sequence, nor do they use all the steps. Furthermore, the emphasis, time allotment, and priorities given to each step vary significantly, not only from one person to another but

### ARE THERE PROBLEM-SOLVING PERSONALITIES?

Hoenig feels that solving any problem involves six essential skills. The more you can master, the better the ultimate result. The six essential skills are generating mind-set, acquiring knowledge, building relationships, managing problems, creating solutions, and delivering results. The tougher, larger, and more demanding a problem or opportunity, and the faster and more competitive your environment, the more important they become.

Each of the six essentials represents a package of habits, skills, and knowledge that effectively comprise a *problem-solving personality*. Each personality draws its strength from a variety of specialties and professions. The six personalities serve as a convenient way to assess oneself and others in the workplace, to identify one's own personal mixture of strengths and weaknesses and how to develop a complete problem-solving capability. Great problem-solvers know the strengths and weaknesses of the different personality types. They build teams that compensate for their weakness, creating wholes that are equal to or greater than the sum of their parts. The problem-solving personalities (and skills) are

- The *Innovator* (generating mind-set) focuses on moving from self-doubt to innovation by developing potent ideas and attitudes, above all through seeking out alternative points of view.
- The *Discoverer* (acquiring knowledge) concentrates on moving from innovation to insight by asking the right questions and getting good, timely information.

- The *Communicator* (building relationships) covers how to move from insight to community by cultivating quality communication and interaction, and so creating an ever expanding circle of relationships based on service, loyalty, and identity.
- The *Playmaker* (managing problems) focuses on moving from building a community to giving the community a sense of direction and clear priorities by choosing destinations and strategies.
- The *Creator* (creating solutions) shows how to move from leadership to power by designing, building, and maintaining optimal solutions.
- The *Performer* (delivering results) concentrates on moving from power to sustainable advantage through intuitive and disciplined implementation.

The difference between the best and the worst problem-solvers is how many of the six essentials they can cultivate (by themselves and/or with others) and how deeply the skills are understood—individually and collectively. To become an expert problem-solver, one must understand the six essentials, practice them, master them at one level and then move on toward the limits of one's potential. An interesting aspect of these skills and personalities is to consider how they mesh with Simon's four phases of decision-making.

*Source: Abstracted from C. Hoenig, "Means to an End," CIO, November 1, 2000, p. 204. Also see C. Hoenig, From the Problem Solving Journey. Perseus Publishing, Cambridge, MA, 2000.*

also from one situation to the next. The manner in which managers make decisions (and the way they interact with other people) describes their decision style. Because decision styles depend on the factors described earlier, there are many decision styles. Personality temperament tests are often used to determine decision styles. Since there are many such tests, it is important to try to equate them in determining decision style. However Leonard et al. (1999) discovered that the various tests measure somewhat different aspects of personality, so they cannot be equated.

In addition to the heuristic and analytic styles mentioned earlier, one can distinguish autocratic versus democratic styles; another style is consultative (with individuals or groups). Of course, there are many combinations and variations of styles. For example, one can be analytic and autocratic, or consultative (with individuals) and heuristic.

For a computerized system to successfully support a manager, it should fit the decision situation as well as the decision style. Therefore, the system should be flexible and adaptable to different users. The ability to ask what-if and goal-seeking questions pro-

vides flexibility in this direction. A Web-based interface using graphics is a desirable feature in supporting certain decision styles. If a management support system is to support varying styles, skills, and knowledge, it should not attempt to enforce a specific process. Rather, it should help decision-makers use and develop their own styles, skills, and knowledge.

Different decision styles require different types of support. A major factor that determines the type of required support is whether the decision-maker is an individual or a group. Individual decision-makers need access to data and to experts who can provide advice, while groups additionally need collaboration tools. Web-based MSS can provide support to both.

There is a lot of information on the Web about cognitive style and decision style (e.g., see Birkman International Inc. at [birkman.com](http://birkman.com); and the Keirsey Temperament Sorter and Keirsey Temperament Theory Web site at [keirsey.com](http://keirsey.com)). Many personality/temperament tests are available to help managers identify their own styles and those of their employees. Identifying an individual's style can help establish the most effective communication patterns and ideal tasks for which he or she is suited.

## 2 . 1 2 T H E D E C I S I O N - M A K E R S

Decisions are often made by individuals, especially at lower managerial levels and in small organizations. There may be conflicting objectives even for a sole decision-maker. For example, in an investment decision, an individual investor may consider the rate of return on the investment, liquidity, and safety as objectives. Finally, decisions may be fully automated (but only after a human decision-maker decides to do so!).

Our discussion of decision-making focused on an individual decision-maker. The Opening Vignette described both individual and group decision-making, with groups taking responsibility for both. Most major decisions in medium-sized and large organizations are made by groups. Obviously, there are often conflicting objectives in a group decision-making setting. Groups can be of variable size and may include people from different departments or from different organizations. Collaborating individuals may have different cognitive styles, personality types, and decision styles. Some clash, whereas others are mutually enhancing. Consensus can be a difficult political problem (see DSS in Action 2.27). Therefore, the *process* of decision-making by a group can be very complicated. Computerized support (Chapter 7) can greatly enhance group

### DSS IN ACTION 2.27

#### GROUP CONSENSUS: THE 23-MILE-PER-HOUR SPEED LIMIT

Consensus by a group can lead to the implementation of unusual and potentially unrealistic solutions. For example, there is a condominium complex in Lake Worth, Florida, where the residents could not agree on a "reasonable" speed limit. They finally came to a consensus

that was a compromise value close to the average of the group members' individual suggestions. The speed limit was set at 23 mph (13.8 kph), whereas 20 mph (12 kph) or 25 mph (15 kph) would have been an acceptable and especially anticipated solution for most drivers.

decision-making. Computer support can be provided at an even broader level, enabling members of whole departments, divisions, or even entire organizations to collaborate online. Such support has evolved over the last few years into enterprise information systems and includes group support systems (GSS), enterprise resource management (ERM)/enterprise resource planning (ERP), supply-chain management (SCM), knowledge management systems (KMS), and customer relationship management (CRM) systems.

