THE CONSTRUCTION OF AN EXPERT SYSTEM TO MAKE MATERIALITY JUDGMENTS

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ABSTRACT

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Previous research on materiality has focused on the judgments that are made when evaluating audit evidence. However, auditors also make materiality judgments to help plan the nature, timing, and extent of the audit procedures that will be used to provide audit evidence. These judgments have a direct effect on audit efficiency and effectiveness. This study examines how auditors make these preliminary judgments of materiality.

Traditional techniques used to study auditor judgments (e.g., the lens model) only measure the relationship between decision inputs and outputs; they do not explain how those inputs are used to make the judgment. This study constructs an expert system, called AUDITPLANNER, which is capable of actually making materiality judgments. Analysis of AUDITPLANNER's decision rules reveals how various input factors are used to make materiality judgments.

Analysis of AUDITPLANNER's decision rules indicates that the preliminary materiality judgment is influenced by (1) the characteristics of the company being audited, (2) the perceived needs of the users of the financial statements, and (3) the degree of risk associated with the audit and the auditor's own attitudes toward such risk.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The concept of materiality is the cornerstone of auditing. The auditor's opinion that an enterprise's financial statements "present fairly" the results of operations implies that those statements are not materially misstated [AICPA, 1983, para. 3]. In planning the audit, a materiality judgment is made to help determine the extent of testing needed to provide sufficient evidence upon which to base an opinion. Another materiality judgment is made to evaluate the results of those tests. No wonder that Statement on Auditing Standards (SAS) No. 1 states that "the concept of materiality is inherent in the work of the independent auditor" [AICPA, 1979, para. 150.04].

The importance of the concept of materiality is also apparent from its inclusion on the Financial Accounting Standards Board's (FASB) original agenda. The FASB issued a Discussion Memorandum [FASB, 1975] on the topic in an effort to develop some guidelines for making materiality judgments. That effort ended, however, with the FASB's decision that such guidelines were not feasible.

> The Board's present position is that no general standards of materiality could be formulated to take into account all the considerations that enter into an experienced human judgment [FASB, 1980, para. 131].

SAS No. 47 describes the resulting state of affairs and summarizes the reason the reasoning behind the FASB's decision:

> The auditor's consideration of materiality is a matter of professional judgment and is influenced by his perception of the needs of a reasonable person who will rely on the financial statements. [Those needs] . . . are recognized in the discussion of materiality [by the FASB, cited above] . . . that discussion recognizes that materiality judgments are made in light of surrounding circumstances and necessarily involve both quantitative and qualitative considerations [AICPA, 1983, para. 6].

Accounting researchers have long been interested in how materiality judgments are made. Holstrum and Messier [1982] review previous empirical research on materiality and conclude that:

> Definitive comprehensive implications for audit practice or policy formulation are difficult to decipher from the materiality research to date [p.59].

They point out that previous research has not examined the effect of the type of entity and its industry classification on materiality judgments, nor has there been an attempt to measure the sensitivity of those judgments to the nature of the event or item for which the judgment is being made.

Moreover, previous research has concentrated on the materiality judgments that are made when evaluating audit evidence. However, auditors also make materiality judgments in the planning stage of the audit to help determine the extent of audit tests and procedures. The lack of attention paid to this type of materiality judgment reflects the general paucity of research on the auditor's initial planning process. Felix and Kinney [1982] state the need for

such research:

> while the amount of research on the auditor's decision processes is growing, the planning decision processes are not being included in this growth. While the complexities of the setting present considerable difficulties, effective planning of the audit is critical to efficient auditing, and research on the planning processes should be encouraged [p.255].

This dissertation seeks to model how materiality judgments are made in the planning stage of the audit. The goal is to explain how circumstantial factors, such as the nature of the company being audited, influence those judgments.

Techniques from the field of artificial intelligence will be used to express the model in the form of a computer program known as a rule-based expert system. Such systems are particularly well-suited to modeling tasks with characteristics such as those found in judgments of materiality.

> When intelligent behavior consists of numerous specialized responses to widely varying and largely unpredictable situations, the antecdent - consequent structure of [rule-based expert systems] isolates and represents the appropriate logic of such data-directed behavior in a natural way [Waterman and Hayes-Roth, 1978, p.22].

The expert systems methodology has been successfully applied to the study of a wide range of tasks in accounting and auditing. Such systems have been built to plan for individual estate taxes [Michaelsen, 1982], to determine the collectibility of delinquent trade accounts receivables [Dungan, 1983; Dungan and Chandler, 1983], to evaluate the causes of fluctuations identified during the process of analytical review [Braun and Chandler, 1982], to analyze EDP controls in an advanced computer system [Hansen and Messier,

1983], to evaluate the quality of internal controls [Gal, 1984], and to decide on the appropriateness of issuing a "subject to" audit opinion [Dillard, Mutchler, and Ramakrishna, 1983].

The construction of an expert system involves the detailed study of the decision making behavior of an expert in order to identify the basis for that behavior. It is, therefore, inherently descriptive research. In fact, one of the principal motivations for using this methodology is to obtain a better unnderstanding of current decision making practices.

> The aim here [in building an expert system] is thus not simply to build a program that exhibits a certain specified behavior, but to use the program construction process itself as a way of explicating knowledge in the field, and to use the program text as a medium of expression of many forms of knowledge about the task and its solution [Davis and Lenat, 1980, p.471].

Descriptive research on current methods of decision making is important.

> The ultimate goal of human information processing research in accounting is to improve decision making. Before decision making can be improved, however, it is useful to evaluate the current quality of decision making, and before decision quality can be evaluated, decision making must be understood [Ashton, 1982, p.vii].

The remainder of this dissertation is organized as follows. Chapter I reviews previous research on materiality. Chapter II discusses the expert system methodology for studying decision making behavior. Chapter III describes the procedure to be used in building the expert system. Chapter IV analyzes the resulting system, examining the rules

contained therein in order to demonstrate how various circumstantial factors affect materiality judgments. Chapter V summarizes the findings and explores possible directions for future research.

CHAPTER I

PREVIOUS RESEARCH ON MATERIALITY

This chapter reviews the results of previous empirical research on materiality. Most of that research has examined materiality in relation to the evaluation of audit evidence. However, materiality considerations also affect the planning of the audit. Consequently, the first part of this chapter discusses the relationship between these two judgments. The second part then examines the research findings on each type of judgment. The final part of the chapter discusses the implications of those results for the current research.

Types of Materiality Judgments

Statement on Auditing Standards (SAS) No. 47 describes two different times during the course of the audit when the auditor needs to consider materiality.

> The auditor should consider . . . materiality both in (a) planning the audit and designing auditing procedures and (b) evaluating whether the financial statements taken as a whole are presented fairly in conformity with generally accepted accounting principles [AICPA, 1983, para. 8].

The purpose of the initial consideration is to ensure that the auditor plans the extent of audit tests so as to provide adequate empirical evidence upon which to base an opinion on the fairness of presentation of the financial statements. In

the second instance, the auditor considers materiality in order to determine the effect on that fairness of presentation of any errors that may have been uncovered by those audit tests.

Theoretical discussions of materiality distinguish between these two judgments, referring to the former as involving "auditing materiality" and the latter as involving "accounting materiality" [CICA, 1965; Leslie, 1977; Thomas and Krogstad, 1978]. These terms will be adopted here. However, it is important to recognize that they do not refer to two different concepts, but only to two different instances of that concept.

In fact, judgments of auditing materiality may be thought of as pro-forma judgments of accounting materiality. Both are concerned with the point at which the amount of errors destroys fairness of presentation: the former makes this determination prior to performing any audit tests, the latter does so after testing is completed. This common concern makes it likely that there are many similarities between the two judgments, so that research on one may provide useful insights into the nature of the other. However, because the two judgments are made at different points in time, they are based on different sets of information and are likely to differ in their conclusions. SAS No. 47 recognizes this difference:

> Assuming, theoretically, that the auditor's judgment about materiality at the planning stage was based on the same information available to him at the evaluation stage, materiality for planning and

> evaluation purposes would be the same. However, it ordinarily is not feasible . . . to anticipate all of the circumstances that may ultimately influence his judgment . . . Thus, his preliminary judgment about materiality ordinarily will differ from his judgment about materiality used in evaluating the audit findings [AICPA, 1983, para. 15].

Consequently, research is needed on both types of materiality judgments. The next section reviews the results of prior research on each judgment.

Determinants of Materiality Judgments

Research on materiality has sought to identify the factors which are used to make materiality judgments and to measure their relative influence on those judgments. Those studies which addressed the issue of accounting materiality are reviewed first.

Judgments of Accounting Materiality

Discussions of materiality in the authoritative literature emphasize that materiality judgments are primarily quantitative in nature, being concerned with whether the item in question is large enough to destroy the fairness of presentation of the financial statements. However, those discussions also point out that it is the relative, rather than the absolute, size of the item that matters. Moreover, qualitative considerations, particularly the nature of the item, also influence those judgments.

> the answer to that question [is the item material?] will usually be affected by the nature of the item; items too small to be thought material if they result from routine transactions may be considered material if they arise in abnormal circumstances [FASB, 1980, para. 123].

The results of empirical research on judgments of accounting materiality tend to support the discussions in the authoritative literature. Studies by Dyer [1975], Pattillo and Siebel [1974], and Pattillo [1975, 1976] used questionnaire cases in which both the characteristics of the firm and the nature of the item upon which the materiality judgment was to be based were varied. The series of studies by Pattillo involved over 700 subjects, and included auditors, bankers, financial analysts, and fincancial executives. Participants were asked to determine the materiality of an error in terms of its effect on the fairness of presentation of the financial statements. Pattillo [1976] summarized the findings of those studies:

> The 'rule of thumb' of 5% to 10% of net income is presently widely used in practice as an overall materiality criterion. The participants demonstrated this criterion to be the primary basis for their initial determination of an item's materiality. However, the criterion was frequently supplemented by other quantitative criteria and was modified when called for by the circumstances existing in the judgment situations [Pattillo, 1976, p.11, emphasis added].

The absolute size of the item and its affect on the earnings trend were two of the other quantitative factors that were consistently ranked high in importance by all participants. However, the nature of the item (e.g., whether it was a contingency, an extraordinary item, etc.) was consistently ranked by all participants across all cases as being the single most important factor influencing their judgments of materiality.

Boatsman and Robertson [1974], Firth [1979], Hofstedt

and Hughes [1977], Messier [1979], and Moriarity and Barron [1976] conducted experimental studies in which several financial characteristics of the firm were systematically varied in order to determine the effects of those characteristics on materiality judgments. These studies all found that the single most important determinant of materiality was the size of the item in relation to net income. The size of the firm [Firth, 1979; Moriarity and Barron, 1976] and the effect of the item on the trend in earnings [Messier, 1982] were quantitative factors of secondary importance.

Most of these experimental studies, however, did not vary the nature of the judgment item. The one exception was the study by Boatsman and Robertson. That study used three types of items: (1) a gain or loss on the sale of noncurrent assets, (2) a change in accounting principle, and (3) a future uncertainty. The nature of the item was found to be significantly related to judgments of its materiality.

In fact, inclusion of this variable in the judgment model markedly improved the model's predictive accuracy. Boatsman and Robertson reported that a simple model based solely on the size of the item expressed as a percentage of income could only accurately predict 65 percent of the subjects' judgments and erred on the side of underdisclosure. However, when two additional variables were added to the model, one to represent the nature of the item, and the other to represent the degree of risk in the audit, the resulting model had a predictive accuracy of 84 percent.

Statistical analysis indicated that most of the improvement was due to the variable representing the nature of the item.

An archival study by Frishkoff [1970] reported similar results about the effect of the nature of the item on judgments of materiality. Frishkoff examined annual reports in an effort to find which variables were useful predictors of a qualified audit opinion. He reported that a discriminant function based solely on the item's effect on net income only classified nine percent of the cases on a better than chance basis. The inclusion of two additional variables, one to represent the size of the client and the other to represent the nature of the item, resulted in a classification accuracy of 91 percent.

Besides the nature of the item, Boatsman and Robertson also found that the level of risk perceived in the audit was significantly related to materiality judgments. Ward [1976] examined auditors' perceptions of the consequences of failing to find an error that affected the amount of net income. There was a large degree of diversity across auditors, with considerable disagreement for those cases in which the effect of the error was to reduce net income. Newton [1977] examined auditors' attitudes towards risk and how the degree of uncertainty about an item's resolution affected judgments of materiality. 55 percent of the auditors were risk-averse, while 34 percent were classified as being risk-seeking. In addition, the degree of uncertainty associated with the item appeared to influence judgments of its materiality.

In summary, previous research indicates that although the size of an item in relation to net income is probably the most important quantitative determinant of accounting materiality, other qualitative factors representing the circumstances in which the judgment is made are also important. In particular, both the nature of the item and the auditor's perception of the personal risk associated with the audit (should material errors go undetected) appear to influence judgments of accounting materiality.

Judgments of Auditing Materiality

Only two studies examined the materiality judgments that are made when planning the extent of audit tests and procedures. Cushing, Searfoss, and Randall [1979] asked auditors to estimate the overall level of materiality for an audit and then tested a model designed to allocate that estimate among various financial statement accounts. The study did not specifically address the issue of how auditors make such estimates, but it did find that auditors expressed a high degree of confidence in the accuracy of those judgments.

Moriarity and Barron [1979] conducted an experiment which did attempt to determine how judgments of auditing materiality are made. Partners of a major public accounting firm were given summarized financial statements for thirty hypothetical companies and asked to establish the overall materiality level that should be used to plan audit tests and procedures. Five financial variables were manipulated:

net income, total assets, the debt-to-equity ratio, the number of shares outstanding, and the trend in earnings. (Total assets was varied by using financial statements that were multiples of one another).

The results indicated that net income was the most important factor affecting the judgments of four of the five partners, with total assets being most important for the fifth. Total assets was second in importance for two partners, while the earnings trend was second in importance for the other three. In addition, there was evidence of a breakeven effect: the importance of net income declined as it approached the breakeven level.

Moriarity and Barron did not provide the participants with any background qualitative information about the firms for which the materiality judgments were to be made. In post-experimental debriefings, the participants complained about the lack of such information.

> Most participants indicated that they would be more familiar with the operations of their clients, the type of management, and management objectives. Thus, some of the participants said they would like to have known what industry we were dealing with, to whom the audit report would be distributed, and what kinds of audit problems had been experienced in the past [Moriarity and Barron, 1979, pp.129-130].

Discussions in the authoritative literature indicate that such information is important.

> an amount that is material to the financial statements of one entity may not be material to the financial statements of another entity of a different size or nature. Also, what is material to the financial statements of a particular entity might change from one period to another [AICPA, 1983, para. 5].

> For example, in an enterprise with few, but large, accounts receivable, the accounts individually are more important and the possibility of material error is greater than in another enterprise that has a great number of small accounts aggregating the same total. In industrial and merchandinsing enterprises, inventories are usually of great importance to both financial position and results of operations and accordingly may require relatively more attention by the auditor than would inventories of a public utility company [AICPA, 1979, para. 150.04].

A study by Gibbins and Wolf [1982] provides some empirical support for the importance of such factors in making judgments of auditing materiality. Auditors from six public accounting firms were asked to rank various environmental factors in terms of their importance in affecting the conduct of an audit at various stages in the audit process. Although the study addressed the conduct of the audit as a whole, and not materiality, the relationship between planning and materiality noted in SAS No. 47 suggests that the findings for the planning stage of the audit may apply to auditing materiality as well.

> the nature, timing, and extent of planning -- and thus of the considerations of audit risk and materiality -- vary with the size and complexity of the entity, the auditor's experience with the entity, and his knowledge of the entity's business [AICPA, 1983, para. 11].

Gibbins and Wolf found that the following qualitative factors were important in the planning stage of the audit: (1) the service needs of the client, (2) information from prior years' audit programs and file notes, (3) plans for the sale or major financing of the client, and (4) the nature of the client's business.

In summary, the results of the three studies reviewed

in this section tend to indicate that there are similarities between the two types of materiality judgments. The primary financial variable used in both judgments appears to be the amount of net income. That factor is supplemented, however, by other qualitative factors. In the case of accounting materiality, the most important qualitative factor is information about the nature of the judgment item. In the case of auditing materiality, because those judgments are estimates of what size errors would be material it is likely that information about the nature of the company should be of primary importance.

Implications of Prior Research Findings

Two aspects of previous research have important implications for this dissertation: (1) the types of cases used to study materiality judgments, and (2) the role of circumstantial variables in those judgments.

Types of Cases Used Previously

A major problem with previous experimental research on materiality judgments is the abstract nature of the cases that were used. Many of the qualitative factors mentioned in both the results of questionnaire studies and in discussions in the authoritative literature as being important determinants of materiality (e.g. the nature of the item, the nature of the company's business) were either omitted entirely or were presented in a summary manner. The quantitative factors used in the cases were also typically highly summarized. The

following example, taken from the Hofstedt and Hughes study is typical. The case deals with a loss from the writedown of a subsidiary, and participants were asked to state the probability that they would disclose it as an extraordinary item because it was material.

Case A:

> The loss is 5% of operating income, 5% of parent investments, and 10% of subsidiary book value [Hofstedt and Hughes, 1977, p.388, format modified].

The use of such predigested and highly aggregated cues may produce behavior different from what would be observed outside the laboratory [Ebbesen and Konecni, 1980]. Indeed, in post-experimental debriefings, participants in many of the studies complained about the abstract nature of the cases and indicated that they would have liked to have had additional information to use in making their judgments. Newton [1977] described the nature of this information:

> All participants claimed that they needed more information because of the many factors which merit consideration in materiality decisions. Typically, questions were asked concerning the firm's balance sheet, environment (industry and economic conditions), history, management, accounting policies, previous materiality decisions, etc. [p.106].

Clearly, future research needs to find ways to use more realistic cases. One advantage of the use of expert systems is that their refinement entails using them to solve real examples of the problem being studied. Thus, all the information normally available is included in the research study.

Role of Circumstantial Variables

The results of previous research indicate that two circumstantial factors, the nature of the item and the level of perceived risk, both influence judgments of accounting materiality. The results of the Gibbins and Wolf study and the discussions in the authoritative literature lead one to suspect that qualitative information about the company being audited plays a similarly important role in judgments of auditing materiality. After all, if the nature of a known error affects judgments about the materiality of that error, then information about the nature of the company and the users of its financial statements should affect judgments about the level of errors that, if found, would be material.

However, although there is some evidence concerning which factors influence materiality judgments, little is known about why those factors are important, and how they enter the judgment process. As Carroll [1980] explains, to acquire such knowledge requires more than merely relating decision variables to the final decisions; it requires examining the processes leading up to the decision:

> The decision analyst is misdirected by the importance of the moment when the decision maker identifies a selection. We are seduced by language and common sense into believing that the choice is the decision. Yet . . . the choice is the end product of the decision, the moment when we see the pigeon in the magician's hand. The decision is the process of arriving at a choice, the process by which the pigeon got into the magician's hand [p.69]

Researchers in the fields of both artificial intelligence and cognitive psychology argue that traditional

statistical modeling methods are inappropriate for building models which really explain how judgments are made.

> The problem, of course, is that statistical methods are not good models of the actual reasoning process, nor were they designed to be. . . . [they are] for the most part, 'shallow', one-step techniques which capture little of the ongoing process actually used by expert problem solvers in the domain [Davis, Buchanan, and Shortliffe, 1977, p.39].

> the output of a quantitative mechanism, be it numerical, statistical, analog, or physical (nonsymbolic), is too structureless and uninformative to permit further analysis. Number-like magnitudes can form the basis of decisions for immediate action, . . . but each is a 'dead end' so far as further understanding and planning is concerned, for each is an evaluation and not a summary. A number cannot reflect the considerations that formed it.
>
> This does not mean that people do not, or even that they should not, use such methods. But because of the block they present to further contemplation, we can predict that they will tend to be focused in what we might call terminal activities. In large measure, these activities may be just the activities most easily seen behavioristically and this might account in part for the traditional attraction of such models to workers in the behavioristic tradition. The danger is that theories based upon them -- response probabilities, subjective probabilities, reinforcement schedule parameters -- are not likely to be able to account for sophisticated cognitive activities. As psychological theories they are very likely to be wrong [Minsky, 1975, p.275].

In place of traditional statistical models, the use of models based on the production system architecture is urged in those situations where the goal of the research is to understand how the decision was made.

> A final advantage of [production systems] is their ability to represent the role of the environment in governing the [subject's] behavior in a way that a more conventional process model cannot. For a [production system] presents the set of possible actions that the subject can take together with the basis on which he decides between them, whereas a flow-chart or algorithm states only the outcome of that decision [Young, 1978, p.397, emphasis added].

