Chapter 2: Decision Making, Systems, Modeling, and Support

Learning Objectives

- Understand the conceptual foundations of decision making
- Understand the need for and the nature of models in decision making
- 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
- Learn how DSS provide support for decision making in practice
- Understand the systems approach

Decision Making: Introduction and Definitions

We are about to examine how decision making is practiced and some of the underlying theories and models of decision making. You will also learn about the various traits of decision makers, including what characterizes a good decision maker. Knowing this can help you to understand the types of decision support tools that managers can use to make more effective decisions. In the following sections, we discuss various aspects of decision making.

Characteristics of Decision Making

In addition to the characteristics presented in the opening vignette, decision making may involve the following:

- Groupthink (i.e., group members accept the solution without thinking for themselves) can lead to bad decisions.
- Decision makers are interested in evaluating what-if scenarios.
- Experimentation with a real system (e.g., develop a schedule, try it, and see how well it works) may result in failure.
- Experimentation with a 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 a 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.
- Too much information may be available (i.e., information overload).

To determine how real decision makers make decisions, we must first understand the process and the important issues involved in decision making. Then we can understand appropriate methodologies for assisting decision makers and the contributions information systems can make. Only then can we develop DSS to help decision makers.

This chapter is organized based on the three key words that form the term DSS: decision, support, and systems. A decision maker should not simply apply IT tools blindly. Rather, the decision maker gets support 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.

A Working Definition of Decision Making

Decision making is a process of choosing among two or more alternative courses of action for the purpose of attaining one or more goals. According to Simon (1977), managerial decision making is synonymous with the entire management process. 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 Disciplines

Decision making is directly influenced by several major disciplines, some of which are behavioral and some of which are 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, and sociology. Scientific disciplines include computer science, decision analysis, economics, engineering, the hard sciences (e.g., biology, chemistry, physics), management science/operations research, mathematics, and statistics.

An important characteristic of management support systems (MSS) is their emphasis on the **effectiveness**, or "goodness," of the decision produced rather than on the computational efficiency of obtaining it; this is usually a major concern of a transaction processing system. Most Web-based DSS are focused on improving decision effectiveness. **Efficiency** may be a by-product.

Decision Style and Decision Makers

In the following sections, we examine the notion of decision style and specific aspects about decision makers.

Decision Style Decision style is the manner by which decision makers think and react to problems. This includes the way they perceive a problem, their cognitive responses, and how values and beliefs vary from individual to individual and from situation to situation. As a result, people make decisions in different ways. 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 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. Because there are many such tests, it is important to try to equate them in determining decision style. However, the various tests measure somewhat different aspects of personality, so they cannot be equated.

Researchers have identified a number of decision-making styles. These include heuristic and analytic styles. One can also distinguish between autocratic versus democratic styles. Another style is consultative (with individuals or groups). Of course, there are many combinations and variations of styles. For example, a person 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 provides flexibility in this direction. A Web-based interface using graphics is a desirable feature in supporting certain decision styles. If a DSS 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 support required 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, whereas groups additionally need collaboration tools. Web-based DSS can provide support to both.

A lot of information is available on the Web about cognitive styles and decision styles (e.g., see Birkman International, Inc., birkman.com; Keirsey Temperament Sorter and Keirsey Temperament Theory-II, 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 the person is suited.

Decision Makers 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, when making 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!).

This discussion of decision making focuses in large part on an individual decision maker. 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. Therefore, the process of decision making by a group can be very complicated. Computerized support can greatly enhance group decision making. Computer support can be provided at a broad level, enabling members
of whole departments, divisions, or even entire organizations to collaborate online. Such support has evolved over the past few years into enterprise information systems (EIS) 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.

Phases of the Decision-Making Process

It is advisable to follow a systematic decision-making process. Simon (1977) said 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 2.1.

There is a continuous flow of activity from intelligence to design to choice (see the bold lines in Figure 2.1), 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 via decision making can be explained by these feedback loops.

