A KNOWLEDGE-BASED MODEL OF AUDIT RISK[1]

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1. Introduction

Many decision-making problems involve making choices with incomplete information. Models of decision-making under conditions of risk are well established in the decision theory literature. In these models, risk and return (payoffs) are specified in terms of numerical estimates, and the goal is to make a decision that maximizes some expected value. In addition, new information can be combined using a decision rule (such as Bayes' rule) for deriving revised estimates of risk.

There are several problems, however, where quantifiable risk estimates are difficult to obtain. In these problems, the decision-maker might have to perform a significant amount of problem solving if asked to provide a numerical estimate of risk associated with a proposition or a state of nature, and even then, attach qualifying comments to the numerical estimate (Dhar and Pople, 1987). In this paper we describe one such problem, where the concept of risk is difficult to conceptualize in terms of quantitative estimates and hence inappropriate to manipulate in terms of standard belief calculi. Specifically, we focus on the problem of an auditor faced with the task of assessing the likelihood that a client's financial statements will contain material errors. Especially for large accounts, it is important that the auditor be confident that the risk of making an erroneous decision is low. Given the increased competitiveness of the auditing profession, however, the auditor is limited from a pragmatic standpoint in terms of time and other resources that can be assigned to each client. Good planning is therefore essential for an efficient audit; before beginning the actual process of information gathering and substantive testing, the auditor must have expectations about specific general ledger accounts that might be particular risky in a specific case, and plan tests accordingly.

We have studied audit planning in two "big eight" accounting firms over the last two years. We have come to recognize the process of risk assessment as a complex one that involves understanding the effects of a variety of economic and organization-specific factors on accounts. We characterize the problem of risk assessment as *knowledge based*, where knowledge about the client's history, recent events specific to a firm or industry, and knowledge about the internals of a firm are crucial in shaping the auditor's judgement about risks associated with accounts, and hence the audit plan.

There is currently much interest in developing knowledge based support systems to support audit planning. Accounting firms are interested in developing systematic methods for risk assessment and audit planning. They feel that knowledge based systems can help in this respect. Secondly, accounting firms are concerned with the loss of knowledge about a client when an auditor leaves the audit team. By preserving the results of past experiences with auditing a client, knowledge based systems might also help educate new members of an audit team. We have concerned ourselves with the first of these objectives by trying to understand and model the process of risk assessment. Once the details of this process is understood, it should provide a sound basis for designing intelligent support systems.

The remainder of this paper is structured as follows. In the next section we define more precisely the different types of risks associated with auditing, and which of these we are interested in modeling. We also make certain assertions about how auditors assess risk. The assertions are based on empirical observations of the audit planning process (tape recordings of actual audit planning meetings as well as interviews). In section three we describe the knowledge based model of audit risk, focusing on the knowledge representation employed in a system designed to assess a certain component of audit risk called inherent risk. We conclude with auditors' reactions about the inadequacies of this system and the types of information that needs to be gathered and modeled in order to overcome these limitations.

2. Risks in Auditing

The problem confronting an auditor is referred to in the accounting literature as one of *audit risk* assessment. Cushing and Loebbecke (1983) provide a detailed discussion of the historical development of a model of audit risk, a review of the literature dealing with the appropriateness of the model and a discussion of the problems that auditors might encounter in trying to implement it. The majority of this literature has focused on the AICPA's audit risk model as presented in SAS 47:

$$Audit\ risk = Inherent\ risk * Control\ risk * Detection\ risk$$

Inherent Risk is the susceptibility of an account balance or class of account balances to error that could be material, assuming that there are no related internal accounting controls. Control Risk is the risk that this error in the account balance will not be caught by the client's internal control system. Detection risk is the risk that any error not detected by the control system will not be detected by the audit procedures, thereby affecting final financial statement balances. The AICPA emphasizes that the above model of audit risk is a purely conceptual one, and says little about whether or how its various components can be measured.

