THREE ESSAYS ON AUDIT TECHNOLOGY: AUDIT 4.0, BLOCKCHAIN, AND AUDIT APP

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ABSTRACT OF THE DISSERTATION

Three Essays on Audit Technology: Audit 4.0, Blockchain, and Audit App

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Technology has deeply influenced the evolution of the auditing profession. New technologies such as Industry 4.0, blockchain, and apps, are expected to dramatically change the both current business model and society at large. The audit profession may need to adjust its existing paradigm in order to adapt to such a rapidly changing environment. Moreover, new audit approaches relying on advanced technologies could be used to improve assurance quality.

This dissertation consists of three essays that explore the potential impact of emerging technologies on audit domain. The study contributes to the auditing literature by introducing Audit 4.0, blockchain, and apps to audit research, analyzing their potential applications in audit procedures, and proposing new paradigms that leverage those technologies to improve audit quality. The first essay foresees the impact of the fourth industrial revolution on the auditing profession, imagineers the use of new technologies promoted by Industry 4.0 for audit purposes, and identifies challenges in the transformation towards the new generation of auditing: "Audit 4.0".

The second essay studies how blockchain technology could contribute to the accounting and auditing profession. Blockchain is the most disruptive information technology in recent years. Although the use of blockchain has been studied in many fields such as banking, financial markets, and government service, its application to accounting and assurance remains under-explored. This chapter discusses how

blockchain could enable a real-time, reliable, and transparent accounting ecosystem, and how it could transform current auditing practices resulting in a more precise, timely, automatic assurance system.

The third essay explores the use of apps to augment existing audit procedures. This essay first proposes a framework that provides guidance on app development and use. Based on this framework, this study designs a planning system that integrates apps into audit plans. Further, an intelligent app recommender system is designed to enable less experienced auditors to perform analytical audits. Finally, the planning system and the app recommender, together with other intelligent systems, are combined to create a new auditing paradigm: app-based auditing.

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Chapter 1. Introduction

1.1. Background

This dissertation consists of three essays exploring how emerging technologies, specifically Audit 4.0, blockchain, and audit apps, could be leveraged to improve assurance quality and promptness and potentially to change the current audit paradigm. Chapter one introduces the motivation for this dissertation and provides an extended literature review on the concepts of Industry 4.0, blockchain, audit apps, and related issues. The three essays are included in chapter two, three and four, respectively. The last chapter concludes the dissertation, and discusses limitations and future research areas.

The evolution of the modern auditing profession has been driven by technology development in the past decades. The traditional, labor-intensive, manual audit left a heavy burden on auditors tasked with providing a reasonable level of assurance upon an entire organization within a limited amount of time. Since the 1970s, auditors have been able to progressively use computing devices, software, and databases to examine electronic accounting data since the 1970s (Cash Jr., Bailey Jr., and Whinston 1977). These tools dramatically reduced auditors' effort on transaction tracing and calculation. Since then, an increasing number of technologies were used in the auditing profession, to increase the efficiency and effectively of audit activities, and ultimately to improve the overall assurance quality. A timeline of technology use in the auditing domain is shown in Figure 1.