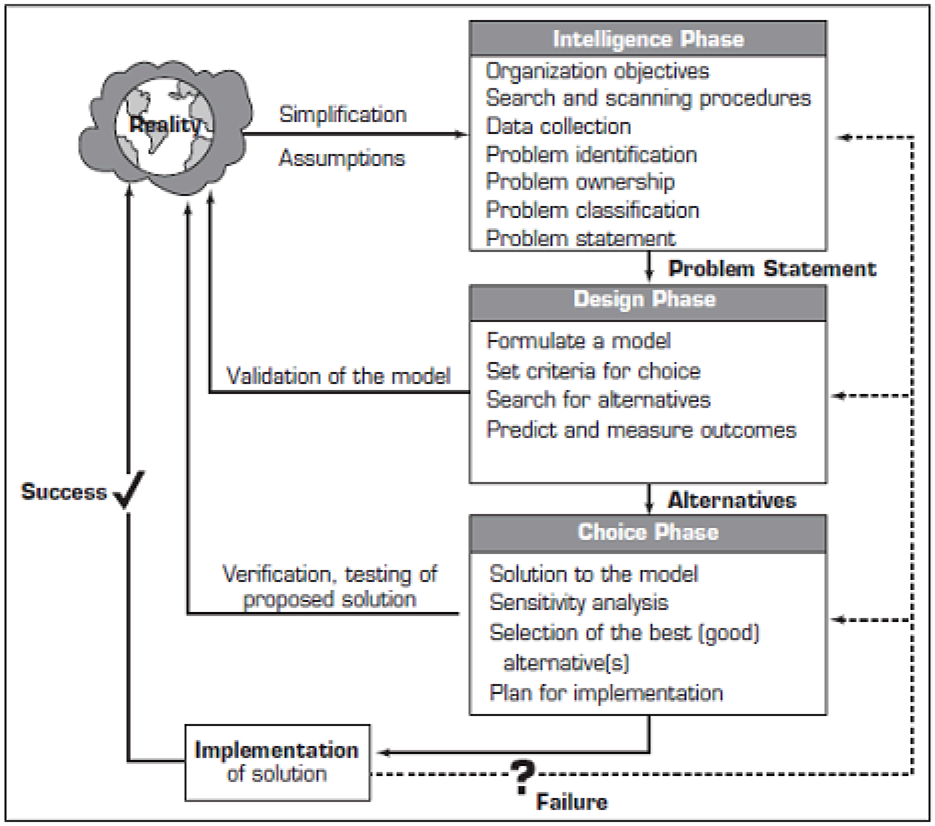

FIGURE 2.1 The Decision-Making/Modeling Process.

The decision-making process starts with the **intelligence phase**; in this phase, the decision maker examines reality and identifies and defines the problem. Problem ownership is established as well. In the **design phas**e, a model that represents the system is constructed. This is 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. When 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 decisionmaking situations described in the opening vignette follow Simon's four-phase model, as do almost all other decision-making situations. Web impacts on the four phases, and vice versa, are shown in Table 2.1.

TABLE 2.1 Simon's Four Phases of Decision Making and the Web

Phase	Web Impacts	Impacts on the Web
Intelligence	Access to information to identify problems and opportunities from internal and external data sources	Identification of opportunities for e-commerce, Web infrastructure, hardware and software tools, etc.
	Access to analytics methods to identify opportunities	Intelligent agents, which reduce the burden of information overload
	Collaboration through group support systems (GSS) and knowledge management systems (KMS)	Smart search engines
Design	Access to data, models, and solution methods	Brainstorming methods (e.g., GSS) to collaborate in Web infrastructure design
	Use of online analytical processing (OLAP), data mining, and data warehouses	Models and solutions of Web infrastructure issues
	Collaboration through GSS and KMS	
	Similar solutions available from KMS	
Choice	Access to methods to evaluate the impacts of proposed solutions	Decision support system (DSS) tools, which examine and establish criteria from models to determine Web, intranet, and extranet infrastructure
		DSS tools, which determine how to route messages
Implementation	Web-based collaboration tools (e.g., GSS) and KMS, which can assist in implementing decisions	Decisions implemented on browser and server design and access, which ultimately determined how to set up the various components that have evolved into the Internet
	Tools, which monitor the performance of e-commerce and other sites, including intranets, extranets, and the Internet	

Note that there are many other decision-making processes. Notable among them is the Kepner-Tregoe method (Kepner and Tregoe, 1998), which has been adopted by many firms because its tools are readily available from Kepner-Tregoe, Inc. (kepner-tregoe.com). We have found that these alternative models, including the Kepner-Tregoe method, readily map into Simon's four-phase model. We next turn to a detailed discussion of the four phases identified by Simon.

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.

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 or 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 people desire (or expect) and what is occurring. In this first phase, a decision maker attempts to determine whether a problem exists, identify its symptoms, determine its magnitude, and explicitly define it. Often, what is described as a problem (e.g., excessive costs) may be only a symptom (i.e., measure) of a problem (e.g., improper inventory levels). Because realworld problems are usually complicated by many interrelated factors, it is sometimes difficult to distinguish between the symptoms and the real problem. New opportunities and problems certainly may be uncovered while investigating the causes of 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. The following are some issues that may arise during data collection and estimation and thus plague decision makers:

- 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 (i.e., 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 this is not the case, the nature of the change has to be predicted and included in the analysis.

When 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, if reports indicate that sales are down, there is a problem, but the situation, no doubt, is symptomatic of the problem. It is critical to know the real problem. Sometimes it may be a problem of perception, incentive mismatch, or organizational processes rather than a poor decision model.

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. This ranges from totally structured (i.e., programmed) to totally unstructured (i.e., unprogrammed), as described in Chapter 1.

Problem Decomposition

Many complex problems can be divided into subproblems. Solving the simpler subproblems may help in solving a 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 whereas other phases are unstructured, so when some subproblems of a decision-making problem are 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.

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. The assignment of authority to solve the problem is called **problem ownership**. For example, a manager may feel that he or she has a problem because interest rates are too high. Because 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.

The intelligence phase ends with a **formal problem statement**.

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. Let us first define a model.

Models

A major characteristic of a DSS and many BI tools (notably those of business analytics) 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 a specific problem.

Mathematical (Quantitative) Models

The complexity of relationships in many organizational systems is described mathematically. Most DSS analyses are performed numerically with mathematical or other quantitative models.

The Benefits of Models

We use models for the following reasons:

- Manipulating a model (changing decision variables or the environment) is much easier than manipulating a real system. Experimentation is easier and does not interfere with the organization's daily operations.
- 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 lower 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 lower when models are used than with 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.