According to the AICPA, the risk assessment process should occur during audit planning. Auditors should determine an acceptable level for audit risk, assess the levels of inherent risk and control risk and then determine the level of detection risk based on these assessments. Auditors should assess the inherent riskiness of specific accounts by reviewing a variety of factors that are specific to the client, the client's industry or the economy in general, and by determining the impact of these factors on individual accounts. This can help determine the nature, timing and extent of tests of the client's internal control systems (AICPA, 1985).

The professional literature also provides lists of factors that should be considered in assessing inherent risk. Peat Marwick's (1985) audit manual, for example, presents a representative list:

1. Monetary amount associated with the account
2. Susceptibility of asset to theft
3. Complexity required to determine amounts to be entered in the account
4. Degree of management judgment involved in valuing the account
5. Degree to which external events affect values in the account

6. Past history of error

7. Degree to which client's financial condition motivates management to misstate the amount in the account

8. Experience of the personnel performing accounting functions involving the account

While the abovementioned model of audit risk and the list of factors provide a conceptual foundation for understanding the role of inherent risk, they do not indicate how experienced auditors actually use the above factors in conjunction with industry and client-specific knowledge in order to form inherent risk judgements. Our central objective in this research has been to explicate this model and make use of it in building a system that can be used to assess inherent risk. In this model, inherent risk is not computed as a numerical estimate for each account. Rather, risk at the account level is expressed in the form of potential reasons or hypotheses which are a by-product of a more general reasoning process involving analysis of financial statements and client and industry factors as a whole. In other words, financial statements are analyzed in the context of industry and client-specific data; this analysis results in potential reasons indicating why there could be errors in specific accounts, without quantified estimates of error. These potential reasons or hypotheses help to target the auditor's evidence gathering in subsequent phases of the audit. The following quote from an experienced auditor provides a succinct description of the information gathering process:

> *I think the process you go through to obtain that knowledge really is to gain an understanding of the client's business, an understanding of the client, an understanding of how the fluctuations in the economy might affect a client's business. You compare the client's business to other businesses in the same industry to see if they are having consistent operating results and if not, if there are logical reasons for it; if they are having consistent operating results, is that what you expected? I mean, you develop expectations in your mind of what you expect to see and, to the extent results don't conform to that yet, you begin asking questions to obtain the necessary knowledge.*

In the remainder of this section we provide a general description of the process of Inherent Risk assessment before describing the details of the model. For descriptive empirical studies of the various types of risks, the reader is referred to Gibbins and Wolf (1982), Jiambalvo and Waller (1984), Libby et.al (1985), and Boritz et.al (1986).

2.1. Inherent Risk Assessment

Based on the results of our two year field research project (more completely described in Peters, et. al., 1987), we characterize the approach toward assessing the inherent risk of material error in a given general ledger account balance as one involving *differential analysis*. The analysis is essentially change driven in that specific changes (external or internal) generate change expectations in accounts.

In our model, the inherent risk evaluation process begins by generating expectations for accounts balances. Specifically, the auditor identifies changes that have occurred in the firm or its environment and determines how those changes should interact with historic trends to produce an expected balance in the account. In order to do this, the auditor uses an understanding of the relationships between firm/environmental factors and general ledger accounts. By making use of these relationships, the auditor develops expectations on how the observed changes *should* affect the balances in a given account. For accounts where actual balances that are outside the expected range, the auditor first reviews factors that might create or affect management incentives to misstate the account balances (e.g. the existence of a compensation plan keyed to reported earnings). At the same time, the auditor considers factors that might impact on the likelihood that management could or would misstate that particular account balance (because of the degree of judgment allowed in the determination of account balances). The auditor also considers the complexity of the transactions or accounting for a particular account since such factors might also be responsible for deviations from expected balances. Based on this analysis, the auditor decides if additional evidence will be needed to determine whether the difference between the expected balance and the actual balance was due to an error in the expectation generating process, a legitimate response by management to a change in the environment, a questionable response by management or an unintentional error.

