

University of Mississippi

eGrove

---

Proceedings of the University of Kansas  
Symposium on Auditing Problems

Deloitte Collection

---

1-1-1988

## Using and evaluating audit decision aids

Robert H. Ashton

John J. Willingham

Follow this and additional works at: [https://egrove.olemiss.edu/dl\\_proceedings](https://egrove.olemiss.edu/dl_proceedings)



Part of the [Accounting Commons](#), and the [Taxation Commons](#)

---

### Recommended Citation

Auditing Symposium IX: Proceedings of the 1988 Touche Ross/University of Kansas Symposium on Auditing Problems, pp. 001-025;

This Article is brought to you for free and open access by the Deloitte Collection at eGrove. It has been accepted for inclusion in Proceedings of the University of Kansas Symposium on Auditing Problems by an authorized administrator of eGrove. For more information, please contact [egrove@olemiss.edu](mailto:egrove@olemiss.edu).

# 1

## Using and Evaluating Audit Decision Aids<sup>1</sup>

**Robert H. Ashton**

Duke University

**John J. Willingham**

Peat Marwick Main & Co.

This paper is intended to stimulate discussion among auditing practitioners and researchers about the use of audit decision aids. While audit decision aids have a long history, they are presently assuming greater importance as the auditing profession is in a period of transition from experience-based to research-based audit approaches. The issues raised in this paper may be of interest to auditing practitioners concerned with managing that transition, and to auditing researchers concerned with the scientific evaluation of audit decision aids.

The types of audit decision aids we discuss are designed to assist auditors in making decisions required in the collection and evaluation of evidence for the purpose of expressing an audit opinion or rendering other audit-related client services. Today's audit decision aids are based increasingly on the implications of research studies, typically rooted in disciplines other than auditing, that examine audit decision making in a controlled, rigorous manner. In saying this, we do not mean to imply that the trend toward research-based audit tools is restricted to the types of decision aids discussed in this paper, nor do we mean to suggest that this is a trend of recent origin. Consider, for example, earlier work in statistical sampling based on the disciplines of mathematics and statistics (e.g., Arkin [1957]), or in systems-based approaches to auditing which relied on the discipline of systems analysis (e.g., Skinner and Anderson [1966]).

The decision aids discussed in this paper are linked to an extensive body of research known as "human information processing" or "behavioral decision theory," which is explicitly concerned with understanding, evaluating, and improving decision making. In auditing, maintaining and improving the quality of decision making has been reinforced recently by governmental activities emphasizing audit effectiveness and by competitive pressures emphasizing audit efficiency. Proponents of decision aids based on the decision research literature maintain that audit efficiency and effectiveness can potentially be improved by employing such aids.

The paper is organized in three major sections. First, we present an

---

<sup>1</sup> We are grateful to Alison Ashton, Lisa Koonce, Jim Loebbecke, Bill Messier and Ira Solomon for comments on an earlier version of this paper.

overview of audit decision research and the decision-aid development efforts to which it is linked. Second, we argue that the effectiveness of audit decision aids should be evaluated, instead of being accepted on faith alone. Topics discussed include: (1) the issue of choosing whether to use audit decision aids or, alternatively, to train auditors to improve their decision making, (2) various claims made by developers and proponents of decision aids (in auditing and elsewhere), and (3) specific considerations involved in the validation of audit decision aids. The final section of the paper outlines some potential effects (both positive and negative) of using decision aids in audit practice. There we examine possible effects on both individual auditor judgment and the auditing firm that employs decision aids.

## **Research & Development in Audit Decision Making**

This section provides an overview of (1) contemporary research in audit decision making, and (2) development efforts, in the form of audit decision aids, which are closely linked to this research. We do not attempt to provide a comprehensive review of audit decision research (see, e.g., Ashton [1982a,b; 1983], Libby [1981], Mock and Turner [1981], and Ashton et al. [1989] for reviews). Moreover, by restricting our focus to audit decision aids we do not mean to imply that this is the only area in which audit decision research has had an impact on practice or policy making (see, e.g., Elliott and Jacobson [1987], Kinney [1981], and Ward [1987] for additional discussion). Instead, the purpose of this section is to provide some perspective for the later discussion of audit decision aids.

Research in audit decision making is based on the theoretical perspectives and research methods of cognitive psychologists, economists, decision theorists and others concerned with how people do (and should) make decisions. The ultimate goal of the research is to provide a scientific basis for improving audit decisions, thus favorably impacting the efficiency and/or effectiveness of audits. More proximate goals are to evaluate audit decision making in order to know whether (or in what respect) decisions might need improvement, and to understand audit decision making in order to be able to evaluate it. Thus, the research is concerned with *how* audit decisions are made, with *how well* they are made, and with ways of making them *better*.

While some audit decision research might be considered basic, most of it has a strong applied flavor. Applied and basic research can be distinguished in that applied research concerns the scientific discovery of knowledge having applicability to specific, identifiable problems in the short run, while problem specificity and a short-run perspective are not necessary features of basic research. Both applied and basic research can be distinguished from development in that development concerns the practical *use* or implementation of knowledge—often by designing and producing new processes, systems or other devices—but does not involve the *discovery* or production of new knowledge [Ashton, 1981; Kaplan, 1977].

### **Research**

Audit decision making research has addressed several phases of the audit, including evaluation of analytical review results, preliminary estimates of

planning materiality, internal control evaluation, decisions about compliance and substantive testing, evaluations of the work of internal auditors, going-concern evaluations, the choice of audit opinions, and reviews of financial forecasts. Most of the research has focused on issues that relate to the “tactical planning” of evidence collection activities, i.e., planning an appropriate mix of compliance and substantive tests to support an opinion on financial statements at a reasonable cost [Felix and Kinney, 1982].

One way of viewing the dominant focus of audit decision research is via the Cushing and Loebbecke [1986] framework depicted in Table 1. This framework outlines five major stages of audit activities which typically are performed in a roughly sequential fashion, as well as a sixth category, called “continuous” activities, which typically are performed at any of several stages of the audit process. Most audit decision research has addressed audit activities in stages 2 through 4 of this framework. Particular emphasis has been placed on 2.0 (i.e., all of stage 2) and on 4.5, with less emphasis on 3.0, and some on 5.1 through 5.3. Loebbecke [1983] provides examples of audit activities in all six stages of the framework to which decision research could contribute.

The existing research in audit decision making has been concerned with two broad, but related, issues—evaluating the quality of audit decision making and exploring ways of improving audit decision making. Three standards for evaluating audit decisions have been employed. First, decision *accuracy* has been used for situations in which an independent, external criterion of “correctness” has been available. Second, *statistical rationality* has been employed by focusing on whether auditors interpret and use audit evidence in a logically consistent manner. This is done by comparing audit decisions with those prescribed by normative models or statistical principles of decision making. Finally, the *consistency* of decisions—both over time and across auditors—has been assessed.

Some typical examples of results from audit decision research are as follows: (1) while auditors often are relatively accurate in repetitive decision situations, room for improvement exists because they do not always (a) perceive correctly the relevance of information used in decision making or (b) use relevant information in a consistent fashion; (2) auditors are often insufficiently sensitive to certain types of information (e.g., base rates of occurrence of certain events), and often do not fully appreciate the inverse relationship between sample size and sampling variability; (3) although individual auditors have been found to make reasonably consistent decisions over time, different auditors using the same evidence often tend to make decisions that disagree markedly. While this lack of consensus among auditors may be considered problematic per se, it also means that the accuracy and statistical rationality of audit decisions are likely to be poor for some auditors [Ashton, 1985].

This summary of typical results suggests that research in audit decision making tends to focus on the shortcomings of “unaided” decision making. In particular, much of the research has sought to identify systematic errors, biases, and inconsistencies in audit decision making. It is important to realize that this research focus describes the *entire field* of decision research, not just that in auditing. However, as von Winterfeldt and Edwards [1986, p. 530] point out in a broader context, “A research focus on systematic errors and

## **Table 1**

**A Comprehensive Outline of the Audit Process  
(From Cushing and Loebbecke [1986, pp. 6-7])**

---

### **1.0 PRE-ENGAGEMENT ACTIVITIES**

- 1.1 Accept/Reject New Client
- 1.2 Establish Terms of Engagement
- 1.3 Assignment of Staff

### **2.0 PLANNING ACTIVITIES**

- 2.1 Obtain Knowledge of the Business
  - 2.11 Preliminary Analytical Review
  - 2.12 Appraisal of Risk
- 2.2 Preliminary Estimation of Materiality
- 2.3 Review of Internal Accounting Control
  - 2.31 Preliminary Phase
  - 2.32 Completion Phase
- 2.4 Develop Overall Audit Plan
  - 2.41 Determine Optimal Reliance on Internal Accounting Control
  - 2.42 Design Compliance Testing Procedures
  - 2.43 Design Substantive Procedures
  - 2.44 Write Audit Program

### **3.0 COMPLIANCE TESTING ACTIVITIES**

- 3.1 Conduct Tests
- 3.2 Make Final Evaluation of Internal Accounting Control
  - 3.21 Make Evaluation
  - 3.22 Modify Audit Plan