Modeling involves conceptualizing a 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 cost–benefit 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. However, 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 which one is applicable to a given situation. As an art, creativity and finesse are 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. Models have decision variables that describe the alternatives from among which a manager must choose (e.g., how many cars to deliver to a specific rental agency, how to advertise at specific times, which Web server to buy or lease), a result variable or a set of result variables (e.g., profit, revenue, sales) that describes the objective or goal of the decision-making problem, and uncontrollable variables or parameters (e.g., economic conditions) that describe the environment. The process of modeling involves determining the (usually mathematical, sometimes symbolic) relationships among the variables.

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 a person establishes decision-making objective(s) and incorporates the objective(s) 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. Among the many principles of choice, normative and
descriptive are of prime importance.

Normative Models

Normative models are models in which the chosen alternative is demonstrably the best of all possible alternatives. To find it, the decision maker should examine all the alternatives and prove that the one selected is indeed the best, which is what the person would normally want. This process is basically optimization. This is typically the goal of what we call prescriptive analytics (Part IV). In operational terms, optimization can be achieved in one of three ways:

1. 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?
2. Find the alternative with the highest ratio of goal attainment to cost (e.g., profit per dollar invested) or maximize productivity.
3. 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).

Are decision makers really rational? Though there may be major anomalies in the presumed rationality of financial and economic behavior, we take the view that they could be caused by incompetence, lack of knowledge, multiple goals being framed inadequately, misunderstanding of a decision maker’s true expected utility, and time-pressure impacts. There are other anomalies, often caused by time pressure. For example, Stewart (2002) described a number of researchers 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 battlefield. 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 (through pattern recognition). Luce et al. (2004) described how emotions affect decision making, and Pauly (2004) discussed inconsistencies in decision making.

We believe that irrationality is caused by the factors listed previously. For example, Tversky et al. (1990) investigated the phenomenon of preference reversal, which is a known problem in applying the AHP to problems. Also, some criterion or preference may be omitted from the analysis. Ratner et al. (1999) investigated how variety can cause individuals to choose less-preferred options, even though they will enjoy them less. But we maintain that 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.

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) on other areas. Consider, for example, a marketing department that implements an electronic commerce (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 possible.

Ideally and independently, the department should produce only a few products in extremely large quantities to minimize manufacturing costs. However, such a plan might result in large, costly inventories and marketing difficulties caused by the lack of a variety of products, especially if customers start to cancel orders that are not met in a timely way. This situation illustrates the sequential nature of decision making.

A systems point of view assesses the impact of every decision 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, timeconsuming 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). By simplifying, the model then does not incorporate certain complicated relationships that describe 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 generally usable results) by analyzing only a portion of a system, without getting bogged down in too many details. After 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 (e.g., large gears, whole assemblies) are expensive (say, $3,000 or more each), built to order in small batches, and inventoried in low quantities; C items (e.g., 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 scheduled but are simply acquired or built based on a policy defined by management with a simple economic order quantity (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 goodenough
solution found already 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 descriptive analysis is optimal. In many cases, it is only satisfactory.

Simulation is probably the most common descriptive modeling method. Simulation is the imitation of reality and 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 because 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, it is possible to measure how batches flow through the system and to use the statistics from 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 can therefore use primarily experimental modeling methods.

Classes of descriptive models include the following:

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

A number of nonmathematical descriptive models are available for decision making. One is the cognitive map (see Eden and Ackermann, 2002; and 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. This 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 understand issues better, focus better, and reach closure. One interesting software tool for cognitive mapping is Decision Explorer from Banxia Software Ltd. (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 helps a decision maker uncover the important aspects of the situation and leads to better understanding and framing. This is extremely effective when a group is making a decision, and it can lead to a more common viewpoint, also called a frame. Juries in court trials typically use narrative-based approaches in reaching verdicts (see Allan, Frame, and Turney, 2003; Beach, 2005; and Denning, 2000).

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, a goal, or a desired level of performance and then searches the alternatives until one is found that achieves this level. The usual reasons for satisficing are time pressures (e.g., decisions may lose value over time), the ability to achieve optimization (e.g., solving some models could take a really long time, and recognition that the marginal benefit of a better solution is not worth the marginal cost to obtain it (e.g., in searching the Internet, you can look at only so many Web sites before you run out of time and energy). In such a 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 would be difficult, if not impossible, to attain it. 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 than actually exist. 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; and
Pauly, 2004).

Because rationality and the use of normative models lead to good decisions, it is natural to ask why so many bad decisions are made in practice. Intuition is a critical factor that decision makers use in solving unstructured and semistructured problems. The best decision makers recognize the trade-off between the marginal cost of obtaining further information and analysis versus the benefit of making a better decision. But sometimes decisions must be made quickly, and, ideally, the intuition of a seasoned, excellent decision
maker is called for. When adequate planning, funding, or information is not available, or when a decision maker is inexperienced or ill trained, disaster can strike.

Developing (Generating) Alternatives

A significant part of the model-building process is generating alternatives. In optimization models (such as linear programming), the alternatives may be generated automatically by the model. In most decision situations, however, it is necessary to generate alternatives manually. This can be a lengthy process that involves searching and creativity, perhaps utilizing electronic brainstorming in a GSS. 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.

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 using 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 occurs after the criteria for evaluating the alternatives are determined. This sequence can ease the search for alternatives and reduce the effort involved in evaluating them, but identifying potential alternatives can sometimes aid in identifying criteria.