Below, we list five assertions that characterize the process of Inherent Risk determination described above. In the following section, we describe in detail, how we model the various knowledge components referenced in the assertions.

Assertion 1: Auditors generate expectations concerning account balances and investigate balances that differ from these expectations.

Assertion 2: Auditors generate expectations about accounts based on changes in events or circumstances relative to prior years.

Assertion 3: Management's incentives and abilities to manipulate account balances affect assessment of inherent risk.

Assertion 4: Inherent risk assessments are generated on an account by account basis.

Assertion 5: To be useful, inherent risk assessments should provide an explanation of why a given account is risky rather than merely a quantitative estimate of risk.

3. Knowledge Representation

Figure 1 shows the general process of inherent risk assessment described above. First, expected values of general ledger accounts are generated. The data inputs to this process are historical data and changes in conditions (external and internal) from last year. The output of the first stage, namely expected account balances, are then compared with the actual general ledger data for the period being audited. A materiality judgement is incorporated in this stage. The output of the second stage is a list of accounts where expectations are not in line with reality. The third stage involves determining whether some of management's incentives or constraints might have caused it to take actions that account for the differences between observed and expected values of accounts. The fourth stage involves making a judgement on management's "track record" (their ability and inclination) for manipulating accounts. Finally, auditors indicated that the complexity associated with computing account balances (i.e. "LIFO is more complex than FIFO for valuing inventory") also affect inherent risk. We refer to these as "mechanical" account specific factors.

In summary, the five main processes are expectation generation, evidence checking, incentive checking, judging management's track record, and evaluation of the mechanical complexity associated with each account. These comprise the overall control structure of the system as shown in figure 1. In our existing system, we have not focused on modeling the last two processes. We shall comment on the consequences of these missing components in the next section. In the remainder of this section, we discuss the first three processes, introducing with each, the knowledge used in each process and how it is represented.

3.1. Expectation Generation

Auditors generally have what we term "base expectations" for a client's accounts. These base expectations result from observations about the client. For example, the auditor might expect that the client's market share this year should have fallen by 5% because a major customer was acquired by a competitor in a vertical merger. For our model, the relevant input is a quantitative one, accompanied by a descriptive explanation of the reason for the quantitative input. Specifically, an input is a three tuple of the form

$$<\textit{firm factor, percent change, comment}>$$

where the firm factor is a general ledger account or an economic factor (for example, market demand) that influences a general ledger account, followed by its percent change, and a comment that denotes the reason for the change. The comment, which is the reason for the base expectation is only for the user's benefit.