The expert system to be built in this dissertation is based on the production system architecture. The next chapter describes the nature of that architecture and discusses its use as a means of studying decision making behavior.

CHAPTER II

THE USE OF EXPERT SYSTEMS TO STUDY DECISION MAKING BEHAVIOR

The production system architecture has been used to build rule-based expert systems which perform a wide variety of tasks. Examples inlcude systems which diagnose infectious diseases [Shortliffe, 1976], analyze the molecular structure of chemical compounds [Buchanan, Sutherland, and Feigenbaum, 1969, 1970], prospect for mineral ores [Gaschnig, 1982], and diagnose faults in computer systems [Hartley, 1979].

This chapter begins by describing the essential features of the production system architecture underlying such systems. Then the theoretical paradigm underlying the use of that architecture to study decision making behavior is presented. The final section of the chapter discusses the status of expert systems as psychological theories of expertise in the task domain being modeled.

The Production System Architecture

A production system consists of three components: (1) a production memory or knowledge base, (2) an executive or inference engine, and (3) one or more working memories [Feigenbaum, 1979; Hayes-Roth, Waterman, and Lenat, 1978; Newell, 1973, 1980a]. The following sections discuss these

three components in more detail.

Production Memory

Production systems get their name because they represent knowledge about relationships among domain variables in th form of conditional rules known as productions. Each rule is of the form: situation => action. The left-hand side of the rule consists of a set of clauses which describe the situation in which that rule applies; the right-hand side describes the actions or inferences that occur when the rule is executed or "fired". Three of the rules found in AUDIT-PLANNER (the name given to the expert system built in this dissertation) are presented below:

Rule 1 IF: 1) the client is a public entity, and
2) there is no significant concern about the liquidity or solvency of the client
THEN: it is assumed that the principal external users of the financial statements are primarily interested in information about the results of current operations.

Rule 2 IF: 1) the principal external users of the financial statements are primarily interested in the results of current operations, and
2) net income is above the break-even point
THEN: the materiality judgment should be

based on net income.

Rule 3 IF: 1) the basis for making the materiality judgment is known, and

2) the percentage rate for making the materiality judgment is known

THEN: the materiality level equals the product of the percentage rate times the base used to make the materiality judgment.

In the next section, these rules will be used to illustrate the various control strategies for production systems.

Inference Engine

The inference engine is the control strategy for guiding the selection and execution of particular rules. This control strategy can be described as a recognize-act cycle. This strategy can be implemented as either a forward- or a backward-chaining reasoning process.

Forward-chaining. In a forward-chaining or data-directed strategy each recognize-act cycle begins by comparing the facts that describe the current state of the world to the situation part of each production rule. Each rule which has its conditions for firing satisfied is placed into a conflict resolution set. After the entire set of production rules has been so examined, one of those in that set is selected and fired. The method of selection is called the conflict resolution rule. The firing of the rule constitutes

the action part of the cycle. An inference is made, and the state of the world is changed. If that change has resulted in the goal being attained, the system stops and reports success. If not, the entire cycle begins again with every rule being compared to the new set of facts describing the world. If no rules have their conditions for firing satisfied on a particular cycle, the system stops and reports failure.

The following example, using the three rules presented earlier, illustrates how this forward-chaining process leads to a particular decision. When information is obtained that the client is a public entity and that there is no concern about liquidity or solvency, rule 1 would fire. Its firing would add to working memory the assertion that the users of the financial statements are primarily interested in the results of current operations. This would satisfy the first premise clause of rule 2. Upon receipt of information that net income is above the break-even point, rule 2 would fire. Its firing would result in the assertion that the materiality judgment should be based on net income. At this point, clause 1 of rule 3 would be satisfied; as soon clause 2 is satisfied, rule 3 would fire and the materiality judgment would be made.

Backward-chaining. In a backward-chaining or goal-directed reasoning strategy each recognize-act cycle begins by examining the action part of the production rules in the knowledge base. Only those rules whose firing will attain

the current goal are checked to see if their situation part is satisfied. If any such rules are found, they are fired and the system stops and reports success. If the rules that will attain the current goal do not have their situation part satisfied, then a new set of sub-goals for satisfying those conditions is established. Each rule in the production memory is then checked to see if its firing would alter the current state of the world and attain the current sub-goals. Those rules are then checked again to see if they can fire. This backward-chaining continues until either some rule is finally found which can fire or no such rule is found. In the former case, firing that rule leads to a chain of firings that eventually attains the goal; in the latter case, the system stops and reports failure.

The set of three rules presented earlier can be used to illustrate this backward-chaining reasoning process. The system begins with the goal of making a judgment of materiality. Scanning the action parts of the three rules reveals that firing rule 3 would satisfy this goal. Consequently, the premises of rule 3 would be matched against the contents of working memory to ascertain whether they are satisfied by the facts known about the current situation. Neither premise is likely to be satisfied at the start of a consultation, so the verification of each of rule 3's premise clauses would become the new subgoals. The system would then scan the action parts of the remaining rules to see if the firing of any of them would satisfy the current subgoals. This would

reveal that firing rule 2 would establish the appropriate base to be used for making the materiality judgment. Both of rule 2's premises would then be checked to see if they were satisfied by the facts and assertions stored in working memory. The process would eventually lead the system to try to establish the premises for rule 1 so that the first premise of rule 2 could be satisfied.

It should be clear that with either type of control strategy the production system architecture exhibits behavior that is responsive to the facts of the case at hand. Although the set of production rules is fixed, the particular set of rules that fires on any session, and the order in which they fire, depends upon the facts that describe the current consultation.

Working Memories

The working memories function as a scratchpad to keep track of the goals being sought and the current state of progress toward their attainment. The set of facts that describes the world and which is compared to the situation part of each rule is contained in these working memories, as are any sub-goals that have been created.

Now that the basic features of the production system architecture have been described, it is time to discuss the theoretical paradigm underlying the use of that architecture as a means of studying decision making behavior.

The Information Processing Paradigm

The information processing paradigm focuses attention on the internal cognitive processes that underly observable behavior. Young [1978] contrasts this approach to the functional or behaviorist paradigm:

> Unlike a functional approach which tends to ask questions about the effect of various controllable factors on certain gross measures of the subject's performance... the information processing approach prefers to ask questions directly about how the [subject] is carrying out the task, seeking an answer in terms of the psychological processes and representations that underlie his behavior [p.360].

Newell and Simon's [1972] study of one basic cognitive activity -- problem solving -- led to the development of many of the essential ideas in the information processing paradigm. Their theory of human problem solving behavior is illustrated in Figure 1.

The figure shows that the problem solver forms an internal representation of the task that reflects how he or she perceives the task. It is this subjective interpretation of the task, rather than the objective statement of the problem, that governs all subsequent cognitive activity. The problem solver possesses a store of methods for solving various tasks and also a store of factual knowledge. The basic cognitive activity consists of a search through these stores for knowledge that can be applied to solve the problem.

Thus, problem solving behavior is basically a function of three variables: (1) the task environment, (2) some basic structural characteristics of the problem solver, and (3) the specific knowledge possessed by the problem solver. The

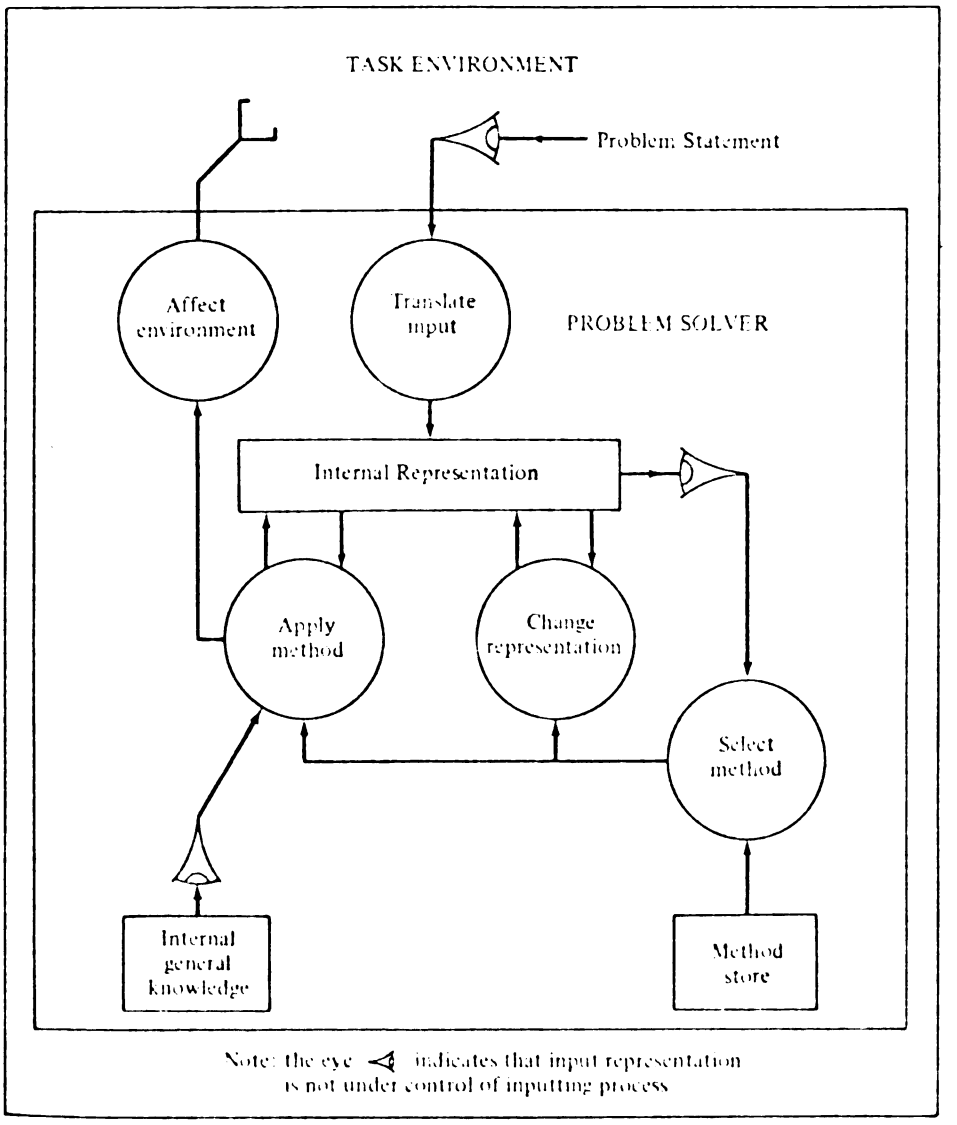

Figure 1. Theory of Problem Solving Behavior

Source: Newell and Simon (1972. p.89)

role of each of these elements is discussed in more detail below.

Effect of the Task Environment

The effect of the task environment on decision making behavior has long been recognized [Brunswik, 1955a,1955b]. The task environment includes both the structural properties of the task and the specific content of the task [Einhorn and Hogarth, 1981; Payne, 1982]. Normative theories get their generality by focusing on the former and ignoring the latter. But Newell and Simon's theory of problem solving indicates that it is the problem solver's subjective perception of the task that governs behavior. A great deal of evidence suggests that the content of the task plays an important role in shaping this subjective representation. Thus, task content may have an even greater effect on behavior than do the formal properties of the task.

For example, Einhorn and Hogarth [1982] found that changes in the composition of the set of alternative hypotheses that did not alter the objective probability of that set did produce a change in its subjective probability. In one experiment, they asked subjects to decide what foreign language was spoken by a group of robbers. Subjects in one condition were told that four eyewitnesses said that they had heard the thieves speaking in German and four others had said that it was Italian. Subjects in the other condition were told that four eyewitnesses said it was German, two said it was French, one said Spanish, and one Italian. Note

that in both conditions one-half of the eyewitnesses said that they had heard the robbers speaking in German. Yet, the subjects in the second condition were were much more certain than were the subjects in the first condition that the language was German.

Changes in task content can directly affect the level of performance. Adelman [1981] found that realistic task content facilitated subjects' ability to learn from outcome feedback. He had subjects predict grade point averages. When given only abstract cues (e.g., Cue 1, Cue 2) outcome feedback was not very helpful. But when the cues were correctly labeled (e.g., expectations for academic achievement) subjects were able to use outcome feedback to markedly improve their performance. Similarly, subjects' performance on a task involving syllogistic reasoning markedly improved when the syllogisms included realistic causal relationships with which the subjects were familiar [Cox and Griggs, 1982; Hoch and Tschirgi, 1983].

Task content can also hide formal task properties, so that subjects cannot apply previously learned strategies. The ease with which problems that have identical formal properties can be solved varies with the particular content of the task [Newell and Simon, 1972; Hayes and Simon, 1977].

Changes in task content induced by altering the way in which the problem is worded can even lead to a reversal in preferences [Kahneman and Tversky, 1979; Tversky and Kahneman, 1981]. Apparently, small changes in wording

dramatically alter the meaning of the choice. Tversky and Kahneman [1981] provide a graphic illustration. They asked subjects to choose one of two strategies for dealing with a flu epidemic that was expected to kill 600 people if nothing was done. One wording of the choice was as follows: Option one will save 200 people, while option two has a one-third chance of saving all 600 but a two-thirds chance of saving no one. The other wording was: Option one will result in the deaths of 400 people, while option two has a one-third chance of no deaths but a two-thirds chance of 600 deaths. Many subjects reversed their choices when the wording was changed.

In summary, the content of the task appears to significantly affect the way in which the task is perceived, and thus the ultimate behavior of decision makers. Since subtle changes in the way in which a task is described can produce major changes in behavior, it is important that the setting of a task be as realistic as possible. A major advantage of using expert systems to study decision making behavior is that subjects are permitted to act in naturally occuring decision settings. The means by which this is achieved is explained in Chapter III's discussion of the research methodology.

Structural Characteristics of the Problem Solver

The structural characteristics of the problem solver include: the size and nature of memory, the speed with which memory can be accessed to either retrieve old knowledge or

to store new knowledge, and the nature of the basic cognitive processes underlying behavior. Two facets of the latter are of particular importance: (1) heuristic search as the fundamental cognitive activity in problem solving, and (2) the use of symbols to represent knowledge and the manipulation of those symbols as the basic means of reasoning.

Heuristic search. Simon [1980] stated that heuristic search is the principal mechanism underlying intelligent problem solving behavior in both humans and computers. To say that search is heuristic means that it is guided by knowledge about the particular task under consideration and uses that knowledge to quickly focus in on the heart of the problem. This is in contrast to a "blind", exhaustive search wherein each possible action that can be taken is tried until either one works or none do.

One reason for heuristic search is that for many problems there does not exist any formal algorithm that is guaranteed to produce a solution. Often there may not even be a clearly defined criterion. Such problems are called ill-structured or ill-defined problems. Judgments of materiality are an example of an ill-structured problem. In contrast, inventory control is a well-structured problem with a known algorithm (the EOQ formula) for its solution.

The problem solver is not left totally in the dark when attempting to solve an ill-structured problem. Often there is a good idea of what the important subgoals are, but no fixed method for achieving them. For example, an auditor

may know that the determination of materiality involves applying some percentage to a base. There just does not exist any general formula that can be applied to all clients. Instead, the auditor relies upon experience gained from prior audits to determine what the appropriate base and percentage is for this particular client. The production system architecture underlying expert systems is well-suited to capturing this type of conditional, pattern-directed behavior.

Even when some general algorithm does exist, time constraints may preclude its use and make an heuristic search necessary. Raphael [1976] gives a good example of this in the context of solving cryptarithmetic problems such as the following:

```
  BEST
+ MADE
------
 MASER
```

The goal is to assign a unique digit to each letter so that the equation is true. A blind, exhaustive search of all possible combinations is certain to produce the answer, but such a search would require considering 1,814,400 possible assignments of digits to letters. This approach is not only inefficient, it is clearly not very intelligent either. Basic knowledge of arithmetic can be used to dramatically reduce the size of the search space. For example, it is obvious that the letter M must be assigned the digit one because that is the largest carry that can be generated by adding two single digits. That fact alone reduces the search

space by a factor of ten. (The answer to the problem is: M=1, A=0, B=9, D=8, S=6, T=7, R=2, and E=5).

In summary, problem solving involves searching for a way to solve the problem. To be effective, the search must utilize knowledge about the domain acquired previously. The use of that knowledge makes the search heuristic. The production system architecture is well-suited for exhibiting this type of behavior.

Reasoning by manipulating symbols. A basic tenet of the information processing paradigm is that concepts are represented by symbols and that reasoning involves the manipulation of those symbols [Lachman, Lachman, and Butterfield, 1979]. Symbols are not merely tokens that label some concept; rather, they contain the essence of the concept and permit that essential meaning to be accessed whenever the symbol is processed [Newell, 1980b]. For example, "Cash" is a symbol, and whenever the problem solver processes that symbol its meaning (e.g., that it is a monetary current asset, is easily misappropriated, etc.) is available and guides the processing. Task context influences behavior by indicating which of these meanings is most relevant for the given situation. Thus, when doing foreign currency translation the fact that Cash is a monetary current asset is most salient and is retrieved first from memory. On the other hand, when evaluating the quality of internal controls, the susceptibility of cash to theft becomes more relevant.

Symbols can be grouped into symbol structures in order

to represent more complex ideas. For example, the following set of symbols represents the current ratio: (Quotient Current-Assets Current-Liabilities). New symbols can be created, in turn, to represent these structures (e.g., Current-Ratio). In this way, the problem solver can react to new situations and "learn".

Human behavior is characterized by its interruptibility and temporal correlations. That is, work on a task can be temporarily suspended and resumed later without having to start over from the beginning (within limits, of course). Most behavior is also purposive; actions are taken in order to accomplish something definite. Such behavior is said to be goal-directed. The existence of goals accounts for the temporal correlations of behavior: a sequence of actions has a common purpose. Goals are also necessary for interruptibility: they serve as reminders of what was being sought after.

Goals can be built directly into the system or represented by means of symbols. Decision flowcharts are an example of the former approach: the problem with adopting that approach is that it limits the ability to adequately respond to minor changes in the task:

> Knowledge about the particular managerial situation is <u>implicit</u>, not explicit, in a decision flow chart .. . because the reasons for a particular branching are not available to the program, in general it cannot make even simple deductions about them. Thus, unless the situation matches exactly a series of branches in the flow chart, the program is helpless. Its lack of underlying knowledge prevents it from adjusting its approach to a variation of the managerial problem [Gorry and Krumland, 1983, p.215].

Representing goals in the form of symbols overcomes these problems. New symbols can be created to represent the features in the task that differ from the "average" task, and that difference can itself be represented symbolically. A new subgoal then is to find some method of resolving that difference. Consequently, Newell [1980b] argues that the ability to manipulate symbols is a prerequisite for intelligent behavior.

The Problem Solver's Knowledge

Symbols are used to represent the problem solver's knowledge, the third major determinant of behavior in Newell and Simon's theory. In Figure 1, that knowledge was seen to consist of a store of problem solving methods and general factual knowledge. Researchers in artificial intelligence have long debated about the nature of that knowledge. In particular, they have argued over whether expertise was due to some powerful, general reasoning techniques or whether it resulted from a large store of specific knowledge.

> The neat view of AI [artificial intelligence] assumes that a few elegant principles underlie all the manifestations of human intelligence. Discovery of those principles would provide the magic key to the workings of the mind. The scruffy view is that intelligence is a kludge: people have so many ad hoc approaches to so many different activities that no universal principles can be found. . . Every application requires a large amount of domain-specific knowledge that cannot be shared with any other application [Sowa, 1983, p.23].

Anecdotal evidence abounds to support the notion that expertise is based on acquiring domain-specific knowledge. Professionals typically specialize in some particular

subpart of their field in order to become recognized as experts (e.g., EDP auditors, tax accountants, divorce lawyers). In fact, it has been argued that professional judgment in auditing consists of such heuristic rules-of-thumb, or norms. Those rules are acquired through experience and capture the commonalities across classes of audits:

> [The absence of such commonalities] would imply that every audit situation must be assessed in isolation and without reference to any other past assessments of materiality. If this were true, then it would be impossible to acquire any judgment through experience. Such a view of completely unrelated audit situations seems unreasonable. Every decision on materiality must surely be based on both (a) the auditor's understanding of what the general level of significance should normally be considered to be, and (b) his assessment of any special conditions creating unusual significance in the situation in question. The second factor can hardly operate without the first. . . . in making any such judgment the auditor must start, at least intuitively, from some norm [CICA, 1965, p.5].

There are solid theoretical arguments and empirical evidence in support of this view that expertise is characterized by the possession of domain-specific knowledge, and that that knowledge is represented in the form of heuristic rules. Each of these sources of support is discussed next.