The outcome of every proposed alternative must be established. Depending on whether the decision-making problem is classified as one of certainty, risk, or uncertainty, different modeling approaches may be used (see Drummond, 2001; and Koller, 2000).

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 through surveys. Ideally, a decision maker would want to deal with a single goal, but in practice, it is not unusual to have multiple goals (see Barba-Romero, 2001; and Koksalan and Zionts, 2001). When groups make decisions, each group participant may have a different agenda. For example, executives might want to maximize profit, marketing might want to maximize market penetration, operations might want to minimize costs, and stockholders might want to maximize the bottom line. Typically, these goals conflict, so special multiple-criteria methodologies
have been developed to handle this.

Risk

All decisions are made in an inherently unstable environment. This is due to the many unpredictable events in both the economic and physical environments. Some risk (measured as probability) may be due to internal organizational events, such as a valued employee quitting or becoming ill, whereas others may be due to natural disasters, such as a hurricane. Aside from the human toll, one economic aspect of Hurricane Katrina was that the price of a gallon of gasoline doubled overnight due to uncertainty in the port capabilities, refining, and pipelines of the southern United States. What can a decision maker do in the face of such instability?

In general, people have a tendency to measure uncertainty and risk badly. Purdy (2005) said that people tend to be overconfident and have an illusion of control in decision making. The results of experiments by Adam Goodie at the University of Georgia indicate that most people are overconfident most of the time (Goodie, 2004). This may explain why people often feel that one more pull of a slot machine will
definitely pay off.

However, methodologies for handling extreme uncertainty do exist. For example, Yakov (2001) described a way to make good decisions based on very little information, using an information gap theory and methodology approach. Aside from estimating the potential utility or value of a particular decision's outcome, the best decision makers are capable of accurately estimating the risk associated with the outcomes that result from making each decision. Thus, one important task of a decision maker is to attribute a level of risk to the outcome associated with each potential alternative being considered. Some decisions may lead to unacceptable risks in terms of success and can therefore be discarded or discounted immediately.

In some cases, some decisions are assumed to be made under conditions of certainty simply because the environment is assumed to be stable. Other decisions are made under conditions of uncertainty, where risk is unknown. Still, a good decision maker can make working estimates of risk. Also, the process of developing BI/DSS involves learning more about the situation, which leads to a more accurate assessment of the risks.

Scenarios

A scenario is a statement of assumptions about the operating environment of a particular system at a given time; that is, it 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 may also provide the procedures and constraints for the modeling.

Scenarios originated in the theater, and 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 (i.e., what-if cases), perform computerized analyses, and learn more about the system and decisionmaking problem while analyzing it. Ideally, the manager can identify an excellent, possibly optimal, solution to the model of the problem.

Scenarios are especially helpful in simulations and what-if analyses. In both cases, we change scenarios and examine the results. For example, we can change the anticipated demand for hospitalization (an input variable for planning), thus creating a new scenario.

Then we can measure the anticipated cash flow of the hospital for each scenario.

Scenarios play an important role in decision making 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 sensitivity 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.

Errors in Decision Making

The model is a critical component in the decision-making process, but a decision maker 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) described “the seven deadly sins of decision making,” most of which are behavior or information related.

Decision Making: the Choice Phase

Choice is the critical act of decision making. The choice phase is the one in which the actual decision and the commitment to follow a certain course of action are made. The boundary between the design and choice phases is often unclear because certain activities can be performed during both of them and because the decision maker can return frequently from choice activities to design activities (e.g., generate new alternatives while performing an evaluation of existing ones). The choice phase includes the search for, evaluation of, and recommendation of an appropriate solution to a model. A solution to a model is a specific set of values for the decision variables in a selected alternative. Choices can be evaluated as to their viability and profitability.

Note that solving a 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. Search approaches include analytical techniques (i.e., solving a formula), algorithms (i.e., step-by-step procedures), heuristics (i.e., rules of thumb), and blind searches (i.e., shooting in the dark, ideally in a logical way).

Each alternative must be evaluated. If an alternative has multiple goals, they must all be examined and balanced against each other. 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 a manager determine values of the decision variables to meet a specific objective.

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 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, the implementation phase involves putting a recommended solution to work, not necessarily implementing 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 information system supported decision making. Indeed, many previous technologyrelated waves (e.g., business process reengineering (BPR), knowledge management, etc.) have faced mixed results mainly because of change management challenges and issues. Management of change is almost an entire discipline in itself, so we recognize its importance and encourage the readers to focus on it independently. Implementation also includes a thorough understanding of project management. Importance of project management goes far beyond analytics, so the last few years have witnessed a major growth in certification programs for project managers. A very popular certification now is Project Management Professional (PMP). See pmi.org for more details.

Implementation must also involve collecting and analyzing data to learn from the previous decisions and improve the next decision. Although analysis of data is usually conducted to identify the problem and/or the solution, analytics should also be employed in the feedback process. This is especially true for any public policy decisions. We need to be sure that the data being used for problem identification is valid. Sometimes people find this out only after the implementation phase.

The decision-making process, though conducted by people, can be improved with computer support, which is the subject of the next section.

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 technologies to the decisionmaking process (see Figure 2.2). Databases, data marts, and especially data warehouses are important technologies in supporting all phases of decision making. They provide the data that drive decision making.