## • CHAPTER HIGHLIGHTS

- Managerial decision-making is synonymous with the whole process of management.
- Problem-solving is also opportunity evaluation.
- A system is a collection of objects, such as people, resources, concepts, and procedures, intended to perform an identifiable function or to serve a goal.
- Systems are composed of inputs, outputs, processes, and decision-makers.
- All systems are separated from their environment by a boundary that is often imposed by the system designer.
- Systems can be open, interacting with their environment, or closed.
- DSS deals primarily with open systems.
- A model is a simplified representation or abstraction of reality.
- Models are used extensively in MSS; they can be iconic, analog, or mathematical.
- Decision-making involves four major phases: intelligence, design, choice, and implementation.
- In the intelligence phase, the problem (opportunity) is identified, classified, and decomposed (if needed), and problem ownership is established.
- In the design phase, a model of the system is built, criteria for selection are agreed on, alternatives are generated, results are predicted, and a decision methodology is created.
- There is a trade-off between model accuracy and cost.
- Rationality is an important assumption in decision-making. Rational decision-makers can establish preferences and order them consistently.
- In the choice phase, alternatives are compared and a search for the best (or a good enough) solution is launched. Many search techniques are available.
- In implementing alternatives, one should consider multiple goals and sensitivity-analysis issues.
- Satisficing is a willingness to settle for a satisfactory solution. In effect, satisficing is suboptimizing. Bounded rationality results in decision-makers satisficing.
- Computer systems, especially those that are Web-based, can support all phases of decision-making by automating many of the required tasks or by applying artificial intelligence.
- Personality types may influence decision-making capabilities and styles.
- Human cognitive styles may influence human-machine interaction.
- Human decision styles need to be recognized in designing MSS.
- There are inconclusive results on how gender differences influence decision-making and computer use in decision-making.
- Individual and group decision-making can both be supported by MSS.

## • KEY WORDS

- |                               |                                  |                        |
|-------------------------------|----------------------------------|------------------------|
| • algorithm                   | • efficiency                     | • problem ownership    |
| • analog model                | • iconic model                   | • problem-solving      |
| • analytical techniques       | • implementation phase           | • programmed problem   |
| • choice phase                | • inputs                         | • satisficing          |
| • cognitive style (cognition) | • intelligence phase             | • scenario             |
| • decision-making             | • interfaces                     | • sensitivity analysis |
| • decision style              | • nonprogrammed problem          | • simulation           |
| • decision variables          | • normative models               | • suboptimization      |
| • descriptive models          | • optimization                   | • system               |
| ◦ design phase                | • personality (temperament) type | • what-if analysis     |
| • effectiveness               | • principle of choice            |                        |

• **QUESTIONS FOR REVIEW**

1. Review what is meant by decision-making versus problem-solving. Compare the two, and determine whether or not it makes sense to distinguish them.
2. Define a system.
3. List the major components of a system.
4. Explain the role of feedback in a system.
5. Define the environment of a system.
6. Define open and closed systems. Give an example of each.
7. Define efficiency, define effectiveness, and compare and contrast the two.
8. Define the phases of intelligence, design, choice, and implementation.
9. Distinguish a problem from its symptoms.
10. Define programmed (structured) versus nonprogrammed (unstructured) problems. Give one example in each of the following areas: accounting, marketing, human resources.
11. List the major components of a mathematical model.
12. Define optimization and contrast it with suboptimization.
13. Compare the normative and descriptive approaches to decision-making.
14. Define rational decision-making. What does it really mean to be a rational decision-maker?
15. Why do people exhibit bounded rationality when problem-solving?
16. Define a scenario. How is it used in decision-making?
17. How can a DSS support the implementation of a decision?
18. Define implementation.
19. What is a personality (temperament) type? Why is it an important factor to consider in decision-making.
20. Define cognition and cognitive style.
21. Define decision style.
22. Compare and contrast decision-making by an individual with decision-making by a group.

• **QUESTIONS FOR DISCUSSION**

1. Specify in a table the inputs, processes, and outputs of the following systems. Determine what is required for each system to be efficient and effective.
  - a. Post office
  - b. Elementary school
  - c. Grocery store
  - d. Farm
2. List possible kinds of feedback for the systems in the preceding question. Explain how feedback is essentially part of Simon's intelligence decision-making phase.
3. A hospital includes dietary, radiology, housekeeping, and nursing (patient care) departments, and an emergency room. List and describe four system interfaces between pairs of these departments.
4. How would you measure the productivity of
  - a. A letter carrier
  - b. A salesperson
  - c. A professor
  - d. A social worker
  - e. A student
  - f. A farmer
5. Give an example of five elements in the environment of a university.
6. Analyze a managerial system of your choice and identify the following:
  - a. The components, inputs, and outputs
  - b. The boundary
  - c. The environment
  - d. The processes
  - e. The system's goals
  - f. The feedback
7. What are some of the measures of effectiveness in a toy manufacturing plant, a restaurant, an educational institution, and the U.S. Congress?
8. Assume that a marketing department is an open system. How would you close this system?
9. Your company is considering opening a branch in China. List typical activities in each phase of the decision to open or not to open (intelligence, design, choice, implementation).
10. You are about to sell your car. What principles of choice are you most likely to use in deciding whether to offer or reject offers? Why?
11. You are about to buy a car. Follow Simon's four-phase model and describe your activities at each step.
12. The use of scenarios is popular in computerized decision-making. Why? For what types of decisions is this technique most appropriate?
13. Explain, through an example, the support given to decision-makers by computers in each phase of the decision process.
14. Some experts believe that the major contribution of DSS is to the implementation of the decision. Why is this so?