### **4.0 SUBSTANTIVE TESTING ACTIVITIES**

- 4.1 Conduct Substantive Tests of Transactions
- 4.2 Conduct Analytical Review Procedures
- 4.3 Conduct Tests of Details of Balances
- 4.4 Post Balance Sheet Review Procedures
- 4.5 Evaluate Results of Substantive Procedures
  - 4.51 Aggregate Findings
  - 4.52 Make Evaluation
  - 4.53 Modify Audit Plan
- 4.6 Obtain Representations
  - 4.61 Management
  - 4.62 Attorneys
  - 4.63 Others

### **5.0 OPINION FORMULATION AND REPORTING ACTIVITIES**

- 5.1 Review Financial Statements
- 5.2 Review Audit Results
- 5.3 Formulate Opinion
- 5.4 Draft and Issue Report

### **6.0 CONTINUOUS ACTIVITIES**

- 6.1 Supervise Conduct of Examination
  - 6.2 Review Work of Assistants
  - 6.3 Consider Appropriateness of Continuing Relationship with Client
  - 6.4 Make Required Special Communications
    - 6.41 Material Weaknesses in Internal Accounting Control
    - 6.42 Material Errors or Irregularities
    - 6.43 Illegal Acts by Client
  - 6.5 Consult With Appropriate Persons in Connection With Special Problems
  - 6.6 Document Work Performed, Findings, and Conclusions in Appropriate Working Papers
-

inferential biases can lead those who read the research with an uncritical eye to the notion that such errors and biases characterize all human thinking.” Common sense and informal observation suggest that this is not the case, in auditing or in the rest of life. On the other hand, it would be naive to think that human decision making is perfect, or that the shortcomings that exist will go away if ignored. Fischhoff [1982, p. 442] concluded a review of the “decision biases” literature as follows:

An elusive summary from the present review is that people’s reservoir of judgmental skills is both half empty and half full. People are skilled enough to get through life, unskilled enough to make predictable and consequential mistakes; they are clever enough to devise broadly and easily applicable heuristics that often serve them in good stead, unsophisticated enough not to realize the limits to those heuristics.

## **Development**

Along with the emphasis on research that documents and evaluates the shortcomings of human decision making is a corresponding emphasis on the development of tools, or decision aids, that may help people to compensate for those shortcomings. The development of decision aids for improving unassisted decision making is perhaps the most direct practical result of audit decision research, as well as of decision research in general. A review of decision research in several fields observed: “The existence of biases and errors in unaided judgments is part of the motivation for aiding the judgment process; the assumption is that aided judgments are less subject to error. The aid is based on a prescriptive formulation that decomposes the problem into its separate elements and presumably helps the decision maker to overcome the limitations of unaided judgments. Thus the development of decision aids requires an understanding of the processes involved in performing the task, together with a suitable prescriptive theory that can serve as a normative formulation for the problem” [Pitz and Sachs, 1984, p. 155].

Following Rohrman [1986, p. 365], we define a decision aid as

“ . . . any explicit procedure for the generation, evaluation and selection of alternatives (courses of action) that is designed for practical application and multiple use. In other words: a [decision aid] is a technology, not a theory.”

Auditing firms have always used decision aids. Examples are audit programs, internal control questionnaires, and various types of checklists [Elliott and Kielich, 1985]. Such aids are simply tools based on the accumulated experience of generations of auditors. In this sense, audit tools are analogous to the tools of everyday life, as experience is the earliest basis for tool development. The archaeological scholar Childe [1954, p. 9] noted that

Even the simplest tool made of a broken bough or a chipped stone is the fruit of long experience—of trials and errors, impressions noticed, remembered, and compared. The skill to make it has been acquired by observation, by recollection, and by experiment. It may seem an exaggeration, but it is yet true to say that any tool is an embodiment of science. For it is a practical application of remembered, compared, and collected experiences of the same kind as are systematized and summarized in scientific formulas, descriptions, and prescriptions.

Such tools are based on organized knowledge, not on the results of research in decision making. In contrast, many of today's audit decision aids are research-based, and it appears that the trend toward the use of research-based audit tools will accelerate. Examples of research-based audit decision aids are paper-and-pencil worksheets and quasi-statistical formulas for determining non-statistical sample sizes [AICPA, 1983; Elliott, 1983], multiple regression and discriminant models for predicting going-concern problems (e.g., Altman and McGough [1974], Kida [1980]), and time series and regression models for identifying unusual fluctuations in analytical review [Arrington et al. 1983; Kinney, 1983]. Audit decision aids of this type are discussed by Ashton [1983] and Libby [1981].

The most elaborate (and costly) form of audit decision aid is knowledge-based expert systems. We rely on Rauch's [1984, p. 55] definition:

. . . a class of computer programs intended to serve as consultants for decision making. These programs use a collection of facts, rules of thumb, and other knowledge about a limited field to help make inferences in the field. They differ substantially from conventional computer programs in that their goals may have no algorithmic solution, and they must make inferences based on incomplete or uncertain information. They are called expert systems because they address problems normally thought to require human specialists for solution, and knowledge based because researchers have found that amassing a large amount of knowledge, rather than sophisticated reasoning techniques, is responsible for the success of the approach.

Essentially, a knowledge-based expert system is a computational method of performing a decision task which uses an explicit representation of an expert's knowledge, generally in the form of a series of "if-then" rules instead of in the form of a statistical formula such as multiple regression or discriminant analysis [Chignell and Smith, 1985b]. Expert systems have received substantial attention from researchers in the field of artificial intelligence (e.g., Bobrow et al. [1986], Chignell and Smith [1985a], Davis [1982], Duda and Shortliffe [1983], Michie [1980], Stefik et al. [1982]), and the accounting profession is currently exploring their potential applications in auditing, taxation, and management advisory services [AICPA, 1987]. Abdolmohammadi [1987] and Messier and Hansen [1987] provide reviews and discussions of expert systems in auditing.

## **Evaluating Audit Decision Aids**

Even though decision research may demonstrate errors, biases and inconsistencies in audit decision making, it does not necessarily follow that decision aids should be developed and used. Lewis et al. [1983] point out that the expected benefits of using decision aids must exceed their costs, and that the *reasons* for biases and inconsistencies must be understood before appropriate aids can be identified. Moreover, using decision aids may not be the only way to reduce biases and inconsistencies. An alternative is to train auditors to improve unassisted decision making.

### **Decision Aids vs. Training**

Under what conditions is the development of audit decision aids preferable

to training? In a more general context, Fischhoff [1982, p. 424] provides some insights into the question of aids vs. training by discussing “whether responsibility for biases is laid at the doorstep of the judge, the task, or some mismatch between the two.” Fischhoff argues that the appropriate “debiasing” strategies depend on the source of the bias, as summarized in Table 2.

The strategies listed in part 1 of Table 2 address potential methodological problems of the research studies which have demonstrated biases. Although of considerable importance in the design of future studies, they need not concern us here. Assuming that current research results in audit decision making can be validly interpreted as indicating biases and inconsistencies, as we believe they can, parts 2 and 3 of the table are relevant to the present discussion.

If the source of the problem is thought to be faulty judges (auditors), Fischhoff argues that the appropriate debiasing strategies depend on whether the judges are considered “perfectible” or “incorrigible.” If they are considered “perfectible,” then some type of training, ranging from a simple

**Table 2**

Debiasing Strategies According to Underlying Assumption About the Source of the Bias (From Fischhoff [1982, p. 424])

<b>Assumption</b>	<b>Strategies</b>
1. Faulty tasks	
a. Unfair tasks	Raise stakes Clarify instructions/stimuli Discourage second-guessing Use better response modes Ask fewer questions
b. Misunderstood tasks	Demonstrate alternative goal Demonstrate semantic disagreement Demonstrate impossibility of task Demonstrate overlooked distinction
2. Faulty judges	
a. Perfectible individuals	Warn of problem Describe problem Provide personalized feedback Train extensively
b. Incorrigible individuals	Replace them Recalibrate their responses Plan on error
3. Mismatch between judges and tasks	
a. Restructuring	Make knowledge explicit Search for discrepant information Decompose problem Consider alternative situations Offer alternative formulations
b. Education	Rely on substantive experts Educate from childhood



warning that judgment biases may exist to an extended training program aimed at controlling particular biases, is suggested. In this case, having auditors participate in “decision exercises” such as those discussed by Ashton [1984] might be useful. However, if the judges are considered “incorrigible,” then Fischhoff suggests replacing people with “some superior answering device” (p. 426), adjusting their responses if the direction and magnitude of their biases are predictable, or somehow allowing for their biases when planning actions based on them. Thus, according to Fischhoff, if individual decision makers are considered “perfectible,” training is suggested, while if they are considered “incorrigible,” some type of decision aid may be more appropriate.

On the other hand, if the source of bias and inconsistency is thought to be a mismatch between the judge and the task (part 3 of Table 2), then either a restructuring of the “person-task system” is needed to increase their compatibility, or extensive education is needed for developing general capabilities (as opposed to training for developing specific skills). Restructuring, which is closely allied with the use of decision aids, can involve “(a) forcing respondents to express what they know explicitly rather than letting it remain ‘in the head’; (b) encouraging respondents to search for discrepant evidence, rather than collecting details corroborating a preferred answer; (c) offering ways to decompose an overwhelming problem to more tractable and familiar components; (d) suggesting that respondents consider the set of possible situations that they might have encountered in order to understand better the specific situation at hand; and (e) proposing alternative formulations of the presented problem. . . .” [Fischhoff, 1982, p. 427].