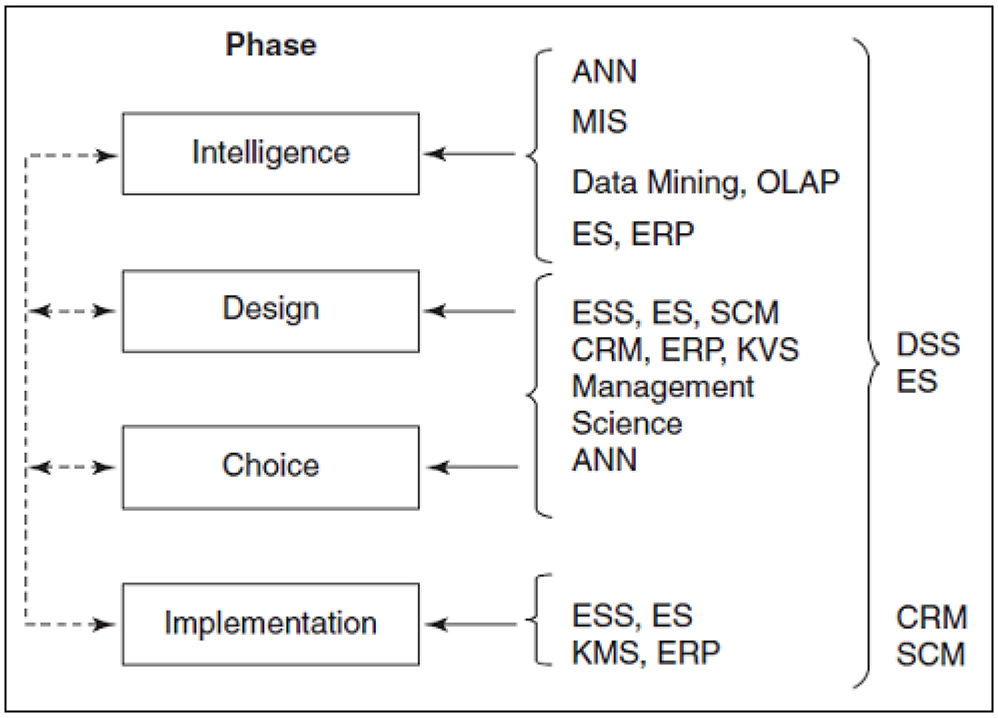

FIGURE 2.2 DSS Support.

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 can be internal or external. Internal sources may be accessible via a corporate intranet. External sources are many and varied.

Decision support/BI technologies can be very helpful. For example, a data warehouse 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 (also called a dashboard). Similarly, (automatic) data (and Web) mining (which may include expert systems [ES], CRM, genetic algorithms, neural networks, and other analytics systems) and (manual) OLAP also support the intelligence phase by identifying relationships among activities and other factors. Geographic information systems (GIS) can be utilized either as stand-alone systems or integrated with these systems so that a decision maker can determine opportunities and problems in a spatial sense. These relationships can be exploited for competitive advantage (e.g., CRM identifies classes of customers to approach with specific products and services). A KMS can be used to identify similar past situations and how they were handled. GSS can be used to share information and for brainstorming. Even cell phone and GPS data can be captured to create a micro-view of customers and their habits.

Another aspect of identifying internal problems and capabilities involves monitoring the current status of operations. When something goes wrong, it can be identified quickly and the problem can be solved. Tools such as business activity monitoring (BAM), business process management (BPM), and product life-cycle management (PLM) provide such capability to decision makers. 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. So are visualization tools and electronic document management systems.

Expert systems (ES), in contrast, can render advice regarding the nature of a 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.

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.

The Internet 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. It is important to recognize some issues in using data and analytics tools for decision making. First, to paraphrase baseball great Vin Scully, “data should be used the way a drunk uses a lamppost. For support, not for illumination.” It is especially true when the focus is on understanding the problem. We should recognize that not all the data that may help understand the problem is available. To quote Einstein, “Not everything that counts can be counted, and not everything that can be counted counts.” There might be other issues that have to be recognized as well.

Support for the Design Phase

The design phase involves generating alternative courses of action, discussing the criteria for choices and their relative importance, and forecasting the future consequences of using various alternatives. Several of these activities can use standard models provided by a DSS (e.g., 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 be provided only by a human, brainstorming software, or an ES. OLAP and data mining software are quite useful in identifying relationships that can be used in models. Most DSS 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 KMS 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. CRM systems, revenue management systems, ERP, and SCM systems software are useful in that they provide models of business processes that can test assumptions and scenarios. If a problem requires brainstorming to help identify important issues and options, a GSS may prove helpful. Tools that provide cognitive mapping can also help. Cohen et al. (2001) described 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. Such DSS are helping engineers in product design as well as decision makers solving business problems.

Support for the Choice Phase

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

Support for the Implementation Phase

This is where "making the decision happen" occurs. 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 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.

As mentioned earlier, reporting systems and other tools variously labeled as BAM, BPM, KMS, EIS, ERP, CRM, and SCM are all useful in tracking how well an 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 of doing so, and then verify that it really worked that way.

All phases of the decision-making process can be supported by improved communication through collaborative computing via GSS and KMS. Computerized systems can facilitate communication by helping people explain and justify their suggestions and opinions.