15. Explain how personality type, gender, cognitive style, and decision style are related. How might these concepts affect the development of decision support systems?
16. Table 2.4 shows the major differences between heuristic and analytic cognitive styles.
  - a. Do you consider yourself heuristic or analytic? Why?
  - b. Assume you are making a presentation to two managers—one heuristic, the other analytic—regarding a decision about adding a service by the bank you work for. How would you appeal to their cognitive styles? (Be specific.)
17. Decision-making styles vary from analytic to heuristic-intuitive. Does a decision-maker consistently use the same style? Give examples from your own experience.
18. Most managers are capable of using the telephone without understanding or even considering the electrical and magnetic theories involved. Why is it necessary for managers to understand MSS tools to use them wisely?

## • EXERCISES

1. Consider the "75 greatest management decisions ever made" described in DSS in Action 2.2. From the articles, examine a subset of five decisions. Compare and contrast them: Identify the similarities and differences. How do you think the intelligence phase was handled for each?
2. Early in the chapter, we mention the Great Wall of China as a major blunder. Investigate it. Study the history of the Great Wall. Look up why it was constructed, how it was done, how long it took, and similar facts. Why did it fail to meet its primary objective? Identify four other equally major blunders, and explain what happened in each case.
3. According to Warren Bennis and Burt Nanus (*Leaders*, HarperCollins, New York, 1997), "Managers are people who do things right and leaders are people who do the right thing. The difference may be summarized as activities of vision and judgment—*effectiveness*—versus activities of mastering routines—*efficiency*" (also see David Baron, *Moses on Management*, Pocket Books, New York, 1999). Explain how this relates to decision-making, managers, executives and systems.
4. Comment on Simon's (1977) philosophy that managerial decision-making is synonymous with the whole process of management. Does this make sense or not? Explain. Use a real-world example in your explanation.
5. Consider a situation in which you have a preference for where you go to college; you want to be not too far away from home and not too close. Why might this situation arise? Explain how this situation fits in with rational decision-making behavior.
6. When you were looking for a college program, somehow you were able to decide on going where you are now. Examine your decision-making process and describe it in a report. Explain how you eliminated the many thousands of programs around the world, and then in your own country or region. What criteria were important? What was your final set of alternatives? And how did you decide among them? Compare your results with those of others in the class.
7. You are about to buy a car. What criteria are important? What specific choices do you have, and how will you limit your choices? Read Case Application 2.3 and structure your problem within the AHP framework. Does this make intuitive sense? Explain why it does or does not.
8. Consider the A/B/C parts inventory management and scheduling situation described under suboptimization). Describe how management of the A items might be viewed as a nonprogrammed (unstructured or least-structured) problem, management of the B parts as a semistructured problem, and management of the C parts as a programmed (structured) problem.
9. Stories about suboptimization issues abound in some formerly centrally planned national economies in which the output of factories was measured by seemingly useful measures, with unexpected and disastrous results. Specifically, a ball-bearing factory's output was measured by the total weight of the ball bearings produced, and so the plant manager decided to produce one very large ball bearing each month. There was a shoe factory where output was measured by the number of left shoes, and so the plant manager decided to make *only left shoes* to double the factory's official output. Explain in detail how the measure of the result variable (output) of a subsystem can lead to bad decisions that lead to suboptimized results for the entire system, and what the conse-

quences might be. Think in terms of **what** it means to *establish a principle of choice*. **This is not unique to centrally planned economies but can happen in any organization. Give an example from your personal or professional life in which this happened.**

10. Explain how Hoenig's (2001) problem-solving personalities (see DSS in Focus 2.26) each focus in on each of Simon's four phases of decision-making.

11. According to H.L. Mencken (1880-1956), "For even-problem there is one solution which is simple, neat and wrong." Explain this statement in the light of the decision-making material in this chapter and examples with which you are familiar.

## • GROUP ASSIGNMENTS AND ROLE-PLAYING

1. Interview a person who was recently involved in making a business decision. Try to identify
- The scope of the problem solved
  - The people involved in the decision (explicitly identify the problem owners)
  - Simon's phases (you may have to ask specific questions, such as how the problem was identified)
  - The alternatives (choices) and the decision chosen
  - How the decision was implemented
  - How computers were used to support the decision-making or why they were not used.

Produce a detailed report describing an analysis of the above and clearly state how closely the real-world decision-making process compares to Simon's suggested process. Clearly identify how computers were used or why they were not used.

2. Have everyone in your group perform a personality type test—either the Myers-Briggs (Keirsey and Bates, 1984) or the True Colors (Birktnan, 1995) type. Compare the results and see if they match up well with each member's *modus operandus*. For each member, how does their type describe the way they make decisions? Is the group made up of different or similar types? How will this help or hinder the group's ability to function? Based on the types, what could each member bring to the table for better group performance? What special things will the group need to consider to enhance communication in the group so that it will function effectively?
3. *Personality Discussion and Role-Play*: For any movie or television show that has four or more main characters (we suggest the popular *Friends* show), identify the temperament type of each character. Describe how each character interacts with the others, and describe how this maps into the personality types described by either Myers-Briggs or True Colors. Get the members of your group to behave like the characters in a real situation (go to a coffeehouse, as in *Friends*). Later describe the experience.
4. Develop a cognitive map of the decision-making problem of selecting a job, or a university program

using Decision Explorer (Banxia Software Ltd., banxia.com). Describe your thought processes and how you developed the map.