In summary, Fischhoff is essentially arguing that using decision aids is likely to be preferable to training when it is possible to restructure the decision task to a form more compatible with the decision maker’s information-processing capabilities, or when the success of training efforts is considered highly uncertain. While Fischhoff does not explicitly consider either the costs of training or the costs of developing decision aids, the relative costs of these two alternatives are obviously important. What do we know about the relative costs (or effectiveness) of training and decision aids in auditing? Under what conditions, or for which types of decisions, is one likely to be more effective or less costly than the other? Which specific form of training, or of decision aid, is likely to be most effective for particular types of decisions? While the present paper deals with decision aids instead of with training, it is important to realize that audit decision aids are but one of a larger class of “decision improvement options” [Libby, 1981] that could be pursued.

### **Claims About Decision Aids**

Suppose the option of developing decision aids has been chosen over training, at least for certain types of audit decisions. What benefits can decision makers expect from using these aids? Rohrman [1986, p. 368] observes that “Decision makers above all ask for ‘good’ decisions that solve their problems, but they also want quick and cheap and comprehensible procedures.” Developers and proponents of decision aids claim that such aids offer all of these features. As Rohrman notes, “The developers claim [that decision aids] make decisions easier and better because they decompose the decision process into comprehensible parts, reveal goals and preferences, guide information search

and integration, and are based on a rational concept . . . for the comparison, evaluation and selection of alternatives” (p. 363). In a similar vein, Hammond et al. [1980] identify six sets of claims that are often made about the value of decision research for aiding decision makers. These claims are summarized in Table 3.

Some of the claims identified by Hammond et al. [1980] are (implicitly or explicitly) made about decision aids in auditing. The principal claims, at least for relatively simple aids involving discriminant and regression models and “structured” paper-and-pencil aids, relate to the accuracy and consistency of audit decisions (e.g., Ashton [1983], Libby [1981]). It is often claimed that (1) when correct answers exist, aided audit decisions will, over a series of decisions, be more *accurate* than unaided audit decisions, and (2) whether or not correct answers exist, aided audit decisions will be more *consistent*, i.e., less variable, both over time and across auditors, than will unaided audit decisions.

The claims for expert systems are similar but, like the systems themselves, are more elaborate. In addition to aiding audit decision making by structuring problems, indicating pertinent information sources, and combining information to reach a preliminary recommendation [Wright, 1984], it is also claimed that expert systems will (1) enable expertise to be distributed throughout the audit firm (e.g., to personnel at multiple locations) and, particularly, to be “pushed down” to lower organizational levels, (2) facilitate

**Table 3**

Claims About the Value of Decision Research for Aiding Decision Makers  
(Adapted from Hammond, McClelland and Mumpower [1980, pp. 108-110])

---

1. Clarifies thinking
  2. Educates the decision maker
    - a. Makes hidden assumptions and implicit tradeoffs explicit
    - b. Forces consideration of the consequences of actions
    - c. Identifies what is important for making decisions and where more information is needed
    - d. Identifies what is *not* important for making decisions (a by-product of 2c)
    - e. Forces explicit recognition of uncertainty
    - f. Facilitates understanding of the complete problem
  3. Promotes improved communication
    - a. Helps decision maker communicate, defend, and justify decisions and actions
    - b. Helps resolve conflicts among decision makers
    - c. Facilitates training of new decision makers
    - d. Facilitates intellectual, nonemotional discussion of important issues
  4. Promotes a policy perspective
    - a. Saves time, money, and unhappiness
    - b. Facilitates adaptation to new information or changing values
    - c. Facilitates the “passing on” of policy to future decision makers (similar to 3c)
    - d. Facilitates dissemination of policy to those affected
  5. Helps distinguish preferences for consequences from beliefs about whether consequences will occur
  6. Creates new solutions, insights, and alternatives
-

staff training by focusing on simulated audit problems and the knowledge needed to solve them, (3) ease documentation efforts by printing out a record of the process used by the system to make a recommendation, (4) improve the consistency of decisions over time and across auditors, and (5) result in less time devoted to decision making by eliminating time that is wasted on factors irrelevant to the decision (e.g., Elliott and Kielich [1985], Wright [1984]).

### Validation of Decision Aids

While the importance of validating decision aids has been recognized (e.g., Gaschnig et al. [1983], O'Leary [1987], Pitz and Sachs [1984]), it has often been noted that few attempts at systematic evaluation have been made, particularly by independent evaluators [Fischhoff, 1980; Hammond et al. 1980; Rohrmann, 1986]. Instead, evidence about the effectiveness or efficiency of aided decision making is largely anecdotal, having been acquired on a trial-and-error basis in the field. However, aided decision making should be evaluated scientifically for the same reasons that *unaided* decision making should be evaluated—to understand the conditions under which it is effective, and to provide a sound basis for improving it when needed. An additional reason for evaluating aided decision making is that decision aids are not costless.

How should one evaluate decision aids? Two broad approaches are to evaluate the *process* embodied in the aid or to focus on the *outcomes* generated by it. Process-oriented evaluations, which may be particularly germane for expert systems, focus on the mechanism by which outputs are generated from inputs, and may include examination of information search, information processing, and the interaction between the aid and the user (e.g., problem clarification, explanation capability, and documentation). The major drawback of process-oriented evaluations is that evidence about improved decisions is only indirect. In contrast, outcome-oriented evaluations focus explicitly on the quality of decisions made with benefit of the aid, but only provide information on *whether* an aid is effective or ineffective, not *why* [Jungermann, 1980; Rohrmann, 1986].

While we recognize that multiple approaches to decision aid evaluation are likely to be necessary, and that different evaluation standards are likely to be most appropriate at different points in the development and use of an aid, more attention to outcome-oriented evaluations seems desirable. The reason is that outcome-oriented evaluations are more direct and meaningful than process-oriented evaluations in terms of discovering how well the aid “really works.” With a few exceptions (e.g., bankruptcy or insolvency predictions), it is likely to be impossible to evaluate the performance of a decision aid against observable, empirical outcomes since unassailable “correct answers” are seldom known in auditing. This does not mean, however, that *all types* of outcome-oriented evaluations are impossible. One alternative, which has been used occasionally, is to compare aided decisions with those prescribed by normative models or statistical principles of decision making.

Another possibility, which seems to have gone largely unnoticed in discussions of decision aids, is to compare decisions aided by one type of decision aid with those aided by some other type of decision aid. Such an evaluation might be especially informative in the case of expert systems, particularly if decisions aided by expert systems are compared with those aided

by simpler tools such as multiple regression or discriminant analysis. In many situations, of course, it will not be possible to construct regression or discriminant models based on relationships among environmental data because correct answers are not known. However, "policy-capturing" models, based on relationships among observable input variables and a series of actual decisions, can still be used. Much research has shown that simple policy-capturing models consistently outperform unaided human judgment in repetitive decision situations (see, e.g., Ashton [1982a], Libby [1981]), and it is an open question as to how well policy-capturing models would fare against complex expert systems. A conceptual (nonempirical) analysis by Carroll [1987] concludes that expert systems are *unlikely* to achieve the performance level of policy-capturing models. (See Hammond [1987; 1988] for related discussions.)

Even if an expert system performs better than a policy-capturing model or some other relatively simple decision aid in the same decision task, the difference in the costs of the two alternatives must be considered. The high cost of expert systems in auditing—related to development, knowledge acquisition, maintenance, updating, and preparation of user guides and training manuals (see Elliott and Jacobson [1987])—suggests that the cost difference between these two alternatives could be substantial. Obviously, if the cost difference between any two types of decision aids is sufficiently large, the one that performs better on such criteria as accuracy and agreement with experts is not necessarily the one that should be used. Of course, a similar statement can be made about comparing any type of aided decision making with *unaided* decision making: the increased cost associated with an aid could more than offset the benefits in terms of improved decision quality. Conversely, if the aid results in net cost savings, for example, by reducing the number of staff personnel required, then some *decrease* in decision quality associated with the aid might be acceptable. The point is that both costs *and* benefits of decision aids are important.

The most common standard against which the outputs of decision aids are compared is unaided decision making. The unaided decisions are sometimes those of the experts whose knowledge was used in developing the aid, and are sometimes those of experts, novices, or other individuals who are independent of the development of the aid. While such comparisons are subject to all of the problems inherent in using consensus as a decision-evaluation criterion (e.g., people's decisions may agree perfectly yet all be wrong [Ashton, 1985]), in some situations this approach to "validation" may be the only one available. However, a standard that may be preferable to an individual's decision is a composite, or average, of the decisions made by several individuals. Research has shown repeatedly that composite decisions are more likely to be correct than are individuals' decisions (e.g., Ashton and Ashton [1985], Ashton [1986]).