The nature of expertise: theory. Card, Moran, and Newell [1983] studied the acquisition of skills in computerized text-editing. They concluded that the development of expertise consisted of the acquisition of domain-specific knowledge to guide the search for a method to solve the task:

> With little control knowledge, the problem solver will wander about the problem space in search of a

> goal state. . . but with training or experience in doing the problem, the problem solver will acquire knowledge for guiding the search and making it more efficient.. . the problem solver may eventually build up enough search control knowledge so that he goes straight to the goal. . . as his search control knowledge increases, he becomes more expert; and his behavior changes from problem solving to cognitive skill [Card, Moran, and Newell, 1983, p.365].

This view of the development of expertise is similar to that found in Anderson's [1982] theory of skill acquisition. Anderson postulated that skill involved the proceduralization of factual knowledge. That is, with experience the factual knowledge of a domain becomes embodied in procedures which can be used to perform the skill. Instead of having to think about what to do in a particular situation, behavior (with practice) becomes automatic. Anderson claims that this is the reason that the verbal protocols of subjects often become less verbose with practice.

Anderson goes on to argue that the refinement of skills involves combining a sequence of simple productions that achieve some action into one larger production; this process is called composition. For example, the first time that a new friend's telephone number is dialed there is a great deal of conscious attention directed to the dialing of each digit. With practice, however, the number can be dialed while carrying on a conversation with someone else. Again, Anderson turns to evidence from verbal protocols. He asked subjects to solve two-column proofs in geometry. As subjects' skill increased with practice, the steps that were verbalized became larger; instead of explaining every little

detail, they began to refer to the rule or principle that was being applied.

Anderson [1982] and Card, Moran, and Newell [1983] both explain that the development of expertise is based on acquiring knowledge about the task through repeated practice. Practice reveals important relationships among variables in the domain. Knowledge of those relationships makes it possible to get to the heart of the matter more quickly.

The nature of expertie: empirical evidence The results of several empirical studies support the notion that expertise is based on domain-specific knowledge. Chi, Feltovich, and Glaser [1981] studied how experts and novices solved physics problems. The main difference was that the experts possessed and effectively used a large body of knowledge about physics principles which the novices did not yet possess. The verbal protocols of the experts contained explicit references not only to the rules that were useful for solving the problem, but also to the reasons for their applicability in the examples. No such references were found in the protocols of novices.

Hunter [1962] studied the ability of the British mathematician, A. C. Aitken, to perform prodigious feats of mental arithmetic. He found that Aitken simply knew a lot of facts about the relationships between various numbers. Aitken also knew when certain rules were appropriate. For example, when asked to decimalize a number, he immediately thought of rules about factoring; when asked to find the

root of a number, different rules came to mind.

Chase and Simon [1973] tested the ability of novice and expert chess players to recall facts from memory. Chess boards were set up based on either a random assignment of pieces or on positions from actual tournament play. Subjects were allowed to look at each board for five seconds and were then asked to reconstruct the positions of the pieces. There was no difference between novices and experts in their ability to recall the random boards, but experts did much better than novices for the realistic boards. The former result indicates that there is no significant difference between expert and novice chess players in their ability to recall facts from their episodic (personal) memory. Therefore, the superior ability of the experts to reconstruct the realistic scenarios must be due to domain-specific knowledge about the relationships between chess pieces that permitted them to store and recall larger "chunks" of the scenarios. With the random boards, experts could not use that knowledge and had to simply try to memorize the positions of the pieces.

Empirical research on expert systems has led to similar conclusions about the nature of expertise. The construction of expert systems has involved extensive examination of the problem solving behavior of experts in a variety of task domains. That body of empirical observation has led to a theory of expertise based on the following two tenets: (1) expertise results from the possession of a large amount of domain-specific knowledge rather than from any superiority

in general reasoning abilities, and (2) the most important part of that domain-specific knowledge consists of heuristic rules of thumb that contain knowledge about relationships among domain variables [Brachman et al., 1983; Feigenbaum, 1979; Hayes-Roth, Waterman, and Lenat, 1983; Stefik et al., 1983a]. It is this store of heuristic knowledge which underlies experts' ability to quickly focus in on the important aspects of a problem and which enables them to deal with incomplete and inaccurate data.

Summary

Lenat [1977] summarizes the theory of cognitive behavior that has been discussed in this chapter:

> The view we choose is that Man is a symbolic information processor. The theory is that sophisticated cognitive tasks can be cast as searches or explorations, and that each human possesses (and efficiently accesses) a large body of informal rules of thumb (heuristics) which constrain his search [p.1093].

Decision making is seen as being a conditional process. The choice of what information to acquire next and the evaluation of that information are both influenced by the information previously acquired. Researchers in artificial intelligence (e.g., Hayes-Roth, Waterman, and Lenat [1983]) and in accounting [Gibbins, 1984] argue that traditional mathematical techniques such as regression cannot be used to model such conditional behavior. (Regression equations, for example, imply that all relevant information is considered simultaneously). Consequently, researchers in both cognitive psychology and artificial intelligence have turned to the

use of the production system architecture to model this type of conditional behavior. The next section discusses the status of the expert systems built on that architecture as theories of the expertise being modeled.

Expert Systems as Psychological Theories

The production system architecture has been used by cognitive psychologists to model a variety of intermediate level tasks such as subtraction [Young and O'Shea, 1981] and speech understanding [Newell, 1980a]. In contrast, research in artificial intelligence has used that same architecture to build systems that perform tasks typically performed by experts (e.g., medical diagnosis). This section discusses the status of both types of systems as being psychological theories of the task being modeled.

The Production System Architecture as a Theory of Cognitive Behavior

Newell and Simon [1972], who developed the essential features of the production system architecture, argued that it accurately modeled the way the mind works:

> We confess to a strong premonition that the actual organization of human programs closely resembles the production system organization. . . . We cannot yet prove the correctness of this judgment, and we suspect that the ultimate verification may depend on this organization's proving relatively satisfactory in many different small ways, no one of them decisive [pp.803-804].

Subsequent research in both cognitive psychology and artificial intelligence has used the production system architecture to successfully model a wide variety of

cognitive behavior. One of the strengths of the production system architecture is that it can be used to implement theories at several different levels of abstraction. Young [1979] lists three levels that are commonly used:

> Firstly, with the least commitment in the architecture, is what one might call the language level. Here, PSs [production systems] are used because of their suitability as a language for expressing certain kinds of computations. The content of the PS may express a psychological theory, but the notation is chosen on grounds of its computational convenience. . . . Secondly one can find a number of studies which operate at what one might call the rule level. At this level there is a commitment to the psychological reality of rules, i.e. to the idea that the cognitive 'program' is structured as a PS, and also perhaps to some aspects of the conflict resolution. But this commitment does not necessarily extend to the details of the architecture adopted. . . . Lastly there is the immediate processor level, at which the PS architecture is itself intended as a theory of the structure of human cognitive processes. The allowable actions on the righthand side of the rules, for example, are taken to be the 'elementary information processes' of the cognitive system [p.43].

Research in cognitive psychology has tended to operate at the rule level and the immediate processor level [e.g., Anderson, [1982,1983]; Newell, [1980a]; Young, [1978]; Young and O'Shea, [1981]). Such work has led to discussions of the mappings between features of the production system architecture and the human mind. The method by which the control processes direct behavior has been likened to the role played by consciousness in directing attention [Ueckert, 1980]. The production memory stores the system's knowledge and,therefore, is seen as filling the same role asthat of human long-term memory. The role of the working memories in holding the facts currently under consideration has been

compared to the role played by short-term memory [Newell, 1970, 1980a; Young, 1979].

Research in artificial intelligence, on the other hand, has tended to operate at the language level or the rule level. Certain features of expert systems violate well-established properties of the human mind in order to attain high levels of performance. For example, most expert systems have extremely large working memories, even though the capacity of human short-term memory appears to be quite limited [Miller, 1956]. In addition, expert systems frequently differ from pure production systems in that they provide a means of marking which rules have been used so that the line of reasoning that was followed can be explained. This feature contributes to the usefulness of expert systems as practical tools and also facilitates their use to study why decisions are made in a particular manner.

The foregoing discussion should not be taken as implying that researchers in artificial intelligence are totally unconcerned with the correspondence between expert systems and human problem solving behavior. On the contrary, a distinction is made between computer programs which can perform complex tasks but do so in a manner which does not even remotely resemble that used by human experts and those programs which attempt to more faithfully reflect human problem solving behavior. The former have been labeled "intelligent artifacts" [Feigenbaum, 1979].

In order to be considered an expert system, a computer

program must meet these two criteria: (1) the program must reason by manipulating symbols, and (2) the program must use heuristic search [Brachman et al., 1983]. Thus, special purpose programs, such as those that solve differential equations by means of numerical analysis, are not expert systems because they do not reason symbolically. Likewise, chess-playing programs are not generally classified as expert systems (in spite of the fact that they have achieved levels of performance rivaling that of master players). The reason is that most of those programs rely on an exhaustive search of all possible moves, while there is evidence (Chase and Simon, [1973]) that human chess experts only consider a few moves but look at the ramifications of that move for many levels ahead.

There is no "correct" level of abstraction at which a theory should be cast; instead, the appropriate choice is dictated by both the nature of the task being studied and the motivations of the researcher. Pylyshyn [1981] and Newell [1982] both discuss a level of abstraction at which behavior is described in terms of the goals, beliefs, and intentions that give rise to observed actions. At this level of abstraction, behavior is viewed as being goal-directed and purposive. The focus is on understanding the logic underlying the performance of some task; there is no need to deal with the mechanics of that process (e.g., the speed at which facts can be recalled, the length of time they can be remembered, etc.).

AUDITPLANNER as a Theory of Professional Judgment

AUDITPLANNER, the expert system designed to make judgments of auditing materiality, operates at what Young [1979] refered to as the rule level. There is a definite commitment to the psychological reality of rules and to the suitability of the production system architecture for explicitly illustrating how those rules interact to produce behavior. No claim is made, however, that the mechanics underlying AUDITPLANNER's behavior accurately reflect the psychological processes underlying auditors' behavior. Rather, the focus is on the content of the knowledge constituting professional judgment, and on illustrating how that knowledge results in particular decisions.

In other words, it is assumed that auditors possess heuristic rules-of-thumb and that the contents of those rules represent the essence of professional judgment. Those rules explain the relationships between various characteristics of the client being audited and the proper level of materiality to use when planning the extent of audit procedures. Indeed, the existence of such rules or norms as the basis of professional judgment has been advanced before (the earlier quotation from the CICA on p.36). The next chapter discusses the process of acquiring such rules and implementing them in an expert system.

CHAPTER III

RESEARCH METHOD

This chapter describes how AUDITPLANNER, an expert system for making judgments of auditing materiality, was built. The chapter is divided into four parts. Part one discusses EMYCIN, the software tool used to help build AUDITPLANNER, and explains the reasons for its selection. Part two describes how the initial prototype version of AUDITPLANNER was built. Part three discusses the refinement of AUDITPLANNER. Part four describes the procedure for testing the finished system.

Research Tool: EMYCIN

Research on expert systems has led to the development of several software tools that are designed to facilitate the construction of such systems. With the use of these tools, researchers in fields outside of artificial intelligence can now build expert systems as a means of studying decision making behavior in a wide variety of task domains. These software tools provide the basic functions needed for managing and manipulating the knowledge base of expertise. Consequently, by using such tools researchers in applied fields of study can concentrate their research effort on identifying and studying the expert's knowledge, rather than

on the programming aspects of expert system construction.

This dissertation makes use of one such tool, EMYCIN [Van Melle et al., 1981]. Figure 2 below illustrates the role played by EMYCIN in the development of AUDITPLANNER. It shows that AUDITPLANNER consists of two basic components: (1) a knowledge base consisting of production rules which represent the auditing expertise used to make judgments of materiality, and (2) EMYCIN, which contains both the bookkeeping functions used to create and maintain the knowledge base and also the inference engine used to manipulate those rules. Thus, the research effort in this dissertation consists of identifying the knowledge used to make materiality judgments, expressing that knowledge in the form of production rules, and then analyzing the content of those rules.

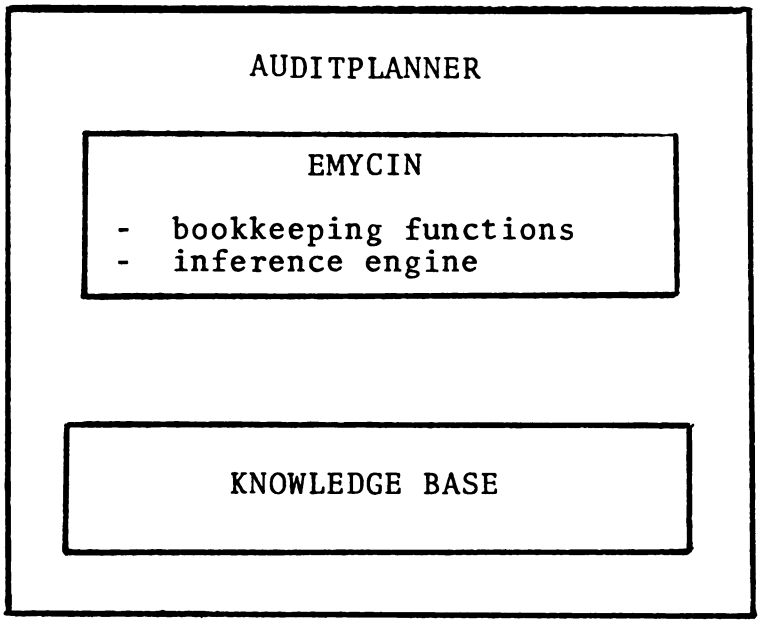

Figure 2. Role of EMYCIN in Construction of an EXPERT SYSTEM

The reasons for choosing EMYCIN as the software tool to be used to help build AUDITPLANNER are discussed next. Following that discussion, the important features of EMYCIN are described in more detail.

Reasons for Choosing EMYCIN

There were three reasons for choosing EMYCIN as the software tool to be used in this dissertation: (1) EMYCIN has been used successfully to build expert systems in a wide variety of task domains, including accounting, (2) the basic features of the task for which EMYCIN was originally created are similar to those found in making judgments of auditing materiality, and (3) EMYCIN contains the functions that a formal task analysis indicated must be present in an expert system designed to make judgments of auditing materiality.

Previous successful use of EMYCIN. Van Melle et al. [1981] report that EMYCIN has been used successfully to build expert systems that perform tasks in a wide variety of domains, including the following: (1) to diagnose lung diseases, (2) to interpret data about the geological characteristics of oil wells, (3) to recommend when structural engineers should use a costly and complex computer program for structural analysis, and (4) to identify the causes of telecommunications system failures. EMYCIN has also been used in accounting to develop an expert system that performs estate tax planning for individuals [Michaelsen, 1982]. The evidence indicates that EMYCIN is a very versatile software

tool for building rule-based expert systems.

Similarity of the original task for which EMYCIN was designed and materiality judgments. A second reason for choosing EMYCIN was that the task for which it was originally designed bears many similarities to the characteristics of making judgments of materiality. EMYCIN is the domain-independent core of the expert system called MYCIN [Shortliffe, 1976]. In fact, EMYCIN stands for Essential MYCIN. MYCIN is an expert system designed to diagnose infectious blood diseases; EMYCIN is MYCIN stripped of its knowledge base of medical expertise.

One can draw an analogy between the diagnosis of a patient by a physician and the examination of a firm's financial statements by an auditor. The physician asks the patient about the presence and nature of any symptoms. Then the physician performs a series of tests to provide evidence upon which to base an opinion about the patient's state of health. If those tests turn up evidence of a disease, the physician then attempts to determine the cause of that evidence, possibly by performing additional tests. The appropriate therapy depends upon the seriousness of the disease; in some cases surgery is required, in other cases a simple presecription drug is sufficient.

Similarly, the auditor begins the examination of a firm's financial statements by inquiring about any important events that have occurred and about any future plans that the client may have. The auditor then designs a set of tests

and procedures that will provide evidence upon which to base an opinion about the fairness of presentation of the financial statements. If those tests and procedures uncover evidence of errors, the auditor then tries to determine the cause of those errors. The appropriate response depends upon the seriousness of the error. In some cases, the auditor may have to give an adverse opinion on the financial statements, while in other cases the item may not even require footnote disclosure.

This analogy between the process of making medical diagnoses and materiality judgments is further supported by the similarities in the state of knowledge about each type of judgment. Shortliffe [1976] describes the characteristics of medical diagnosis:

> It is unfortunately the case that most human disease states are not sufficiently well understood to be characterized by well-defined mathematical formulae. Even causal relationships are seldom understood. MYCIN is a program that attempts to use AI [Artificial Intelligence] techniques to model decision making in ill-defined areas such as these. After all, experts do reach decisions when such medical problems arise, and they can usually offer theoretical arguments for making the judgments that they do. Our goal has been to capture such judgmental knowledge and to create a program that uses the information effectively and in a way that is acceptable to the physician for whom it is designed [p.32].

Similarly, the causal relationships behind materiality judgments are not understood well enough yet to permit the establishment of any general quantitative guidelines. Nevertheless, auditors routinely make such judgments and often document the rationale underlying those judgments in their working papers.

Formal task analysis of judgments of auditing materiality. A formal analysis of the task of making judgments of auditing materiality was undertaken in order to reveal the requirements that an expert system must meet in order to make those judgments. This analysis was based initially on a review of discussions about auditing materiality in the authoritative literature. Those readings were later supplemented by discussions of materiality in the audit manuals of public accounting firms and by interviews with members of several of those firms.

The first standard of fieldwork requires auditors to adequately plan the audit engagement. An important part of such planning involves determining the extent and nature of the audit tests and procedures that need to be performed. Both SAS Nos. 22 and 47 require auditors to consider their judgments of materiality when making that determination.

SAS No. 22 discusses the types of information upon which these planning judgments are based. That information includes knowledge about (1) the client's type of business, capital structure and form of organization, (2) the industry in which the client operates, (3) the general economic conditions facing the client, and (4) the intended purpose of the financial reports being audited.

SAS No. 47 points out that these judgments are based on the auditor's perception of the needs of the users of the financial statements. It also notes that the judgments are based on uncertain information that is subject to revision.

> In some situations, the auditor considers materiality for planning purposes before the financial statements to be examined are prepared. In other situations, his planning takes place after the financial statements under examination have been prepared, but he may be aware that they require significant modification. In both types of situations, th auditor's preliminary judgment about materiality might be based on the entity's annualized interim financial statements or financial statements of one or more prior annual periods, as long as he gives recognition to the effects of major changes in the entity's circumstances (for example, a significant merger) and relevant changes in the economy as a whole or the industry in which the entity operates [AICPA, 1983, para. 14].

The end result of the auditor's consideration of materiality is an estimate of the level of errors which, if found, would diminish the fairness of presentation of the financial statements. SAS No. 47 states that such an estimate may or may not be explicitly quantified. Discussions of auditing materiality in the audit manuals of public accounting firms indicate that those judgments are usually quantified explicitly whenever statistical sampling is going to play a major role in the audit. In such cases, the materiality judgment is one factor that is used to set the precision level of audit tests. That precision level is then used to help establish required sample sizes.

In summary, the task analysis indicates that judgments of auditing materiality require the auditor to interpret a great deal of qualititative and quantitative information about the client in order to determine the likely needs of the users of the client's financial statements. Some of the information used to make this judgment is incomplete and subject to revision (e.g., interim financial statements),

and some of it is inherently uncertain (e.g., the perceived level of risk associated with the audit). Consequently, an expert system designed to make judgments of auditing materiality must be able to handle information possessing these characteristics. Further, because the judgments inherently involve important assumptions (e.g., about the needs of the users of the statements), the system should be able to explain the basis for its interpretation of the data and the nature of any assumptions that it made. Indeed, most public accounting firms require such documentation of the materiality judgments made when planning the audit.

EMYCIN's satisfaction of the requirements of the formal task analysis. EMYCIN, as mentioned earlier, was designed to perform diagnostic tasks. Stefik et al. [1983] discuss the properties of the various tasks performed by experts. They point out that a major component of diagnosis is the interpretation of data. They then describe the features that an expert system must possess in order to interpret data.

> The main requirement of the task is to find consistent and correct interpretations of the data. It is often important that analysis systems be rigorously complete, that is, that they consider the possible interpretations systematically and discard candidates only when there is enough evidence to rule them out. The key problem is that data are often noisy and errorful; that is, data values may be missing, erroneous, or extraneous. (1) This means that interpreters must cope with partial information. (2) For any given problem the data may seem contradictory, so the interpreter must be able to hypothesize which data are believable. (3) When the data are unreliable, the interpretation will also be unreliable. Thus for credibility it is important to

> identify where information is uncertain or incomplete and where assumptions have been made. (4) Since reasoning chains can be long and complicated, it is helpful to be able to explain how the interpretation is supported by the evidence [p.83].