5. Compare the results for gender differences and similarities described by Smith (1999) and Leonard et al. (1999) with the case of gender differences described by R. L. Fox, and R. A. Schuhmann in "Gender and Local Government: A Comparison of Women and Men City Managers" (*Public Administration Review*, Vol. 59, No. 3, May/June, 231-242, 1999). Do the results for city managers match those found in the other literature? If so, in what ways?
6. Watch the movie *12 Angry Men* (1957) starring Henry Fonda. Comment on the group decision-making process followed by the jury. Explain how this is a demonstration of group decision-making. Does it fit into Simon's four-phase model? Explain why or why not, citing examples from the movie.
7. Watch the movie *The Bachelor* (1999) starring Chris O'Donnell. In it, a man must marry by a deadline to inherit \$100 million. There are many alternatives, but the criteria are quite fuzzy. Watch the scene toward the end of the movie where about a thousand brides converge on a church and want to know "What are the criteria?" Explain how the main character describes his criteria, and what they are. Explain why they are quite vague. Explain what his criteria really are. Given enough time, compare your answers to S. Piver, *The Hard Questions: 100 Essential Questions to Ask Before You Say "I Do"* (New York: J.P. Tarcher, 2000).
8. Sometimes you find yourself between the proverbial rock and hard place. All the alternatives (discovered so far) are bad or infeasible. Then you have a *real problem*. Examine the decision-making situation about the *Alexander Hamilton*, described in DSS in Action 2.12. Explore the situation regarding the ship, and suggest some possible alternatives and why they are feasible. E-mail good suggestions to Jay Aronson at [jaronson@uga.edu](mailto:jaronson@uga.edu) so he can forward them to Dennis Lafko.

## INTERNET EXERCISES

1. Search the Web for material on managerial decision-making. What general classes of materials can you identify in a sample of 10 sites?
2. Many colleges and universities post their course catalogs, course descriptions, and syllabi on the Web. Identify a sample of 10 decision-making courses that are posted and compare their topical material. What is the major focus of these courses? What percentage of them includes computerized support? In which departments or colleges are they typically found?
3. Search the Web for companies and organizations that provide computerized support for managerial decision-making. Take a sample of five software vendors and characterize their products based on specific functional market area (marketing, manufacturing, insurance, transportation, etc.), level of managerial support (strategic, tactical, operational, transactional), type of computerized tool (e.g., DSS, data mining, business intelligence, OLAP, EIS, ES, ANN, cluster analysis), and how they utilize Web technologies. Take a sample of 10 nonvendors (e.g., consultants). What kinds of support do they provide?
4. Some companies and organizations have downloadable demo or trial versions of their software products on the Web so that you can copy and try them out on your own computer. Others have online demos. Find one that provides decision support, try it out, and write a short report about it. You should include details about the intended purpose of the software, how it works, and how it supports decision-making.
5. Visit the [teradatauniversitynetwork.com](http://teradatauniversitynetwork.com) Web site. Explore the public areas. Describe five of the types of decision-making studies and cases that are listed.

## CLAY PROCESS PLANNING AT IMERYS: A CLASSICAL CASE OF DECISION-MAKING

### *Part 1: The Go/No Go Decision for the Process Optimization (POP) DSS*

#### INTRODUCTION

IMERYS (formerly English China Clay International, ECCI) in Sandersville, Georgia, mines crude kaolin (China) clay and processes it into a wide variety of products (dry powders, slurries, etc.) that add gloss to paper, cardboard, paint, wallpaper, and other materials. Kaolin clay is also used to make ceramics, tableware, and sculptures. It can also be used for processing aluminum, making toothpaste, and as a medication for soothing stomach upset (yes, the crude clay is edible right from the ground). Between 50 and 100 million years ago, during the Cretaceous and Tertiary geological periods, kaolin deposits formed on the Atlantic seacoast along the Fall Line that crosses central Georgia. In 1880 the first clays were mined and processed, and since then the industry has expanded dramatically. The total annual economic impact in Georgia was \$824 million in 1996. Georgia's total kaolin production capacity was about 8.3 million tons (half the world's production), of which some 6.8 million tons were processed in 2001. This represents the bulk of kaolin processing in the United States. Major deposits are also mined and processed in Brazil, China (PRC), the Czech Republic, France, Germany, and the United Kingdom. Georgia supplies more than half the kaolin used by paper-makers worldwide. The middle-Georgia kaolin deposits are the largest in the world. Sandersville is called the *kaolin capital of the world*. See the China Clay Producers Association ([kaolin.com](http://kaolin.com)) and IMERYS ([imerys.com](http://imerys.com)) Web sites for more information on the geology, history, mining, products, and economic impacts of kaolin clay.

#### THE SITUATION

In late 1998, as part of a continuous improvement initiative, ECCI managers, engineers, and IS analysts met to determine the feasibility of applying mathematical programming (optimization) to clay mining and production. The need to process lower-quality crude clays, the depletion of higher-quality crude clays, and some new processing methods prompted a fresh look at the various aspects of clay processing and scheduling.

Several members of the continuous-improvement initiative team had previously been involved in the develop-

ment of large, complex linear and mixed-integer programming models for kaolin clay production planning at other organizations (the models were used mostly for capacity planning and had several thousand relationships and variables). None of these models had taken the clay all the way from the mines to the customer in the detail that would ideally be required now. Also, determining blends of clays had never been modeled before.