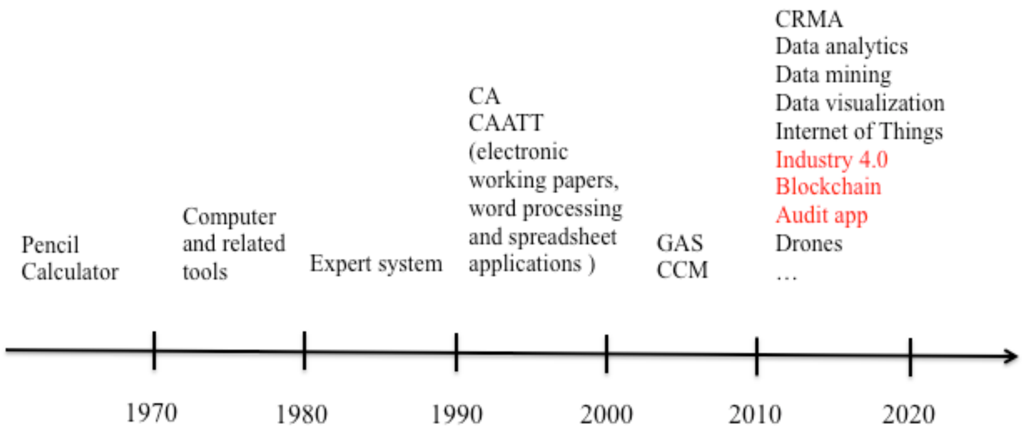

Figure 1: The timeline of the use of audit-oriented technologies

Expert systems were among the initial attempts to use intelligent technologies in auditing practice, starting in the late ‘70s and early ‘80s (Gray, Chiu, Liu, and Li 2014). Both researchers (Dungan1983; McCarty, 1977; Michaelsen 1982) and accounting firms (Brown 1991) were making great efforts in developing auditing-related expert systems. By the 1990s, Computer Assisted Audit Techniques and Tools (CAATTs) were being progressively adopted as a fundamental part of audit methodologies (CICA 1994; Coderre 1999; Hudson 1998; Lovata 1990; Mahzan and Lymer 2008). In general, CAATTs refer to any technologies that can “assist in the completion of an audit” (Braun and Davis 2003). In their earliest forms, CAATTs mainly included electronic working papers and traditional word processing and spreadsheet applications (Braun and Davis 2003). Later on, the scope of CAATTs are expanded to include a broad set of audit-aid technologies such as general audit software (GAS), network security evaluation software, audit reporting software, databases of audit history, etc. (Mahzan and Lymer. 2014; Sayana 2003). GAS is among the most commonly used CAATTs, which mainly uses data extraction and analysis techniques to perform audit routines and statistical tests (Ahmi and Kent 2012). In the 2000s, internal auditors and IT auditors started to use GAS for investigations (Debreceny, Lee, Neo, and Toh 2005; Singleton 2006), while utilization of GAS by external auditors remains low (Ahmi and Kent 2012).

By 1991, the concept of continuous auditing (CA) was proposed and its first application was developed for a corporate billing system (Vasarhelyi and Halper 1991). Early CA systems aimed to check the data flowing through a system against auditor-defined rules, and trigger alarms when rule-violations were detected. After two decades, CA has evolved into a much broader concept called "continuous assurance" (Vasarhelyi, Alles, and Williams 2010), which consists of three main technologies: continuous data assurance (CDA) (Kogan, Alles, Vasarhelyi, and Wu 2014), continuous controls monitoring (CCM) (Alles, Brennan, Kogan, and Vasarhelyi 2006), and continuous risk monitoring and assessment (CRMA) (Moon 2016), providing assurance close to real time. CDA executes continuous and automatic transaction verification in order to provide timely assurance (Kogan et al. 2014). CCM monitors employees' behaviors against internal control policies for violations (Alles et al. 2006; Chan and Vasarhelyi 2011). CRMA focuses on business risk monitoring by identifying significant risks and prioritizing audit and risk management control procedures (Moon 2016). These components provide comprehensive, timely, and accurate assurance and preemptively address significant risks.

Technological innovations and their utilizations in the auditing profession continue growing in this decade. Advances in various technologies, such as data analytics, data mining, RFID, Internet of Things, blockchain, audit app, drones, etc., exert a deep influence on the life-style of human-beings. Researchers are devoting efforts in exploring the use of those technologies to enable investigations upon entire population (Vasarhelyi, Kogan, and Tuttle 2015), to seek new type of audit evidence from non-financial data (Yoon 2016), to effectively visualize audit-related data in order to facilitate auditors' judgment-making (Alawadhi 2015), and to detect anomalies and fraud on a continuous basis (Issa 2013; Kim and Kogan 2014; Kim and Vasarhelyi 2012; Thiprungsri and Vasarhelyi 2011). While some technologies have been studied in the auditing domain, a large portion of them remains under-explored, including industry 4.0, blockchain, and audit apps. To fill the gap in the literature, as well as provide insights into practice, this dissertation aims to explore the potential application of those emerging technologies for audit purposes, and further imagine the future audit paradigm in which these technologies will automatically collect audit evidence, monitor business processes, protect data from cyber attacks, and enable analytical audits.

The first essay of this dissertation foresees the potential impacts of the fourth industrial revolution, Industry 4.0, on the auditing profession. The current audit paradigm could be significant changed because of the new technologies promoted by Industry 4.0, which may impel the auditing profession towards a new generation that this dissertation terms "Audit 4.0". This essay illustrates the definition and essential elements of Audit 4.0, showing how Industry 4.0 technologies could be used in order to collect valid audit evidence in real time and continuously monitor business processes. It also discusses how auditors could be trained to accommodate the technology adoption and paradigm transformation. Challenges in the transformation towards the new generation of auditing are also identified.