As noted earlier, little evidence is available about the impact of decision aids on outcome-oriented decision variables. Most of the research in this area involves complex decision support systems in non-auditing settings. Sharda et al. [1988] review 24 such evaluations and report an additional study of their own. The studies reviewed are grouped into four types, according to research method: case studies (4), field studies (6), field tests (3), and laboratory studies

(11). Field studies are distinguished from field tests in that the former typically involve no experimental control, while in the latter, the evaluator tries to manipulate some aspect(s) of the decision aid and control for other factors that could influence the study's results.

Sharda et al. [1988, p. 140] point out that most claims regarding the effectiveness of decision support systems are based on case and field studies instead of on field tests or laboratory studies, which they maintain "is unfortunate as the latter two methods . . . allow for stronger inferences to be drawn." Their review of field tests and laboratory studies finds that the evidence is inconclusive, as evaluations have uncovered positive effects, no effects, and negative effects of decision support systems on various output-oriented measures of decision quality (e.g., average profit per period, variability of profit over periods, cost, and decision time). Aldag and Power [1986] review several additional studies of computer-assisted decision making with similarly inconclusive results.

Two studies have focused on the use of simple decision aids in auditing. Butler [1985] had 18 auditors from five firms of varying sizes make an assessment of sampling risk when evaluating the sample results of accounts receivable confirmations. Prior to making their risk assessments, 11 of the auditors had to answer four questions that were intended to remind them of factors relevant to an assessment of sampling risk, while the remaining seven auditors were not exposed to these questions. This "attention directing" device was considered a decision aid for the purposes of this study. A statistically-determined measure of sampling risk, based on a multinomial dollar-unit sampling program, constituted a normative criterion against which the aided and unaided risk assessments were compared. The results showed that the auditors who were exposed to the decision aid made risk assessments that were closer to the normative criterion, and also made more correct accept/reject decisions about the account balance, than the auditors who were not exposed to the aid.

While Butler [1985] focused on the evaluation of sample results, Kachelmeier and Messier [1988] studied the choice of sample sizes by auditors. In a supplies inventory context, 180 auditors from two Big Eight firms (1) provided sample sizes without the availability of a decision aid (the "intuitive" group), (2) calculated sample sizes using a formal decision aid (the "aid" group), or (3) provided only the input parameters required by the aid (the "parameters" group) which the researchers then used to calculate sample sizes. The decision aid employed was the formula and tables contained in the SAS 39 Guide [AICPA, 1981; 1983]. Since a normative criterion for evaluating the auditors' sample sizes was not available, the analysis focused on differences in sample sizes for the three groups.

The results showed that, on average, the "intuitive" group chose smaller sample sizes than the "aid" group, which chose smaller sample sizes than the "parameters" group. The difference in sample sizes between the latter two groups was interpreted as indicating a "working backward" effect; that is, the "aid" group's desired sample sizes might have affected their choice of input judgments for use in the decision aid. Additional analyses found, contrary to expectation, that the "parameters" group showed greater variability (less consistency) across auditors in sample sizes than the "aid" group, which

showed greater variability than the “intuitive” group. (A study in a non-auditing context by Peterson and Pitz [1986] found that the availability of a decision aid (a multiple regression equation) was associated with greater consistency over time, as well as greater accuracy of individuals’ decisions.)

## **Effects of Audit Decision Aids**

In this section, we discuss several possible effects of using decision aids in audit practice. Some of these effects are “positive” in the sense of leading to improvements in audit decision making; others are “negative” in the sense of representing problems that must be controlled. Some of the effects are suggested by research studies; others are more speculative. These potential effects of audit decision aids are divided into two main categories: effects on individual judgment and effects on the auditing firm. We also discuss the potential importance of the initial implementation or introduction of decision aids.

### **Effects on Judgment**

*Increased emphasis on judgment:* Instead of decreasing the importance of professional judgment in the audit process, as is sometimes feared, the use of decision aids might *increase* the importance of judgment. Note that a major role of audit decision aids is to combine several input judgments to reach a decision or recommendation, while it is the auditor’s responsibility to supply those input judgments. For example, Elliott and Jacobson [1987] argue that, although the guidance on audit sampling adopted in 1981 added structure to the audit process, it also increased the number of judgments required of the auditor (pertaining to, e.g., the effect on sample size of control reliance, evidence from related tests, audit risk, and tolerable error). One implication of this shift from holistic to decomposed judgments may be the need for firms (and researchers) to pay more attention to training auditors in the proper formulation of input judgments for decision aids. A corollary issue, noted by both Elliott and Jacobson [1987] and Ashton [1983], is the possibility that auditors who provide such inputs will view their task as “mechanical” and not exercise their judgment carefully. Another issue of potential concern is the question of who is authorized to override the recommendations made by audit decision aids (and under what conditions, and to what extent).

*Structuring judgment inputs:* The use of decision aids will likely require an increase in the structure of the input information. Prior research in other fields suggests that information processing is facilitated when the decision model employed and the information presentation structure are congruent (e.g., Bettman and Kakkar [1977], Bettman and Zins [1979]). Note that structured information differs from a structured decision aid, in that the former refers to *inputs* to decisions while the latter concerns the *process* by which inputs are combined. Structured input information may lead to greater decision consistency, perhaps because structure makes it easier for people to use decision aids [de Hoog and van der Wittenboer, 1986], or perhaps because it facilitates unassisted information processing even *in the absence* of decision aids.

*Justifying decision aid outputs:* Decision aids not only require auditors to execute a logical sequence of procedures and decisions, but also to document that they have done so. Documentation is one aspect of the broader area of

justifying, and being held accountable for, one's decisions [Staw, 1980; Tetlock, 1983; 1985]. The potential importance of the justifiability of a decision is often noted by decision researchers (e.g., Tversky [1972], Adelbratt and Montgomery [1980], Gibbins [1984]), but the effects of justification have not been systematically explored. However, some research suggests that one effect of having to justify decisions is an increase in the consistency of those decisions (e.g., Cvetkovich [1978], Hagafors and Brehmer [1983]). An important issue for research and practice is the extent to which increased consistency is due to using the aid as opposed to the accompanying emphasis on justification. A related question is the extent to which consistency could be increased by emphasizing justification *in the absence* of a decision aid. These issues may be particularly important when one considers that the cost of an increased emphasis on justification is likely to be considerably less than the cost of developing and maintaining decision aids.

*Increasing vs. decreasing consistency:* As noted earlier, increasing the consistency of audit decisions—both over time and across auditors—is a major rationale for using audit decision aids. It is possible, however, that consistency could be *decreased* by the use of audit decision aids. Consider, for example, the sample size equation and tables described in the SAS 39 Guide [AICPA, 1981; 1983]. Use of this decision aid requires that one judgment (sample size) be replaced by *three* judgments (tolerable error, degree of desired assurance, and error expectation). If sufficient variability exists across auditors in specifying these three inputs, then the resulting sample sizes computed by the formula could be more variable across auditors than the sample sizes determined by unaided judgment. Variability in input specification may explain Kachelmeier and Messier's [1988] finding of less agreement in aided than in unaided sample size decisions, as well as Bamber and Snowball's [1988] finding of no relationship between agreement in sample size decisions and the degree of structure of firms' audit methodologies. Thus, while decision aids are capable of "amplifying expertise" [Davis, 1984], they also are capable of amplifying judgment biases and inconsistencies.

This possibility is discussed in a general setting by Slovic et al. [1977], and in an audit setting by Jiambalvo and Waller [1984]. Slovic et al. [1977, p. 27] warn of "the risk of grinding through highly sophisticated analyses on inputs of very little value," and argue that "'garbage in—garbage out' applies to decision aiding—with the particular danger that undue respect may be given to garbage produced by high-powered and expensive grinding." Thus, while the decomposition, or "divide-and-conquer" strategy on which many decision aids rely can lead to greater decision consistency and accuracy (e.g., Armstrong et al. [1975], Cornelius and Lyness [1980], Lyness and Cornelius [1982]), results such as those of Burns and Pearl [1981] and Chakravarti et al. [1979] suggest that "one should approach the 'divide and conquer' ritual with caution; not every division leads to a conquest . . ." [Burns and Pearl, 1981, p. 379]. As noted earlier, auditors might benefit from training in the proper formulation of input judgments.

*Circumventing the aid:* Perhaps one of the more troublesome aspects of audit decision aids is the extent to which they might allow the user to circumvent their intent. For example, the intent of the sample size determination worksheet described by Elliott [1983], as well as the sample size equation

and tables described in the SAS 39 Guide, can be circumvented by “working backward.” That is, an auditor could first select the sample size he or she desires and then provide input values which would yield this sample size. In that case, the judgmental inputs provided by the auditor could be determined in part by the chosen sample size, not vice versa as intended. As noted earlier, Kachelmeier and Messier [1988] found results consistent with this possibility. Ensuring the proper use of decision aids provides an interesting challenge for auditing firms.

### **Effects on the Firm**

*Increased structure of audit methodologies:* A major way in which the use of audit decision aids is likely to impact audit firms is by increasing the degree of structure of the audit process [Willingham, 1986]. Cushing and Loebbecke [1986, p. 32] define a structured audit methodology as “a systematic approach to auditing characterized by a prescribed, logical sequence of procedures, decisions, and documentation steps, and by a comprehensive and integrated set of audit policies and tools designed to assist the auditor in conducting the audit.” The similarity between this definition and our earlier definition of decision aids should be apparent.