#### DECISION-MAKING: DECISION NUMBER 1:

##### GO/NO GO

The initial decision-making process began with the continuous-improvement team recognizing that there was an opportunity, exploring potential impacts, and taking ownership of the problem (intelligence). The ECCI team was charged with exploring any potential improvement methodology. Such improvements could include making better decisions, making faster decisions, and so on. Initially, there was no way to know that such an approach would really work, but some team members were familiar with mathematical programming and knew that it was certainly worth exploring because it had produced favorable results for other problems in other organizations with which they had been associated. The next step was to seek out additional knowledge, information, and expertise and establish the likelihood of success. This included meeting with managers and other potential users who needed accurate production plans to determine what new sales could be accepted and how they could be made. The decision to pursue the development of a system was based on mental and simple spreadsheet models, and past experience (design). Influencing the decision was the fact that the IS department was implementing a forecasting model that was part of a staged development enterprise resource planning (ERP) system. Given a set of forecasts, this new mathematical programming model, as part of a decision-support system, could potentially drive the ERP in overall organizational planning. This was decision-making under uncertainty, where the risk of failure (or success) had yet to be assessed. Analysts find these problems most challenging because they eventually may have to build a system that has never

been developed before. Following a workshop, the team decided that the initiative had merit, and recognizing that the project would be a major initiative requiring substantial resources in personnel and money, they reached a consensus and decided to proceed with development of the system (choice). The implementation phase involved assembling a formal team to move forward with development of the decision-support system. The consequences of the decision follow in the subsequent IMERYS case narratives.

### CASE QUESTIONS

1. Why did the continuous-improvement team start exploring the use of mathematical programming for clay process planning?
2. Why do you think that earlier models and systems developed to solve similar types of problems were not directly applicable in this case?
3. For this first go/no go problem, describe how the decision was made. Relate your explanation to Simon's four-phase decision-making model. Do you think that this was a crucial decision in light of this project?
4. In 1999, the industry experienced a downturn. How could using a model like the one that ECCI decided to develop help it compete?

## CASE APPLICATION 1.1

# CLAY PROCESS PLANNING AT IMERYS: A CLASSICAL CASE OF DECISION-MAKING

### *Part 2: The Decisions of the Process Optimization (POP) DSS*

#### KAOLIN PROCESSING

Kaolin production involves mining a variety of crude clays followed by a number of purification, grinding, separation, heating, blending, and other steps (for a description of typical steps, see kaolin.com). Different crude clay recipes can be used to produce similar and different final products; and, at a number of points in production, alternative blends can be used in creating final products with identical properties (brightness, gloss, etc.). Some processes can be performed on different pieces of equipment, and sometimes there are several units of similar equipment that can be aggregated into a single one (to simplify the model). Further complicating the decision-making situation, different initial crude blends typically require different rates for several pieces of equipment used for different processes. For example, a lower percentage of a *fine* (smaller-particle-size) crude clay blended with *coarse* clays generally requires additional time (a slower rate) to crush the coarser clay sufficiently for further processing. Costs per hour, costs per ton, recovery factors (which may vary by clay), and rate (in tons per hour) are specified for

each process for each clay for each recipe (blend). These data are estimates because the times vary with subtle changes in the clay, depending on the mine, and even the particular pit in the mine from which the clay is extracted.

#### ALTERNATIVE RECIPES AND NEW PROBLEMS

One of the problems facing ECCI in late 1999 was that some of the mines with high-quality crude clays were almost depleted. Alternative crude recipes, process adjustments, and new processes had to be instituted to produce final clays identical in quality to existing products. New final clay products (pure and blends) are continually being developed as well. The clays also follow different step orderings through the production process, depending on their major class of products. One class of clays is wet; the other is dry. Within each major class are several pure finished products, and hundreds of blends of these are needed to obtain the desired properties required by customers in the global marketplace. Kaolin (dry) clays have three major products with about 20 final blends, while hydrous (wet) clays have six major products with several

hundred final blends. Clays may also be processed at different plants. There are transfers of clays from other plants, some of which were initially modeled in this phase of the project, while others were placed on hold. Some crude clays and finished clays can be purchased on the open market, while others cannot (these are uniquely produced by ECCI in Sandersville). Chemicals are added at a number of different steps in the process. There is a direct relationship between chemical use and the processing rates of several pieces of equipment. The use of more chemicals may typically require less processing time in one or more production steps. ECCI ships finished products to customers on every continent. They also maintain warehouses on several continents. They ship products by rail, truck, and ship.

Clearly, there are many decisions to be made, hence many decision variables. There are many constraints due to time and tonnage capacity limits, and these vary depending on the rates. There are many constraints that describe the flows through each process; and many that relate the flows from each piece of equipment to the others. There are many intermediate variables representing the amount of clay that flows from the output of one process to the input of another. There are many combinations of clays, dramatically increasing the number of decision variables. The result variable is profit, which is to be maximized. Also, certain assumptions that bound rationality must be made, in order to develop a reasonable-sized model that can be solved in a finite amount of time. For example, although the model can be assumed to be linear, within the normal operating parameters of the plants, the engineers and scientists who design and run the processes have indicated that there are some subtle nonlinearities.

## DECISION-MAKING: DECISION NUMBER 2: OPTIMAL CLAY PROCESSING

The primary goal is to determine the optimal way (i.e., maximizing net profit) to process clays all the way from the mines to the customers. This model can determine how the clays should be optimally blended, and at which stages, and which equipment should run at capacity. Later, capacity expansion can be added to the model to determine which equipment should have additional production capacity, again to maximize profit. The model can also determine which demand from the open market has to be met if existing capacity proves insufficient.