Decision implementation can also be supported by ES. 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 EIS through a Web-based enterprise information portal, are typically identified by BAM, BPM, SCM, and ERP systems. CRM systems report and update internal records, based on the impacts of the implementation. These inputs are then used to identify new problems and opportunities—a return to the intelligence phase.

Decision Support Systems: Capabilities

The early definitions of a DSS identified it as a system intended to support managerial decision makers in semistructured and unstructured decision situations. DSS were meant to be adjuncts to decision makers, extending their capabilities but not replacing their judgment. They were aimed at decisions that required judgment or at decisions that could not be completely supported by algorithms. Not specifically stated but implied in the early definitions was the notion that the system would be computer based, would operate interactively online, and preferably would have graphical output capabilities, now simplified via browsers and mobile devices.

A DSS Application

A DSS is typically built to support the solution of a certain problem or to evaluate an opportunity. This is a key difference between DSS and BI applications. In a very strict sense, business intelligence (BI) systems monitor situations and identify problems and/or opportunities, using analytic methods. Reporting plays a major role in BI; the user generally must identify whether a particular situation warrants attention, and then analytical methods can be applied. Again, although models and data access (generally through a data warehouse) are included in BI, DSS typically have their own databases and are developed to solve a specific problem or set of problems. They are therefore called DSS applications.

Formally, a DSS is an approach (or methodology) for supporting decision making. It uses an interactive, flexible, adaptable computer-based information system (CBIS) especially developed for supporting the solution to a specific unstructured management problem. It uses data, provides an easy user interface, and can incorporate the decision maker's own insights. In addition, a DSS includes models and is developed (possibly by end users) through an interactive and iterative process. It can support all phases of decision making and may include a knowledge component. Finally, a DSS can be used by a single user or can be Web based for use by many people at several locations.

Because there is no consensus on exactly what a DSS is, there is obviously no agreement on the standard characteristics and capabilities of DSS. The capabilities in Figure 2.3 constitute an ideal set, some members of which are described in the definitions of DSS and illustrated in the application cases.

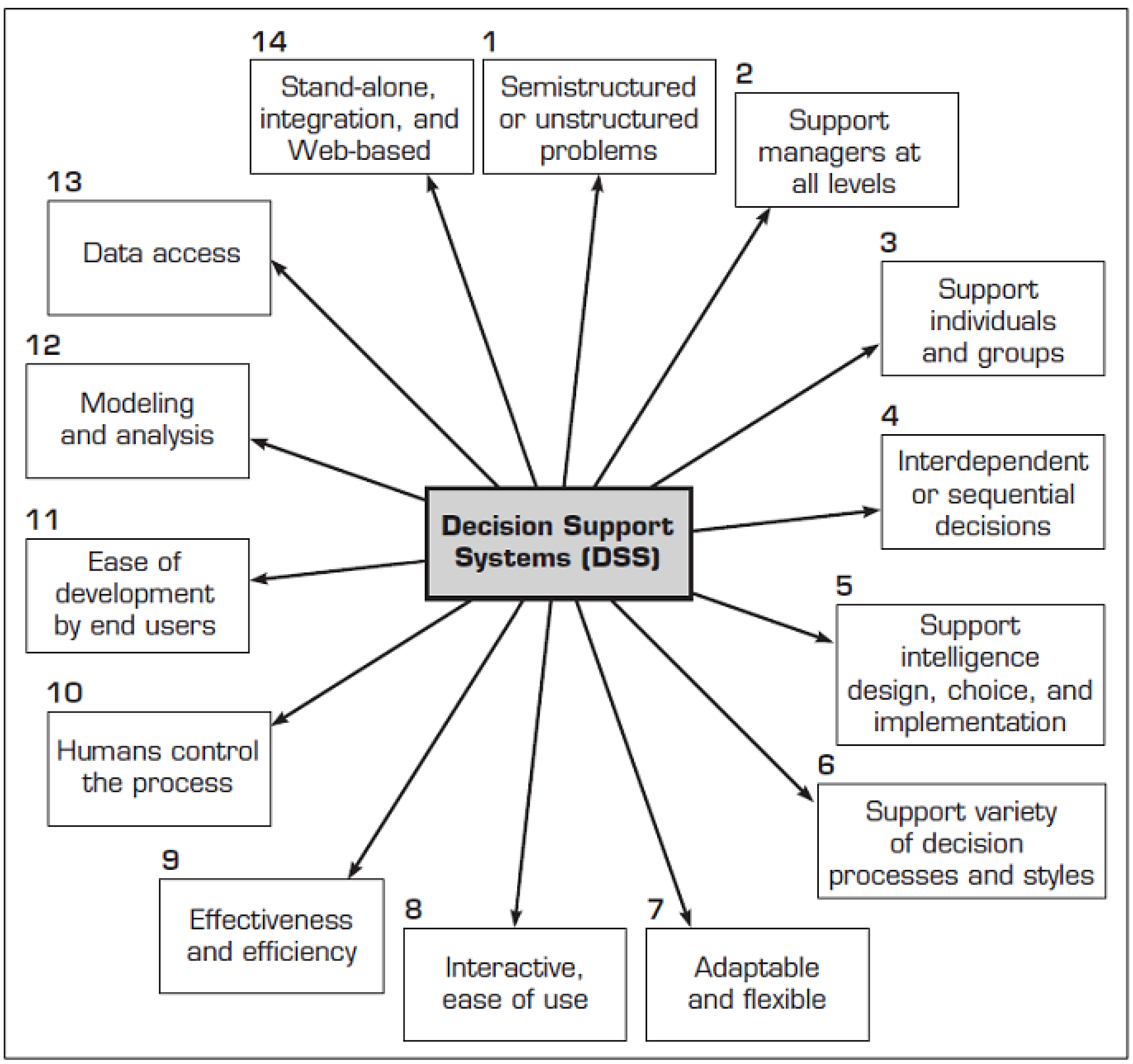

FIGURE 2.3 Key Characteristics and Capabilities of DSS.

