

# Research Streams in Continuous Audit: A Review and Analysis of the Existing Literature

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**Abstract:** Advances in information technology and web-based applications are making monitoring and control of operations through continuous auditing increasingly important. The objective of our paper is to summarize and provide a framework for classifying the contributions of the diverse literature addressing the topic of continuous audit. Research streams are divided into five major categories: demand factors, theory and guidance, enabling technologies, applications, and impacts. Over sixty papers have been identified that relate to these areas. Many more articles exist especially in the area of enabling technologies. However, the focus of our paper is the literature most closely related to continuous audit.

## I. Introduction

Continuous auditing is based on multiple research streams. Researchers have investigated theories behind continuous auditing, developed concepts of continuous auditing, built a framework for developing continuous audit, and have put together a substantial research agenda. Research in continuous audit has provided substantial guidance for implementation of continuous auditing, particularly in studies supported by professional organizations. Considerable research has been performed to develop the enabling technologies that make continuous auditing possible. Several continuous auditing applications have been described. Researchers have investigated the cost-benefit dynamic and examined the environmental influences that provide impetus and impede development of continuous auditing. Each of these areas will be discussed in the following sections.

Continuous auditing, continuous assurance, continuous monitoring, real-time auditing, and a variety of other terms are used to describe work in this area. Sometimes the terms are used interchangeably and sometimes authors make distinctions regarding which particular activities are described by the different terms. For purposes of this paper we have not attempted to differentiate among the terms. Accordingly, we make no distinctions about the frequency with which auditing procedures are deployed or the intervals of time which are covered. Kogan, et al (1999) provide a short historical perspective on continuous auditing.

Our review of the literature is arranged as follows: section II discusses why continuous audit is in demand, section III describes continuous auditing theory and guidance, section IV discusses various enabling technologies that support continuous auditing, section V addresses continuous audit applications, section VI describes issues related to impacts, and section VII provides concluding comments and ideas for future work.

## II. The Demand for Continuous Audit

The demand for continuous audit has arisen from several sources, and information technology has advanced to the point where it seems feasible for this demand to be met. Demand is primarily derived from the users' needs for more relevant or reliable information and changes in the regulatory environment.

### *External Disclosure*

The auditing process has been transformed by the way companies process their transactions and store their data. The audit process has progressed from a largely manual operation to becoming increasingly computer-based (Rezaee, et al., 2002). The next step in computer-based auditing is the continuous audit process. The speed and timeliness offered by continuous auditing practices offers benefits to users of financial information. One of the characteristics of relevant financial information is that it is presented on a timely basis. Increasing the frequency of disclosure improves the timeliness of financial information.

More timely disclosure of financial information is being driven by users' needs, and advances in technology have made more frequent releases of financial information possible. Rezaee et al (2002) assert that real-time financial reporting is a driving force behind the demand for continuous audit. Elliott (2002) indicates that increasing the frequency of disclosure for continuous reporting will drive changes to audit procedures to assure the reliability of the disclosures. The authors predict that the information technology advances that allow for more frequent reporting will enable continuous auditing and that one possible advantage of reporting reliable information on a continuous basis is reducing the cost of capital because of a richer disclosure environment. One study supports the usefulness of more frequent reporting to decision makers. Hunton, et al (2002) conducted an experiment with varying intervals of financial reporting and found that more frequent reporting enhanced the usefulness of information for decision making. Additionally, more frequent disclosures improved the quality of earnings, reduced management's aggressiveness with discretionary accruals and reduced stock price volatility. Hunton, et al (2002) also found that adding auditor assurance to the frequency of reporting resulted in more pronounced effects among participants in the experiment.

**Table 1: The Demand for Continuous Audit****External Disclosure***Electronization of Business*

**Vasarhelyi and Greenstein 2003:** Underlying Principles of the Electronization of Business: A Research Agenda  
Drives need for CA

*More Frequent Disclosure*

**Huton et al 2002:** Assessing the Impact of More Frequent External Financial Statement Reporting and Independent Auditor Assurance on Quality of Earnings and Stock Market Effects  
Improved the quality of earnings, reduced management aggressiveness and stock price volatility

**Elliott 2002:** Twenty-First Century Assurance  
Increasing the frequency of disclosure will drive the nature of audit procedures

**Rezaee et al 2002:** Continuous Auditing: Building Automated Auditing Capability  
Real-time reporting, Computer-based IT, Timeliness of reporting

*More Timely Detection of Abnormalities*

**Krass 2002:** The Never-Ending Audit: Can Software Prevent Future Enrons?  
Not capable of preventing Enron or WorldCom type failure

**Vasarhelyi et al 2002:** Would Continuous Auditing Have Prevented The Enron Mess?  
Enron's special purpose entity abnormalities

**Internal Focus***Assure integrity of the transactions*

**Greenstein and Ray 2002:** Holistic, Continuous Assurance Integration: e-Business Opportunities and Challenges  
Electronic Commerce

**Vasarhelyi et al 2004:** Principles of Analytic Monitoring for Continuous Assurance  
Outsourcing and EDI

**Van Decker 2004:** The Need for Continuous Controls Monitoring  
Outsourcing and EDI

**Laws and Regulations***Other Regulation*

**Harrison 2005:** Embracing Compliance with Continuous Online Auditing  
Federal regulations require enforceable and auditable controls

*Sarbanes-Oxley*

**Vasarhelyi et al 2004:** Principles of Analytic Monitoring for Continuous Assurance  
Section 404 compliance

**White 2005:** Does Internal Control Enhance or Impede  
Important monitoring device that enhances management control

**Means and Warren 2005:** Continuous Financial Controls Review Processes (CFCRP) ...  
Sections 302 and 404 compliance

**Technology***Audit Data Warehouse*

**Rezaee et al 2002:** Continuous Auditing: Building Automated Auditing Capability  
Illustrates the functional interrelationships between the audit data warehouse and other users/providers

*Electronic Transactions*

**Kogan et al 1999:** Continuous Online Auditing: A Program of Research  
Rapid growth of online retailing, securities trading, and procurement systems

*ERP environment*

**Vasarhelyi et al 2004:** Principles of Analytic Monitoring for Continuous Assurance  
Take advantage of the automation and integration

More timely detection of abnormalities within business and accounting processes is a distinct benefit of continuous auditing. Vasarhelyi, et al (2002) speculates that the abnormal nature of Enron's special-purpose entity accounting would have come to the attention of external auditors sooner had continuous auditing procedures been in place. However, Krass (2002) speculates that continuous auditing would not be capable of detecting fraud perpetrated at a high level and would not be able to stop the next Enron or WorldCom type accounting-related failure.