The overall decision-making problem is: given a set of demands for final clay products (possibly obtained from a forecasting system), determine how to process the clay optimally (maximize net profit). This involves determining

- A time horizon (typically 1 year, 3 months, or 2 weeks)
- Which mines to use, which days from these mines to extract, and how much to extract

- Which crude blends to use
- Which processes to run the clays through and at which rates
- Chemicals to be used and where they should be used
- Which intermediate blends to use
- How best to blend the finished products.

These decisions involved establishing standard rates and costs for equipment for the various clays, as well as determining which specific pieces of equipment could be utilized for specific clays. Because a new process was coming online in late 1999, it was modeled as well, along with discontinuing use of the old crude clays, as they would soon be depleted, and activating new ones.

Given a set of demands for finished clay products, specific decisions included

1. How much of each kind of crude clay to mine (before and after the depletion of high-quality grades)
2. What crude blends (recipes) to use (which impacts certain equipment process rates)
3. Which production processes to use for crude clay blends
4. How to further blend processed crude clay blends into intermediate clays (which impacts certain equipment process rates)
5. Which specific processes to use on intermediate clays
6. How to recycle coproducts back into the production stream
7. How to blend intermediate clays into final clays
8. What demands to really meet from existing production capacity
9. How much clay should be purchased from external sources to blend into intermediate and final products
10. How much of each chemical should be used
11. Which final processes to use on final clay blends
12. Which final demands should be met by external market purchases or by production at other plants in the organization.

A linear programming model can support this kind of decision-making within a DSS. Data gathering for the model and integrating the two could (and did) prove difficult and time-consuming. Development of the Process Optimization (POP) linear programming model and the DSS are described as case applications in Chapters 4 and 6.

## THE PROTOTYPING APPROACH

Early in the project it was decided that a DSS prototyping approach would be used. One small calcine (dry) plant would be modeled first to develop the necessary features, familiarize the team members with the tools and methodologies, and establish the database structures that would guide the rest of the system development.

## NEW COMPLICATIONS

Impacting directly on the POP project, IMATEL, a French mining consortium, purchased ECCI and in early 1999 and merged it into their holdings under the name IMERYYS later in the year. These holdings included the Dry Branch Kaolin Company located in Dry Branch, Georgia. The

European Community (EC) approval agency quickly approved the purchase, but the U.S. Justice Department added some restrictions: some of the ECCI plant processing operations had to be quickly sold to obtain approval. It turns out that this included our test plant.

## CASE QUESTIONS

1. Why was it important for the model to handle blends and recipes?
2. The linear programming model to be developed will describe several plants and be rather large. The version of the model that represented two plants had on the order of 10,000 constraints and 40,000 variables (the version deployed in July 2002 had over 80,000 constraints and 150,000 variables). How does one go about verifying that the model is correct, that is, getting the right answer? How can one "manage" the data? Who should be allowed to update the model structure? Update the demands? Update other aspects? Why?
3. Pick three decisions listed and explain their importance to the company.
4. Why was a prototyping (evolutionary design) approach adopted by the team? Did this make sense? Why or why not?
5. How could the external event of the purchase of ECCI by IMATEL and its merger into IMERYYS affect the model and the system development? Why was this an important event with regard to the DSS and the model?
6. The mining and materials-processing industries typically lag behind other industries in the development and use of DSS and modeling. Why do you think this is so, and what can be done to advance these industries so that they can and will use advanced tools?

## CASE APPLICATION 2.1



# KEY GRIP SELECTS FILM PROJECTS BY AN ANALYTICAL HIERARCHY PROCESS

## INTRODUCTION

In the motion picture industry, the workers called grips are "intelligent muscle on set." Grips are responsible for setting up lights, cameras, and other materials on the set. Not just muscle is required, however. Grips must be able to make decisions as to how best to do setups, which can be quite complex. In fact, many grips have a B.A. or M.A. degree in theater. The *key grip* is responsible for all the grips on the set and is essentially their manager, as well as a liaison between the other grips and the production company. The primary concern of the key grip is safety on the set.

Charles N. Seabrook, of Charleston, South Carolina, is a key grip, an important job in the filmmaking industry. Charles has been in the business for nearly 20 years and has an excellent reputation. He is one of the best.

Consequently, he often has problems deciding which job offer (movie) to accept. Even when there are no competing offers, he sometimes has to decide whether or not he wants to work a particular job.

The Analytical Hierarchy Process (AHP) (Forman and Selly, 2001; Saaty, 1999) is an excellent method for selecting competing activities using distinct criteria. The criteria can be quantitative or qualitative in nature, and even quantitative criteria are handled by a decision-maker's preference structure rather than numerically. To develop a DSS to solve Seabrook's recurrent (institutional) problem, we developed an AHP model in Expert Choice (Expert Choice, Inc.; a downloadable demo is available at [expertchoice.com](http://expertchoice.com)). Our decision-making approach fits the Simon four-phase model. We decided to

use the Ratings Module of Expert Choice to formulate a model to aid Seabrook in his decision-making.

## CRITERIA

Our first step was to interview Seabrook regarding the general aspects of his professional life and how he goes about making decisions. Then we interviewed him to establish the important criteria for job selection. Initially, he stated the following eight potential criteria:

- Location of filming.  
The distance from Seabrook's home in Charleston, South Carolina.
- Time away from family.  
Seabrook is dedicated to his family and prefers not to spend long periods away from home.
- Reputation of the production company.  
The company producing the film plays an important part in how well people get along on the set and how well the filming is organized.
- Film budget.  
Often, if a film has a low budget, there are problems in obtaining equipment and general dissatisfaction among the crew.
- Pay.  
Obviously, the hourly rate paid to Seabrook is a high priority.
- Union involvement.  
If the union is involved in the film, working conditions are usually better and, more important, employee benefits are paid.
- « Quality of best boy available.  
The best boy is the key grip's assistant and is heavily involved in the large amount of paperwork required on the set. Having a reliable best boy is crucial to the film. However, later we learned that this criterion is not necessary, because Seabrook does not accept a film if his regular best boy, Jack Gilchrist, is not available.
- Quality of grips available for hire.  
A film often functions as a virtual company with technically qualified individuals hired to do particular jobs. If there is a lack of competent grips available, the key grip's tasks become much more difficult.