In order to assess the impacts of these changes on specific accounts, the system makes use of what has been termed by us and previously by Bouwman (1983) as an "internal model of the firm". This model consists of three types of firm factors, namely, general ledger accounts, financial statement totals or sub-totals, and exogenous factors (such as

```
 -------------------                     ----------------------
| Observed changes |                    | Historical firm data |
 -------------------                     ----------------------
          |                                          |
          |<-----------------------------------------|
          V
 -----------------------------
| Develop expected values for |
| general ledger accounts     |
 -----------------------------
          |
          V
 -----------------------------           -------------------------
| Compare expected values to |<---------| Current year's general |
| actual                     |          | ledger data            |
 -----------------------------           -------------------------
          |
          V    (The enclosed processes are potentially concurrent)
 ----------------------------------------------------------------
|                                                                |
|   ---------------------------------                            |
|  | Determine potential management |       ------------------   |
|  | motives for misstatement based |<-------| Incentives      |  |
|  | on constraints                 |       ------------------   |
|   ---------------------------------                            |
|                                                                |
|   ----------------------------------   ----------------------- |
|  | Evaluate degree of flexibility  |  | Historic evaluation of ||
|  | management might have to        |<--| management and control ||
|  | misstate account                |  | environment            ||
|   ----------------------------------   -------------------------|
|                                                                |
|   ----------------------------------                           |
|  | Evaluate potential degree of    |                           |
|  | error due to mechanical, account|                           |
|  | specific factors                |                           |
|   ----------------------------------                           |
|                                                                |
 -----------------------------------------------------------------
          |
          V
 ------------------------------------
| Review evidence, identify accounts |
| that may have higher risk and      |
| present reasons for riskiness      |
 ------------------------------------
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Figure 1
The Process of Inherent Risk Assessment

market demand). These factors are related through algebraic equations. In effect, the internal model of the firm is comprised of a node-link structure, with nodes being the arithmetic operators involved in the equations, and links representing the three types of firm factors involved in these algebraic equations. Figure 2 shows a graphical representation of a segment of the internal model of the firm.

Nodes and links are represented as structured objects. The operator object has three slots, namely, operator, inputs, and output. This object type also has two types of functions associated with it that perform computation (in object oriented language, these functions are called methods). The first type are for computing an output value (in absolute or percentage terms) from inputs. The second type compute qualitative directional change in the output given a qualitative change in only one of the inputs. The usefulness of both types of methods will become apparent shortly.

The firm factor object has slots that contain the following information: type of node (whether it represents a general ledger account or not), historic value, current value, change value, pointers to operator objects that compute the current value of the firm factor, and expectation values (generated as a consequences of changes of other firm nodes' values) which are posted for further analysis. There can be several ways of computing the value of a firm factor.