***Internal focus – controls over day-to-day operations***

Many businesses face a complex web of information processing and exchange. Firm-wide information linkages have become more prevalent with the advent of integrated enterprise information systems. The operating environment for firms that are interlinked with others as members of supply chains has become a complex set of relationships which require that data be exchanged between firms. As firms partner with other entities via outsourcing and engage in the exchange of information or transaction processing data through electronic data interchange and other means, the need for scrutinizing the integrity of the transactions is very important (Van Decker, 2004. Vasarhelyi, et al, 2004). Greenstein and Ray (2002) emphasize the importance of assuring integrity in operational data generated by an increasingly electronic commerce environment. Managerial decision models depend upon qualitative and non-financial data generated from closely related (e.g. vendors and customers) and more general sources (e.g. industry benchmarks) in addition to traditional financial data.

***Laws and Regulation***

Legislative efforts to improve financial reporting accuracy and transparency in the wake of highly publicized corporate accounting failures culminated in the Sarbanes-Oxley act of 2002. The act intensified the focus of both corporate managers and external auditors on internal controls over the processing of information used to produce financial reports. Management is now responsible for assessing the effectiveness of their internal control structure, including any shortcomings. External auditors are required to attest to the accuracy of management's assertion that internal accounting controls are in place, operational, and effective. The continuous monitoring of transactions can assist managers, internal auditors, and external auditors with discovering errors, defalcations, and other breaches of the internal control system in complex, data-intensive environments.

Means and Warren (2005) assert that the complexity of information systems and processes require audit procedures beyond traditional approaches that stress sampling and the presence of internal control procedures. A methodology for continuous financial controls review is suggested by the authors in their paper as one promising way to cope with the demands of the Sarbanes-Oxley act. Vasarhelyi, et. al (2004) assert that continuous auditing

and analytic monitoring techniques may assist Section 404 compliance by (1) providing evidence that controls are functioning and providing an understanding of the consequences of ineffective or non-operational controls, (2) can repeat data operations to assure controls are working, and (3) can query specially designed controls to assure that they are operating. Since continuous auditing and analytic monitoring are able to bring increased assurance to lower level of aggregation at the transaction level, data integrity and reliability are higher, which can reduce risk and the amount of additional work needed for internal and external audits.

Continuous auditing is seen as being an important asset to comply with the Sarbanes-Oxley act, from the perspective of internal auditors. White (2005) asserts that continuous auditing is an important monitoring device that enhances management control of an entity.

Harrison (2005) believes that continuous auditing techniques are the only way to achieve compliance with governing Federal regulations requiring enforceable and auditable controls that will satisfy federal auditors.

### Technology-Related

Kogan, et al (1999) state that the rapid growth of online retailing, securities trading, and procurement systems has fueled the need for continuous online assurance. The Elliott Committee (AICPA Special Committee on Assurance Services, 1997) provided further impetus for continuous audit by suggesting that continuous oversight is needed to deal with the substantial changes in societal, economic, and technological developments.

Vasarhelyi, et. al (2004) theorize that continuous auditing is uniquely able to take advantage of information in an enterprise resource planning (ERP) environment. ERP seamlessly integrates and automates certain business processes to achieve real-time information flows. Given the need for real time data, continuous auditing achieves its full potential only when being built on ERP systems that automate business processes and integrate information flows. Computer assisted auditing techniques (CAATS) have limitations because they do not take advantage of the automation and integration of brought about by ERP.

In contrast to Vasarhelyi, et. al (2004), Rezaee et al (2002) suggests that ERP is not a necessary condition, but an audit data warehouse is. The authors illustrate the functional interrelationships between the audit data warehouse and other users/providers of data, including business unit managers, vendors, business end users, and audit end-users.

## III. Continuous Auditing Theory and Guidance

Researchers have explored the theory of continuous auditing and have provided substantial guidance for implementation of continuous auditing systems.

Table 2 provides a summary of the major contributions to continuous audit theory and guidance.