The potential advantages and disadvantages of structured audit methodologies are topics of debate (e.g., Mullarkey [1984], Sullivan [1984]), and the correlates of structure are becoming topics of research. For example, Kinney [1986] found an association between the voting patterns of members of the Auditing Standards Board and the degree of structure of the members’ firms. Morris and Nichols [1988] found an association between audit firm structure and the predictability of firm-level materiality judgments. Bamber et al. [1987] found an association between firm structure and audit seniors’ perceptions of their firms’ organizational characteristics related to role conflict and role ambiguity. Bamber and Snowball [1988] found that auditors from structured firms were more likely to consult with peers and superiors as the uncertainty of their decision tasks increased than those from unstructured firms. Williams and Dirsmith [1987] found that in the U.S., clients of more structured audit firms announced earnings on a more timely basis than did clients of less structured firms. In contrast, Newton and Ashton [1988] found that in Canada, there was a positive relationship between audit firm structure and clients’ “audit delay,” i.e., the time from fiscal year-end to the audit report date. Whatever the effects of structured audit methodologies, they are likely to be amplified by the increased use of audit decision aids.

*Substitution of capital for labor:* One implication of increased audit structure and increased use of decision aids is a greater investment in capital such as hardware and software, with possible impacts on pricing and management strategies within auditing firms. A corollary effect is a potential decrease in staff time required because of the automation of certain tasks traditionally performed at the staff level. This could translate into decreased hiring for auditing jobs (with attendant consequences for accounting educators) and decreased turnover [Elliott and Kielich, 1985]. The base of the traditional pyramid in the organization of auditing practice could be narrowed.

*Accepting error:* There is no doubt that the recommendations of audit decision aids will sometimes be in error (or at least will be judged to have been



in error in the light of subsequent information). While this is not a compelling reason to abandon such aids (people make errors too), auditors and auditing firms might have great difficulty accepting the error inherent in imperfect decision aids. However, the following example (adapted from Einhorn [1986; 1988]) illustrates that accepting error can be wise.

Imagine that you are placed in front of a panel that displays a red light and a green light. Your job is to predict which of the two lights will be illuminated on each of a series of trials. Each time your prediction is correct, you are given a cash payoff; if your prediction is wrong, there is no payoff. However, unknown to you, the lights are programmed to go on according to a random process with a given proportion of red and green, say 60% red and 40% green.

If you approach this decision task like most people do, you will respond to the lights in the same proportion as they occur. For example, in this case people predict "red" 60% of the time and "green" 40% after they have had some experience with the task. Your expected payoff for such a strategy can be calculated as follows. Since you predict red on 60% of the trials and red occurs on 60%, you will be correct (and receive the payoff) on 36% ( $.60 \times .60$ ) of the trials. Similarly for green; you predict green on 40% of the trials and green occurs on 40%. Hence, 16% ( $.40 \times .40$ ) of the trials will be correctly predicted. Therefore, over both red and green predictions, you will be correct on  $36\% + 16\% = 52\%$  of the trials.

Now consider how well you could do by using a decision aid that said: always predict the most likely color. Note that such a strategy accepts error; however, it also leads to 60% correct predictions (you always predict red, and red occurs 60% of the time). Since 60% is greater than 52%, you would make more money if you accepted error and consistently used the decision aid. However, most people try to predict perfectly . . .

This example suggests that the *relative* amount of error inherent in aided versus unaided decision making is the important factor, not the absolute amount of error associated with the imperfect decision aid. It is not clear, however, that errors made by auditors and by audit decision aids would be equally acceptable (to either the auditor or the firm), or would result in the same amount of "regret" [Bell, 1982; Loomes and Sugden, 1982] for not having made a different decision. The same is true for errors made by different *types* of decision aids; for example, it is conceivable that errors made by expert systems would be more acceptable and result in less regret than errors made by multiple regression models because the former type of aid may seem more "human" than the latter. The choice among complex expert systems, simpler models, and unaided human judgment could amount to a choice among living with the consequences of different types of error (cf. Carroll [1987, p. 289]).

*Increased competition from non-accountants:* One benefit often mentioned for expert systems in auditing is the dissemination of expertise throughout the firm. The negative side of this benefit is that such dissemination will not necessarily remain within the firm's boundaries. As Elliott and Kielich [1985, p. 134] note, "anyone with the capability to develop or purchase such systems will become a potential competitor." Since the consulting and tax areas are not subject to as much regulation as auditing, they could be especially prone to this

possibility. (Michaelsen and Messier [1987] provide a review of expert systems in taxation.)

*Security considerations:* Related to such competition is the possibility that decision aids, particularly expert systems, could be copied and passed along to competitors [O'Brien, 1985]. This could be particularly problematic for expert systems that contain confidential information about long-range firm strategies, and for expert systems or other types of decision aids developed for sensitive areas like fee determination.

*Legal liability:* Ellis [1983, p. 4] suggests that expert systems "will be a minefield for professional bodies, especially over the question of legal accountability." If this is correct, then a possibility of some concern to auditors is that of being held liable for failure to follow the recommendations of expert systems or other aids. Under some circumstances, overriding a decision aid's recommendations might be taken, *prima facie*, as evidence of "a lack of prudent regard for the rights of shareholders, employees, and other publics" [O'Brien, 1985, p. 296].

### **Implementation of Decision Aids**

To this point, we have concentrated on the evaluation of audit decision aids, and on some possible effects of using them in practice. We conclude by drawing attention to the potential importance of the manner in which such aids are initially introduced or implemented. Although this topic has been virtually ignored by decision researchers in auditing, it is likely to be of great practical importance. However, some literature exists on the implementation of management science models, computer-based information systems, and other types of managerial technology, and it may provide useful insights into preferred ways of implementing audit decision aids. A sample of this literature is contained in the Appendix.

The literature on implementation has a strong how-to-do-it (or how-*not*-to-do-it) flavor. As Lichtenstein et al. [1977, p. 317] said in a different context: "The most striking aspect of [this literature] is its 'dust-bowl empiricism.' Psychological theory is largely absent, either as motivation for the research or as explanation of the results." Nevertheless, the references contained in the appendix may provide clues about successful implementation for practitioners, and they may suggest testable hypotheses about implementation for researchers. Implementation research based on some theory or model of the implementation process, or at least on some systematic body of empirical data, could have substantial practical benefit.

### **Conclusion**

A basic tenet of professional auditing is that independent auditors should maintain an attitude of "professional skepticism" about their clients' financial statements. Research in audit decision making suggests that some skepticism about professional audit *judgment* might also be appropriate. The reason is not because audit judgment is poor, but because a skeptical attitude may lead to ways of making it better. Auditing practitioners prize their judgment and tend to emphasize its strong points. Auditing researchers explore the limitations of judgment and tend to emphasize its weak points. More importantly, both

parties recognize that strong *and* weak points exist, and that it may be possible to capitalize on the strengths while compensating for the weaknesses. To the extent that this is effected through decision aids, it becomes important to validate decision aids and to understand the effects of using them in practice.

While we believe that the shift from experience-based to research-based auditing and the related emphasis on decision aids will continue, it must be remembered that the purpose of such aids is to augment rather than replace human judgment. Moreover, since many audit decision aids are *built upon* human judgment and require judgmental inputs for their operation, research that improves our understanding of auditors' knowledge, expertise, and decision making skills will be even more important in the future than it is today. At the very least, cost-effective resource allocation will require an understanding of which decisions need aiding and which do not [Ashton et al. 1989]. As Fischhoff [1982, p. 444] said in a more general context, "Good practice will require better theory about how the mind works. Good theory will require better practice, clarifying and grappling with the conditions in which the mind actually works." In audit decision making, we believe that both better theory and better practice can be achieved by efforts at all points along the research/development continuum and, especially, by sharing the results of those efforts among researcher and practitioner members of the auditing community.

## References

- Abdolmohammadi, M. J., "Decision Support and Expert Systems in Auditing: A Review and Research Directions," *Accounting and Business Research* (Spring 1987), pp. 173-185.
- Adelbratt, T., and H. Montgomery, "Attractiveness of Decision Rules," *Acta Psychologica* (August 1980), pp. 177-185.
- Adelman, L., "Involving Users in the Development of Decision-Analytic Aids: The Principal Factor in Successful Implementation," *Journal of Operations Research* (April 1982), pp. 333-342.
- Alavi, M., and J. C. Henderson, "An Evolutionary Strategy for Implementing a Decision Support System," *Management Science* (November 1981), pp. 1309-1323.
- Aldag, R. J. and D. J. Power, "An Empirical Assessment of Computer-Assisted Decision Analysis," *Decision Sciences* (Fall 1986), pp. 572-588.
- Alter, S., "Why is Man-Computer Interaction Important for Decision Support Systems?" *Interfaces* (February 1977), pp. 109-115.
- Altman, E. I., and T. P. McGough, "Evaluation of a Company as a Going Concern," *The Journal of Accountancy* (December 1974), pp. 50-57.
- American Institute of Certified Public Accountants, *Audit Sampling*, Statement on Auditing Standards No. 39, New York, AICPA (1981).
- American Institute of Certified Public Accountants, *Audit Sampling*, Audit and Accounting Guide, New York, AICPA (1983).
- American Institute of Certified Public Accountants, *An Introduction to Artificial Intelligence and Expert Systems*, Management Advisory Services Special Report, New York, AICPA (1987).
- Anderson, J., and R. Narasimhan, "Assessing Project Implementation Risk: A Methodological Approach," *Management Science* (June 1979), pp. 512-521.
- Annino, J. S., and E. C. Russell, "The Seven Most Frequent Causes of Simulation Analysis Failure—And How to Avoid Them," *Interfaces* (June 1981), pp. 59-63.
- Argote, L., P. S. Goodman, and D. Schkade, "The Human Side of Robotics: How Workers React to a Robot," *Sloan Management Review* (Spring 1983), pp. 31-41.
- Arkin, H., "Statistical Sampling in Auditing," *New York Certified Public Accountant* (July 1957), pp. 454-469.
- Armstrong, J. S., W. B. Denniston, and M. M. Gordon, "The Use of the Decomposition Principle in Making Judgments," *Organizational Behavior and Human Performance* (October 1975), pp. 257-263.