The key characteristics and capabilities of DSS (as shown in Figure 2.3) are:

1. Support for decision makers, mainly in semistructured and unstructured situations, by bringing together human judgment and computerized information. Such problems cannot be solved (or cannot be solved conveniently) by other computerized systems or through use of standard quantitative methods or tools. Generally, these problems gain structure as the DSS is developed. Even some structured problems have been solved by DSS.
2. Support for all managerial levels, ranging from top executives to line managers.
3. Support for individuals as well as groups. Less-structured problems often require the involvement of individuals from different departments and organizational levels or even from different organizations. DSS support virtual teams through collaborative Web tools. DSS have been developed to support individual and group work, as well as to support individual decision making and groups of decision makers working somewhat independently.
4. Support for interdependent and/or sequential decisions. The decisions may be made once, several times, or repeatedly.
5. Support in all phases of the decision-making process: intelligence, design, choice, and implementation.
6. Support for a variety of decision-making processes and styles.
7. The decision maker should be reactive, able to confront changing conditions quickly, and able to adapt the DSS to meet these changes. DSS are flexible, so users can add, delete, combine, change, or rearrange basic elements. They are also flexible in that they can be readily modified to solve other, similar problems.
8. User-friendliness, strong graphical capabilities, and a natural language interactive human–machine interface can greatly increase the effectiveness of DSS. Most new DSS applications use Web-based interfaces or mobile platform interfaces.
9. Improvement of the effectiveness of decision making (e.g., accuracy, timeliness, quality) rather than its efficiency (e.g., the cost of making decisions). When DSS are deployed, decision making often takes longer, but the decisions are better.
10. The decision maker has complete control over all steps of the decision-making process in solving a problem. A DSS specifically aims to support, not to replace, the decision maker.
11. End users are able to develop and modify simple systems by themselves. Larger systems can be built with assistance from information system (IS) specialists. Spreadsheet packages have been utilized in developing simpler systems. OLAP and data mining software, in conjunction with data warehouses, enable users to build fairly large, complex DSS.
12. Models are generally utilized to analyze decision-making situations. The modeling capability enables experimentation with different strategies under different configurations.
13. Access is provided to a variety of data sources, formats, and types, including GIS, multimedia, and object-oriented data.
14. The DSS can be employed as a stand-alone tool used by an individual decision maker in one location or distributed throughout an organization and in several organizations along the supply chain. It can be integrated with other DSS and/or applications, and it can be distributed internally and externally, using networking and Web technologies.

These key DSS characteristics and capabilities allow decision makers to make better, more consistent decisions in a timely manner, and they are provided by the major DSS components, which we will describe after discussing various ways of classifying DSS (next).

DSS Classifications

DSS applications have been classified in several different ways (see Power, 2002; Power and Sharda, 2009). The design process, as well as the operation and implementation of DSS, depends in many cases on the type of DSS involved. However, remember that not every DSS fits neatly into one category. Most fit into the classification provided by the Association for Information Systems Special Interest Group on Decision Support Systems (AIS SIGDSS). We discuss this classification but also point out a few other attempts at classifying DSS.

The AIS SIGDSS Classification for DSS

The AIS SIGDSS (ais.site-ym.com/group/SIGDSS) has adopted a concise classification scheme for DSS that was proposed by Power (2002). It includes the following categories:

- Communications-driven and group DSS (GSS)
- Data-driven DSS
- Document-driven DSS
- Knowledge-driven DSS, data mining, and management ES applications
- Model-driven DSS

There may also be hybrids that combine two or more categories. These are called compound DSS. We discuss the major categories next.

Communications-Driven and Group DSS Communications-Driven and Group DSS (GSS) include DSS that use computer, collaboration, and communication technologies to support groups in tasks that may or may not include decision making. Essentially, all DSS that support any kind of group work fall into this category. They include those that support meetings, design collaboration, and even supply chain management. Knowledge management systems (KMS) that are developed around communities that practice collaborative work also fall into this category. We discuss these in more detail in later chapters.

Data-Driven DSS Data-driven DSS are primarily involved with data and processing them into information and presenting the information to a decision maker. Many DSS developed in OLAP and reporting analytics software systems fall into this category. There is minimal emphasis on the use of mathematical models.

In this type of DSS, the database organization, often in a data warehouse, plays a major role in the DSS structure. Early generations of database-oriented DSS mainly used the relational database configuration. The information handled by relational databases tends to be voluminous, descriptive, and rigidly structured. A database-oriented DSS features strong report generation and query capabilities. Indeed, this is primarily the current application of the tools marked under the BI umbrella or under the label of reporting/business analytics. The chapters on data warehousing and business performance management (BPM) describe several examples of this category of DSS.