**Table 2: Theory/Guidance**

Guidance
<p><i>Concepts</i></p> <p><b>Vasarhelyi 2002:</b> Concepts in Continuous Assurance Outlines continuous assurance concepts</p>
<p><i>Effects on Audit Process</i></p> <p><b>Rezaee et al 2002:</b> Continuous Auditing: Building Automated Auditing Capability Relevance Reliability, Internal control</p>
<p><i>Identify Research Opportunity</i></p> <p><b>Vasarhelyi and Greenstein 2003:</b> Underlying Principles of the Electronization of Business: A Research Agenda Development of monitoring devices and related alarms that support continuous assurance and the assessment of their relative effectiveness.</p>
<p><i>Reviews SAS 94 guidance</i></p> <p><b>Rezaee et al 2002:</b> Continuous Auditing: Building Automated Auditing Capability Effects of IT on internal control structure, types of IT controls, and reporting process under real-time accounting</p>
Framework
<p><i>Generalized Approach</i></p> <p><b>Vasarhelyi et al 2004:</b> Principles of Analytic Monitoring for Continuous Assurance  <p><i>Four Levels of Analysis:</i> 1 transaction evaluation, 2 measurement rule assurance, estimate assurance and 3 consistency of aggregate measures, and 4 judgment assurance</p> <p><i>Hierarchy of audit processes:</i> Primary, internal controls - activities compared to benchmarks; secondary, external auditing; tertiary, independent review of audit processes</p> </p> <p><b>Rezaee et al 2002:</b> Continuous Auditing: Building Automated Auditing Capability Integrates data sources, an audit data server, and audit data users Corporate data system, data download, data conversion, audit data warehouse, data transformation, audit workstations</p> <p><b>Woodroof and Searcy 2001b:</b> Continuous Audit: Model Development and Implementation within a Debt Covenant Compliance Domain  <p>Components: (1) the various interconnected Web servers; (2) the continuous audit environment; (3) the continuous audit agreement; (4) the characteristics of a reliable system; (5) the characteristics of a secure system; and (6) the evergreen reports.</p> </p>
Techniques
<p><i>Continuous Financial Controls Review Process</i></p> <p><b>Means and Warren 2005:</b> Continuous Financial Controls Review Processes (CFCRP) . . . Methodology suggested - "A+++" software – All of the data, fully Audited, All the time</p>
<p><i>Embedded Audit Modules</i></p> <p><b>Groomer and Murthy 1989:</b> Continuous Auditing of Database Applications: An Embedded Audit Module Approach Demonstrates approach, advantages and disadvantages discussed</p>
<p><i>Five classes of tools</i></p> <p><b>Vasarhelyi et al 2004:</b> Principles of Analytic Monitoring for Continuous Assurance Continuity equations, transaction tagging, time-series and cross-sectional statistical analyses, automatic confirmation, and control tags.</p>
<p><i>Query Based</i></p> <p><b>Borthick et al 2001:</b> Developing Database Query Proficiency: Assuring Compliance for Responses to Web Site Referrals Teaching case demonstrating queries for continuous audit</p>
<p><i>System Performance</i></p> <p><b>Murthy 2004:</b> An Analysis of the Effects of Continuous Monitoring Controls on e-Commerce System Performance Performance implications of alternative categories of controls</p>

Continuous auditing requires two components:

- an information technology structure for data processing and storage, and
- some type of analytic monitoring methodology to support the assurance function.

Vasarhelyi, et. al (2004) propose an general architecture for continuous auditing that integrates a firm's ERP system, legacy systems, and monitoring and control systems.

### ***Framework for continuous auditing***

Vasarhelyi, et. al (2004) develop a theoretical framework for continuous audit that relates the levels of assurance and audit objectives to describe four different levels of analysis in a financial audit. The different levels are characterized by their audit objectives, procedures, level of automation, and paradigms used for their analysis. Each successive level, starting with level one, involves more complexity and judgment than the next. By stratifying the types of assurance functions into levels of complexity or judgment, Vasarhelyi, et. al provide an approach to continuous auditing that attempts to achieve the best match between techniques and audit objectives. The levels in the model are described in the next four paragraphs.

Level 1, *transaction evaluation*, includes the frequent and ongoing transaction flow through corporate information systems. Automated continuous auditing procedures can verify steps taken in transaction processing, and structural knowledge of workflow allows the integrity of transactions processed to be analyzed. Transaction flow verification has implications for extension beyond the borders of an enterprise to supply chain linkages with business partners.

Level 2, *measurement rule assurance*, relates to determining the degree of correspondence between the information and some established criteria such as Generally Accepted Accounting Principles (GAAP). Since many rules within GAAP are "grey" and involve some degree of judgment, simple rule-based continuous auditing techniques may not be able to perform the task of verification.

Level 3, *estimate assurance and consistency of aggregate measures*, encompasses such estimates as warranty expenses and the allowance for bad debts. While such measures may depend on human intuition and judgment, they may sometimes be incorporated into continuous auditing systems if human expertise can be captured and formalized into a model. While such models may be difficult to derive in full, partial implementation of estimate assurance can reduce the workload on human auditors and possibly expand the scope of real-time assurance.

Level 4, *judgment assurance*, relates to the most complex and high-level judgments essential for the future of the organization. The degree of automation at this level is limited. However, continuous auditing systems may be of assistance by providing exogenous data and high-level analysis that will improve the quality of judgments and in turn reduce audit risk. This level requires the most judgment and may require the largest degree of human intervention. Vasarhelyi, et. al (2004) provide an example of the four levels of continuous auditing using pension accounting.

Along with the framework for continuous auditing, Vasarhelyi, et. al (2004) describe a hierarchy of auditing processes comprising primary, secondary, and tertiary processes driven by the degree of connectivity to management and control activities.

- The primary monitoring and controlling process relates to internal control processes whereby enterprise activities are recorded and measured against performance benchmarks to assess how well key activities are meeting the expectations of management.
- The secondary monitoring process takes the perspective of the external auditing function by an independent entity.
- Tertiary monitoring is performed in part by the independent auditor, and in part by another trusted independent party in circumstances such as peer review by another accounting firm or the Public Company Accounting Oversight Board.

Rezaee et al (2002) provide a generalized continuous auditing approach that integrates data sources, an audit data server, and audit data users. Rezaee et al (2002) cite Statement of Auditing Standards (SAS) 94<sup>1</sup> as a source of authoritative literature in auditing that provides some guidance on the effects of information technology and internal control structures important to continuous auditing of a financial reporting process. In particular, SAS 94 provides guidelines for auditors to better understand (1) the effects of information technology on the internal control structure, (2) types of information technology controls that are important to continuous auditing, and (3) the financial reporting process under real-time accounting systems.

### ***Techniques for continuous auditing***

Vasarhelyi, et. Al (2004) identified tools to provide new continuous auditing assurance technologies. These tools help to monitor systems largely by detecting variances or exceptions to systems norms as they occur and allowing these exceptions to be investigated to find the root causes. One common consideration with these tools is that they permit continuous auditing at a low incremental cost. Techniques and tools for continuous audit outlined by Vasarhelyi, et. Al (2004) fall into several categories and are briefly described next.

- Continuity equations use business process knowledge and related performance measures to evaluate the reasonableness of actual transactional information. One of the challenges of continuity equations is determining the measurements that accurately and quickly reflect the actions in business processes.
- Transaction tagging allows the transaction flow from one application to the next to be evaluated for data accuracy and integrity. A continuous auditing environment could employ tags that identify the source, nature, assessor and transformation of data. Data level assurance is an important function but presents a challenge in that it is an intricate process and data flows are massive.
- Time-series and cross-sectional statistical analyses are useful in developing models to compare against actual results. The availability of continuous flows of information may make

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<sup>1</sup> "The Effect of Information Technology on the Auditor's Consideration of Internal Control in a Financial Statement Audit", April 2001. Amends SAS No. 55 (1998)

time-series regressions more useful than in the past when monthly or quarterly data have been used.