- Arrington, C. E., W. Hillison, and R. C. Icerman, "Research in Analytical Review: The State of the Art," *Journal of Accounting Literature* (1983), pp. 151-185.
- Ashton, A. H., "Does Consensus Imply Accuracy in Accounting Studies of Decision Making?" *The Accounting Review* (April 1985), pp. 173-185.
- Ashton, A. H., and R. H. Ashton, "Aggregating Subjective Forecasts: Some Empirical Results," *Management Science* (December 1985), pp. 1499-1508.
- Ashton, R. H., "Some Observations on the Auditing Research Environment," In *1981 Accounting Research Convocation*, ed. J. O. Mason, Tuscaloosa, University of Alabama (1981).
- Ashton, R. H., *Human Information Processing in Accounting*, Studies in Accounting Research No. 17, Sarasota, American Accounting Association (1982a).
- Ashton, R. H., "Human Information Processing Research in Auditing: A Review and Synthesis," In *Auditing Symposium VI*, eds. D. R. Nichols and H. F. Stettler, Lawrence, University of Kansas (1982b).
- Ashton, R. H., *Research in Audit Decision Making: Rationale, Evidence, and Implications*, Research Monograph No. 6. Vancouver, Canadian Certified General Accountants Research Foundation (1983).
- Ashton, R. H., "Integrating Research and Teaching in Auditing: Fifteen Cases on Judgment and Decision Making," *The Accounting Review* (January 1984), pp. 78-97.
- Ashton, R. H., "Combining the Judgments of Experts: How Many and Which Ones?" *Organizational Behavior and Human Decision Processes* (December 1986), pp. 405-414.
- Ashton, R. H., and A. H. Ashton, "The Use of Management Science Models in Human Resource Planning," *OMEGA, The International Journal of Management Science* (March 1988), pp. 153-157.
- Ashton, R. H., D. N. Kleinmuntz, J. Sullivan, and L. A. Tomassini, "Audit Decision Making," In *Research Opportunities in Auditing, The Second Decade*, eds. A. R. Abdel-khalik and I. Solomon, Sarasota, American Accounting Association (1989).
- Bamber, E. M., and D. Snowball, "An Experimental Study of the Effects of Audit Structure in Uncertain Task Environments," *The Accounting Review* (July 1988), pp. 490-504.
- Bamber, E. M., D. A. Snowball, and R. M. Tubbs, "Audit Structure and its Relationship to Role Conflict and Role Ambiguity: An Empirical Investigation," Working Paper, University of Florida (1987).
- Bell, D. E., "Regret in Decision Making Under Uncertainty," *Operations Research* (September-October 1982), pp. 961-981.
- Bell, M. Z., "Why Expert Systems Fail," *Journal of the Operational Research Society* (July 1985), pp. 613-619.
- Bettman, J. R., and P. Kakkar, "Effect of Information Presentation Format on Consumer Information Acquisition Strategies," *Journal of Consumer Research* (March 1977), pp. 233-240.
- Bettman, J. R., and M. A. Zins, "Information Format and Choice Task Effects in Decision Making," *Journal of Consumer Research* (September 1979), pp. 141-153.
- Bobrow, D. G., S. Mittal, and M. J. Stefik, "Expert Systems: Perils and Promise," *Communications of the ACM* (September 1986), pp. 880-894.
- Burns, M., and J. Pearl, "Causal and Diagnostic Inferences: A Comparison of Validity," *Organizational Behavior and Human Performance* (December 1981), pp. 379-394.
- Butler, S. A., "Application of a Decision Aid in the Judgmental Evaluation of Substantive Test of Details Samples," *Journal of Accounting Research* (Autumn 1985), pp. 513-526.
- Cain, H., "The Intangibles of Implementation," *Interfaces* (November 1979), pp. 144-147.
- Carroll, B., "Expert Systems for Clinical Diagnosis: Are They Worth the Effort?" *Behavioral Science* (October 1987), pp. 274-292.
- Carter, N. M., "Computerization as a Predominate Technology: Its Influence on the Structure of Newspaper Organizations," *Academy of Management Journal* (June 1984), pp. 247-270.
- Chakravarti, D., A. Mitchell, and R. Staelin, "Judgment Based Marketing Decision Models: An Experimental Investigation of the Decision Calculus Approach," *Management Science* (March 1979), pp. 251-263.
- Chignell, M. H., and P. J. Smith, "A Bibliography of Knowledge-Based Systems," Working Paper, Department of Industrial and Systems Engineering, University of Southern California (1985a).
- Chignell, M. H., and P. J. Smith, "An Introduction to Knowledge-Based Systems," Working Paper, Department of Industrial and Systems Engineering, University of Southern California (1985b).
- Childe, G., *What Happened in History*, Hammondsworth (Eng.), Penguin (1954).

- Cornelius, E. T., and K. S. Lyness, "A Comparison of Holistic and Decomposed Judgment Strategies in Job Analyses by Job Incumbents," *Journal of Applied Psychology* (April 1980), pp. 155-163.
- Cushing, B. E., and J. K. Loebbecke, *Comparison of Audit Methodologies of Large Accounting Firms*, Accounting Research Study No. 26, Sarasota, American Accounting Association (1986).
- Cvetkovich, G., "Cognitive Accommodation, Language, and Social Responsibility," *Social Psychology* (June 1978), pp. 149-155.
- Davis, R., "Expert Systems: Where Are We? And Where Do We Go From Here?" *The AI Magazine* (Spring 1982), pp. 3-22.
- Davis, R., "Amplifying Expertise with Expert Systems," *Artificial Intelligence*, eds. P. H. Winston and K. A. Prendergast, Cambridge, Massachusetts Institute of Technology (1984).
- de Hoog, R., and G. van der Wittenboer, "Decision Justification, Information Structure and the Choice of Decision Rules," In *New Directions in Research on Decision Making*, eds. B. Brehmer, H. Jungermann, P. Lourens, and G. Sevon, Amsterdam, North-Holland (1986).
- Duda, R. O., and E. H. Shortliffe, "Expert Systems Research," *Science* (April 15, 1983), pp. 261-268.
- Einhorn, H. J., "Accepting Error to Make Less Error," *Journal of Personality Assessment* (June 1986), pp. 387-395.
- Einhorn, H. J., "Diagnosis and Causality in Clinical and Statistical Prediction," In *Reasoning, Inference, and Judgment in Clinical Psychology*, eds. D. C. Turk and P. Salovey, New York, Free Press (1988).
- Elam, J. J., and B. Konsynski, "Using Artificial Intelligence Techniques to Enhance the Capabilities of Model Management Systems," *Decision Sciences* (Summer 1987), pp. 487-502.
- Elliott, R. K., "Unique Audit Methods: Peat Marwick International," *Auditing: A Journal of Practice and Theory* (Spring 1983), pp. 1-12.
- Elliott, R. K., and P. D. Jacobson, "Audit Technology: A Heritage and a Promise," *The Journal of Accountancy* (May 1987), pp. 198-218.
- Elliott, R. K., and J. A. Kielich, "Expert Systems for Accountants," *The Journal of Accountancy* (September 1985), pp. 126-134.
- Ellis, P., "Expert Systems—A Key Innovation in Professional and Managerial Problem Solving," *Information Age* (January 1983), pp. 2-6.
- Emshoff, J. R., "Experience-Generalized Decision Making: The Next Generation of Managerial Models," *Interfaces* (August 1978), pp. 40-48.
- Evan, W. M., and G. Black, "Innovation in Business Organizations: Some Factors Associated with Success or Failure of Staff Proposals," *The Journal of Business* (October 1967), pp. 519-530.
- Felix, W. L., and W. R. Kinney, "Research in the Auditor's Opinion Formulation Process: State of the Art," *The Accounting Review* (April 1982), pp. 245-271.
- Fischhoff, B., "Clinical Decision Analysis," *Operations Research* (January-February 1980), pp. 28-43.
- Fischhoff, B., "Debiasing," In *Judgment Under Uncertainty: Heuristics and Biases*, eds. D. Kahneman, P. Slovic, and A. Tversky, New York, Cambridge (1982).
- Fuerst, W. L., and P. H. Cheney, "Factors Affecting the Perceived Utilization of Computer-Based Decision Support Systems in the Oil Industry," *Decision Sciences* (October 1982), pp. 544-569.
- Gaschnig, J., P. Klahr, H. Pople, E. Shortliffe, and A. Terry, "Evaluation of Expert Systems: Issues and Case Studies," In *Building Expert Systems*, eds. F. Hayes-Roth, D. A. Waterman and D. B. Lenat, Reading, Addison-Wesley (1983).
- Gibbins, M., "Propositions about the Psychology of Professional Judgment in Public Accounting," *Journal of Accounting Research* (Spring 1984), pp. 103-125.
- Ginzberg, M. J., "Steps Toward More Effective Implementation of MS and MIS," *Interfaces* (May 1978), pp. 57-63.
- Ginzberg, M. J., "Early Diagnosis of MIS Implementation Failure: Promising Results and Unanswered Questions," *Management Science* (April 1981), pp. 459-478.
- Glen, T. N., and C. F. James, "Difficulties in Implementing Management Science Techniques in a Third World Setting," *Interfaces* (February 1980), pp. 39-44.
- Grayson, C. J., "Management Science and Business Practice," *Harvard Business Review* (July-August 1973), pp. 41-48.
- Green, T. B., W. B. Newsom, and S. R. Jones, "A Survey of the Application of Quantitative Techniques to Production/Operations Management in Large Corporations," *Academy of Management Journal* (December 1977), pp. 669-676.