Since 2009, blockchain has served as a major disruptive information technology expected to be as revolutionary as the Internet (Swan 2015a). Originally developed as a methodology to record crypto-currency transactions, blockchain's functionality has evolved into a large number of applications such as banking, financial markets, insurance, voting systems, leasing contracts, government service, etc. (Deloitte 2016; PwC 2016; Swan 2015a). However, its applications in accounting and assurance remain under-explored. To fill this gap in the literature, the second essay aims to provide an initial discussion on how blockchain could be leveraged to enable a real-time, reliable, and transparent accounting ecosystem. It also discusses how it could help the current auditing paradigm become a more precise, timely, and automatic assurance system.

Although analytical audit apps are becoming a more popular tool that can facilitate efficient and effective analytics-based investigation, auditors are still new to the technology and desire guidance when using apps in an engagement. The third essay first proposes a framework for both auditors and tool developers that provides guidance on creating and using apps. Existing audit apps that have been developed by a large audit analytics software company are then summarized and categorized in the framework. Next, a preliminary Audit Data Analytics (ADA) planning system is designed, which efficiently integrates audit apps into audit plans using an efficient manner. Since the planning system relies heavily on auditor judgment and ignores the impact of audit clients' attributes on the use of apps, an intelligent app recommender system is further proposed to mitigate those drawbacks and enable less experienced auditors to conduct analytical audits, as well as to improve the quality of ADA plans. Illustrations are also presented on the use of the ADA planning system and the app recommender system. Finally, an app-based audit paradigm is proposed to demonstrate the entire process of using apps to perform analytical audits.

1.2. Industry 4.0[1]

Industry 4.0 was introduced at the Hannover Fair in 2011 (Drath and Horch 2014). It incorporates many state-of-the-art technologies, such as Internet of Things (IoT), Internet of Service (IoS), Cyber-Physical Systems (CPS), and smart factories, into the manufacturing environment, which enables fundamental improvement to the industrial processes of manufacturing, engineering, material usage and supply chain and life cycle management (Kagermann, Helbig, Hellinger, and Wahlster 2013). IoT is a novel paradigm in which objects interact and cooperate with each other through unique addressing schemes (Atzori, Iera, and Morabito 2010). IoS is a paradigm that allows vendors to offer their services via the Internet, where they can be combined by various suppliers via various channels (Buxmann, Hess, and Ruggaber 2009). CPS integrates computation and physical processes. Embedded computers and networks monitor and control the physical processes, with feedback loops where physical processes affect computations and vice versa (Lee 2008). The smart factory is a new model that assists people and machines in executions of tasks using the state-of-the-art computing technologies and tools (Lucke, Constantinescu, and Westkämper 2008). The German federal government announced Industry 4.0, or the fourth industrial revolution, as one of the key initiatives to implement the German high-tech strategy 2020 (Anderl 2014; Hermann, Pentek, and Otto 2015).

The objective of industry 4.0 is to increase the flexibility of existing value chains via maximizing transparency of inbound and outbound logistics, manufacturing, marketing, and all other business functions such as accounting, legal, human resources, etc. Industry 4.0 emphasizes the use of emerging technology in

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[1] The basic concept and components of industry 4.0 were discussed in the Journal of Emerging Technologies in Accounting (Dai and Vasarhelyi 2016).

three domains: data collection, transmission, and analysis. It utilizes special equipment, such as sensors, actuators, RFID tags, embedded computers, to capture all data generated in manufacturing and business processes that reflect machine heath, product quality, surrounding environment, energy expense, labor cost, inventory location, etc. Such information is exchanged among objects (e.g., machines, devices, products, etc.) within and across a firm, and even with outside entities such as suppliers and customers, via an always-on network. Data analytics techniques are employed to build models upon those data for the purposes of monitoring product quality, identifying machine faults, saving costs, and facilitating decision-making. Industry 4.0 is gradually transforming and impacting European companies in the manufacturing and engineering, automotive, as well as the electronics and electrical industries. Surveys (Deloitte 2014; PwC 2014) indicate that Research and Development (R&D), procurement and purchasing, production, and warehousing and logistics have adopted industry 4.0, and this transformation is expected to increase the manufacturing and resource efficiency by 18% within five years.