- Automatic confirmations made possible through extranets can substantially increase the amount of audit evidence supporting the existence, value, and other assertions about transactions. Vasarhelyi, et. Al (2004) believe that automatic confirmation procedures have the potential to change the nature, scope, and procedures of an audit because of their ability to fulfill audit objectives at the transaction level.
- Control tags that can contain a range of information can help mark data paths or serve other audit purposes to provide assurance about transaction processing. Such tagging procedures have audit implications for both substantive and control testing. In light of the increased testing of controls required by the Sarbanes Oxley act, control tags may play an important role to cost-effectively provide assurance about the system of internal controls.

Rezaee et al 2002 provide an approach for building continuous audit capacity. Their approach downloads information from the corporate data system, converts it to an appropriate format to store in a audit data warehouse from which it can be used directly at audit workstations or transformed and stored in a data mart for use.

Groomer and Murthy (1989) demonstrate the use of an embedded audit module (EAM) approach in a database environment to capture information about exceptions and violations to the defined data access restrictions. They note that an EAM may have a negative impact on the performance of the application, may generate large data sets and are at risk of being modified by application programmers. They note that with an EAM: violation and exception information can be captured on a real time basis; all events can be screened, not just a sample; and the extent of compliance testing may be reduced. To make an EAM approach viable, auditors must be knowledgeable about application and database environment, have the client cooperation, and have a stable hardware and software environment in which to implement.

Murthy (2004) examines the effects of adding continuous auditing processing loads to overall system processing capacity. The authors analyze the system performance implications that alternative categories of continuous auditing monitoring controls have on web-based e-commerce applications under varying system load conditions. This paper provides a methodology that can be used by potential implementers of continuous auditing to investigate the effects of incorporating various monitoring controls into their application systems. Three categories of controls were examined, ranging from relatively simple controls involving only calculations to complicated controls requiring the use of structured query language aggregate functions. It was found that aggregate function controls had very detrimental effects on system performance even under light system load conditions. Capacity planning is an essential consideration for information technology system architects.

#### IV. Enabling Technology

Several enabling technologies have been identified for continuous auditing.

These include: belief functions, databases, expert systems, intelligent agents, neural networks, real time accounting and XBRL/XML. How each of these areas relates to continuous auditing is discussed in more depth below. Highlights of relevant research in each of these areas are summarized in Tables 3a through 3g.

##### ***Belief Functions:***

The belief function framework is an evidential reasoning approach for mathematically combining evidence for and against an assertion. It differs from probabilistic methodologies in that lack of evidence is not interpreted as either supporting or invalidating the assertion. Belief functions have been demonstrated to provide a good method for aggregating audit evidence (Gillett and Srivastava 2000; Shafer and Srivastava 1990; Srivastava and Mock 2000; and Srivastava and Shafer 1992 and Sun et al 2006). Sun et al (2006) describes real world implementation of belief functions for information system security risk analysis from the perspective of the auditor. The environments in which continuous audit systems must operate are complex, having multiple types of interrelated transactions, objectives, vulnerabilities, and controls. The belief function framework provides structured yet tractable approach to risk assessment in complex environments, making it an approach that may prove useful for continuous audit.

**Table 3a: Enabling Technology**

##### **Belief Functions**

###### *Assurance Services for Electronic Commerce*

**Srivastava and Mock 2000:** Evidential Reasoning for WebTrust Assurance Services  
Evidential network (belief function) model and decision-theoretic model for WebTrust assurance

###### *Audit Risk*

**Srivastava and Shafer 1992:** Belief-Function Formulas for Audit Risk  
Relates belief functions to the structure of audit risk

###### *Compare with Bayesian*

**Shafer and Srivastava 1990:** The Bayesian and Belief-Function Formalisms: A General Perspective for Auditing  
Compares the Bayesian formalism with the belief-function formalism

###### *Information System Security Risk*

**Sun et al 2006:** An Information Systems Security Risk Assessment Model under the Dempster-Shafer Theory of Belief Functions  
Information system security risk analysis using belief functions

###### *Integrating Sampling Results*

**Gillett and Srivastava 2000:** Attribute Sampling: A Belief-Function Approach to Statistical Audit Evidence  
How statistical evidence obtained by means of attribute sampling may be represented as belief functions

##### ***Databases and data analysis technology:***

Business processes have become increasingly reliant on electronic processing and storage. Simultaneously, the tools for enabling continuous auditing methods have manifested themselves along with technological advances. This section discusses the technological factors that are a necessary condition for continuous audit.

Kogan, et al (1999) state that continuous auditing is only feasible if implemented as a fully automated process



and one that allows instant access to relevant events and their outcomes. Electronic data, plus the dramatic reduction in the cost of hardware and gains in processing power, have paved the way for continuous auditing. Rezaee et al (2002) suggest that the standardization of data sources, particularly from legacy systems, will be the most complex and challenging aspect of building continuous auditing capacity. The risks and costs of introducing errors and duplicate records can create huge obstacles to the development of an end-user continuous auditing, testing, and analysis systems.