- Gupta, J. N. D., "Management Science Implementation: Experiences of a Practicing O.R. Manager," *Interfaces* (May 1977), pp. 84-90.
- Hagafors, R., and B. Brehmer, "Does Having to Justify One's Judgments Change the Nature of the Judgment Process?" *Organizational Behavior and Human Decision Processes* (April 1983), pp. 223-232.
- Hammond, J. S., "The Roles of the Manager and Management Scientist in Successful Implementation," *Sloan Management Review* (Winter 1974), pp. 1-24.
- Hammond, K. R., "Toward a Unified Approach to the Study of Expert Judgment," In *NATO ASI Series F: Computer and Systems Sciences: Vol. 35. Expert Judgment and Expert Systems*, eds., J. L. Mumpower, L. D. Phillips, O. Renn, and V. R. R. Uppuluri, Berlin, Springer-Verlag (1987).
- Hammond, K. R., "Moving Results from Research to Practice," *Judgment/Decision Making Society Newsletter* (April 1988), pp. 3-4.
- Hammond, K. R., G. H. McClelland, and J. Mumpower, *Human Judgment and Decision Making: Theories, Methods, and Procedures*, New York, Praeger (1980).
- Hayes, R. H., and R. L. Nolan, "What Kind of Corporate Modeling Functions Best?" *Harvard Business Review* (May-June 1974), pp. 102-112.
- Huber, G. P., "Cognitive Style as a Basis for MIS and DSS Designs: Much Ado About Nothing?" *Management Science* (May 1983), pp. 567-579.
- Ives, B., and M. H. Olson, "User Involvement and MIS Success: A Review of Research," *Management Science* (May 1984), pp. 586-603.
- Jiambalvo, J., and W. Waller, "Decomposition and Assessments of Audit Risk," *Auditing: A Journal of Practice and Theory* (Spring 1984), pp. 80-88.
- Jungermann, H., "Speculations About Decision-Theoretic Aids for Personal Decision Making," *Acta Psychologica* (August 1980), pp. 7-34.
- Kachelmeier, S. J., and W. F. Messier, "An Investigation of the Influence of a Nonstatistical Decision Aid on Auditor Sample Size Decisions," Working Paper, University of Florida (1988).
- Kaplan, R. S., "The Roles for Research and Development in Auditing," In *Symposium on Auditing Research II*, Urbana, University of Illinois (1977).
- Kida, T., "An Investigation Into Auditors' Continuity and Related Qualification Judgments," *Journal of Accounting Research* (Autumn 1980), pp. 506-523.
- Kinney, W. R., "The Impact of Auditing Research on Practice and Policy," In *Proceedings of the Arthur Young Professors' Roundtable*, ed. J. W. Buckley, Reston (Va.): Arthur Young and Co. (1981).
- Kinney, W. R., "Quantitative Applications in Auditing," *Journal of Accounting Literature* (1983), pp. 187-204.
- Kinney, W. R., "Audit Technology and Preference for Auditing Standards," *Journal of Accounting and Economics* (March 1986), pp. 73-89.
- Lawless, M. W., "Institutionalization of a Management Science Innovation in Police Departments," *Management Science* (February 1987), pp. 244-252.
- Leonard-Barton, D., and W. A. Kraus, "Implementing New Technology," *Harvard Business Review* (November-December 1985), pp. 102-110.
- Lewis, B., M. D. Shields, and S. M. Young, "Evaluating Human Judgments and Decision Aids," *Journal of Accounting Research* (Spring 1983), pp. 271-285.
- Libby, R., *Accounting and Human Information Processing: Theory and Applications*, Englewood Cliffs, Prentice-Hall (1981).
- Lichtenstein, S., B. Fischhoff, and L. D. Phillips, "Calibration of Probabilities: The State of the Art," In *Decision Making and Change in Human Affairs*, eds. H. Jungermann, and G. deZeeuw, Amsterdam, Reidel (1977).
- Little, J. D. C., "Models and Managers: The Concept of a Decision Calculus," *Management Science* (April 1970), pp. 466-485.
- Loebbecke, J. K., "A Plan for Research in Audit Judgment-Making," In *1983 Accounting Research Convocation*, ed. K. R. Bindon, Tuscaloosa, University of Alabama (1983).
- Loomes, G., and R. Sugden, "Regret Theory: An Alternative Theory of Rational Choice Under Uncertainty," *The Economic Journal* (December 1982), pp. 805-824.
- Lucas, H. C., *Implementation: The Key to Successful Information Systems*, New York, Columbia University Press (1981).
- Lyness, K. S., and E. T. Cornelius, "A Comparison of Holistic and Decomposed Judgment Strategies in a Performance Rating Simulation," *Organizational Behavior and Human Performance* (February 1982), pp. 21-38.

- McArthur, D. S., "Decision Scientists, Decision Makers, and the Gap," *Interfaces* (February 1980), pp. 110-113.
- McInnes, J. M., and J. W. Carleton, "Theory, Models and Implementation in Financial Management," *Management Science* (September 1982), pp. 957-978.
- Meredith, J. R., "The Importance of Impediments to Implementation," *Interfaces* (August 1981), pp. 71-74.
- Messier, W. F., and J. V. Hansen, "Expert Systems in Auditing: The State of the Art," *Auditing: A Journal of Practice and Theory* (Fall 1987), pp. 94-105.
- Michaelsen, R. H., and W. F. Messier, "Expert Systems in Taxation," *The Journal of the American Taxation Association* (Spring 1987), pp. 7-21.
- Michie, D., "Expert Systems," *The Computer Journal* (November 1980), pp. 369-376.
- Mock, T. J., and J. L. Turner, *Internal Accounting Control Evaluation and Auditor Judgment*, Audit Research Monograph No. 3, New York, AICPA (1981).
- Mohan, L., and A. S. Bean, "Introducing OR/MS Into Organizations: Normative Implications of Selected Indian Experience," *Decision Sciences* (January 1979), pp. 136-150.
- Morris, M. H., and W. D. Nichols, "Consistency Exceptions: Materiality Judgments and Audit Firm Structure," *The Accounting Review* (April 1988), pp. 237-254.
- Mullarkey, J., "The Case for the Structured Audit," In *Auditing Symposium VII*, eds. H. F. Stettler and N. A. Ford, Lawrence, University of Kansas (1984).
- Newton, J. D., and R. H. Ashton, "The Association Between Audit Technology and Audit Delay," Working Paper, Duke University (1988).
- O'Brien, W. R., "Developing 'Expert Systems': Contributions from Decision Support Systems and Judgment Analysis Techniques," *R&D Management* (1985), pp. 293-303.
- O'Leary, D. E., "Validation of Expert Systems—With Applications to Auditing and Accounting Expert Systems," *Decision Sciences* (Summer 1987), pp. 468-486.
- Peterson, D. K., and G. F. Pitz, "Effect of Input From a Mechanical Model on Clinical Judgment," *Journal of Applied Psychology* (January 1986), pp. 163-167.
- Pitz, G. F., and N. J. Sachs, "Judgment and Decision: Theory and Application," *Annual Review of Psychology* (1984), pp. 139-163.
- Rauch, H. E., "Probability Concepts for an Expert System Used for Data Fusion," *The AI Magazine* (Fall 1984), pp. 55-60.
- Richels, R., "Building Good Models is Not Enough," *Interfaces* (August 1981), pp. 48-54.
- Robey, D., and R. L. Zeller, "Factors Affecting the Success and Failure of an Information System for Product Quality," *Interfaces* (February 1978), pp. 70-75.
- Rohrmann, B., "Evaluating the Usefulness of Decision Aids: A Methodological Perspective," In *New Directions in Research on Decision Making*, eds. B. Brehmer, H. Jungermann, P. Lourens, and G. Sevon, Amsterdam, North-Holland (1986).
- Schultz, R. L., and D. P. Slevin, (eds.) *Implementing Operations Research/Management Science*, New York, Elsevier (1975).
- Schultz, R. L., D. P. Slevin, and J. K. Pinto, "Strategy and Tactics in a Process Model of Project Implementation," *Interfaces* (May-June 1987), pp. 34-46.
- Sharda, R., S. H. Barr, and J. C. McDonnell, "Decision Support System Effectiveness: A Review and an Empirical Test," *Management Science* (February 1988), pp. 139-159.
- Sheil, B., "Thinking About Artificial Intelligence," *Harvard Business Review* (July-August 1987), pp. 91-97.
- Skinner, R. M., and R. J. Anderson, *Analytical Auditing*, Toronto, Pitman (1966).
- Slovic, P., B. Fischhoff, and S. Lichtenstein, "Behavioral Decision Theory," *Annual Review of Psychology* (1977), pp. 1-39.
- Staw, B. M., "Rationality and Justification in Organizational Life," *Research in Organizational Behavior* (1980), pp. 45-80.
- Stefik, M., J. Aikins, R. Balzer, J. Benoit, L. Birnbaum, F. Hayes-Roth, and E. Sacerdoti, "The Organization of Expert Systems: A Tutorial," *Artificial Intelligence* (March 1982), pp. 135-173.
- Sullivan, J. D., "The Case for the Unstructured Audit Approach," In *Auditing Symposium VII*, eds. H. F. Stettler and N. A. Ford, Lawrence, University of Kansas (1984).
- Tetlock, P. E., "Accountability and Complexity of Thought," *Journal of Personality and Social Psychology* (July 1983), pp. 74-83.
- Tetlock, P. E., "Accountability: The Neglected Social Context of Judgment and Choice," *Research in Organizational Behavior* (1985), pp. 297-332.
- Tversky, A., "Elimination, by Aspects: A Theory of Choice," *Psychological Review* (July 1972), pp. 281-299.