EMYCIN contains functions to deal with partial information, to reason under uncertainty, and to explain the line of reasoning that led to its recommendations. Thus, EMYCIN appears to be a logical choice as the tool to be used to build an expert system that makes judgments of auditing materiality. The next section describes the features found in EMYCIN which enable expert systems based on it to perform the functions listed above.

Features of EMYCIN

This section describes some of the structural features of EMYCIN. The search strategy in EMYCIN's inference engine, which ensures that its interpretation of the data is rigorously complete, is discussed first. The methods used to represent the knowledge used by that strategy are discussed next. Following that, EMYCIN's provisions for dealing with uncertainty are described. The facilities which allow EMYCIN to explain the line of reasoning that it followed to make its recommendations are discussed later, in the section that discusses the refinement of the system.

Search strategy. EMYCIN-based expert systems follow a goal-directed or backward-chaining search strategy. Thus, AUDITPLANNER begins with the goal of making a judgment of materiality that will be used to plan the scope of the

audit. Those rules which, if fired, could conclude about the materiality level have their premises examined to see if they are satisfied by the data known about the client. If the data required to determine whether or not those premises are satisified is not known, then AUDITPLANNER establishes a new goal of obtaining that data. This causes it to examine the conclusions of all the rules in its knowledge base to see which can satisfy the new subgoals. In this way, a tree of goals is created which represents the line of reasoning used to make the materiality judgment.

The process of creating new subgoals and looking for rules which can satisfy those subgoals continues until one of three things happens. First, a rule is found which has its premises satisfied by the data already known about the client. In this case, that rule fires and the conclusions it makes enables the next higher subgoal to be satisfied and so on up the tree until a materiality judgment is made. The second alternative is that a rule is found and it is known that its premises are not satisfied by the known about the client. In that case, the tree of goals cannot be satisfied and AUDITPLANNER fails to determine a materiality level. The third option is that no additional rules can be found that conclude about the current subgoals. In that case, AUDIT-PLANNER asks the user a question in order to determine whether the premises of the rule it last considered are satisfied. These questions typically involve objective data such as the amounts of various financial statement accounts

or the type of business of the client.

Thus, AUDITPLANNER interacts with the user as would a consultant. The backward-chaining search strategy ensures that the questions asked of the user are focused, because the sequence of questions follows the logical structure of the goal tree. In contrast, a forward-chaining search strategy often produces a sequence of questions that reflects more of a "shotgun" approach, because the answer to one question may satisfy the premises of a rule about a quite unrelated variable and thereby trigger a question about an entirely different topic.

EMYCIN's use of backward-chaining can not only be defended on the basis of its effects on the interaction with the user, but also in terms of overall performance. Aiello [1983] compared the efficiency and effectiveness of several different search control strategies by building different versions of the same expert system. There were no significant differences between the forward- and backward-chaining strategies in terms of (1) the number of rules considered, (2) the number of rules fired, or (3) the amount of data examined. However, the backward-chaining strategy produced a line of reasoning that users judged to be easier to follow and understand.

The reader may question whether the use of a backward-chaining strategy reflects the process used by auditors to make materiality judgments. The discussion in Chapter 2 indicated that (1) there is some evidence that for tasks

involving deliberate planning that a backward-chaining or goal-directed strategy is probably followed, and (2) the purpose of constructing AUDITPLANNER is not to try to model the search process underlying judgments of auditing materiality, but rather to model the role played by various situational factors in making those judgments. In other words, the focus is on the content of the system, as reflected in the production rules, and not on its architecture.

Representation of knowledge. EMYCIN-based systems represent knowledge about a task domain in the form of production rules. Such rules serve four distinct purposes : (1) to make inferences, (2) to establish default values of certain parameters, (3) to control the ordering of subtasks, and (4) to describe the contextual setting in which some goal is appropriate.

EMYCIN uses its backward-chaining search strategy to implement functions 1, 3, and 4 described above. The rules involved are called consequent rules, because their premises are checked only if the actions accompanying their being fired help to satisfy the current goal being pursued. The second function, establishing default values, is implemented by the use of antecedent rules. These rules fire in a forward-chaining manner whenever data is obtained which satisfies their premises. They are used to make definitional conclusions and to avoid asking redundant questions. For example, AUDITPLANNER contains an antecedent rule which states that if the client's main line of business falls into

one of several categories (e.g., manufacturing or retail sales), then the client is definitely not a nonprofit organization. This rule prevents AUDITPLANNER from asking whether General Motors is a nonprofit entity.

EMYCIN-based systems store factual knowledge about the subject of a consultation in the form of fact triples such as the following: (CLIENT TYPE-OF-ENTITY PUBLIC). The first element is termed the context; it serves to associate facts about an object in the domain. In this case, it states that the fact represented here pertains to the client being audited. (If the client is a nonprofit organization, some attributes may only apply to certain funds or fund types; in that case, the context variable would be the name of the relevant fund). The second element of the triple is the name of the attribute, in the example, the type of entity that the client is. The third element represents the value of that attribute; in this case, the client is a public entity. These fact triples are formed in response to user answers to questions and to the firing of production rules.

Reasoning under uncertainty. The task analysis indicated that some of the information upon which judgments of auditing materiality are based is inherently uncertain. For example, the amounts of the items in interim financial statements are used to estimate what the final, annual amounts of those items will be. EMYCIN-based expert systems deal with this type of reasoning by assigning certainty factors (CFs) to the facts about the consultation and also

to the rules used to manipulate those facts.

Shortliffe and Buchanan [1975] explain the mathematics underlying the manipulation of CFs. CFs represent subjective degrees of belief and are defined to be the difference between the degree of belief in some assertion, given the available evidence, and the degree of disbelief in that assertion given that same evidence. This definition is similar to Einhorn and Hogarth's [1982, 1984] concept of the net strength of a hypothesis being the difference between the weight of the evidence in favor of and against that hypothesis.

CFs range in value from -1.0, representing absolute certainty that the assertion is not true, to +1.0, which represents absolute certainty that it is true. As mentioned above, CFs are associated with both fact triples and with the actions of rules. Thus, a CF of .9 attached to the fact triple (CLIENT TYPE-OF-ENTITY PUBLIC) means that there is a high degree of belief (but not absolute certainty) that the client is a public entity. A CF of 1.0 attached to the action of a rule means that whenever that rule's premises are satisfied the specified inference can be made with absolute certainty.

A rule is fired in EMYCIN-based systems only if the absolute value of the CF associated with its situation part is at least equal to .2. The calculation of the CF of the situation part of a rule depends upon the relationship among the clauses that make up that situation. For example,

AUDITPLANNER contains the following rules:

Rule 40 IF: 1) the client has publicly-traded debt or equity securities, or

2) the client has restrictive debt covenants that are measured in terms of results of current operations

THEN: it is definite that the client is a public entity. (1.0)

Rule 11 IF: 1) the client is a public entity, and

2) there is no concern about liquidity or solvency

THEN: it can be assumed that the users of the financial statements are primarily interested in the results of current operations. (1.0)

The first rule is a disjunctive rule: that is, it can fire if either of its premises are satisfied. Therefore, the CF attached to the assertion that is made when the rule is fired equals the product of the maximum CF of the premises and the CF of the action. In this case, if the CF of premise 1 was .7 and the CF of premise 2 was .9, the CF of the resulting assertion would be .9 (the maximum of the two premises) times 1.0 (the CF of the rule's action).

The second rule, on the other hand, is a conjunctive rule: that is, both of its premises must be satisfied in order to fire the rule. In this case, the value of the resulting assertion equals the value of the minimum CF attached to either premise times the CF of the rule. Thus, if the CF of premise 1 was .7 and that of premise 2 was .9, then the CF of the assertion would be .7 times 1.0. This

ensures that the degree of belief attached to an assertion cannot exceed the degree of belief in the weakest link supporting that assertion.

To ensure that the CF of an assertion never exceeds 1.0 in absolute value, EMYCIN uses the following method for dealing with the situation where several rules fire and make the same conclusion. The first rule to fire attaches a CF with the assertion as described above. Any additional rules which fire, however, serve only to reduce any remaining uncertainty. For example, if the first rule makes an assertion with a CF of .8, and another rule fires which makes the same assertion with a CF of .7, the combined CF after both rules have fired is .8 + (.7 x (1- .8)) = .94.

EMYCIN-based systems will attempt to apply all rules that conclude about a given assertion unless the firing of a rule would lead to absolute certainty (CF = +1.0 or -1.0) in the assertion, in which case only that rule is fired. Thus, EMYCIN-based systems meet the requirement that interpretation systems rigorously examine all possible values of a parameter. Moreover, the mechanics of the CF calculation permit EMYCIN-based systems to deal with incomplete data in an effective manner that results in only a gradual degradation in the quality of performance. If some of the information discussed in the previous example was missing, so that only one rule could fire, the system would still be able to make a conclusion about the type of entity that the client is (albeit with less certainty than if both rules had

fired).

Summary

The use of a software tool such as EMYCIN enables the accounting researcher to use the expert system methodology to study decision making behavior without having to devote an inordinate amount of time to programming. EMYCIN has been used successfully to build expert systems in a wide variety of task domains. The task analysis indicated that judgments of auditing materiality require auditors to interpret a large body of uncertain information about a client. EMYCIN contains the procedures necessary for a rule-based expert system to perform tasks of that type. The next part of this chapter describes how the initial prototype version of AUDITPLANNER was built.

Construction of Prototype System

The process of acquiring expertise and encoding it into the knowledge base of an expert system is referred to as "knowledge acquisition" [Buchanan et al., 1983]. EMYCIN permits most of this knowledge acquisition to be done interactively with an expert. The expert uses the current version of the system to perform the task, notes the areas where there are gaps or flaws in the system's logic, and suggests changes or additions to the knowledge base to correct those problems. This interactive process presupposes, however, the existence of a working version of the system. This section describes how the initial prototype version was built.

Choice of Subjects

A major constraint on the choice of subjects for this dissertation is that EMYCIN, as well as other software tools available for building expert systems, cannot accomodate conflicting rules based on different judgment models. There is considerable evidence that there is a lack of consensus among auditors from different accounting firms for a wide range of judgments, including materiality. Moreover, several studies indicate that this lack of consensus also exists among auditors from the same accounting firm. Because of this apparent lack of consensus, and also due to the time required to build and refine an expert system, AUDITPLANNER is an expert system reflecting the rules-of-thumb used by an audit partner of a single accounting firm. The remainder of this section reviews the evidence of a lack of consensus among auditors and also examines the role of individual-specific models in the study of decision making behavior.

Lack of consensus across firms. Holstrum's [1981] review of empirical research on consensus in a wide range of audit judgments lead him to conclude that there is a lack of consensus among auditors for many of those judgments.

> In general, the most crucial aspect of the auditor judgment research to date is the lack of consensus among auditors in typical judgments made in the audit process [Holstrum, 1981, pp.31-32].

Previous research on materiality indicates that there is a lack of consensus on these judgments. Pattillo [1976] reports that the level of consensus among auditors regarding

the materiality of various errors was quite low, and in fact was lower than that for any other group in his study which included bankers, financial analysts, and financial executives. Firth [1979] also measured the consensus of auditors in comparison to bankers, financial analysts, and chief accountants and similarly found the lowest degree of consensus among auditors. In fact, he reported that there was no consensus among auditors in about one-third of the cases. Lewis [1980] found significant differences among auditors from four different public accounting firms in terms of the threshhold at which they would disclose a contingent liability arising from a lawsuit.

One possible cause of the lack of consensus in these studies is that they all confounded the decision about the materiality of the item with the decision about the proper method of its disclosure. Indeed, in its Discussion Memorandum on Materiality, the FASB explicitly distinguishes between these two judgments:

> The determination of the materiality of an item, transaction, or situation is just one step in the financial accounting and reporting process. For example, in considering the disclosure of litigation, a determination that a suit is material is only part of the process. A judgment must also be made as to the type and extent of disclosure to be made in the circumstances, considering the degree of materiality involved [FASB, 1975, para. 169].

Thus, it is possible that the reported lack of consensus found in the studies cited above may be due to (1) a lack of consensus about the materiality of the item , (2) a lack of consensus over the proper method of disclosing that item,

given that it is material, or (3) both of the previous reasons.

A study by Ward [1976] provides some support for the second explanation. He asked auditors to rank the importance of twenty factors representing legal and technical aspects of the audit environment and found a statistically significant level of agreement on those rankings. However, he also found a marked lack of consensus about the impact of an error on the auditor's legal liability.

On the other hand, Messier [1982] did ask auditors to make separate decisions about the materiality of a writedown of inventory and its proper method of disclosure. He found a lack of consensus among auditors from "Big-8" and "non Big-8" accouting firms. Mayper [1982] asked auditors to evaluate the materiality of of various internal control weaknesses. He reported that the level of consensus across auditing firms was only 45 percent.

The evidence for a lack of consensus across auditing firms regarding judgments of materiality should not be surprising. Einhorn [1974] points out that differences in background and training can lead to a lack of consensus among experts. Each accounting firm has its own audit methodology which is reflected in its audit manuals and in its training programs. The Gibbins and Wolf [1982] survey found that one factor which significantly affected all phases of the audit was the firm's general audit methodology. Cushing and Loebbecke [1983] read the audit manuals of twelve public

accounting firms and classified each firm into one of four categories reflecting the degree of structure reflected in their written materials. The author of this study also noticed distinct differences in the discussions of auditing materiality in the audit manuals of ten different accounting firms.

Lack of consensus within firms. Few studies have examined the degree of consensus on audit judgments among auditors from the same accounting firm. However, two studies do report a lack of such consensus. The first is a study by Mock and Turner [1979] about auditors' evaluations of the quality of internal control and their subsequent choice of sample sizes for substantive tests. Although all auditors were members of the same accounting firm, there were considerable differences in their choices of sample sizes.

More important, the lone previous empirical study of auditing materiality [Moriarity and Barron, 1979] found a lack of consensus in those judgments among partners from the same accounting firm. Only two partners were in agreement on a majority of the cases.

The differences found in the Moriarity and Barron study probably reflect significant differences in the background of the participants. Some of the partners had had experience primarily with profit-oriented firms, while others had dealt mainly with nonprofit organizations. Post-experimental interviews indicated that these two groups had distinct differences in the types of problems they looked

for in an audit. Moreover, only two of the partners had had much experience in statistical sampling applications where this type of materiality judgment is more frequently made and explicitly quantified. In fact, the lack of such experience caused a sixth subject to refuse to perform the task.

Implications. It appears that there are significant differences in the audit judgments made by members of different accounting firms. There is also some evidence that there is a similar lack of consensus in the judgments of auditing materiality made by members of the same accounting firm. This evidence should not be surprising. A basic tenet of human information processing research is that the task environment typically contains many items of information which are redundant in nature; this redundancy, and the adaptive nature of human behavior can produce a variety of equally useful strategies for solving a particular problem.

> We must expect to find different systems (even of the same species) using quite different strategies to perform the same task. I am not aware that any theorems have been proved about the uniqueness of good, or even best, strategies. Thus, we must expect to find strategy differences not only between systems at different skill levels, but even between experts [Simon, 1980, p.42].

The construction of an expert system which reflects one strategy for making judgments of auditing materiality may play an important role in understanding how those judgments are made. Simon [1980] argues that progress in understanding problem solving behavior depends upon developing a taxonomy of the alternative strategies for solving a given

task:

> research on the performance of adaptive systems must take on a taxonomic, and even a sociological aspect. We have a great deal to learn about the variety of strategies, and we should neither disdain nor shirk the painstaking, sometimes pedestrian, tasks of describing that variety. That substrate of description is as necessary to us as the taxonomic substrate has been to modern biology [p.42, emphasis added].

This dissertation represents one step toward developing such a taxonomy for the task of making materiality judgments. Moreover, Dukes [1965] points out that studies of an individual subject in which the researcher is focusing on how a particular problem is solved have played a major role in psychological studies of behavior.

> Problem-centered research on only one subject may, by clarifying questions, defining variables, and indicating approaches, make substantial contributions to the study of behavior. Besides answering a specific question, it may (Ebbinghaus' work, 1885, being a classic example) provide important groundwork for the theorists [Dukes, 1965, p.78].

The construction of AUDITPLANNER will be based on the materiality judgments of an expert auditor in many different situations. Previous research, as pointed out in Chapter One, either held the situation in which materiality judgments were to be made constant, or else only varied them slightly. The use of the expert systems methodology, on the other hand, permits for more complex and realistic decision settings. Such variation of situations is essential if the goal is to explain the role of that factor in making materiality judgments. In this regard, this dissertation should add to our knowledge of the materiality judgment process.

Subject selection. Eleven public accounting firms with offices in Detroit were contacted in order to find a subject for this study. Ten of those firms agreed to provide either their entire audit manual or those portions which described their approach to making materiality judgments. Reading those manuals indicated that there were considerable differences across firms in terms of (1) how judgments of auditing materiality were made, and (2) how those judgments fit into the planning stage of the audit.

Interviews were arranged with managers or partners of five firms whose manuals indicated that there was some degree of structure in the firm's approach to making those judgments, but at the same time the judgment had not been reduced to a general formula applied across all clients (Elliott [1983] provides an example of the use of such a formula by one major firm).

The interviews indicated that one of the five firms routinely made judgments of auditing materiality as part of the process of establishing the precision levels for audit tests. That firm's audit manuals contained extensive discussions of how those judgments were to be made, but did not set forth a general formula that applied to all clients. That firm was therefore chosen to serve as the subject of this research.

The next step involved securing the cooperation of an expert who would provide the rules that would be included in AUDITPLANNER's knowledge base. The sensitive nature of the

materiality judgment process meant that the subject's cooperation could only be obtained upon a guarantee of anonymity. However, some general demographic information is permitted. The subject is a partner in a major international public accounting firm. The firm would probably fall into one of the two more structured categories in Cushing and Loebbecke's [1983] taxonomy. The subject has had a broad range of experience in auditing both profit-oriented and nonprofit organizations, with particular emphasis on finance companies and health care firms.

Source of Knowledge for Prototype

The initial set of rules included in AUDITPLANNER's knowledge base came from the discussions of materiality in the audit manuals of the firm to which the subject belonged. Those manuals contain the firm's basic approach to making such judgments and should reflect some of the techniques used by the subject to make those judgments.

Textbook knowledge has been successfully incorporated in EMYCIN-based systems which perform medical diagnosis [Van Melle et al., 1981] and plan for individual estate taxes [Michaelsen, 1982]. In fact, a large proportion of the rules in the latter system were taken from directly from the tax code. Moreover, because textbook knowledge underlies many domains of expertise, a major topic of current research in expert systems focuses on the development of text understanding systems which can acquire this knowledge directly by reading the textbooks themselves [Buchanan et al., 1983].

Many of the "rules" or guidelines contained in the audit manual were quite vague. Consequently, an initial interview with the subject was arranged in order to clarify the meaning of those rules.

The final result was a knowledge base which contained enough rules to enable the system to make fairly accurate materiality judgments for clients with characteristics that matched those of the "textbook cases" found in the audit manual. This was sufficient, however, to begin in earnest the knowledge acquisition process. The expert could use the prototype system to make materiality judgments for actual clients, and in the process begin to fill in rules which reflected the professional judgment acquired through experience. The details of this process are described in the next section on the refinement process.

Refinement of the System

The refinement stage constitutes the majority of the time spent in developing an expert system. It is an iterative process in which the expert uses the existing version of the system and suggests changes that need to be to it. The system builder then makes the recommended changes and arranges for another session with the expert. The expert then uses the revised version to make additional judgments for actual clients, and may suggest additional changes. This process took five months to construct AUDITPLANNER.

The question-answering and explanation capabilities of EMCYIN greatly facilitated this process. At any time during

or after a consultation, the expert could examine the basis for AUDITPLANNER's recommendations.

Explanation of Reasoning During a Consultation

EMYCIN provides functions which allow the expert to interrupt the consultation at any point and examine the logic being followed. In response to any question that the system asks, the subject can refuse to answer and instead type in the word "why". An example of this interaction is included in Appendix I; following that transcript may be helpful in understanding the following description of the process.

AUDITPLANNER responds to the word "why" by printing an interpretation of what it thinks the user is asking, and then displays an English translation of the current decision rule which generated the most recent question the system asked. The user may then either continue the consultation or pursue the system's line of reasoning further. To do the latter, the user simply types "why" again. Notice that AUDITPLANNER correctly interprets the meaning of the second "why".

It is also possible to ask the system how it arrived at any conclusion it mentions when it explains why it is asking some question. To do this, the user simply types "how n.n", where n.n refers to the particular conclusion to be explained. As the transcript indicates, AUDITPLANNER's initial response is to simply state which rule was used. Although this may make sense to the system builder, the user

typically has to type in "how" again, in order to get an English translation of that rule.