**Table 3b: Enabling Technology**

**Databases**

*Data Source*

**Rezaee et al 2002:** Continuous Auditing: Building Automated Auditing Capability

List necessary conditions; Scalable audit data warehouse

**Murthy and Groomer 2004:** A Continuous Auditing Web Services Model for XML-Based Accounting

List necessary conditions

**Kogan et al 1999:** Continuous Online Auditing: A Program of Research

Fully automated process that allows instant access to relevant events and their outcomes

*Database Queries*

**Borthick et al 2001:** Developing Database Query Proficiency: Assuring Compliance for Responses to Web Site Referrals

Teaching case demonstrating queries for continuous audit

Rezaee et al (2002) propose a model of continuous auditing that does not require an ERP data warehouse, but does require an audit data mart. Data collected and transformed for data marts of various business units will be physically stored in an audit data server for easy access, analysis, and reporting. The essence is not to duplicate corporate databases, but to selectively collect transactions that have been defined to pose an audit issue and store them in a separate data warehouse. According to Rezaee et al (2002), an integrated audit data mart must have, at minimum, the following characteristics:

- Integrated query, analysis, and reporting through a unified user interface
- An easy-to-use product line, yet powerful enough for the most sophisticated analytical users.
- Capacity to export the results of queries easily to common spreadsheets and database systems.
- A query engine capable of retrieving and processing large volumes of data.
- Data aggregation and multidimensional database capability
- Capabilities for: advanced statistical modeling and data exploration.
- Data visualization capability for data mining exploration and identification of patterns and trends in the data.

Murthy and Groomer (2004) have a similar list of necessary conditions including:

- A highly reliable client system that can provide the necessary information to the auditors on a timely basis.
- The subject of the audit must be electronically accessible.
- The auditor must be proficient in information systems computer technology and what is to be audited.

- Automated procedures must reliably provide the needed audit evidence.
- A highly placed executive must champion continuous auditing.

Borthick et al (2001) developed a teaching case to demonstrate a query-based approach to continuous monitoring. They note that this approach is likely to become more common as trading partners increasingly use networks to directly interact with each others systems.

**Expert Systems**

Expert systems have been applied to a variety of audit tasks. Expert systems were the first application of AI in auditing, with significant growth in this area beginning in the 1980s (Denna et al 1991, Brown and Murphy 1990, Abdolmohammadi 1987, Hansen and Messier 1987). Successful applications of AI to audit tasks have mostly addressed structured repetitive tasks where the human expertise is not extremely hard to acquire. This research stream has resulted in a number of expert systems in use at public accounting firms, including ADAPT (Gillett 1993), Deloitte Touche's Audit Planning Advisor, Price Waterhouse's Planet, Arthur Andersen's WinProcess and KPMG's KRisk (Zhao et al 2004, Bell et al. 2002, Brown 1991). The computational models developed by those early expert systems researchers have facilitated the automation of the audit process and continuous audit.

**Table 3c: Enabling Technology**

**Expert Systems**

*Research Review*

**Denna et al 1991:** Development and Application of Expert Systems in Audit Services

Evaluate research and development in the design of expert systems for the audit domain

**Abdolmohammadi 1987:** Decision Support and Expert Systems in Auditing: A Review and Research

Audit domain

**Hansen and Messier 1987:** Expert Systems in Auditing: The State of the Art

Literature review

*System Descriptions*

**Brown 1991:** Expert Systems in Public Accounting: Current Practice and Future Directions

Deloitte Touche's Audit Planning Advisor, Price Waterhouse's Planet, Arthur Andersen's WinProcess

**Brown and Murphy 1990:** The Use of Auditing Expert Systems in Public Accounting

Review of systems in use by big 6

**Gillett 1993:** Automated Dynamic Audit Programme Tailoring: An Expert System Approach and KPMG's KRisk

ADAPT

**Zhao et al 2004:** Auditing in the E-commerce Era

Deloitte Touche's Audit Planning Advisor, Price Waterhouse's Planet, Arthur Andersen's WinProcess and KPMG's KRisk

**Bell et al 2002:** KRisk: A Computerized Decision Aid for Client Acceptance and Continuance Risk

KPMG's KRisk

**Intelligent Agents**

An intelligent agent is goal-oriented software that uses the internet to seek out information to achieve its specific goal.

The FRAANK (Financial Reporting and Auditing Agent with Net Knowledge) system (Bovee et al 2005, Kogan et al 2002) acquires, parses, and converts financial information available on the WEB to XBRL, which can then be automatically processed to achieve an audit objective. FRAANK's earlier incarnation EDGAR Agent (Nelson et al 2000; Nelson et al 1998) searched for the current cash balance and calculated some financial ratios of a user-specified firm, whether or not the user specified the firm name in exactly the same way as it is filed in the EDGAR database. Woodroof and Searcy (2001, 2001b) demonstrate the use of an intelligent agent to continuously assure debt covenant compliance. These systems demonstrate that intelligent agents can be used in continuous auditing systems to either query on-line databases or to query trading partners for information. This capability can facilitate much richer continuous audit applications, potentially giving the capability of continuously confirming receivables and payables with large trading partners or comparing reported financial information of trading partners and competitors with that of the firm being audited.

### Figure 3d: Enabling Technology

#### Intelligent Agents

##### *Debt Covenant Compliance*

**Woodroof and Searcy 2001:** Audit Implications of Internet Technology: Triggering Agents Over the Web in the Domain of Debt Covenant Compliance  
Describes implementation

##### *EDGAR Agent*

**Nelson et al 1998:** Virtual Auditing Agents: The Edgar Agent Example  
Quality service/framework; expand audit practice; use in audit

**Nelson et al 2000:** Virtual Auditing Agents: The EDGAR Agent Challenge  
Quality service/framework

##### *FRAANK*

**Bovee et al 2005:** Financial Reporting and Auditing Agent with Net Knowledge (FRAANK) and extensible Business Reporting Language (XBRL)  
Describes development and application

**Kogan et al 2002:** Design and Applications of an Intelligent Financial Reporting and Auditing Agent with Net Knowledge (FRAANK)  
Describes prototype

#### *Neural Networks:*

A neural network is a type of artificial intelligence system that connects relatively simple processing elements to form a network. The number of processing elements, how they are connected and the weights of the connections determine the output based on specified inputs. A neural network can be created to model any function. Neural networks are particularly effective when a large database of prior examples exists with known inputs and outputs.

Neural networks have been investigated for a variety of audit tasks. Calderon and Cheh (2002) and Koskivaara (2004) provide an in-depth review of audit research using neural network technology. Fadlalla and Lin (2001) look more broadly at financial tasks, including bankruptcy prediction and credit granting among others. Fadlalla and Lin note that application categories suitable for neural networks are "unstructured and data intensive and involve much uncertainty, hidden relationships, and noise," (2001 p.115) which is an apt description of the continuous audit area.