1.3. Big Data and Audit Data Analytics

In recent years, “big data” has received increasing attention from accounting practice, because more data have been collected by organizations in the recent two years than in the previous 2000 years (Syed, Gillela, and Venugopal 2013). For example, Walmart is collecting more than 1 million customer transactions every hour, and Facebook is collecting more than 200 GB data per night (Cao, Chychyla, and Stewart 2015). In addition to data stored in traditional accounting systems, auditors are also able to collect vast amounts of evidence from other data types, such as non-financial data extracted from modern ERPs or online databases, RFID and networked sensors, social media, and even closed-circuit television (CCTV) videos in stores

(Moffitt and Vasarhelyi 2013). In addition, many countries have made government administrative information available to the public, which provides auditors even more data for monitoring and investigations (Dai and Li 2016; O'Leary 2015; Schneider, Dai, Janvrin, Ajayi, and Raschke 2015).

To extract and process data from a variety of sources to identify risks and collect evidence, and ultimately support decisions, auditors start to use an emerging technology known as Audit Data Analytics (ADA). ADA is defined as a science of "discovering and analyzing patterns, identifying anomalies, and extracting other useful information in data underlying or related to the subject matter of an audit through analysis, modeling, and visualization for the purpose of planning or performing the audit" (AICPA 2015, page 92). The predecessor of ADA is the analytical procedure, which has long been used as an external audit technique during planning, substantive tests, and final audit review (AICPA 2015). Since analytical procedures performed in the planning phase typically "use data aggregated at a high level" (AICPA 2012), "the results of those analytical procedures provide only a broad initial indication about whether a material misstatement may exist" (AICPA 2012 page 281). ADA techniques could be used on transaction level of data because such techniques generally maintain good performance even on large and high-dimensionality datasets. As a result, ADA can enhance risk assessment accuracy and further improve the planning quality. In addition, traditional analytical procedures usually rely heavily on sampling of audit-related data (AICPA 2015). However, as large-scale Enterprise Resource Planning (ERP) systems are rapidly growing in popularity among businesses, sufficient evidence could not be collected from only a sample of data. ADA increases the tested population from hundreds of records for an assessment to millions of transactions, which enlarges the audit coverage from a small percent of overall transactions to the entire population (AICPA 2015). Besides data recorded by a business' ERP system, auditors also have access to public data such as social media postings (Moon 2016), government open data (Dai and Li 2016, Kozlowski 2016), weather data (Yoon 2016), etc. Emerging data analytics technology has the capability to explore such vast amounts of data in various structures and formats, which cannot be handled by traditional analytical procedures.

Audit data analytics offer several advantages over traditional approaches. First, ADA is more cost-effective in terms of evidence collection. On average, it costs $0.01 to collect a parcel of evidence via ADA compared to $4 for the same evidence collected via standard audit procedures [2]. Second, many data analytics techniques are scalable and can generally maintain good performance when handling huge and high-dimensionality datasets (Alpaydin 2010). Last, some ADA techniques can identify data patterns in an unsupervised learning paradigm such that the training data sets for building detection models contain no class label information (Byrnes 2015; Thiprungsri and Vasarhelyi 2011).

Auditing researchers have devoted significant efforts to integrate ADA techniques into risk discovery, anomaly identification, internal control, and fraud detection. Byrnes (2015) explored the use of clustering methodologies in identifying risky customer groups for a bank's credit card department. After grouping customers with similar characteristics and purchasing/paying behaviors into clusters, the bank could manage each partition differently and take actions upon high-risk credit card holders. Similar approaches were also employed to identify abnormal life insurance claims by Thiprungsri and Vasarhelyi (2011). This study used a simple K-means

[2] http://raw.rutgers.edu/node/89.html

clustering model to group claims with similar characteristics together, and flagged small-sized clusters for further investigation. Internal control is an important and complex area that could obtain large benefits from ADA. For example, Jans, Alles, and Vasarhelyi (2014) illustrated the potential utilization of process mining as an audit approach to identify violations of control policy. By analyzing system logs, process-mining models could compare real business processes against companies' control policies to detect abnormal activities. Liu (2014) summarized Exploratory Data Analysis (EDA) techniques that could be employed in various audit stages for both internal and external audits. This research also conceptualized the process of implementing EDA in audit procedures.