Explanation After a Consultation is Over

In addition to querying the system about its line-of-reasoning during a consultation, the user can also examine that line-of-reasoning after the consultation is over and the system has displayed its recommendations. This can be done in one of two ways.

The user can use the system's REVIEW feature to look at each conclusion the system made. Should the user disagree with any conclusion, the cause of the error can be tracked down by the use of the structured "how" and "why" questions. This process can be guided by either the user or by the system.

The structured REVIEW procedure only works for conclusions with which the user disagrees. A different interaction technique is used to examine the basis for conclusions with which the user agrees. This is known as the Explanation or QA mode, an example of which is presented in Appendix II.

As that transcript shows, the user can ask relatively open-ended questions about how the system made various conclusions. EMYCIN provides functions which enable the system builder to create a domain-specific dictionary which is used to answer these type of questions.

Summary

The ability to track down the rules that led to certain conclusions is very helpful in increasing the system's overall performance. The process often elicited additional rules from the expert to deal with special exceptions that may be present in the particular consultation being run that were not adequately dealt with by more general rules. Without these question-answering and explanation features, the refinement of the system would have been subject to the expert's ability to generate (1) the general rules which failed in a specific situation, and (2) the appropriate methods for dealing with that situation.

This iterative refinement process continued until the expert was satisfied that AUDITPLANNER was performing satisfactorily on the set of cases used to develop the system (which occurred after five months of development). At that time, AUDITPLANNER's performance was formally tested and the contents of its knowledge base analyzed. The procedures for this testing are described in the next section.

Testing AUDITPLANNER

Davis and Lenat [1980] point out that the refinement of an expert system is a never-ending process, because it is always possible to improve performance by adding more rules either to cover additional facets of the task or to handle changes that have taken place in the nature of the task itself. Nevertheless, there must be some point at which this iterative testing and refinement of the system is suspended,

its performance is measured, and the contents of its knowledge base are examined and analyzed. Indeed, the major motivation behind the construction of AUDITPLANNER is the analysis of the heuristic rules used to make materiality judgments.

The previous section stated that the refinement of AUDITPLANNER would be suspended when the system reached an acceptable level of performance. However, defining "acceptable performance" in making materiality judgments is a problem. It is not possible to simply compare the system's judgments to some objective standard and state that when the system attains a certain percentage of correct answers, then it is evidencing expertise. No such objective standard of materiality exists.

How, then, can expertise be tested? There are no generally accepted methods for evaluating the expertise of auditors. Although auditors must pass an examination in order to become certified, that test is not used later to evaluate their expertise. This problem is not unique to accounting; it is faced in many fields of professional endeavor. Needless to say, the absence of any simple means of testing and evaluating human expertise makes the evaluation of expert systems difficult. Nevertheless, guidelines do exist for evaluating expert systems.

Gaschnig et al. [1983] point out that the appropriate method for evaluating the performance of an expert system depends upon its stage of development. Systems in the early

stages should be evaluated in terms of the correctness of their general line of reasoning, while systems that are approaching the stage of commercial release must undergo more extensive testing of the "correctness" (or at least the "acceptability") of their recommendations.

Gaschnig et al. explain why they feel that systems in the early stages of development should not be evaluated only in terms of the "correctness" of their recommendations:

> One problem with this emphasis on final performance is that it fails to take into account the microstructure of problem-solving behavior, which can be extremely important in permitting the extrapolation from representative instances of behavior to make judgments concerning overall competence. Evaluators want to be convinced that the system is consistently getting the right answers for the right reasons [p.252, emphasis added].

Gaschnig et al. then describe a method of evaluating expert systems which will provide such assurance:

> the expert system needs to be exercised within a wide-ranging series of test situations aimed at discovering ways to make the system fail. The experts engaged in evaluating system performance must have full access to all aspects of behavior, so that they can push and probe, looking for weaknesses and deficiencies. This would seem to rule out blinded, comparative studies as an appropriate framework for expert-system evaluation, at least at the early stages in the development life cycle [p.252, emphasis added].

Consequently, the evaluation of AUDITPLANNER consists of two separate procedures. First, the expert auditor who served as the source of the expertise embedded in the system was asked to determine whether the system is adequately performing on the types of clients which have been used to test it during the refinement stage. Although this evaluation is

subjective, it is similar to the manner in which the subject evaluates the performance and expertise of junior auditors.

Once the expert felt that the system was performing adequately on the test cases, a more formal evaluation by other experts was then made. This evaluation entailed using the system to make materiality judgments for clients that differ in a number of ways from those used to develop the system. The purpose of the testing was to discover the limits of the system's expertise. The focus is on identifying areas where additional rules are needed if the system is ever to be useful as a practical tool.

The use of these "outside experts" provides two other benefits. First, it provides a general measure of the degree generality of the problem solving strategy of the system. The question is whether the rules used by one expert to make materiality judgments are considered reasonable by other experts. Second, it permits an assessment of the potential usefulness of the system. In other words, do the experts see any use for AUDITPLANNER?

It is important to stress that this evaluation by the "outside experts" is not used to determine whether the system is finished. Rather, it is intended solely to provide additional data for analyzing the rules contained in the knowledge base. It is worthwhile to reiterate at this point the underlying purpose of this research: to increase our understanding of how various environmental factors affect materiality judgments. As Gaschnig et al. [1983] point out,

it is not necessary to have a fully-developed, commercially usable system in order to accomplish such a purpose:

> Once a system begins generating performance, it becomes an important part of the laboratory apparatus available to the knowledge engineer and cognitive analyst to gain fresh insights into the domain of expertise for which that system was built. The true goal of evaluation should not be to show how well a system does what it was designed to do but, rather, to gain a greater appreciation of the process, structure, and limits of expertise. This system can later be parlayed into new levels of expert performance in successive system developments [p.252, emphasis added].

The remainder of this section discusses the methods and results of the testing of AUDITPLANNER.

Subjects

Three managers and three seniors in the same public accounting firm as that of the expert subject participated in the evaluation of AUDITPLANNER. Their cooperation was secured by means of an office memo written by the partner who served as the subject for this research.

The managers ranged in experience from six to nine years, with a mean of eight years. The seniors had from three and one-half to four and one-half years experience, with a mean of four years. The seniors had at least one and one-half years experience in making judgments of auditing materiality.

The subjects also had fairly diverse backgrounds, with areas of special expertise including insurance companies, savings and loans, and closely-held businesses.

Test Cases

Each participant was asked to bring the working papers for two clients to the evaluation session. The clients that were used in the evaluation were not a random sample; instead, they were chosen in order to maximize the breadth of situations over which AUDITPLANNER would be tested. This was necessary in order to obtain an accurate assessment of its overall level of competency and also in order to obtain additional information about the generality of the knowledge contained in the system. In addition, some of the test clients had characteristics not present in any of the clients used to develop AUDITPLANNER. The reason for this was to provide another test of the system's competency: would it at least take a logical approach to new situations? The exact charac-teristics of the test clients are listed in Table 1.

Procedure

Each evaluation session lasted one hour, during which time the participants used AUDITPLANNER to make materiality judgments for their clients. After collecting demographic information about the participant, the author provided instructions on the use of AUDITPLANNER. The participant used AUDITPLANNER to make a materiality judgment for one of the test clients, compared that judgment to the actual materiality level used for that client, and evaluated the quality of AUDITPLANNER's judgment. This process was then repeated for the other test client.

TABLE 1. Characteristics of test clients

CLIENT	FEATURES
Machine tool manufacturer	involved in a major acquisition
Machine tool manufacturer	a subsidiary of a foreign parent
Insurance company	a subsidiary
Restaurant	profitable
Automobile dealership	
School district	nonprofit organization
Boy Scout Council	nonprofit organization
Computer manufacturer	
Retail supermarket	
Retail supermarket	suffered a loss for the current year
Common carrier - trucking	subject of litigation and made some major acquisitions
Common carrier - trucking	subject of an inquiry by a regulatory agency
Microcomputer retailer	private entity undergoing incorporation

Upon completion of the one hour session, each participant was given a questionnaire with which to evaluate the overall performance of AUDITPLANNER, as well as several aspects of its usefulness. Participants completed the questionnaire in their own offices and returned it to the author later that day. Appendix IV contains a copy of the questionnaire.

Results

AUDITPLANNER was used to make materiality judgments for 13 clients. (The last session lasted two hours and used three test clients). Eight of those recommendations were judged as being acceptable. In general, AUDITPLANNER usually was more conservative than the auditors; that is, the materiality levels it recommended were lower than those recommended by the participants. The possible causes for this conservatism are discussed in the next chapter's analysis of the system's materiality judgment model.

The test sessions were useful as another form of system refinement, as additional rules were suggested for several new types of clients. Discussions with the principal subject indicated that these rules should be added to the system because they reflected expertise in areas outside of the subject's prior experiences.

Overall, the six managers and seniors said that they felt that AUDITPLANNER approached the materiality judgment in a reasonable and logical manner. Moreover, all six indicated that they would like to be able to use such a tool if

it ever became available.

Table 2 presents a frequency distribution of the responses to the questionnaire evaluation of AUDITPLANNER. The remainder of this section discusses those results.

Competence of AUDITPLANNER. Questions 7 and 22 addressed the issue of AUDITPLANNER's general competence. Five of the six participants disagreed with the statement that AUDITPLANNER was not competent, and four of the six agreed with the statement that it was competent. The one subject who felt that AUDITPLANNER was not competent was also the one subject who indicated that he would approach the materiality judgment in a different manner than did AUDITPLANNER. Discussions during the sessions indicated that the subject had a consistently higher materiality threshhold than did AUDITPLANNER.

Three of the subjects indicated that they would accept AUDITPLANNER's recommendations about the materiality level to be used in planning the audit (question 8). Taken together, the responses to these three questions indicate that the evaluators felt that AUDITPLANNER showed evidence of a basic level of confidence in making judgments of auditing materiality, but that they were not yet ready to accept its recommendations in every situation.

Reasonableness of model. Questions 24, 3, 15, and 19 addressed the issue of the generality and reasonableness of AUDITPLANNER's approach to making materiality judgments. The

TABLE 2. Responses to test questionnaire

QUESTION TOPIC	SA	A	N	D	SD
7. AUDITPLANNER not competent	0	1	0	3	2
22. AUDITPLANNER is competent	0	4	2	0	0
8. Would accept AUDITPLANNER's recommendations	0	3	1	2	0
24. Would approach judgment in different manner than did AUDITPLANNER	0	1	0	5	0
3. AUDITPLANNER asked irrelevant questions	0	0	0	3	3
15. AUDITPLANNER's logic hard to follow	0	0	0	3	3
19. AUDITPLANNER's logic easy to follow	2	4	0	0	0
4. AUDITPLANNER would be useful as a training device	2	3	1	0	0
18. Would not want subordinates to use AUDITPLANNER as a training device	0	0	1	4	1
5. AUDITPLANNER would be useful as a decision aid (see note 1)	1	4	0	0	0
6. Would want to use AUDITPLANNER as a decision aid	0	6	0	0	0
14. Would permit subordinates to use AUDITPLANNER as a decision aid	0	5	0	0	1
11. AUDITPLANNER would be more useful as a training device than as a decision aid	0	0	4	2	0
12. No conceivable use for AUDITPLANNER	0	0	0	4	2
21. Flow of dialogue easy to follow	2	4	0	0	0

TABLE 2 (continued)

	SA	A	N	D	SD
1. Easy to use	2	4	0	0	0
25. AUDITPLANNER jumped around from topic to topic	0	0	0	5	1
13. Hard to use	0	0	0	4	2
9. Did not enjoy using AUDITPLANNER	0	0	0	4	2
20. Enjoyed using AUDITPLANNER	1	4	1	0	0
10. AUDITPLANNER was too slow	0	0	0	3	3
2. poor help facilities	0	0	2	3	1
17. inadequate question-answering capabilities	0	1	1	4	0
23. HOW and WHY features useful	2	1	3	0	0
16. Used question-answering features extensively	0	2	3	0	1

Key:
SA = Strongly Agree
A = Agree
N = Don't know or neutral
D = Disagree
SD = Strongly Disagree

note 1 - one person did not answer question 5. His responses to the other questions about usefulness were:
as a training device - agree
want to use as decision aid - agree
more useful for training than as decision aid - neutral
no use at all - disagree
permit subordinates to use as a decision aid - agree
would not let subordinates for training - disagree

responses indicate that the evaluators agreed with the logic of the model. Five of the six evaluators indicated that they approached judgments of auditing materiality in the same way that AUDITPLANNER did. All six indicated that AUDITPLANNER did not ask irrelevant questions; and all six agreed that it was easy to follow the system's line-of-reasoning.

Usefulness of AUDITPLANNER. An important question in building an expert system is whether there is any potential use for it other than as a method for studying decision making behavior. Questions 4, 5, 6, 11, 12, 14, and 18 all addressed this issue of usefulness. The responses to those questions support the comments made during the sessions that the evaluators would like to use a tool like AUDITPLANNER. All six evaluators agreed with the statement that they would like to use AUDITPLANNER as a decision aid. All agreed that it would be useful as a decision aid (question 5) and five of the six indicated that they would permit their subordinates to use it as a decision aid.

Five of the evaluators indicated that they thought that AUDITPLANNER would be useful as a training device. They also indicated that they would not mind having their subordinates use it as a training device. The responses to question 11 (whether AUDITPLANNER would be more useful as a training device than as a decision aid) were inconclusisve, although there was a slight bias in favor of its use as a decision aid.

Ease of use and enjoyment. Several questions also addressed the evaluators' general attitude towards the system in terms of ease of use and enjoyment (questions 1, 9, 10, 13, 20, 21, and 25). The responses were quite favorable. Of particular interest is the uniformly favorable reaction to the system's sequencing of questions and flow of dialogue (questions 21 and 25). All six evaluators agreed that the system asked questions in a natural order that was easy to follow and understand. This reaction is in agreement with the findings by Aiello [1983] that users found the backward-chaining control strategy easy to understand.

Adequacy of question-answering facilities. Responses to questions 17 and 23 indicate that the evaluators felt that AUDITPLANNER's question-answering capabilities were quite helpful. However, during the sessions most evaluators made only limited use of those facilities, preferring to just answer the system's questions and then examining its recommendations. This subjective impression is supported by the responses to question 16, which indicate that four of the six evaluators felt that they did not make extensive use of those facilities. Apparently, however, the little use that was made generated a favorable response.

Summary. The six auditors who used AUDITPLANNER to make materiality judgments for their own clients indicated that they found the system easy and enjoyable to use. The flow of dialogue was natural and easy to follow.

The evaluators indicated that they felt that AUDITPLANNER exhibited a basic level of competence in making judgments of auditing materiality. However, they were not willing to always accept its recommendations. The major source of disagreement centered on the proper materiality threshhold to be used. Subsequent discussions indicated that disagreements on this point are defensible differences of opinion. Indeed, the evaluators did agree that the logic of the model employed by AUDITPLANNER was reasonable and easy to follow.

Finally, the evaluators were unanimous in their enthusiasm for the system and their belief that it would be useful both as a training device and as a decision aid. Several rules were suggested for dealing with clients outside the principal subject's primary areas of expertise and a willingness to help in further development of the system was expressed.

In conclusion, AUDITPLANNER was able to competently and successfully make materiality judgments for clients with which the partner who served as the subject of this research had previous experience. The results of having six other auditors from the same accounting firm use AUDITPLANNER to make materiality judgments for their clients indicates that the logic underlying AUDITPLANNER's approach toward making those judgments reflects the general approach used by that accounting firm. The next chapter describes the nature of that judgment process.

CHAPTER IV

ANALYSIS OF THE SYSTEM

This chapter examines the model of the materiality judgment process that is represented in the production rules of AUDITPLANNER. First, the setting in which those judgments are made is described. This description explains the role played by materiality in the audit planning process of one public accounting firm. Then the method by which those judgments are made is discussed. English translations of the system's rules are presented in order to illustrate exactly how various qualitative factors enter into the materiality judgment process.

The Decision Setting

Figure 3 illustrates the role played by judgments of auditing materiality in the audit planning process of the firm studied in this dissertation. The figure shows that those judgments are used to set the precision level of the audit tests. However, materiality is not the only factor that affects the precision level. The client's service needs and certain aspects of audit risk also influence the choice of a precision level.

Figure 3 shows business risk as a factor that affects materiality. Business risk represents risks to the auditor

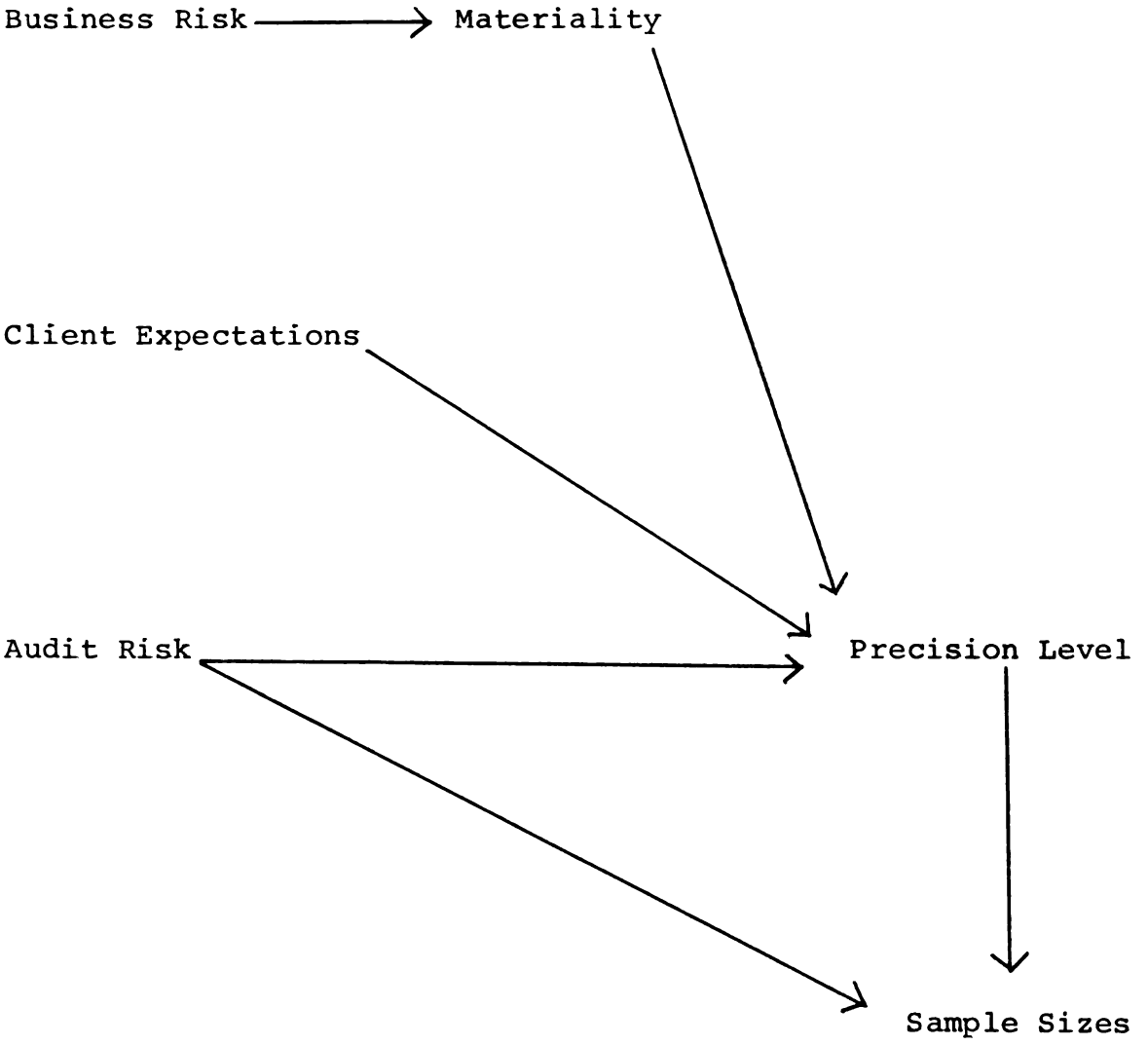

Figure 3. Causal Model of Auditing Materiality

(e.g., litigation) arising from the expression of an opinion on the client's financial statements. In response to such risks the auditor may choose to reduce the materiality level used to plan the extent of audit tests. Boatsman and Robertson [1974] found that business risk was a significant predictor of their subjects' materiality judgments.

Figure 3 shows that the precision level is then used to help determine sample sizes for audit tests. Audit risk also affects the choice of sample sizes. Thus, Figure 3 illustrates the relationship between audit risk and materiality that is discussed in SAS No. 47:

> Audit risk and materiality, among other matters, need to be considered together in determining the nature, timing, and extent of auditing procedures [AICPA, 1983, para. 1].