### Figure 3e: Enabling Technology

#### Neural Networks

##### *Analytical Review*

**Lin et al 2003:** A Fuzzy Neural Network for Assessing the Risk of Fraudulent Financial Reporting  
Integrated fuzzy neural network (FNN) for fraud detection

**Coakley and Brown 1993:** Artificial Neural Networks Applied to Ratio Analysis in the Analytical Review Process  
Error Detection - seeded material errors in monthly data

**Green and Choi 1997:** Assessing the Risk of Management Fraud Through Neural Network Technology  
Management Fraud Detection

**Fanning and Cogger 1998:** Neural Network Detection of Management Fraud Using Published Financial Data  
Fraud Detection - used published financial data

**Koskivaara 2000:** Artificial Neural Network Models for Predicting Patterns in Auditing Monthly Balances  
Built models using the 72 monthly balances of a manufacturing firm

**Fanning et al 1995:** Detection of Management Fraud: A Neural Network Approach  
Fraud Detection

##### *Control Risk Assessment*

**Ramamoorti et al 1999:** Risk Assessment in Internal Auditing: A Neural Network Approach  
Research investigates whether neural networks can help enhance auditors risk assessments

**Davis et al 1997:** Supporting Complex Audit Judgment Tasks: An Expert Network Approach  
Prototype expert network to support internal control risk assessment

##### *Review of Research*

**Koskivaara 2004:** Artificial Neural Networks in Analytical Review Procedures  
Overview of artificial neural network (ANN) studies conducted in the auditing field

**Fadlalla and Lin 2001:** An Analysis of the Applications of Neural Networks in Finance  
Financial tasks

**Calderon and Cheh 2002:** A roadmap for future neural networks research in auditing and risk assessment  
Audit neural network

##### *Screening*

**Baker 2005:** Fraud and Artificial Intelligence  
Transaction screening: fraud detection and prevention

**Viaene et al 2002:** A Comparison of State-of-the-Art Classification Techniques for Expert Automobile Insurance Claim Fraud Detection  
Claims screening: automobile insurance claim fraud detection

The most relevant individual studies for continuous audit are those investigating control risk assessment (Ramamoorti, et al 1999; Davis et al 1997); and, analytical review including error and fraud detection (Coakley and Brown 1993; Fanning and Cogger, 1998; Fanning et. al. 1995; Green and Choi 1997, Koskivaara 2000, Lin et al 2003). Neural networks have long been used to screen transactions and claims for fraud prevention by banks, credit card companies and the insurance industry (Baker 2005; Viaene et al 2002). The success of neural networks in these areas holds promise for the use of neural networks in continuous audit applications. Although the black box nature of neural networks poses some issues, the ability of neural networks to quickly tag unusual transactions for additional screening could prove useful as a way to minimize the impact of continuous audit on the performance of accounting systems.

## Real-time Accounting

Scanners, card readers, databases, enterprise-wide management systems, supply chain management systems and networks have made much of today's transaction processing a real-time activity. At the retail end, transactions are recorded with electronic cash registers that are connected to the company's inventory and accounting records and the credit card and electronic funds transfer systems. EDI and just-in-time inventory systems have brought much of the manufacturing and wholesale accounting to real-time processing as well. Rezaee et al (2000) and Alles et al (2004b) argue that as accounting becomes increasingly real-time, continuous auditing must follow.

### Figure 3f: Enabling Technology

#### Real-time Accounting

##### *Discusses Issues*

**Alles et al 2004:** Restoring Auditor Credibility: Tertiary Monitoring and Logging of Continuous Assurance Systems.

##### *Impact on Auditing*

**Rezaee et al 2000:** Real-Time Accounting Systems  
Preventive and detective controls

#### XBRL/XML

XBRL (eXtensible Business Reporting Language) is an XML (eXtensible Markup Language) based standard for communicating financial information. "The purpose of XBRL is to facilitate the preparation, publishing, exchange and analysis of financial statements and the information they contain. It serves as an open specification for data, developed by a global, non-profit consortium comprising companies, associations, and government agencies" (Baldwin et al 2006). XBRL comprises a standard or specification, a family of taxonomies, instance documents and style sheets.

The use of XBRL allows systems to understand the meaning of the tagged data from the definitions in the taxonomy used. Style sheets can be used to present the information in an appropriate format, whether for a human or computer system reader. The use of XBRL technology can facilitate the development of reusable continuous audit modules as well as gathering relevant data from external sources. The FRAANK system (Bovee et al 2005, Kogan et al 2002) demonstrates how it can be used to facilitate analytical review. Murthy and Groomer (2004) presents a model for continuous auditing web services (CAWS) using XML and web services.

### Table 3g: Enabling Technology

#### XBRL/XML

##### *Analytical Review*

**Kogan et al 2002:** Design and Applications of an Intelligent Financial Reporting and Auditing Agent with Net Knowledge (FRAANK)

FRAANK/XBRL

**Bovee et al 2005:** Financial Reporting and Auditing Agent with Net Knowledge (FRAANK) and eXtensible Business Reporting Language (XBRL)

FRAANK/XBRL

##### *Indirect Link to Client Database*

**Woodroof and Searcy 2001b:** Continuous Audit: Model Development and Implementation within a Debt Covenant Compliance Domain

XML/XBRL Downside - push rather than pull technology

##### *Monitoring*

**Murthy and Groomer 2004:** A Continuous Auditing Web Services Model for XML-Based Accounting  
Continuous Monitoring Web Services/XML

##### *Standardization of Data*

**Rezaee et al 2002:** Continuous Auditing: Building Automated Auditing Capability  
XBRL

##### *Validating Mechanism*

**Debreceeny and Gray 2001:** The Production and Use of Semantically Rich Accounting Reports on the Internet: XML and XBRL  
Validating mechanism for Internet published statements

## V. Continuous Audit Applications

Continuous auditing will involve different processes than the traditional audit. Vasarhelyi, et. al (2004) outline a series of steps that begin with a considerable amount of front-end architectural work. Key features of the processing steps outlined by Vasarhelyi, et. al (2004) are the identification of key performance metrics, identification of factors that cause discrepancies between actual results and those that are modeled, and continuous updating of the process models over time.