Fraud detection is a domain in which ADA are well studied. By analyzing transaction-level data, ADA can capture unusual data flow and abnormal patterns. Nigrini and Miller (2009) examined the use of second-order tests of Benford's Law for checking the authenticity and reliability of transaction-level accounting data. This approach detected three types of data-level fraud, including rounded numbers, replaced data (with similar descriptive statistics) generated by statistical procedures, and inaccurately sorted data. Neural networks have long been considered as effective tools to detect complex financial frauds because they are usually proficient in pattern discovery and robust to noise (Fanning and Cogger 1998; Kirkos, Spathis, and Manolopoulos 2007). Several neural-network-based fraud classification models (Fanning and Cogger 1998; Green and Choi 1997; Lin, Hwang, and Becker 2003) were created to detect fraud using financial ratios and other predictors as inputs. Rule-based systems could facilitate fraud detection by incorporating expert knowledge into models. For example, Kim and Vasarhelyi (2012) detected fraudulent transactions in a wire transfer payment process by identifying potential fraud indicators, each of which was assigned an arbitrary score based on perceived severity. Payments with total scores exceeding a threshold would be considered suspicious and suggested for further investigation. Several studies (Kirkos et al. 2007; Viaene, Derrig, Baesens, and Dedene 2002) were also conducted to evaluate the performance of the state-of-the-art fraud detection models, such as logistic regression, decision tree, k-nearest neighbor, neural network, support vector machine, naive Bayes classification, Bayesian belief networks, etc. Those studies showed that logistic regression, support vector machine, naive Bayes classification, and Bayesian Belief Network generally have excellent predictive capabilities, while decision tree classification models was relatively disappointing in terms of prediction accuracy.

1.4. Blockchain and Smart Contract[3]

1.4.1. Background and Applications

Blockchain technology was conceived and initiated by Nakamoto (2008). He used a chain of blocks to create a decentralized, public-available, and cryptographically secure digital currency system. The system, named Bitcoin, enables peer-to-peer digital currency trading. This eliminates the need for financial intermediaries while maintaining transaction safety. The Bitcoin blockchain can be viewed as a new type of accounting database, which records the transactions of the digital currency into blocks. The blocks are arranged in linear, chronological order, and shared to a network (Fanning and Centers 2016; Peters and Panayi 2015; Swan 2015a; Yermack 2017). The main characteristics of Bitcoin blockchain include: 1) decentralization, 2) strong authentication, and 3) tamper-resistance. The operation and management of the Bitcoin system is designed to be decentralized. This means that all

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[3] The basic concepts of blockchain and smart contracts were discussed in the Journal of Information Systems (Dai and Vasarhelyi 2017).

nodes in the system have access to the entire list of transactions. Such access allows nodes to both verify and publish new transaction records onto blocks, which are then periodically added to the end of the main blockchain with a time stamp (Nakamoto 2008). The system is also able to verify the identity of every payer and payee involved based on a public-key cryptography system (Diffie 1988). It also examines whether the payer possesses enough money for the transaction to occur. Moreover, the process of creating a block on the chain is designed to require costly computational resources. This is to ensure the integrity and irreversibility of published transactions, and makes it almost impossible for a single or a small group of malicious parties to tamper with any blockchain records.

The blockchain architecture is designed to be a decentralized public database. Every party in the network has the right to read, verify, and update transactions to the chain. In many modern applications however, this is undesirable. In many cases, such as the use of blockchain within a business or a group of companies, read and write permissions should be restricted to certain entities. Such systems, known as private blockchains (Pilkington 2016), involve a limited number of participants. The advantage of a private blockchain is that information stored in the chain is only accessible to predetermined entities (e.g., companies only need to share certain accounting records among departments within the organizations or with their suppliers and customers). This design can protect the privacy and confidentiality of business data. Another type of blockchain is a permissioned blockchain (Peters and Panayi 2015). In a permissioned blockchain, trusted parties are preselected by a central authority and given the authorization to verify transactions. The benefit of a permissioned blockchain is that the role of transaction verification is withheld from irrelevant parties, simplifying the verification process and avoiding unwanted exposure. In addition, private or permissioned blockchains are generally more scalable (Peters and Panayi 2015). Since only a limited number of parties can verify transactions, the consensus on validated transactions can be reached much more quickly. One potential drawback is that these types of blockchains are based on a highly trusted entity model. Such a model requires that verifying entities do not collude to create false transactions. Since many entities within a business relationship have already established a certain level of trust, this concern can be minimized, and private or permissioned blockchain models may still be more appropriate.