Audit risk is the risk that the auditor will conclude that the financial statements are not materially misstated when, in fact, material errors do exist. SAS No. 47 breaks audit risk down into three components: (1) inherent risk, which is the risk that material errors would occur in the absence of a system of internal controls, (2) control risk, which is the risk that any errors which do occur will not be detected or prevented by the system of internal controls, and (3) detection risk, which is the risk that the auditor's procedures will fail to find any material errors that may exist.

Figure 3 indicates that audit risk affects both the precision level and the choice of sample sizes. The inherent risk component of audit risk affects the precision level by

reducing that level for the amount of uncorrected errors the auditor expects to find, based on previous audits of the client. The control and detection risk components of audit risk both directly influence the choice of sample sizes. The level of control risk is derived from the assessment of the quality of internal controls. That assessment is then used to determine the level of detection risk that can be accepted and still achieve the desired overall level of audit risk. The actual sample sizes that will be used in audit testing are then determined by means of a formula that uses both the precision level and the level of detection risk.

In summary, judgments of auditing materiality are but one factor used to establish the precision level of audit tests. Those judgments of materiality are influenced by the auditor's assessment of business risk. Consequently, AUDITPLANNER contains rules to deal with both materiality and the evaluation of business risk. The remainder of this chapter describes the logic of that judgment model.

The Judgment Model

Appendix III contains a sample consultation with AUDITPLANNER. That transcript shows that AUDITPLANNER asks the user for basic facts about the client being audited and then uses those facts to recommend an overall materiality to be used in planning audit tests.

Overview

Figures 4-7 illustrate AUDITPLANNER's judgment model. These figures are based on the data flow diagrams that are

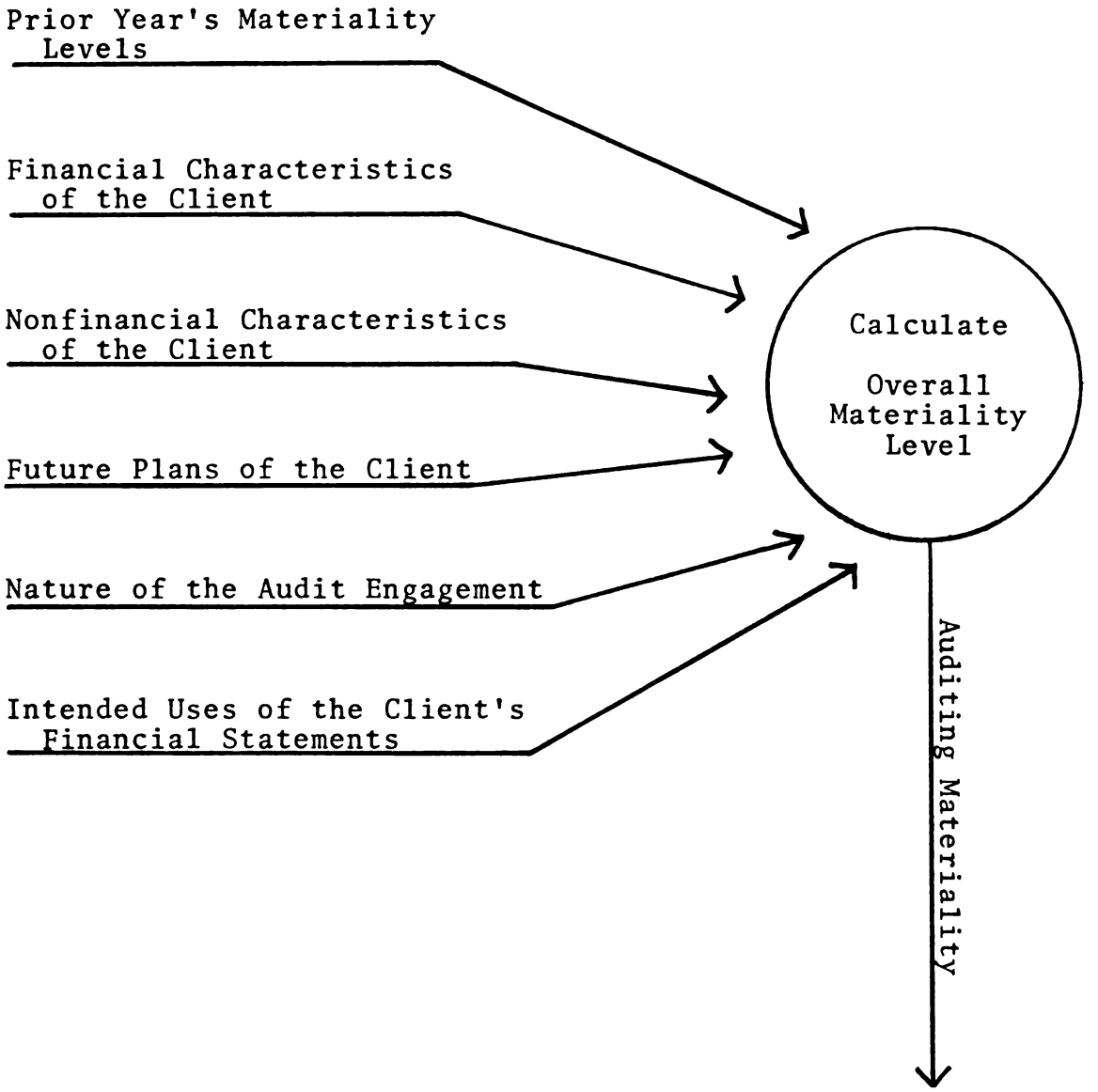

Figure 4. Overview of AUDITPLANNER'S Judgment Model

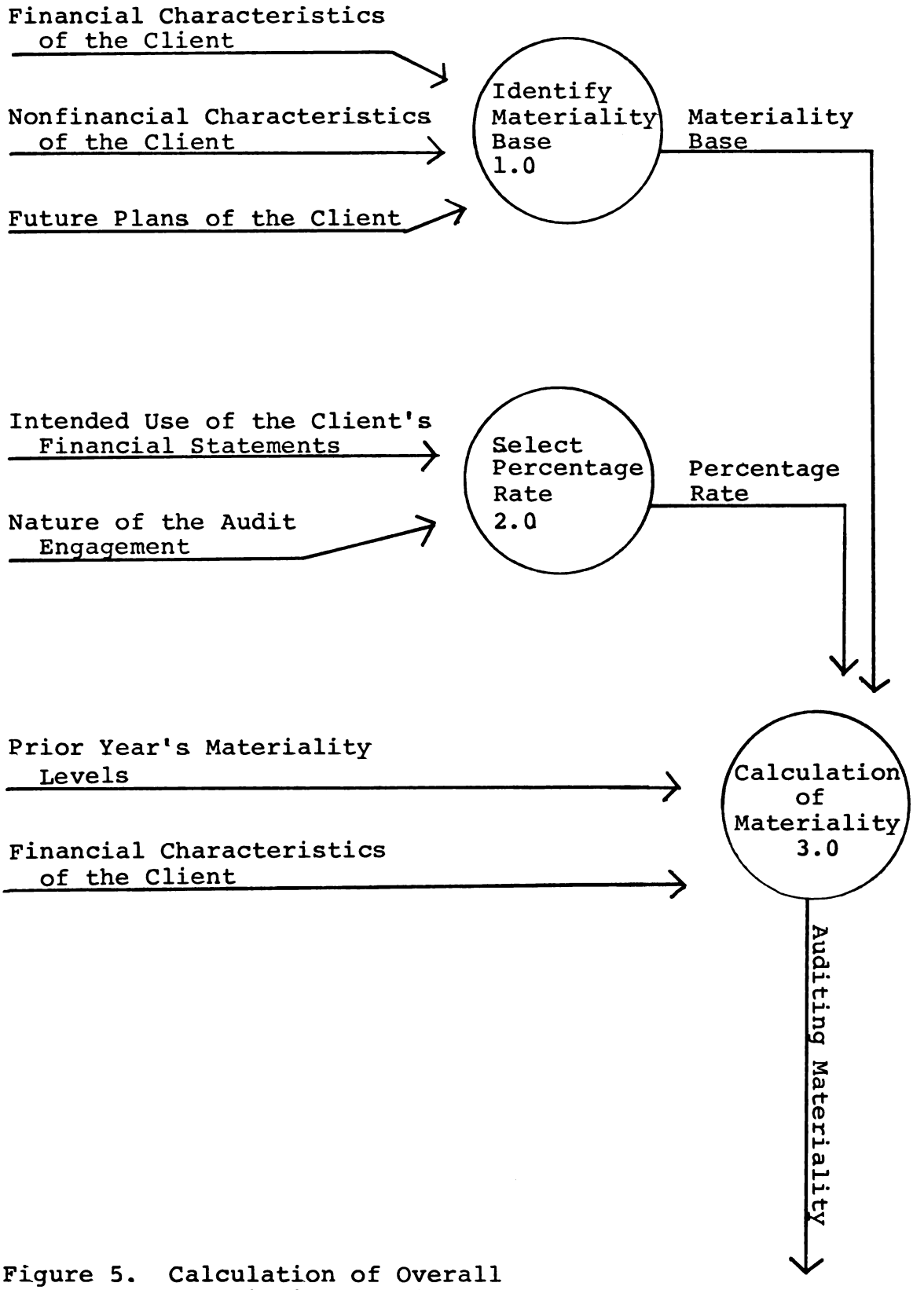

Figure 5. Calculation of Overall Materiality Level

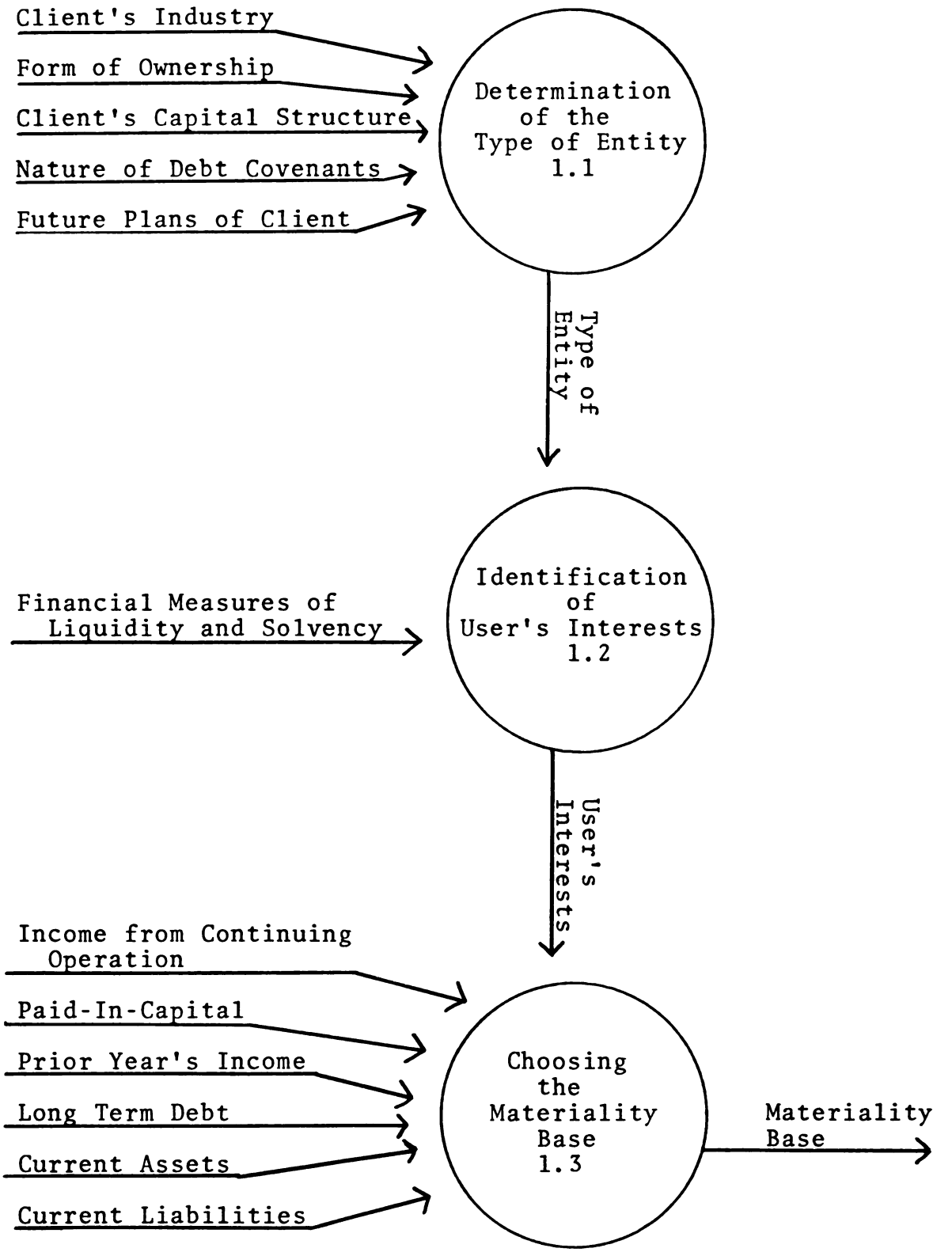

Figure 6. Identification of Materiality Base

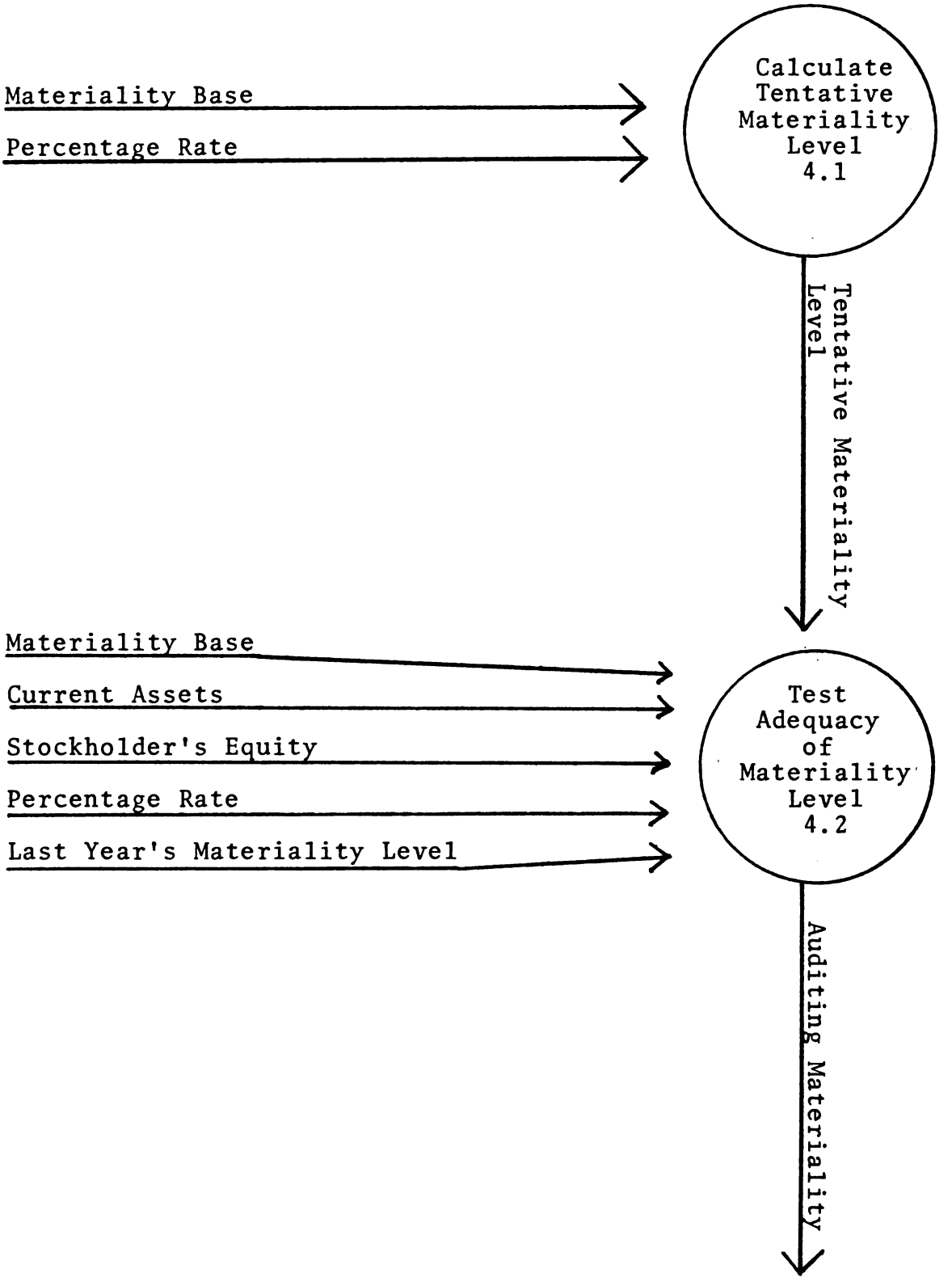

Figure 7. Calculation of Materiality

used in the structured analysis of information systems [DeMarco, 1979]. The bubbles represent the processes or decisions that are made during a consultation. The labeled arcs represent the information that is used to make those decisions.

Figures 4-7 represent the judgment model in increasing levels of detail. Figure 4 provides a highly summarized picture of the entire process. It indicates that the following information is used to calculate the overall materiality level:

1. The materiality levels used in prior audits of the client.
2. Various financial characteristics of the client.
3. Various nonfinancial characteristics of the client.
4. Future plans of the client.
5. The nature of the audit engagement.
6. The intended uses of the client's financial statements.

The financial characteristics of the client that are used to calculate an overall materiality level include the following:

1. Current assets
2. Current liabilities
3. Long-term debt
4. Paid-in capital
5. Retained earnings
6. Income from continuing operations
7. Prior years' income

The nonfinancial characteristics include:

1. The industry of the client
2. The client's capital structure
3. The nature of the client's debt covenants
4. The nature of the client (is it a subsidiary)

The future plans of the client refer to any client plans for the issuance of additional debt or equity securities. The nature of the audit engagement refers to whether or not this is the initial audit of the client. The intended uses of the client's financial statements represent certain types of business risks which affect the materiality calculation.

Figure 5 illustrates the major steps involved in this calculation. Various financial and nonfinancial characteristics of the client, together with information about the client's future plans, are used to select the appropriate base for the materiality calculation (bubble 1.0). Information about the intended use of the financial statements and the nature of the audit engagement is used to select the percentage rate to use in calculating materiality (bubble 2.0). The percentage rate, the materiality base, prior years' materiality levels, and various financial characteristics of the client are all used to make the actual materiality calculation (bubble 3.0).

AUDITPLANNER uses the following production rule, known as a goal rule, to ensure that each of these three major activities is performed during the course of a consultation:

Rule 80 (note: the numbers on rules are for reference purposes only)

IF: 1) It is definite that the client is not a nonprofit organization, and

2) Information has been gathered about the appropriate base for the materiality calculation and whether there are any special business risks which need to be considered when planning the audit, and

3) An attempt has been made to deduce the percentage rate used to determine the materiality level, and

4) An attempt has been made to deduce the overall materiality level that will be used to plan the extent of audit procedures and tests

THEN: It is definite that a judgment of auditing materiality which will be used to plan the extent of audit procedures has been made.

This rule is called a goal rule because its action part satisfies the goal of the consultation: making a judgment about the overall materiality level to be used in planning audit tests. (The reason for clause 1 is that the procedure for dealing with nonprofit organizations differs somewhat from the procedure for profit-oriented entities. Each fund or fund type of a nonprofit organization has its own materiality level).

The attempt to satisfy the premises of rule 80 results in the creation of a goal tree which orders the major subtasks that have to be performed. First, AUDITPLANNER determines whether or not the client is a nonprofit organization. If it is, then a different goal rule is tried. If not, AUDITPLANNER then gathers background information about the client in order to identify the appropriate base for the

materiality calculation. Next, information about any special business risks is gathered and evaluated. That information is used to select a threshold rate. The materiality base is then multiplied by the threshold rate to derive an overall materiality level.

The reader is reminded that this ordering of the materiality judgment process was designed to produce a consultation whose logic was easy to follow. No claim is made that the subject necessarily follows the steps in the sequence outlined above. For example, an auditor may assess the risks associated with the audit prior to determining the basis for the materiality calculation. Nevertheless, these steps are all part of the process of making the materiality judgment, and the rules used by AUDITPLANNER to perform those steps do accurately reflect the way that the expert subject makes those decisions.

The remainder of this section describes how each of these three major decisions (represented by bubbles 1.0, 2.0, and 3.0 in Figure 5) is made.