Glover et al (2000) conducted a survey of 2,700 members of the Institute of Internal Auditors to assess how and to what extent software was being used for their work, including continuous monitoring. Nearly half of the respondents reported that they use some type of continuous monitoring software, which is up from twenty-four percent reported in a similar survey in 1998. The authors surmised that the ability of commercial software to meet the specific needs of internal auditors for continuous monitoring may be increasing.

Rezaee et al (2002) believe that the use of data extraction and analysis software by audit departments has been increasing rapidly and has been supplanting the traditional manual methods of auditing. In their paper, Rezaee et al (2002) note two companies that are using continuous audit applications: Carolina Power and Light, and Exxon Company, USA.

"Carolina Power and Light has adopted Selective Monitoring and Assessment of Risks and Trends or SMART Auditing to identify potential problems, unfavorable trends, and unusual variances measured by key indicators. Using CATTs, the Audit Services



identify testing criteria, (4) automate tests, (5) communicate test results, (6) receive feedback, and (7) track progress of continuous auditing results. Nelson (2004) walks through the seven steps as they were applied by the implementation team at HCA, Inc.

One interesting application domain for continuous auditing has been described by Turoff et al (2004). The authors contend that continuous auditing techniques can be integrated with the Emergency Response Management Information System to form a more effective and reliable supporting component of homeland security. Other applications for continuous audit are likely to emerge as the use of continuous auditing becomes more widespread.

Sigvaldason and Warren (2005a, 2005b) describe a relatively new continuous auditing software application with the brand name AuSoftware designed to continuously monitor the enterprise systems of large companies and governmental agencies. The software imports data into an audit data mart, as described by Rezaee (2002), that facilitates continuous assessment and analysis with selected algorithms. The data is stored for subsequent analyses such as time series analysis.

## VI. Impacts – costs and benefits

The trend towards increasingly affordable computing power may translate to continuous auditing being a cost-effective assurance tool. Means and Warren (2005) state that continuous audit (continuous financial controls review processes) software will automate and replace some manual and visual assurance processes that will provide ongoing efficiencies and savings.

Benefits may be difficult to quantify, but are often linked to two factors. The first is more timely disclosure of accurate financial information to market participants. The second factor is timelier discovery of errors, omissions, and defalcations. Automated, software-driven audit procedures are often more cost-effective than their manual predecessors. Benefits and cost savings accrue to both internal and external monitors (auditors) of the firm.

Rezaee et al (2002) discuss factors related to continuous audit that can help to reduce the costs of monitoring. Costs related to the basic audit assignment may be reduced by allowing auditors to test client's transactions in a manner that is faster and more efficient than manual testing. In addition to the efficiencies of testing, a larger sample (up to 100%) of the population may be tested, potentially increasing the quality of evidence gathered and reducing audit risk. Efficiencies in testing also allow the auditor to spend more time on understanding the client's business/industry and internal control structure within the time constraints allocated to a particular audit.

Searcy and Woodroof (2003b) point out various types of inefficiencies faced by external auditors that continuous auditing can mitigate. Continuous auditing techniques may reduce the time that it takes for the client to provide auditors with data needed to complete their audit tasks. The review process used as a quality control measure

during the audit may be automated to shorten the time taken through continuous auditing procedures. In addition, continuous audit can reduce inefficiencies in the audit process and reduce errors and mistakes (Searcy and Woodroof 2003).

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### Table 5: Impacts – costs and benefits

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#### *Benefit*

**Rezaee et al 2000:** Real-Time Accounting Systems  
CA increases quality

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#### *Database Access Audit*

**Pathak et al 2005:** Minimizing Cost of Continuous Audit: Counting and Time Dependent Strategies  
Focus on the long run operating cost of running database audit

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#### *Efficiencies and Cost Savings*

**Means and Warren 2005:** Continuous Financial Controls Review Processes (CFCRP) Using Powerful New Technologies may be the Only Real Answer to the Demands of Sarbanes-Oxley

A+++ is far less costly approach that lowers overall risk

**Searcy and Woodroof 2003:** Continuous Auditing: Leveraging Technology

Reduce time to get information and do procedures

**Rezaee et al 2002:** Continuous Auditing: Building Automated Auditing Capability

Reduces cost of audit. Reduces amount of time spent on audit.

Specifies testing criteria for auditing throughout the year.

Simultaneously performs substantive and control tests.

**Woodroof and Searcy 2001:** Audit Implications of Internet Technology: Triggering Agents Over the Web in the Domain of Debt Covenant Compliance

Reduce overall audit staff.

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#### *Increased Effectiveness and Efficiency*

**Searcy and Woodroof 2003:** Continuous Auditing: Leveraging Technology

Reduce time delays due to not having needed information, reduce inefficiencies and starts and stops in the audit process, automate and shorten the review process and reduce errors and mistakes.

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#### *Reduce Audit Risk*

**Rezaee et al 2002:** Continuous Auditing: Building Automated Auditing Capability

Increases quality of audit, test larger sample or population.

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#### *Reduce Cost of Capital*

**Elliott 2002:** Twenty-First Century Assurance

Reduce the cost of capital because of a richer disclosure environment.

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#### *Behavioral Impacts*

**Hunton et al (2002):** Assessing the Impact of More Frequent External Financial Statement Reporting and Independent Auditor Assurance on Quality of Earnings and Stock Market Effects.

Behavioral impacts (reduced management's aggressiveness with discretionary accruals and reduced stock price volatility) on users of more frequent disclosures is more pronounced when information is audited

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## VII. Conclusions and Direction for Future Work

A wide and varied literature exists relating to continuous audit. Substantial work still needs to be done to develop a clear understanding of how the various research streams relate to each other. Additional literature related to the enabling technologies must be identified and how those technologies relate to continuous audit should be clarified.

As business processes become increasingly more interlinked through the use of information technology and web-based applications, continuous auditing will become a more important monitoring and assurance device. Other

factors creating the demand for continuous auditing are the Sarbanes-Oxley act, and the needs of external users for reliable financial disclosures that are released frequently. The question remains, will the demand factors identified actually lead to more continuous audit applications? Will demand factors lead to different models of who pays for the cost of audits?