A base expectation is indexed to the internal model by its first component, which is a pointer to a firm factor object. When a base expectation is entered as a change, it specifies a change in the firm factor object to which it points, which in turn causes the operator objects that compute its value to recompute their output values. This procedure is carried out recursively until all changes have been propagated through the network. The end result of the propagation is that each general ledger account object's expectation slot consists of a list of expectations for that account -- each of these generated using a particular formula.[1]

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[1]Since an account can be computed in several ways, the values could be in opposite directions and hence cancel out. We preserve all values since they contain information that would be lost in adding them up.

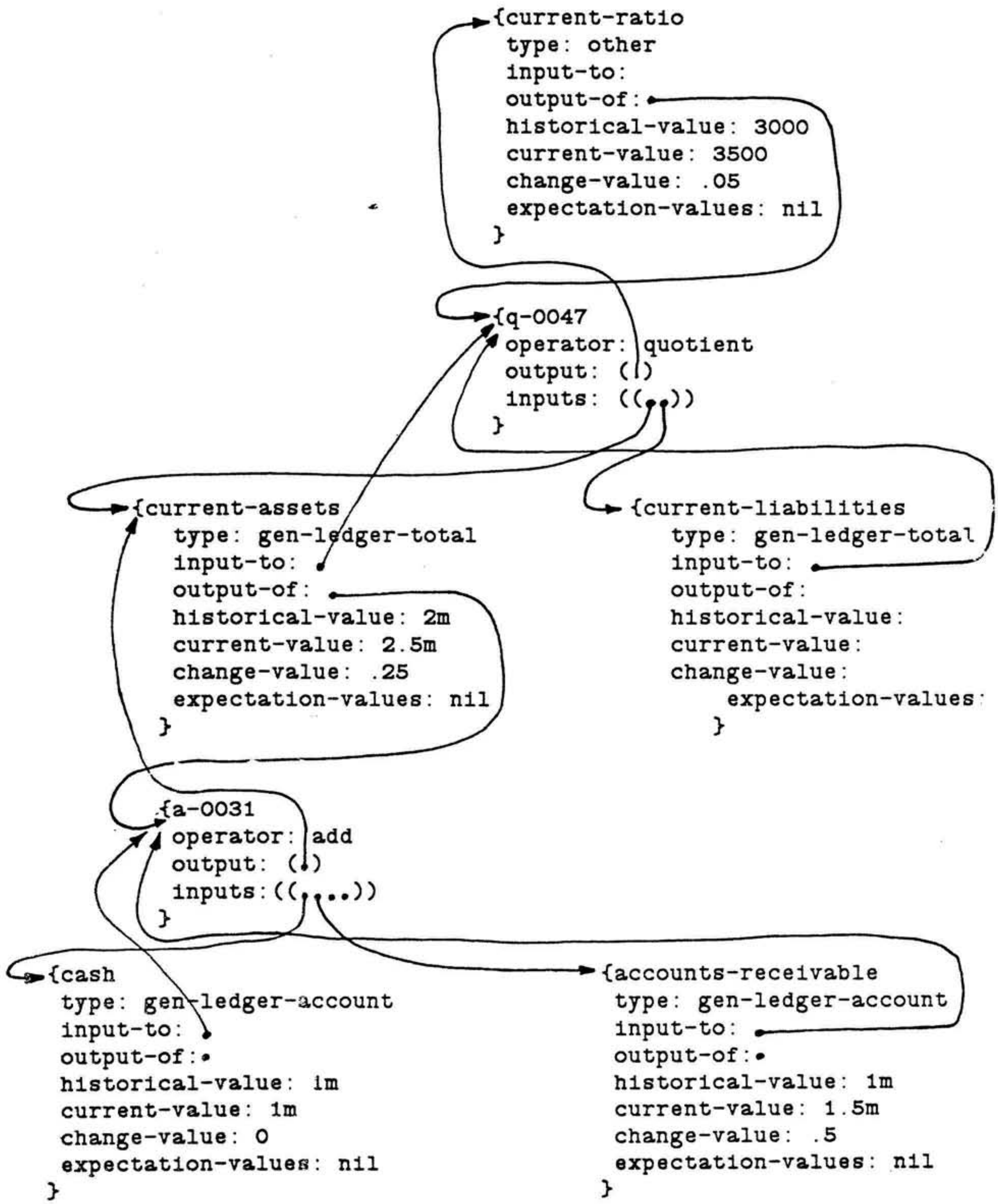

Figure 2

A Segment of the internal model of the firm

3.2. Evidence Checking

The second stage is a straightforward one. The percentage value change in the expectation is checked against the actual change computed from the general ledger data. A *material* difference exists if the difference exceeds a pre-set range. Expectations that are not materially different from actuals are excluded from further consideration, while the remainder are put into a "flagged accounts list". This latter set also includes accounts for which no expectations were generated by the system but for which material changes have occurred.

3.3. Incentive Checking

Determining discrepancies is only part of the overall auditing process. It is equally important to understand the reasons for the discrepancies. This problem is one of determining whether and how management discretion might have been exercised with respect to these accounts. To do this, it is necessary to know management's motivations and how these motivations affect specific accounts.

We refer to motivational factors as incentives, which are represented as constraints. An incentive can represent either a restriction placed on account balances as part of a contract (e.g. bond covenants), contractual arrangements that tie management's compensation to levels in account balances, or expectations by outsiders concerning levels of account balances (e.g. public expectations of steadily growing earnings). Examples of incentives might include a management bonus plan that provides additional compensation if gross profit exceeds 110% of last year's, or a bond covenant that requires the current ratio to be greater than 2.

Incentives are represented as constraints consisting of any relational operator (except equality) with two arguments. The arguments can be constants or functions that return values of firm factor nodes. At least one of the arguments must be of the latter type. In effect, incentives are indexed to the internal model of the firm via these constraints. To illustrate, the second incentive listed above would be represented in prefix Lisp-like notation as

(>= **cvalue**(*current-ratio*) *2.0*)

where **cvalue** is a function that returns the current value of the current-ratio object.

The default assumption used by the system is that account balances have been influenced by the incentives. The problem is to determine how the manipulations might have occurred. Given the structure of the internal model of the firm, it is clear that there are an infinite number of ways of manipulating an account because of the infinite number of combinations of values of its inputs that can produce a certain output. The problem is therefore one of limiting this search so that only relevant combinations are considered.

The incentive checking process proceeds as follows. For each constraint, a materiality computation is applied in the same way as for general ledger accounts. If we denote the actual value of the object referenced in the constraint as A, the expected as E, and the relational operator in the constraint as R, then for a constraint of the form "(R arg1 arg2)" , the following decision rules are applied:

Incentive Rule 1:

```
If A = E
 then if R is of type ">" or ">="
       then management have been motivated to increase arg1
                                              (or decrease arg2)
      else  management have been motivated to decrease arg1
                                              (or increase arg2)
```

The rationale for this rule is that A has been manipulated to be equal to E.

Incentive Rule 2:

```
If A <> E
 then if R is of type "<" or "<="
       then management have been motivated to decrease arg1
                                              (or decrease arg2)
      else  management have been motivated to increase arg1
                                              (or increase arg2)
```

The logic embedded in this rule is that when there is a significant difference between the actual and expected values, the difference stems from management having either given up the constraint as not achievable and hence shifting accounts values so that they may be favorable for the following period, or management having satisfied the constraint by a large enough margin and hence shifting account values (in a direction opposite to the operator) in order to position the firm more favorably for the following period without compromising this year's objective. In effect, the rule incorporates a "shifting logic" that might be used by management in order to plan for subsequent periods.

Applying the decision rules above results in a hypothesis of the form:

Account i has been increased.

To investigate this hypothesis, the system sets up the goal:

Determine how account i has been increased.

This involves a search beginning at object i in the firm model, determining ways in which i can be increased. As we pointed out above, there can be numerous combinations by which this result can be achieved. For example, current ratio could be increased by increasing current assets or decreasing current liabilities in various combinations, each of which could in turn be manipulated by other firm factors (for example, current assets might be increased by over-stating accounts receivable). The heuristic used in focusing the search comes from the deviant expectations generated in the previous stage. Specifically, given the hypothesis "account i has been increased", the system computes which of the inputs in its equation must be increased *holding all other components of the equation constant* in order to make the hypothesis true. The analysis makes use of knowledge about the type of operator being applied. Evidence confirming the hypothesis is deemed to be found if there is an account which deviates from expectations in a direction that matches the hypothesis. For example, if there existed a bond covenant that the firm maintain a current ratio of greater than 2, then an unexpected increase in accounts receivable (determined in the expectation generation phase) would suggest that the bond covenant constraint had in fact played a role in inflating accounts receivable. In effect, this reasoning would constitute the explanation for the deviant expectation.

4. Evaluation and Summary

The model described above has been demonstrated to several auditors who were responsible in helping us design it. Their comments and critiques have been useful in helping us understand the limitations of the existing system and what must be done to alleviate them.

4.1. Overly Data Driven Expectation Generation

Our system's control of attention is driven by the base expectations specified by the user. However, we have now come to realize that auditors' analyses are to a large extent driven by the structure of the general ledger, beginning with current assets (accounts such as cash) and ending with extraordinary items. More importantly, as this "downward scanning" proceeds, expectations about values of accounts yet to be reviewed become increasingly constrained. If the observed value does not fit with expectations, a reinterpretation of the accounts reviewed thus far becomes necessary. This type of progressive constraint posting does not take place in our model.

For example, suppose that the auditor observes inventory to be low and that this is in line with the base expectation for this account. This might cause him to expect that payables will also be low (because of decreasing purchases). If payables are observed not to be low, the original interpretation needs to be altered. It could be the case that there has been a sharp increase in sales (causing a depletion in inventory) whereby re-orders have been lagging (and hence not yet reflected in payables). A different explanation might be that a technological change in the client's industry has rendered inventory obsolete, making it necessary to mark down its value. Similarly, other explanations can be generated, some more plausible than others. Fundamentally, the more plausible of these explanations make use of "compiled knowledge", that is, typical patterns in relationships among firm factors observed by experienced auditors.