Identification of the Materiality Base

Figure 6 illustrates the steps involved in identifying the appropriate base for the materiality calculation (bubble 1.0 in Figure 5). Three steps are involved. First, nonfinancial client characteristics and the client's future plans are used to determine what type of entity the client is. Then that decision and various financial measures of liquidity and solvency are used to infer the primary interests of

the users of the client's financial statements. Finally, the inferred users' interests and other financial characteristics of the client are used to select the materiality base.

Determination of the type of entity. Figure 6 shows that the following information is used to determine what type of entity the client is:

1. The client's industry
2. Whether or not the client is a subsidiary (form of ownership)
3. The client's capital structure
4. The nature of any debt covenants
5. Future plans of the client

These factors are all mentioned in SAS No. 22 as being items that should be considered when planning an audit. Subjects in previous empirical studies also mentioned that they would like to have such information upon which to base their materiality judgments. However, neither the authoritative literature nor previous empirical research has explained how these factors influence materiality judgments. Figure 6 shows that they are used to help determine what type of entity the client is, and this information in turn is used to eventually select the appropriate base for calculating the overall materiality level. Moreover, examination of the rules used to determine the type of entity the client is shows exactly how these qualitative factors influence materiality.

AUDITPLANNER has seven rules which it uses to deter-

mine what type of entity the client is (bubble 1.1).

Rule 7

IF: 1) It is likely that the client may be a private entity, and

2) The client is not filing with a regulatory agency in preparation for the sale of its securities in a public market, and

3) The client does not intend to "go public" in the next two or three years

THEN: The client is a private entity.

Rule 26

IF: 1) It is likely that the client may be a private entity, and

2) A: The client is filing with a regulatory agency in preparation for the sale of its securities in a public market, or

B: The client intends to go public in the next two or three years

THEN: The client is a public entity.

Rule 40

IF: 1) The client has publicly traded debt or equity securities, or

2) The client has restrictive debt covenants that are measured by or depend on periodic financial statement amounts or ratios that involve results of operations

THEN: The client is a public entity.

Rule 53

IF: The client's main line of business or industry classification is insurance

THEN: The client is a public entity.

Rule 56

IF: 1) The client does not have any publicly traded debt or equity securities, and

2) The client does not have any restrictive debt covenants that are measured by or depend on periodic financial statement amounts or ratios that involve results of operations, and

3) The client is not controlled by a public entity

THEN: It is likely that the client may be a private entity.

Rule 94

IF: 1) The client does not have any publicly traded debt or equity securities, and

2) The client does not have any restrictive debt covenants that are measured by or depend upon periodic financial statement amounts or ratios that involve results of operations, and

3) The client is controlled by a public entity, and

4) The client is a wholly-owned subsidiary, and

5) The principal external users of the client's financial statements are creditors or others who are primarily interested in the client's financial position rather than in results of operations, and

6) The client's parent considers it to be a private subsidiary

THEN: It is likely that the client may be a private entity.

Rule 95

IF: 1) The client does not have any publicly traded debt or equity securities, and

2) The client does not have any debt covenants which are measured by or depend on periodic financial statement amounts or ratios that involve results of operations, and

3) The client is controlled by a public entity, and

4) A: The client is not a wholly-owned subsidiary, or

B: The principal users of the client's financial statements are not creditors or others who are more interested in the client's financial position than in results of operations, or

C: The client's parent does not consider it to be a private subsidiary

THEN: The client is a public entity.

These rules represent the firm's definitions of public and private entities. Rules 40 and 56 define the clear-cut situations. Rules 94 and 95 deal with the situation where the client is a subsidiary of a public entity, and outline the conditions that must be met in order for it to be considered a private entity. The transcript in Appendix III indicates that the user is asked to supply the information needed to establish the validity of the premises in these seven rules.

Rule 53 is particularly worth noting, because it is an example of the importance of information about the client's industry classification. The justification for this rule is that the regulatory agencies which are among the major users of insurance companies' financial statements are interested in their results of operations, regardless of the form of ownership.

This rule illustrates one of the advantages of using the expert systems methodology to study the materiality judgment process. Rule 53 represents one way in which information about the client's industry can influence those

judgments. However, because there are many other variables which intervene between this factor and the ultimate materiality level, it is not likely to be a statistically significant predictor of those judgments.

Gibbins and Wolf [1983] reported that plans for future sales or financing by the client were an important factor influencing the conduct of the audit. Rules 7 and 26 show one way in which that factor affects materiality judgments. If the auditor knows that a privately-held client is going to become publicly-held in the near future, it is considered to be a public entity. The rationale is that current owners are likely to become shareholders and will have the same interests as do the owners of publicly-held entities.

With these seven rules AUDITPLANNER is able to determine what type of entity the client is. Figure 6 shows that this decision is then used as one of the factors that helps to identify the primary interests of the users of the financial statements (bubble 1.2). The next section explains how these interests are inferred.

Identification of users' interests. SAS No. 47 states that " the auditor's consideration of materiality . . . is influenced by his perception of the needs of a reasonable person who will rely on the financial statements "[AICPA, 1983, para. 6]. Figure 6 shows that information about the type of entity the client is and financial characteristics relating to measures of solvency and liquidity are used to infer those needs. This decision is based on a model that

assumes that different classes of users (e.g., creditors, investors, etc.) have different needs and interests. Creditors and owners are assumed to be more interested in measures of liquidity and solvency than in results of operations because the former more directly affect their claims. On the other hand, investors are assumed to be more interested in results of operations than in measures of liquidity or solvency, because the former more directly affect future returns (dividends) on their investments.

Although several previous studies of materiality compared auditors to various user groups (e.g., Boatsman and Robertson [1974], Firth [1979]), only Pattillo [1976] provides any data about the differences between user groups. He reported that bankers used consistently higher materiality thresholds than did financial analysts. This difference existed across every decision setting that was used. These results do indicate that there may be some differences in the interests of different user groups.

AUDITPLANNER has three rules which it uses to infer the primary interests of the users of the client's financial statements.

Rule 11

IF: 1) The client is a public entity, and

2) There is not significant concern about the client's liquidity or solvency

THEN: It is definite that the principal external users of the client's financial statements are primarily interested in the results of current operations.

Rule 12

IF: 1) The client is a private entity

THEN: It is definite that the principal external users of the client's financial statements are primarily interested in the client's financial position.

Rule 42

IF: 1) The client is a public entity, and

2) There is significant concern about the liquidity or solvency of the client

THEN: It is definite that the principal external users of the client's financial statements are primarily interested in the client's financial position.

Rules 11 and 12 deal with the ordinary situation when the client is profitable. Rule 42 deals with the situation where a public entity's continued viability is in question; in this case, the interests of investors are assumed to become the same as those of owners and creditors. Because the judgment of auditing materiality precedes any detailed analytical review, only a crude test of the client's liquidity or solvency is made by looking at the current ratio and retained earnings.

Choosing the materiality base. Figure 6 indicates that information about the interests of the users of the client's financial statements and various financial characteristics of the client are used to select the base for the materiality calculation (bubble 1.3). AUDITPLANNER has five rules which are used to make this decision.

Rule 17

IF: 1) The principal external users of the client's financial statements are primarily interested in the results of operations, and

2) Income from continuing operations is greater than 0

THEN: It is definite that the materiality judgment should be based on the amount of income from continuing operations.

Rule 18

IF: 1) The principal external users of the client's financial statements are primarily interested in the results of operations, and

2) Income from continuing operations is less than or equal to zero, and

3) Last year's income from continuing operations is greater than 0, and

4) The number of times in the past three years that income has been at or below the breakeven point is less than 2

THEN: It is definite that the materiality judgment should be based on the trend in past earnings.

Rule 19

IF: 1) The principal external users of the client's financial statements are primarily interested in the results of operations, and

2) Income from continuing operations is less than or equal to 0, and

3) A: Last year's income from continuing operations was less than or equal to 0, or

B: The number of times in the last three years that income has been at or below the breakeven level is greater than or equal to 2

THEN: It is definite that the materiality judgment should be based on the amount of owners- or stockholder's-equity

Rule 23

IF: 1) The principal external users of the client's financial statements are primarily interested in the client's financial position, and

2) The amount of current assets is greater than or equal to the amount of owners- or stockholder's-equity

THEN: It is definite that the materiality judgment should be based on the amount of owners- or stockholder's-equity

Rule 24

IF: 1) The principal external users of the client's financial statements are primarily interested in the client's financial position, and

2) The amount of current assets is less than the amount of owner's- or stockholder's-equity

THEN: It is definite that the materiality judgment should be based on the amount of current assets.

Rule 17 indicates that normally, investors are assumed to be interested in the results of current operations. Rules 18 and 19 deal with breakeven situations. If current income is at or below the breakeven level, a surrogate is used. If the breakeven situation is unique (i.e., has not occurred frequently in the past), rule 18 fires and materiality is based on the trend in past earnings. If, on the other hand, the client has experienced several years of losses recently, rule 19 fires and the materiality judgment is based on the amount of stockholders equity.

These three rules provide one explanation of the breakeven effect found by Moriarity and Barron [1979]. They

also account for the relatively low significance of the trend in earnings as a predictor of materiality judgments. Rules 18 and 19 indicate that this trend is only used as a surrogate for current income when the breakeven situation is relatively rare. If the client has experienced several bad years recently, attention shifts away from results of current operations to measures of financial position.

Rules 23 and 24 deal with the materiality bases for private entities. They indicate a risk-averse attitude where the materiality base selected is the one that results in the most conservative materiality level. This reflects the general attitude toward risk of the expert subject of this study.

This completes the description of Figure 6. At this point AUDITPLANNER has selected the base for the materiality calculation. The next step is to choose the percentage rate (threshold level) to be used with that base. This involves the assessment of business risk.

Choosing a Percentage Rate

The causal model of the materiality judgment in Figure 3 indicated that business risk affected the calculation of the overall materiality level. Figure 5 indicated that this occurs through the effect of business risk on the choice of a percentage or threshold rate for the materiality calculation. AUDITPLANNER contains one general rule to guide the collection of information about such risks.

Rule 47

IF: Information has been gathered about

1. Whether the financial statements are going to be used in connection with a public offering of securities by the client, and

2. Whether the financial statements are being used in connection with a transfer of interests in the client, and

3. Whether the financial statements are being used in connection with a contest for the control of the client, and

4. Whether the financial statements are going to be used to settle some litigation in which the client is involved, and

5. Whether the financial statements are being used in an inquiry by a regulatory agency, and

6. Whether the client appears to be in violation of any restrictive debt covenants

THEN: The existence of any special business risks that need to be considered when choosing a percentage rate has been assessed.

This rule causes AUDITPLANNER to ask a series of questions about the intended uses of the client's financial statements. The nature of these events may cause users' materiality thresholds to be lower than otherwise. For example, when the financial statements are being used in a purchase of the client, the purchase price may be related to the account balances in the financial statements. As a result, users are going to be concerned about much smaller errors than may otherwise be true.

Should any of the six questions be answered in the affirmative, AUDITPLANNER asks additional questions to

evaluate the degree of risk involved. For example, if the client is being investigated by a regulatory agency, AUDITPLANNER asks further questions about the reason for the investigation.

AUDITPLANNER has ten rules which it uses to determine the appropriate percentage rate to use in calculating the overall materiality level. These rules reflect the expert's views regarding the relative severity of different types of situations representing business risk. Because business risk refers to potential losses to the auditor, the expert who participated in this study requested anonymity. Similar reasons preclude the publication of the rules which relate specific business risks to choices of materiality threshold rates.

AUDITPLANNER uses the following rule for the situation where there are no special business risks.

Rule 27

IF: 1) The financial statements are not going to be used in connection with a public offering of securities, and

2) The financial statements are not being used in connection with a transfer of interests in the client, and

3) The financial statements are not being used in connection with a contest for the control of the client, and

4) The financial statements are not being used to settle some litigation involving the client, and

5) The financial statements are not being used in connection with an inquiry by a regulatory agency, and

6) The client is not in violation of, and is not likely to be found in violation of, any restrictive debt covenants relating to the results of continuing operations.

THEN: A percentage rate of 5 percent should be used to calculate the overall materiality level.

Thus, this rule represents the expert's default rule for a "normal" audit. The expert indicated that the accounting firm's policy did not specify what this default percentage rate had to be, but did recommend an appropriate range in which might fall. Consequently, different auditors in the firm may use different default rates, depending upon their general attitude toward risk.

Figure 5 indicates that the nature of the engagement also affects the choice of the percentage rate. The following rule shows how this factor enters the judgment process.

Rule 101

IF: 1) This is the first time that we have audited the client, and

2) A: This is the first time that the client has ever been audited, or

B: The client's previous auditors left because of a dispute with the client

THEN: The materiality level needs to be reduced to reflect the increased uncertainty associated with an initial audit.

The next section discusses the rules which use the percentage rate to calculate the overall materiality level.

Calculation of the Materiality Level

Figure 7 illustrates how AUDITPLANNER calculates the materiality level to be used in planning the extent of audit

tests. The percentage rate representing the materiality threshold is multiplied by the amount of the materiality base. This produces a tentative materiality level. That level is then tested to see whether it is either so small that it would result in an inordinate amount of testing or so large that most users would question its usefulness. There are separate rules to deal with each situation.

Tentative level too small. The expert indicated that too low of a materiality level would result in a level of audit testing that would not be economically justified for most clients. AUDITPLANNER has three rules for calculating an alternative materiality level in such situations.

Rule 60

IF: 1) The materiality base used to calculate the tentative materiality level is current assets

THEN: Recalculate the materiality level using owners- or stockholders-equity as the materiality base.

Rule 61

IF: 1) The materiality base used to calculate the tentative materiality level is owners- or stockholders-equity

THEN: Recalculate the materiality level using current assets as the materiality base.

Rule 65

IF: 1) The materiality base used to calculate the tentative materiality level is income from continuing operations, or

2) The materiality base used to calculate the tentative materiality level is the trend in past earnings

THEN: Recalculate the materiality level using owners- or stockholders equity as the materiality base.

Rules 60 and 61 refer to the situation where the materiality base is either owners-equity or current assets. Earlier, rules 23 and 24 were shown to select the lower of these two financial account balances as the materiality base to use in calculating the tentative materiality level. Thus, rules 60 and 61 serve to offset the effects of being too conservative in the choice of a percentage rate.

Rule 65 fits into the general model of user interests that was discussed earlier. If the materiality level relating to results of operations is too low, this means that although the client has been profitable in the past, that profitability was only marginal. Consequently, it is assumed that in such situations investors are more interested in measures of the client's financial position than in results of operations.

AUDITPLANNER has two other rules which check the adequacy of the alternative materiality level.

Rule 59

IF: 1) The alternative materiality level is also too low, and

2) A: The original materiality base was income from continuing operations, or

B: The original materiality base was the trend in past earnings, and

3) The alternative materiality level was calculated using owners- or stockholders-equity

THEN: Recalculate the materiality level using current assets as the materiality base.

Rule 120

IF: 1) An attempt has been made to calculate an alternative materiality level, and
2) The alternative materiality level is itself too low

THEN: Set the overall materiality level at the absolute minimum level that is economically justifiable for any client.

These five rules illustrate how cost considerations influence judgments of auditing materiality. They serve to counterbalance the generally conservative approach taken by AUDITPLANNER, yet do not deviate from the model of user interests that is part of AUDITPLANNER's logic.

Tentative level too large. The expert expressed a belief that above a certain point users would regard the absolute value of the materiality level as itself being material. Two rules deal with this situation.

Rule 66

IF: 1) The tentative materiality level is too high and

2) The tentative materiality level is greater than or equal to the materiality level that was used last year

THEN: Set the tentative materiality level to be equal to last year's materiality level plus 20 percent of the difference between last year's level and the tentative materiality level.

Rule 67

IF: 1) The tentative materiality level is too high

2) The materiality level used last year is greater than the tentative materiality level calculated this year

THEN: Use the tentative materiality level to plan this year's audit.

These two rules once again reveal the conservative risk attitude of the expert. If the client has a better year than last year, the tentative materiality level will be greater than the materiality level used last year. Rule 66 serves to discount the effect of such "good news" events. On the other hand, if the client had a worse year than last year, the tentative materiality level is accepted. Thus, rule 67 serves to accept "bad news" at face value.

Special Situations

At this point all of the bubbles in Figures 4-7 have been explained. This section discusses two other situations that have not yet been covered: (1) audits of nonprofit organizations, and (2) audits of financial institutions.

Audits of nonprofit organizations. AUDITPLANNER has a different goal rule for the audits of nonprofit organizations. That rule serves to generate a materiality level calculation for each major fund or fund type. The calculation, however, is still the result of multiplying the materiality base by a percentage rate.

AUDITPLANNER has two rules for identifying the materiality base of a fund or fund type.

Rule 72

IF: The fund balance is less than 20 percent of the fund's total assets

THEN: The materiality base is the total assets of the fund.

Rule 73

IF: The fund balance is greater than or equal to 20 percent of the fund's total assets

THEN: The materiality base is the general expenditures of the fund.

These two rules reflect a model of the needs of the users of the financial statements. Rule 73 assumes that the users of the financial statements are primarily interested in how the entity spends the money it has received. Rule 72, however, assumes that if the fund's future viability becomes a matter of concern, that users' interests shift to measures of the fund's financial position.

Audits of financial institutions. Financial institutions often have large portfolios of interest-bearing investments. The size of those portfolios is such that it would not be economical to design tests of those portfolios on the basis of the overall materiality level. Therefore, AUDITPLANNER contains rules which calculate a separate materiality level for those portfolios.

Rule 37

IF: Stockholders-equity times the percentage rate used to calculate the overall materiality level is greater than the result of dividing income from continuing operations by the average rate of return on the investment portfolio

THEN: The materiality level for the investment portfolio is equal to the amount of income from continuing operations divided by the average rate of return on the investment portfolio.

Rule 46

IF: Stockholders-equity times the percentage rate used to calculate the overall materiality level is less than or equal to the result of dividing income from continuing operations by the average rate of return on the investment portfolio

THEN: The materiality level for the investment portfolio is equal to the amount of stockholders-equity times the percentage rate used to calculate the overall materiality level.

These rules again reflect a conservative bias. The impact of the investment portfolio on the results of current operations is compared to its impact on financial position, and the separate materiality level is calculated for the item which is affected most by the investment portfolio. The existence of these rules is also another example of how the client's industry classification affects judgments of auditing materiality.

Summary

This section described the model of the materiality judgment process that is reflected in the rules used by AUDITPLANNER to make those judgments. The calculation of the overall materiality level was seen to be the product of multiplying the materiality base deemed most relevant to the users of the financial statements by a percentage rate which reflects the degree of business risk associated with the audit. The rules used to make these decisions were presented in order to illustrate how various qualitative factors were used to make the judgments. The effects of those factors are

summarized in Table 3.

This section has described the process of making judgments of auditing materiality at a very detailed level. The next section describes the materiality judgment process from a more general perspective, focusing on what the detailed analysis implies about the nature of that judgment process.

The Nature of the Materiality Judgment Process

The purpose in building AUDITPLANNER was to obtain a better understanding of the materiality judgment process, specifically the role of materiality in planning an audit. The previous section presented the rules that reflect the auditing expertise used to make those judgments. That analysis indicated that the calculation of materiality involves choosing an appropriate base for the calculation and then multiplying that base by a percentage rate that represents the appropriate threshhold given the intended use of the financial statements.

These two major components of the materiality judgment process have markedly different characteristics. The choice of the appropriate base for the materiality calculation is a function of the auditor's perceptions of the needs and interests of different classes of users of the financial statements. Rules 11, 12, and 42 present the essence of the model underlying those perceptions. These rules are based on objective data about the client and represent the standard policy of the accounting firm. Therefore, there is almost total agreement among members of the firm concerning the

TABLE 3. Effect of qualitative factors on judgments of auditing materiality

QUALITATIVE FACTOR	EFFECT
Client's industry	Choice of materiality base. Need for additional materiality levels.
Capital structure: lines of credit debt subordinated debt shares outstanding	Type of entity.
Type of entity (subsidiary)	Choice of materiality base.
Future plans of client	Choice of materiality base. Materiality threshhold.
Events (e.g., major acquisitions, new products)	Choice of materiality base.
Solvency/Liquidity measures	Choice of materiality base.
Profitability	Choice of materiality base.
Initial audit	Materiality threshhold.
Purpose and intended use of the financial statements	Materiality threshhold.
Prior years' materiality levels	Overall materiality level.

appropriate base for the calculation of materiality.

The choice of the appropriate percentage rate to use in calculating the overall materiality was seen to depend on the auditor's assessment of the degree of business risk present for a particular audit engagement. The accounting firm has a standard approach to determining whether any such risks exist (see rule 47). However, the appropriate response to those risks is determined by the individual auditor's own attitude towards risk. Thus, this component of the materiality judgment process is highly idiosyncratic.