- Urban, G. L., "Building Models for Decision Makers," *Interfaces* (May 1974), pp. 1-11.
- Vazsonyi, A., "Decision Support Systems: The New Technology of Decision Making?" *Interfaces* (November 1978), pp. 72-77.
- von Winterfeldt, D., and W. Edwards, *Decision Analysis and Behavioral Research*, New York, Cambridge (1986).
- Wagner, G. R., "Decision Support Systems: The Real Substance," *Interfaces* (April 1981), pp. 77-86.
- Ward, B., "The Proposed Analytical Procedures Standard: A Postprandium," *The Auditor's Report* (Summer 1987), pp. 1-3.
- Watson, H. J., and P. G. Marett, "A Survey of Management Science Implementation Problems," *Interfaces* (August 1979), pp. 124-128.
- Williams, D. D., and M. W. Dirsmith, "The Effects of Audit Technology on Auditor Efficiency: Auditing and the Timeliness of Client Earnings Announcements," Working Paper, The Pennsylvania State University (1987).
- Willingham, J. J., "Audit Research and its Role at Peat Marwick," Internal Memorandum, New York, Peat Marwick Main & Co. (1986).
- Wolek, F. W., "Implementation and the Process of Adopting Managerial Technology," *Interfaces* (May 1975), pp. 38-46.
- Wright, W. F., "Discussant's Comments on: 'Expert Systems in Accounting and Auditing: A Framework and Review'," In *Decision Making and Accounting: Current Research*, eds. E. Joyce and S. Moriarity, Norman, University of Oklahoma (1984).
- Zand, D. E., and R. E. Sorensen, "Theory of Change and the Effective Use of Management Science," *Administrative Science Quarterly* (December 1975), pp. 532-545.
- Zmud, R. W., "Individual Differences and MIS Success: A Review of the Empirical Literature," *Management Science* (October 1979), pp. 966-979.

## Appendix

A sample of "implementation studies" is included in this Appendix. Most of these studies involve computer-based information and decision support systems, or operations research/management science models. Similarities may exist between the problems encountered in introducing or implementing information systems or management science models and those likely to be encountered in implementing audit decision aids. Almost all of the articles listed here have an extremely "practical" orientation, focusing on factors claimed to affect the successful or unsuccessful introduction of an information system or a management science model. The articles describe surveys of developers and users of systems or models, as well as personal experiences of the authors with successful and unsuccessful implementation efforts. Eighteen articles are briefly annotated, and the references for another 26 are provided without comment. We regard the annotated articles as potentially more promising for auditing practitioners and researchers; the others tend to be less comprehensive or somewhat redundant with those that are annotated.

1. Adelman [1982]: Presents the author's view that unsuccessful implementation of decision aids is caused largely by lack of user involvement in the development process; offers the argument that user involvement enhances understanding of, and commitment to, the aid and enables the aid to be tailored to the user's needs.

2. Elam and Konsynski [1987]: Argues that decision support systems are not being used as interactive problem solving vehicles as originally envisioned; offers advice on how this situation might be rectified.

3. Fuerst and Cheney [1982]: Reviews a large amount of research literature on the implementation and use of computerized decision support systems. Factors found to affect the use of such systems are discussed under



three headings: characteristics of the decision maker, characteristics of the implementation process, and characteristics of the decision support system.

4. Ginzberg [1978]: Discusses types of implementation research that have been conducted and concludes that the only firmly-established research result is the importance of management support and user involvement; offers advice about successful implementation, including the importance of recognizing that several users may be involved and that they are likely to have different goals and expectations about the model or system being implemented.

5. Ginzberg [1981]: Analyzes the role of users' unrealistic expectations as a factor in the failure of management information systems and decision models; has some suggestions about bringing expectations in line with the capabilities of the system/model, and vice versa.

6. Green, Newsom and Jones [1977]: The principal findings relate to potential barriers to the use of quantitative techniques. While a lack of knowledge of such techniques by management is the most important barrier, lack of useful training, difficulty of quantifying data, and cost are also important barriers.

7. Gupta [1977]: Offers advice based on the author's personal experience; advises not threatening the user's authority, among other things.

8. Huber [1983]: Reviews research on the relationship between the use of decision support systems and the "cognitive styles" of users; concludes that cognitive style is not related to the use of decision support systems; suggests, among other things, that it is better to train users in the appropriate use of such a system than to try to design the system to fit particular cognitive styles.

9. Ives and Olson [1984]: Reviews research on the effects of user involvement in the development of computer-based information systems; concludes that because of poor grounding in theory and methodological problems, a positive relationship between user involvement and system success has not been convincingly demonstrated.

10. Leonard-Barton and Kraus [1985]: Discusses obstacles that must be overcome in the implementation of new technology; suggests strategies for successful implementation, with particular attention to the composition of the implementation team.

11. Little [1970]: Provides an excellent discussion, distilled from the author's own experience, of why managers often do not use models that have been developed for them; also discusses six characteristics that a model should possess in order to be useful (and used). Several worthwhile points are made.

12. McArthur [1980]: Based on personal experience, the author discusses three reasons for the gap between development and use of management science models: (1) technical elegance vs. "people factors"; (2) reluctance of decision makers to admit they sometimes need help with decisions; (3) confidentiality of certain types of important decisions.

13. Mohan and Bean [1979]: Four case studies of implementation efforts are described, and several implications for successful implementation are derived. These implications fall into three broad categories, with a number of useful points made within each: (1) preconditions for successful introduction, (2) introductory period requirements, and (3) on-going period requirements.

14. Robey and Zeller [1978]: Analyzes the successful adoption and use of an information system in one department of a company, and the rejection and

failure of the same system in a similar department of the same company; makes a number of points about the organizational and human factors that were important in the success (and in the failure).

15. Urban [1974]: Based on the research literature and the author's experiences with actual companies, an eight-point plan for building useful models is presented. Several relevant points are made.

16. Watson and Marett [1979]: A survey of management scientists, disclosing ten major reasons for implementation problems; lack of understanding by users is most important, but other reasons are also discussed.

17. Wolek [1975]: Views the adoption of models and other quantitative technology in terms of the theory of adoption/diffusion of innovations, on which there is a substantial literature; a useful perspective on the factors that are important in successful adoptions.

18. Zand and Sorensen [1975]: Applies a general theory of social change, proposed in 1947 by psychologist Kurt Lewin, to the problem of implementing management science methods/models; oriented toward an "academic" research audience; contains a useful overall perspective on change, as well as several specific ideas.

Other references that may be helpful are Alavi and Henderson [1981], Alter [1977], Anderson and Narasimhan [1979], Annino and Russell [1981], Argote et al. [1983], Ashton and Ashton [1988], Bell [1985], Cain [1979], Carter [1984], Emshoff [1978], Evan and Black [1967], Glen and James [1980], Grayson [1973], Hammond [1974], Hayes and Nolan [1974], Lawless [1987], Lucas [1981], McInnes and Carleton [1982], Meredith [1981], Richels [1981], Schultz and Slevin [1975], Schultz et al. [1987], Sheil [1987], Vazsonyi [1978], Wagner [1981], and Zmud [1979].