Conceptually, the type of analysis described above makes use of knowledge about qualitative (directional) relationships between accounts and other firm factors. This knowledge is in fact available in our model of the firm. However, our system only makes use of the model of the firm in trying to determine whether any incentives could be responsible for a deviant expectation. In contrast, it is now clear that the compiled knowledge about relationships among firm factors in this model needs to be used in determining whether an account is deviant in the first place. In order to implement this functionality, this knowledge will have to be gathered from further observations of experienced auditors and represented as "compiled knowledge" links between nodes in the model of the firm. Such links been used to great advantage in the CADUCEUS system (Pople, 1982) as a way of focusing search.

4.2. Over-emphasis on Incentives

A second criticism, related to the one above, was that our model emphasized management motives too strongly. This effect becomes even more noticeable since the system ignores the relationships among firm factors described above. While incentives are an important determinant of inherent risk, we have now found that they are usually not considered by auditors unless the value of the constrained item in the incentive formula is close to the boundary. That is, our default assumption that account balances have been influenced by incentives is not an accurate one. In fact, the opposite is often the case. Also, the second decision rule that shifting may occur when the value of the constrained item in the incentive formula is some distance from the bound is often applied inappropriately. This decision rule needs to be specialized. Also, auditors did not view all incentives as having equal potential impact on management's actions. For example, violating a bond covenant would be considered more serious than not achieving a budgeted goal. In summary, a hierarchy of incentives and accounts is necessary in order to distinguish the important determinants of risk from the incidental.

4.3. Extrapolation of Data to Year End

Audit planning typically occurs prior to the client's year end. Because of this, auditors do not have actual, unaudited year end balances with which to test their expectations. The existing system uses a simple trend extrapolation to compute year end balances. It turns out that the extrapolation is more complex than we had envisioned and can involve various factors. For example, seasonality is an important component in estimating year end balances and varies according to industry. Our model does not make distinctions among industries. Further, some accounts such as extraordinary items are not even extrapolatable.

4.4. Unintentional Errors

An important addition to the current model that auditors deemed necessary was some mechanism for dealing with unintentional errors. Unintentional errors are errors that occur in a given account balance without any intentional act by management or employees to create the error. The lack of intention differentiates them from those potential errors dealt with by the incentive checking portion of the existing model. Examples would include miscalculating inventory values or accidentally failing to include all outstanding invoices in the accounts payable balance. Our system has no way to deal with such errors. In addition, our conceptual model does not deal with characteristics of the firm's management environment that could effect all, or at least a broad range, of accounts (e.g. management's concern for the internal control environment or high employee turnover in the accounting department). The auditors felt that these two classes of factors that influence the likelihood of an unintentional error in an account were extremely important in determining the appropriate inherent risk for a given account. Further interaction with auditors will be needed to determine how they use these factors to assess inherent risk and how their assessment of these factors is combined with the expectation and incentive data currently being processed by the model.

4.5. Summary and Conclusion

The model described here is a summary of a two year research effort, during which time we attempted to observe in as much detail as possible, the audit planning process with real cases. On the basis our evidence, we have come to recognize the divergence in the normative literature and what actually occurs in practice. It is clear that auditors do not consider it appropriate to generate numerical estimates of risk on an account by account basis, but reason about a client's financial statements using knowledge about changes in the industry and/or the client, management's motivations, prior track record, and so on. It has become increasingly apparent to us that if computer based systems are to play a role in supporting auditors with this task, they must be capable of modeling this range of knowledge. While our model is still inadequate in the ways described above, it is proving to be very useful in sharpening our understanding of the process of inherent risk assessment. In particular, giving auditors a real system to use (however limited) helped elicit data which would have been virtually impossible using interviewing and other data gathering techniques. We are continuing to work with several of the auditors that helped us design the first version of the model. We hope to address the limitations of this model that we outlined above and report on progress with the new model in the near future.

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