After further discussion, the criteria were reduced to a more manageable set of five, for which further clarifications of their definitions were developed. The final five were

- Location of filming.  
This implies that there will be time away from family, as the distance from home determines the amount of time he is away.
- Pay.

- Working conditions.  
This factor includes how lenient the budget is, as well as how many days per week and hours per day are required. Because this also determines how much overtime is available, it is closely tied to pay.
- Union involvement.
- Reputation of production company.

Note that in developing the criteria, we did not discuss specific alternative choices.

## AHP: EXPERT CHOICE MODELS AND DEVELOPMENT

The structure of an AHP model as implemented in Expert Choice is that of an inverted tree. There is a single *goal* node at the top that represents the goal of the decision-making problem. One hundred percent of the weight of the decision is in this node. Directly under the goal are leaf nodes representing all the *criteria*, both qualitative and quantitative. The weight of the goal must be partitioned among the criteria nodes as ratings. There are several methods built into Expert Choice to do this. All are based on comparing all pairs of criteria to establish how the weight of the goal is to be distributed. The software also provides a measure of the inconsistency of the comparisons. Thus, if the decision-maker prefers criterion 1 to criterion 2 at a certain preference level (say, moderate) and compares criterion 1 to criterion 3 identically, then for consistency in decision-making, he or she should compare criteria 2 and 3 as equally preferred. After the decision-maker completes the comparisons, the weight of the decision-making problem is distributed among the criteria in accordance with the preference structure derived from the pairwise comparisons. Expert Choice provides an inconsistency ratio indicating how *consistent* the decision-maker is in making judgments.

There are two ways to build the model. If the problem is ad hoc (occurs one time) and there are few alternatives (say, seven plus or minus two), then the decision-maker enters the *choice nodes* (alternatives) beneath the first criterion and replicates them to all its peers (the other criteria). Then the decision-maker pairwise compares the choices under the first criterion, under the second one, and so on, until all are compared. From each set of comparisons, Expert Choice divides the problem's weight in the specific criterion among the choices and calculates an inconsistency ratio within the criterion. Once all the choices have been compared, the results are synthesized, the choice with the most weight becomes the "expert choice," and the inconsistency ratio indicates how trustable the decision is (0 indicates perfectly consistent; 1 indicates perfectly inconsistent).

If the problem is recurring or there are many alternatives to select among, the ratings model can be used. The leaf nodes below each criterion describe the scale for each

criterion. For example, working conditions might be characterized as excellent, good, fair, or poor. The decision-maker pairwise compares these scale characterizations just like choices. Excellent is clearly preferred to good, good to fair, and fair to poor. The weights of these characterizations establish a scale for a specific movie project.

Once all the criteria have their scales and have been pairwise compared, we switch to the ratings model, where each choice is represented by the rows of a spreadsheet-like framework and a column represents each criterion. The decision-maker then clicks on the appropriate rating for each criterion for each movie. Once all criteria ratings are selected, a value for the alternative is computed. The decision-maker may decide to accept movies only if their values exceed a minimum level, or may sort the choices and select the most highly rated one. Regardless of which method is used, the AHP, essentially as implemented in Expert Choice, extracts the decision-maker's utility function through the decision-maker's preferences.

MODEL BUILDING

The goal and five criteria were entered into our Expert Choice model, and a rating scale was determined for each of the criteria by Seabrook. The screenshot in Figure 2.4 shows the goal (Which movie to choose?), the five criteria, and the scale for each.

A pairwise comparison analysis was then performed, and the priorities were determined. At this point, another conference with Seabrook allowed us to fine-tune the priorities. The results are shown in the screenshot in Figure 2.5 and also in the weights in the criteria nodes in

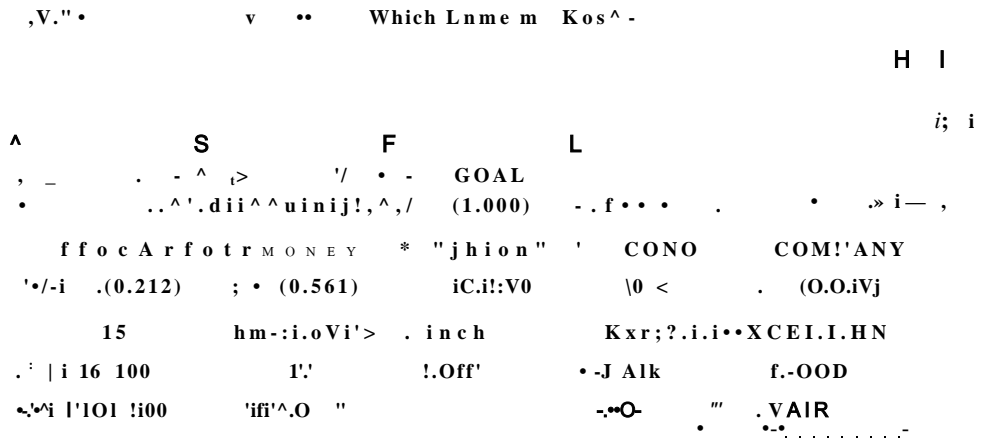
Figure 2.4. Note the overall inconsistency ratio of 0.07. Attempts to reduce this number led to priorities that Seabrook felt did not match his preferences, and so we returned to the earlier values. Generally, if the ratio is less than 0.1, the comparisons can be considered consistent.