The existing literature provides a good theoretical framework that provides academics and practitioners with valuable guidance for implementing and maintaining continuous auditing applications. An excellent example is Vasarhelyi et al (2004), which provides a conceptual framework for continuous auditing. While the literature is becoming more developed, work remains to be done in this relatively young discipline.

More descriptions of actual systems are needed along with descriptions of their architecture and the techniques used. Performance data from actual implementations would be helpful. Research on the impacts of continuous audit systems is needed. What are the actual costs to develop and run systems? What are the actual benefits? How do such systems change behaviors?

Two papers assist in providing future direction for research in continuous auditing. Hunton et al (2004) explore opportunities for future work related to the use of continuous auditing procedures. They assert that the advent of continuous auditing will provide behavioral accounting researchers with many topics to study related to how frequency of reporting and assurance affect judgment and decision-making processes. The authors suggest that bounded rationality and cognitive limitations may come into play with the possible overload of available information. Although the article is not a recent one, Kogan, et al (1999) outline a number of areas for research related to continuous auditing that are still relevant and of interest to academics and practitioners.

## References

- Abdolmohammadi, Mohammad J. 1987. Decision Support and Expert Systems in Auditing: A Review and Research Directions. *Accounting and Business Research* (Spring) 173-185.
- Abdolmohammadi, M. J. and Sharbatouglie, A., 2005, *Continuous Auditing: An Operational Model for Internal Auditors*, The Institute of Internal Auditors Research Foundation, Altamonte Springs, Florida, 1-159, [http://www.theiia.org/bookstore.cfm?fuseaction=product\\_detail&order\\_num=5001](http://www.theiia.org/bookstore.cfm?fuseaction=product_detail&order_num=5001).
- Alles, Michael; Brennan, Gerard; Kogan, Alexander and Vasarhelyi, Miklos A..2006. Continuous monitoring of business process controls: A pilot implementation of a continuous auditing system at Siemens. *International Journal of Accounting Information Systems*, 7(2), 137-161.
- Alles, M., Kogan, A., and Vasarhelyi, M.A., 2002, Feasibility and Economics of Continuous Assurance, *Auditing: A Journal of Practice and Theory*, 21(1), 125 – 138.
- Alles, M., Kogan, A., and Vasarhelyi, M. A., 2004a, Restoring Auditor Credibility: Tertiary Monitoring and Logging of Continuous Assurance Systems, *International Journal of Accounting Information Systems*, 5(2), 183-202.
- Alles, M., Kogan, A., and Vasarhelyi, M.A., 2004b, Real Time Reporting and Assurance: Have Their Time Come?, *ICFAI Reader*, Institute of Chartered Financial Analysts of India, Special issue: Finance in 2004.
- Baker, N., 2005, Fraud and Artificial Intelligence, *Internal Auditor*, 61(1), 29-31.
- Baldwin, A. A.; Brown, C. E. and Trinkle, B. S. 2006. XBRL: An Impacts Framework and Research Challenge, *Journal of Emerging Technologies in Accounting*, forthcoming.
- Bell, Timothy B., Jean C. Bedard, Karla M., Johnstone and Edward F. Smith. 2002. KRisk: A Computerized Decision Aid for Client Acceptance and Continuance Risk Assessments. *Auditing: A Journal of Practice & Theory* 21(2:September) 97-113.
- Boccasam, P. V. and Kapoor, N., 2003, Managing Separation of Duties Using Continuous Monitoring, *IT Audit*, 6:, The Institute of Internal Auditors, , Available online: <http://www.theiia.org/itaudit/index.cfm?fuseaction=forum&fid=5433>.
- Borthick, A. F.; Jones, D. R. and Kim, R., 2001, Developing Database Query Proficiency: Assuring Compliance for Responses to Web Site Referrals, *Journal of Information Systems*, 15(1), 35-56.
- Bovee, M.; Kogan, A.; Nelson, K.; Srivastava, R. P.; Vasarhelyi, M. A. 2005. Financial Reporting and Auditing Agent with Net Knowledge (FRAANK) and extensible Business Reporting Language (XBRL). *Journal of Information Systems*, Spring, 19(1), 19-41.
- Brown, Carol E. 1991. Expert Systems in Public Accounting: Current Practice and Future Directions. *Expert Systems with Applications*, 3(1: June), 3-18.
- Brown, Carol E. and Murphy, David S. 1990. The Use of Auditing Expert Systems in Public Accounting. *Journal of Information Systems* 4(2:Fall) 63-72
- Calderon, T. G. and Cheh, J. J., 2002, A roadmap for future neural networks research in auditing and risk assessment, *International Journal of Accounting Information Systems*, 3(4), 203-236.
- CICA/AICPA, 1999, *Continuous Auditing, Research Report*, The Canadian Institute of Chartered Accountants, Toronto, Canada.
- Coakley, J. R. 1995. Using Pattern Analysis Methods to Supplement Attention-Directing Analytical Procedures, *Expert Systems with Applications*, 9(4), 513-528.
- Coakley, J. R. and Brown, C. E., 1993, Artificial Neural Networks Applied to Ratio Analysis in the Analytical Review Process, *International Journal of Intelligent Systems in Accounting, Finance and Management*, 2(1), 19-39.
- Coderre, David 2006, A Continuous View of Accounts. *Internal Auditor*, April, 63(2), 25-31.
- Davis, J. T.; Massey, A. P. and Lovell R. E. R. 1997. Supporting Complex Audit Judgment Tasks: An Expert Network Approach. *European Journal of Operations Research*. 103(2), 350-372.
- Debreceny, R., and Gray, G. 2001. The Production and Use of Semantically Rich Accounting Reports on The Internet: XML and XBRL. *International Journal of Accounting Information Systems* 2(1:January) 47-74
- Debreceny, R., G. Gray, J. Ng, K. Lee, and W. Yau. 2005. Embedded Auditing Modules in Enterprise Resource Planning