Document-Driven DSS Document-driven DSS rely on knowledge coding, analysis, search, and retrieval for decision support. They essentially include all DSS that are text based. Most KMS fall into this category. These DSS also have minimal emphasis on utilizing mathematical models. For example, a system that we built for the U.S. Army's Defense Ammunitions Center falls in this category. The main objective of document-driven DSS is to provide support for decision making using documents in various forms: oral, written, and multimedia.

Knowledge-Driven DSS, Data Mining, and Management Expert Systems Applications These DSS involve the application of knowledge technologies to address specific decision support needs. Essentially, all artificial intelligence–based DSS fall into this category. When symbolic storage is utilized in a DSS, it is generally in this category. ANN and ES are included here. Because the benefits of these intelligent DSS or knowledgebased DSS can be large, organizations have invested in them. These DSS are utilized in the creation of automated decision-making systems, as described in Chapter 12. The basic idea is that rules are used to automate the decision-making process. These rules are basically either an ES or structured like one. This is important when decisions must be made quickly, as in many e-commerce situations.

Model-Driven DSS The major emphases of DSS that are primarily developed around one or more (large-scale/complex) optimization or simulation models typically include significant activities in model formulation, model maintenance, model management in distributed computing environments, and what-if analyses. Many large-scale applications fall into this category. Notable examples include those used by Procter & Gamble (Farasyn et al., 2008), HP (Olavson and Fry, 2008), and many others.

The focus of such systems is on using the model(s) to optimize one or more objectives (e.g., profit). The most common end-user tool for DSS development is Microsoft Excel. Excel includes dozens of statistical packages, a linear programming package (Solver), and many financial and management science models. We will study these in more detail in Chapter 9. These DSS typically can be grouped under the new label of prescriptive analytics.

Compound DSS A compound, or hybrid, DSS includes two or more of the major categories described earlier. Often, an ES can benefit by utilizing some optimization, and clearly a data-driven DSS can feed a large-scale optimization model. Sometimes documents are critical in understanding how to interpret the results of visualizing data from a data-driven DSS.

An emerging example of a compound DSS is a product offered by WolframAlpha (wolframalpha.com). It compiles knowledge from outside databases, models, algorithms, documents, and so on to provide answers to specific questions. For example, it can find and analyze current data for a stock and compare it with other stocks. It can also tell you how many calories you will burn when performing a specific exercise or the side effects of a particular medicine. Although it is in early stages as a collection of knowledge components from many different areas, it is a good example of a compound DSS in getting its knowledge from many diverse sources and attempting to synthesize it.

Other DSS Categories
Many other proposals have been made to classify DSS. Perhaps the first formal attempt was by Alter (1980). Several other important categories of DSS include (1) institutional and ad hoc DSS; (2) personal, group, and organizational support; (3) individual support system versus GSS; and (4) custom-made systems versus ready-made systems. We discuss some of these next.

Institutional and Ad Hoc DSS Institutional DSS (see Donovan and Madnick, 1977) deal with decisions of a recurring nature. A typical example is a portfolio management system (PMS), which has been used by several large banks for supporting investment decisions. An institutionalized DSS can be developed and refined as it evolves over a number of years, because the DSS is used repeatedly to solve identical or similar problems. It is important to remember that an institutional DSS may not be used by everyone in an organization; it is the recurring nature of the decision-making problem that determines whether a DSS is institutional versus ad hoc.

Ad hoc DSS deal with specific problems that are usually neither anticipated nor recurring. Ad hoc decisions often involve strategic planning issues and sometimes management control problems. Justifying a DSS that will be used only once or twice is a major issue in DSS development. Countless ad hoc DSS applications have evolved into institutional DSS. Either the problem recurs and the system is reused or others in the organization have similar needs that can be handled by the formerly ad hoc DSS.

Custom-Made Systems Versus Ready-Made Systems
Many DSS are custom made for individual users and organizations. However, a comparable problem may exist in similar organizations. For example, hospitals, banks, and universities share many similar problems. Similarly, certain nonroutine problems in a functional area (e.g., finance, accounting) can repeat themselves in the same functional area of different areas or organizations. Therefore, it makes sense to build generic DSS that can be used (sometimes with modifications) in several organizations. Such DSS are called ready-made and are sold by various vendors (e.g., Cognos, MicroStrategy,
Teradata). Essentially, the database, models, interface, and other support features are built in: Just add an organization's data and logo. The major OLAP and analytics vendors provide DSS templates for a variety of functional areas, including finance, real estate, marketing, and accounting. The number of ready-made DSS continues to increase because of their flexibility and low cost. They are typically developed using Internet technologies for database access and communications, and Web browsers for interfaces. They also readily incorporate OLAP and other easy-to-use DSS generators.

One complication in terminology results when an organization develops an institutional system but, because of its structure, uses it in an ad hoc manner. An organization can build a large data warehouse but then use OLAP tools to query it and perform ad hoc analysis to solve nonrecurring problems. The DSS exhibits the traits of ad hoc and institutional systems and also of custom and ready-made systems. Several ERP, CRM, knowledge management (KM), and SCM companies offer DSS applications online. These kinds of systems can be viewed as ready-made, although typically they require modifications
(sometimes major) before they can be used effectively.