Next, we pairwise compared the ratings scales beneath each criterion. Finally, we switched to the Ratings Module and contacted Seabrook again to obtain a set of usable real-world data on movies he had considered in the past to validate the model. We prepared a survey form for him to rate the last four jobs he had been offered. It was a simple circle-the-correct-response survey. The data were entered into the model, with the ratings results shown in Figure 2.6.

RESULTS

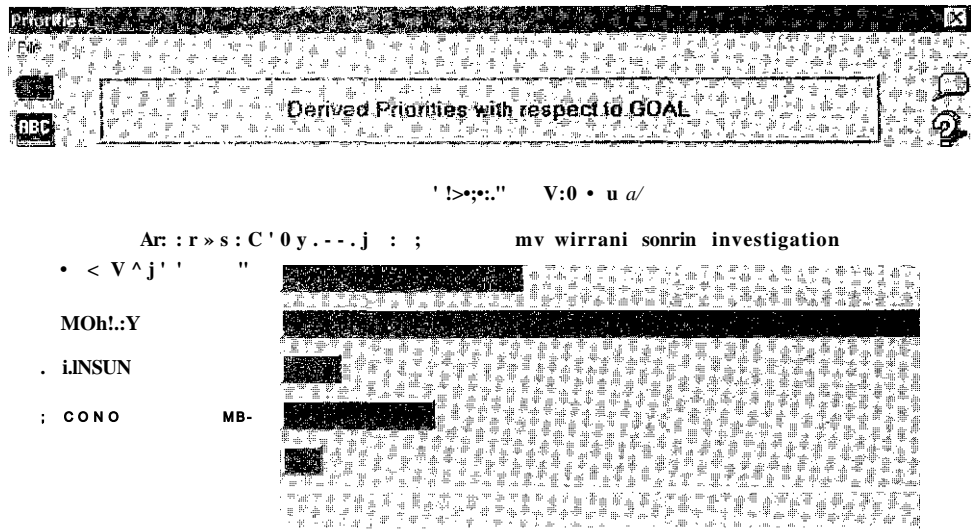
The names of the movies are omitted for confidentiality, but the results matched Seabrook's decisions. Movie 1, with a rating of only 0.279, was rejected by both the model and Seabrook. Seabrook accepted all of the other three movies and, as a result, felt that the ideal cutoff rating should be set to 0.4, since the lowest rated accepted movie was only 0.001 points less than that. This level may change when Seabrook adopts the model, for he will be able to update the model as his priorities change. One month following the initial model and system development, we installed Expert Choice on Seabrook's computer and provided training to ensure that he could use the model to its fullest potential. He is very pleased with the system and has incorporated it into his decision-making process.

FIGURE 2.4 EXPERT CHOICE MODEL SHOWING THE CRITERIA AND THEIR RATING SCALES



By permission of Expert Choice Inc.

FIGURE 2.5 EXPERT CHOICE: PRIORITY COMPARISONS FOR THE CRITERIA



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**CONCLUSION**

Charles Seabrook can now use a specific DSS application that provides assistance in his rational decision-making process of determining which job offers he should accept or reject. Up until now, he used the same criteria as are in the model. But he used a mental model in which it can be difficult, if not impossible, to consider all criteria while simulta-

neously weighing the importance of each. Using the AHP through Expert Choice to transfer his knowledge and preferences into a formal decision-making model leads to more consistent and higher-quality decision-making. Previously, Seabrook generally made decisions based on one factor that was overwhelmingly good or bad. Now, he is able to weigh the importance of all the factors in a rational way.

FIGURE 2.6 EXPERT CHOICE: SAMPLE REAL-WORLD DECISION MAKING RESULTS

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By permission of Expert Choice Inc.

### CASE QUESTIONS

1. Do you think that Seabrook really used *all* eight criteria in his decision-making before this DSS was developed? Why or why not? How much information would be needed if he were selecting from among 12 movies and used all eight criteria? Is this a feasible way to go about working with information? Why or why not?
2. Describe how the process and model fit into the Simon four-phase decision-making model.
3. Explain the differences between the "standard" AHP model with goal/criteria/choices and the ratings AHP model with goal/criteria/ratings scales/choices.
4. Why was it more appropriate to use the ratings-model approach than the standard one?
5. How did the AHP Expert Choice model assist Seabrook in providing a more rational framework in his decision-making?
6. Do you think that this project would have been as successful if the development team had not worked closely with the decision-maker? Why or why not?

## CASE APPLICATION M

### MMS RUNNING CASE: SUMMARY AND CONCLUSION

MMS ran into new problems when it changed its fleet. CLAUDIA was not equipped to handle new cars, unlike others from past experience, and did not track events as well as trends. Simon's four phases of decision-

making, along with feedback, were followed, even though the problems were not really identified in the first phase. Successful problem-solving was ultimately accomplished using Web-based DSS.

### CASE QUESTIONS

- 1» What is meant by a symptom versus a problem? Relate these ideas to the case.
2. Why is problem ownership so important?
3. Even though the problem was not identified at the end of the intelligence phase, what was?
4. How was the design phase performed?
5. The choice phase seemed like a combination of design, choice, and implementation. Is this a problem?
6. The implementation phase seemed to involve elements of all the phases. Is this a problem?
7. How were new problems or opportunities handled as they arose?
8. Why do you suppose some alternatives were either modified or postponed?