Exhibits I and II present the logic of the procedures for choosing the appropriate materiality base and percentage rate, respectively. Close examination of each Exhibit makes the difference between the two component decisions readily apparent. Exhibit I reflects a policy that can be uniformly followed by all decision makers. Exhibit II highlights the role of individual values in making materiality judgments.

This difference in the nature of the two major parts of the materiality judgment process may provide an explanation of the findings of a lack of consensus among auditors regarding materiality. It is possible that auditors may agree on the base for materiality judgments and on the types of situations which represent a greater than normal degree of business risk. However, because the response to those risks is based on personal attitudes towards risk, there may be disagreements about the appropriate percentage rate and thus about the appropriate materiality level.

EXHIBIT 1. PROCEDURE FOR IDENTIFYING MATERIALITY BASE
(bubble 1.0, figure 5)

1. PROCEDURE FOR DETERMINING TYPE OF ENTITY
(bubble 1.1, figure 6)

Select the policy which applies:

Case 1 (Client has publicly traded debt or equity securities);
Client is a public entity.

Case 2 (Client has covenants on debt or lines of credit that are related to results of operations);
Client is a public entity.

Case 3 (Client is not controlled by public entity);
If (client is not filing with regulatory agency in preparation for sale of its securities in a public market and does not intend to do so in the next two or three years)
Then client is a private entity.
Otherwise,
Client is a public entity.

Case 4 (Client is controlled by a public entity);
Select the case which applies:

Case 4a (Client is not a wholly-owned subsidiary);
Client is a public entity.

Case 4b (Principal users of client's financial statements are interested in results of current operations);
Client is a public entity.

Case 4c (Client's parent considers it to be a public entity);
Client is a public entity.

Case 4d
If (client is not filing with a regulatory agency in preparation for the sale of its securities in a public market and does not intend to do so in the next two or three years)
Then client is a private entity.
Otherwise,
Client is a public entity.

Exhibit 1. (continued)

2. PROCEDURE FOR DETERMINING PRIMARY INTEREST OF PRINCIPAL EXTERNAL USERS OF CLIENT'S FINANCIAL STATEMENTS
(bubble 1.2, figure 6)

Select the case which applies:

Case 1 (client is a public entity)
If (there is no concern about the liquidity or solvency of the client)
Then assume primary interest is in results of current operations.
Otherwise,
Assume primary interest is in financial position.

Case 2 (client is private entity)
Assume primary interest is in financial position.

3. PROCEDURE FOR SELECTING MATERIALITY BASE
(bubble 1.3, figure 6)

Select the case which applies:

Case 1 (Primary interest is in results of current operations)
If (income from continuing operations is above the breakeven level),
Then materiality base is income from continuing operations.
Otherwise,
If (last year's income was above the break-even point and there losses in no more than one of the prior three years)
Then materiality base is the trend in past earnings.
Otherwise,
Materiality base is stockholders equity.

Case 2 (Primary interest is in financial position)
If (current assets is greater than or equal to stockholders equity)
Then materiality base is stockholders equity.
Otherwise,
Materiality base is current assets.

EXHIBIT 2. PROCEDURE FOR SELECTING MATERIALITY THRESHOLD
(bubble 2.0, figure 5)

1. Determine if there are any intended uses of the client's financial statements which may indicate the presence of special audit risks.

2. For each such risk identified in step 1, obtain additional information to determine the seriousness of the situation.

3. Choose percentage (threshold) rate.

   Select the case which applies:

   Case 1 (no special audit risks);
   Use your default materiality threshold.

   Case 2 (special audit risks exist);
   Reduce default materiality threshold by an amount appropriate to the level of risk, given personal risk attitude.

Indeed, previous empirical research on materiality judgments found that auditors had different attitudes toward risk in general [Newton, 1977] and toward the business risk associated with particular situations [Ward, 1976]. The comments of the auditors who evaluated AUDITPLANNER also support this possibility. The evaluators generally agreed with each other and with AUDITPLANNER regarding the types of situations which represented increased business risk. There was also a general consensus that each of these situations warranted a reduction in the percentage rate used to calculate the overall materiality level. However, there was no consensus about either (1) how much the percentage rate should be reduced for a given situation, or (2) the appropriate default percentage rate to use when no special business risks existed.

This concludes the analysis of the mechanics and nature of the materiality judgment process. The next chapter summarizes the findings, discusses the implications of this research for future attempts to develop general standards for making materiality judgments, and suggests possible future extensions to this research.

CHAPTER V

CONCLUSIONS AND SUGGESTED EXTENSIONS

The previous four chapters presented the theoretical justification for and the analysis of an expert system which makes judgments of auditing materiality. This chapter begins by summarizing the results of this research effort and its contributions to accounting research. Then several suggestions for possible future extensions to the work are presented.

Research Contribution

Participants in previous empirical studies of the materiality judgment process frequently complained about the artificiality of the cases that were used, particularly the absence of many qualitative environmental factors that serve to put the decision into context. The primary purpose of this dissertation was to use the expert systems methodology to obtain a better understanding of how such factors affect judgments of auditing materiality. The successful use of that methodology is seen as the major contribution of this research.

AUDITPLANNER, the expert system built in this dissertation, makes judgments of auditing materiality. The rules which constitute its knowledge base describe how various

factors influence those judgments. The analysis in Chapter IV indicated that the judgment process consists of two separate decisions: (1) the identification of an appropriate base for the materiality judgment, and (2) the selection of a percentage (threshhold) rate to be applied to that base.

The first decision, identification of the materiality base, depends upon the auditor's perceptions of the needs of the users of the financial statements. It is at this point where many of the qualitative environmental factors which together describe the nature of the client (e.g., industry, form of ownership, etc.) enter into the materiality judgment process. The second decision, selection of a percentage (threshhold) rate, depends upon the auditor's perceptions of the risk associated with the audit. That assessment relies primarily on information about the intended use of the financial statements being audited.

Although AUDITPLANNER is based on the judgment model of one member of one public accounting firm, the analysis of the logic of that model is consistent with the results of previous research. Moriarity and Barron [1979] found that net income was the primary basis for judgments of auditing materiality. Their study used only publicly-owned profit-oriented companies. AUDITPLANNER's rules likewise choose income as the materiality base for such companies. Moriarity and Barron also observed a break-even effect; AUDITPLANNER, too, has rules which choose an alternative materiality base whenever income is at or near the breakeven point.

Gibbins and Wolf [1982] reported that information about the nature of the client, the client's plans for future financing, and prior years' audit decisions all had a significant effect on planning and designing an audit. These factors also appear in AUDITPLANNER's rules. The client's industry and form of ownership influence the choice of the materiality base. Client plans for future financing affect both the choice of a materiality base (by possibly changing a client's classification from that of a private to a public entity) and also the percentage rate itself (due to the increased level of risk when the financial statements are going to be used in connection with the issuance of public debt or equity securities). AUDITPLANNER also has a rule which compares this year's materiality level to that used last year, in order to evaluate the reasonableness of the former.

Finally, the logic of AUDITPLANNER's model is also consistent with the judgments of the other auditors who used it to make materiality judgments for their clients.

The expert systems methodology does more than merely indicate which factors significantly affect (i.e., are highly correlated with) the decision criterion. It also explains <u>how</u> those factors influence the criterion. For example, the analysis of AUDITPLANNER's rules indicated that the nature of any debt covenants affected the classification of the client as either a public or a private entity. This, in turn, affected the auditor's perception of the primary

interests of the users of the financial statements, and thus determined the choice of a materiality base. It is this ability to explain at a very detailed level how various factors affect a decision criterion which makes the expert systems methodology well-suited to studying and understanding decision making behavior.

Libby [1982] points out, however, that accountants study decision making in order to find ways to improve the quality of the decisions that are made. He lists three basic options for improving decision making: (1) changing the information used to make the decision, (2) teaching the decision maker to change the way he or she makes decisions, or (3) replacing the decision maker with a model of the decision process.

The capability of expert systems to explain the basis for making decisions means that they are useful not only as a means of studying decision making, but also as a means of improving decision quality. In particular, an expert system can be used as either (1) a training device, to teach the decision maker how to make a decision, or (2) as a decision aid which the decision maker can use to help make the actual decision. In fact, the auditors who evaluated AUDITPLANNER expressed great interest in further developing the program so that it could be used for both purposes. The next section describes some of the possibilities for such further development.

Possible Future Extensions to the Work

Future extensions of this dissertation fall into three areas: (1) further development of AUDITPLANNER to enable its use as either a decision aid or training device, (2) comparative studies of the materiality judgment processes of auditors from different accounting firms, and (3) experimental studies of some of the implications drawn here.

Further Development of AUDITPLANNER

As mentioned earlier, the auditors who evaluated AUDITPLANNER expressed great interest in its further development so that it could be used either as a training device or as a decision aid. Such development could involve either broadening its current domain of expertise in regard to new types of clients, or integrating the judgments of auditing materiality with other judgments that are made during the course of an audit.

Broadening AUDITPLANNER's domain of expertise. The testing of AUDITPLANNER resulted in the acquisition of additional rules to handle clients which were different from those used to develop the system. One possible future extension would be to work with other experts to cover areas not adequately covered at present (e.g., small clients). The ultimate objective would be to have AUDITPLANNER contain rules that would allow it to deal with almost every conceivable type of company that might be audited.

Integrating with other audit judgments. One of the auditors who evaluated AUDITPLANNER suggested that the system be extended to work with the analytical review techniques currently used by that firm. Another possibility is to integrate AUDITPLANNER with an expert system which evaluates internal control, so that the entire planning process could be performed. Another extension would involve adding rules for making judgments of accounting materiality.

Comparative Studies

AUDITPLANNER represents the materiality judgment process of one auditor from one public accounting firm. Future work could involve the construction of similar systems for other firms in order to develop a complete taxonomy of materiality judgment models. Once such a taxonomy was developed, comparative analysis may suggest methods for increasing comparability across accounting firms. Such a taxonomy would also permit the development of general theories of the materiality judgment process, playing a role similar to that played by taxonomies in biology.

Experimental Studies

The analysis of AUDITPLANNER suggests numerous possibilities for controlled experimental studies of the effect of various background variables. One obvious candidate is the comparison of materiality judgments for different types of companies (e.g., public versus private versus nonprofit). Such studies would be an important step towards developing a

consensus about appropriate bases for judgments of auditing materiality. Another major line of research would involve the study of the needs of different types of users (e.g., creditors versus investors).

Conclusion

This dissertation demonstrated the usefulness of applying the expert system methodology to the study of materiality, a topic of long-standing interest both to practicing accountants and to academic researchers. The ability of this methodology to make explicit the role played by the different factors used to make materiality judgments represents a major methodological advance. The favorable reception of the system by those who evaluated its performance suggests that it may not only be useful as a research tool, but that it may also be useful as a practical tool as well.

APPENDICES

Appendix I
Example of AUDITPLANNER's explanation capabilities during a consultation

Below are some examples of the WHY and HOW questions that can be asked during the course of a consultation. The question numbers are from an actual consultation.

3) Is this the first tame we have audited Example ?

** WHY

[i.e. WHY is it important to determine whether this is the first time that we have audited CLIENT-3?]

[1.0] Whether this is the first time that we have audited a client is one of the 5 standard parameters that identify a client. This may be useful later in the consultation. For example, it is relevant in determining whether there is a need to reduce the calculated materiality level due to the increased risk associated with an initial audit of the client and is relevant in determining the percentage rate used to determine the materiality level.

[back to question 3...]
** YES

(note: several questions asked by AUDITPLANNER are skipped here, until the next time the user asks "WHY")

10) Is Example filing with a regulatory agency in preparation for the sale of its securities in a public market?
** WHY

[i.e. WHY is it important to determine whether CLIENT-4 is filing with a regulatory agency in preparation for the sale of its securities in a public market?]

[2.0] This w ill aid in determining the type of entity CLIENT-4 is.
It has already been established that
[2.1] it is suspected that the type of entity Example is is private.
Therefore, if
[2.2] Example is not filing with a regulatory agency in preparation for the sale of its securities in a public market, and

[2.3] Example does not intend to go public within the next two or three years
then
it is definite (1.0) that the type of entity Example is is private.
[RULE007]

[back to question 10...]
** WHY

[i.e. WHY is it important to determine the type of entity CLIENT-4 is?]

[3.0] This will aid in determining what the principal external users of the financial statements are primarily interested in.
It has already been established that
[3.1] the type of entity Example is is private
Therefore
it is definite (1.0) that what the principal external users of the financial statements are primarily interested in is financial-position
[RULE012]

[back to question 10...]
** HOW 2.1

[i.e. HOW was it established that it is suspected that the type of entity Example is is private?]

[2.4] RULE056 was used to conclude that the type of entity Example is is private (.9).

Thus, it has been established that it is suspected that the type of entity Example is is private.

[back to question 10...]
** HOW 2.4

[i.e. HOW was RULE056 used?]
It has already been established that
[4.1] Example does not have publicly traded debt or equity securites, and
[4.2] Example does not have restrictive debt covenants that are measured by or depund on periodic financial statement amounts or ratios that involve results of operations, and
[4.3] Example is not controlled by a public entity
Therefore
there is strongly suggestive evidence (.9) that the type of entity Example is is private
[RULE056]

Appendix II
Example of AUDITPLANNER's explanation capabilities after a consultation

Several types of questions which may be asked after a consultation is over are presented below.

** WHAT TYPE OF ENTITY IS THE CLIENT?
The type of entity Example is is public

** WHY DID YOU ASK WHETHER THE CLIENT HAS ANY PUBLICLY TRADED DEBT OR EQUITY SECURITIES?
RULE040 used:
whether Example has publicly traded debt or equity securities. This information also would have been used in: 56, 94, 95. However, none of these succeeded in the context of Example. If you would like an explanation for why any of these rules failed, please enter their numbers:
**
** PR 40

RULE040

[This rule applies to clients, and is tried in order to find out about the type of entity the client is]

If: 1) The client has publicly traded debt or equity securities, or
2) The client has restrictive debt covenants that are measured by or depend on periodic financial statement amounts or ratios that involve results of operations
Then: It is definite (1.0) that the type of entity the client is is public.

**WHY DID YOU ASK QUESTION 13?
Question 13 was asked in order to find out whether the financial statements are being used in connection with a contest for the control of Example in an effort to execute RULE047.

** WHAT RULES TELL YOU ABOUT THE MATERIALITY PERCENTAGE RATE?
The following rules conclude about:
the percentage rate used to determine the materiality level 21, 77, 78, 89, 114, 115, 116, 117, 118, 27
The parameters most frequently used in these rules are:
whether the financial statements are going to be used

in connection with a public offering of securities
whether the financial statements are being used in connection with a transfer of interests in the client

Would you like a summary of ALL the parameters used by these rules?
** YES

Parameter (rules with this parameter)
whether the financial statements are going to be used in connection with a public offering of securities (78, 89, 27)
whether the financial statements are being used in connection with a transfer of interests in the client (115, 116, 27)
whether the financial statements are being used in connection with an inquiry by a regulatory agency (77, 27)
whether the financial statements are being used in connection with a contest for the control of the client (114, 27)
whether the financial statements are being used to settle some litigation involving the client (117, 27)
whether the client has violated some of its debt covenants (118, 27)
whether the regulatory agency conducting the inquiry is the IRS (77)
whether the inquiry is a routine audit by the IRS (77)

whether this is the initial public offering of securities by the client (78)
whether this is the first time that we have audited the client (78)
whether the client is making a large offering of securities (78)
whether the client is offering a warranty on the financial amount included in the financial statements being audited, or the sales price is directly dependent upon the amounts stated in those statements (115)

Which of the rules do you wish to see?
**

Appendix III
Sample session with AUDITPLANNER

Below is a sample session with AUDITPLANNER.

```
24-Oct-84 13:00:13
You will be asked a series of questions about a client
you are about to audit. On the basis of your answers to
those questions, a set of recommendations will be presented
about the appropriate materiality level(s) to be used in
planning the extent of audit procedures.
  --------CLIENT-2--------
   1) What is the name of the client?
   ** EXAMPLE
   2) What is Example 's main line of business or industry
      classification?
   ** MANUFACTURING
   3) Is this the first time we have audited Example ?

   ** NO
   4) Have there been any acquisitions which either singly
       or in total amount to 10 percent or more of the
      client's total assets?
   ** NO
   5) Some of the questions that follow will ask you to
       input dollar amounts from the client's financial
       statements. Will your answers be in terms of
      thousands of dollars?
   ** YES
   6) Does Example have  any publicly traded debt or
      equity securities?
   ** YES
   7) What do you project retained earnings to be?
   ** 7616
   8) What is the amount of current assets?
   ** 5822
   9) What is the amount of current liabilities?
   ** 3009
   10) What do you estimate the annual income from
       continuing operations (before taxes) to be?
   ** 3786
   11) Are the financial statements going to be used in
       connection with a public offering of securities?
   ** NO
   12) Are the financial statements being used in
       connection with a transfer of interests in
       Example ?
   ** NO
```

13) Are the financial statements being used in connection with a contest for control of Example?
** NO
14) Are the financial statements being used to settle some litigation involving Example ?
** NO

15) Are the financial statements being used in connection with an inquiry be a regulatory agency?
** NO
16) How much long-term debt does Example have?
** 882
17) Does Example have any covenants on either its long-term debt or existing lines-of-credit?
** YES
18) Does Example have any debt covenants which restrict dividends to a percentage of either current earnings or cash flow?
** NO
19) Do any of Example 's debt covenants require it to maintain some level of earnings?
** NO
20) Does Example have any debt covenants which require it to use part of its cash flow to retire its debt?
** NO

The overall materiality level to be used in planning the extent of audit procedures is 189300.0 .

The reasons for the materiality judgment are as follows:

The calculation of the materiality level was based on the use of income-from-continuing-operations as the base for the materiality calculation.
The materiality level was calculated using a rate of .05.

APPENDIX IV

Evaluation questionnaire

Read each question and circle the response which best represents your feelings to that statement.

Where SA = Strongly Agree
A = Agree
N = Neutral
D = Disagree
SD = Strongly Disagree

1. I found AUDITPLANNER easy to use.	SA	A	N	D	SD
2. AUDITPLANNER did not provide adequate HELP facilities to make it easy to use.	SA	A	N	D	SD
3. AUDITPLANNER asked too many questions - often about irrelevant information.	SA	A	N	D	SD
4.I think AUDITPLANNER would be useful as a training device.	SA	A	N	D	SD
5. I think AUDITPLANNER would be useful as a decision aidwhen planning an audit.	SA	A	N	D	SD
6. I would like to use AUDITPLANNER as a decision aid.	SA	A	N	D	SD
7. AUDITPLANNER does not exhibit a basic level of competencein making materiality judgments.	SA	A	N	D	SD
8. I would accept AUDITPLANNER´s recommendations.	SA	A	N	D	SD
9. I did not enjoy using AUDITPLANNER.	SA	A	N	D	SD
10. AUDITPLANNER was too slow in making its recommendations.	SA	A	N	D	SD
11.AUDITPLANNERwould be more useful as a training device than as a decision aid.	SA	A	N	D	SD
12. I can see no use for a program like AUDITPLANNER.	SA	A	N	D	SD
13. AUDITPLANNER was hard to use.	SA	A	N	D	SD

14. I would not mind my subordinates using AUDITPLANNER as a decision aid.	SA	A	N	D	SD
15. It was hard to follow AUDITPLANNER's flow of logic.	SA	A	N	D	SD
16. I made frequent use of AUDITPLANNER's question answering facilities.	SA	A	N	D	SD
17. AUDITPLANNER's question answering facilities did not adequately explain what it was doing.	SA	A	N	D	SD
18. I would not want my subordinates to use AUDITPLANNER as a training device.	SA	A	N	D	SD
19. AUDITPLANNER's line of reasoning was logical and easy to follow.	SA	A	N	D	SD
20. I enjoyed using AUDITPLANNER.	SA	A	N	D	SD
21. The sequencing of questions in AUDITPLANNER was easy to follow.	SA	A	N	D	SD
22. I think that AUDITPLANNER's recommendations and rationale were sound and reflected professional competence.	SA	A	N	D	SD
23. AUDITPLANNER's ability to respond to HOW and WHY questions was very helpful.	SA	A	N	D	SD
24. I would not approach the planning materiality decision the way that AUDITPLANNER did.	SA	A	N	D	SD
25. AUDITPLANNER jumped around from topic to topic.	SA	A	N	D	SD

26. Please write down your overall impressions of AUDITPLANNER. Discuss what you think it could best be used for, needed improvements, potential role in an audit, etc. Use as much space as you need, including the backs of the questionnaire pages.

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