Since 2009, blockchain has evolved through three phases: 1.0, 2.0, and 3.0 (Swan 2015a). Blockchain 1.0 purely focuses on the trading of crypto-currency. The functions of digital money transfer, remittance, and payment, comprise a new ecosystem: the "Internet of money" (Peters and Panayi 2015). Blockchain 2.0 involves similar trading but with a much broader scope of financial applications. Such applications include derivatives, digital asset ownership, smart property, etc. (Fanning and Centers 2016; Swan 2015a). The focus of the second generation of blockchain moves toward a new type of application called a "smart contract". Blockchain-based smart contracts are computer programs that autonomously verify, enforce, and execute terms in contracts (Kiviat 2015; Peters and Panayi 2015; Zhang, Cecchetti, Croman, Juels, and Shi 2016). Smart contracts allow for the encoding of tasks, rules, and situations that are agreed upon by the various participating parties. These contracts autonomously execute pre-specified tasks, or settle a contract, by examining changing conditions in conjunction with the contract's embedded rules. The concept of a "smart contract" was first proposed by Szabo (1994), which noted that the execution and monitoring of contracts mainly relies on a trusted central authority. The new blockchain-based smart contracts decentralize the enforcement power to each node in the blockchain network. This helps to dramatically reduce the counterparty risk (Kiviat 2015). Figure 2 illustrates an example where a blockchain-based smart contract is used to automatically monitor and operate a loan covenant. When a company and a bank agree upon a covenant, this conditional term is encoded into a smart contract that is then deployed into a blockchain. The blockchain network will continuously monitor the conditions and activities of the company against the requirements outlined in the smart contract. Once a violation of the covenant is detected, the blockchain network will automatically activate the portion of the smart contract pertaining to that violation. This could result in actions such as calling in the loan, increasing the interest rate, or the issuance of a warning, based on what was previously agreed upon by the parties.

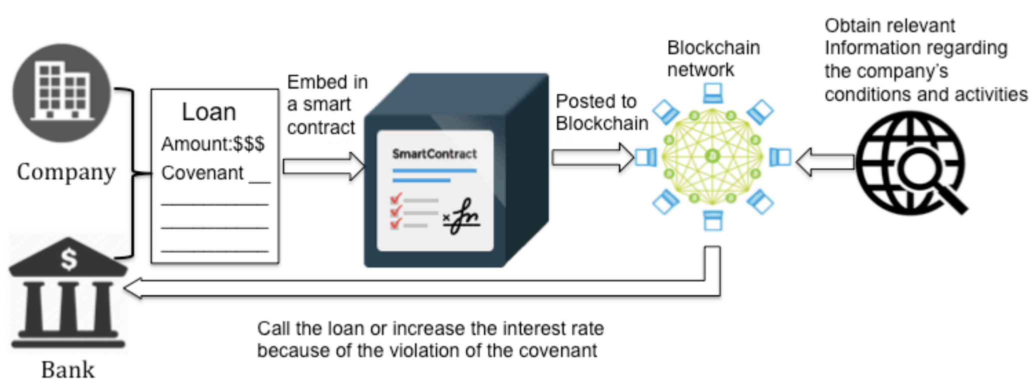

Figure 2: A demonstration of smart contracts

As the complexity and automation of smart contracts increase, their applications could be broadened. Future applications may range from peer-to-peer ridesharing to self-issuing bonds or crowd-funding with the promise of future dividends (Jacynycz, Calvo, Hassan, and Sánchez-Ruiz 2016; Yuan and Wang 2016). In the long-term, smart contracts could facilitate the development of Decentralized Autonomous Organizations/Corporations (DAO/DAC) that are able to self-organize and operate on blockchain. In DAO/DACs, management programs their governance rules and decision-making processes into smart contracts. This creates a structure with decentralized controls on a blockchain network (Jarvenpaa and Teigland 2017). The governance of a DAO/DAC can be achieved by distributing decision-making power to multiple participants within the blockchain network.

Blockchain 3.0 expands blockchain systems further, beyond financial and business applications. Cloud storage products, voting systems, attestation services, or even government administration could be dramatically transformed towards decentralized, self-managing and monitoring models (Swan 2016). Linking the IoT with blockchain technology is another novel application (Christidis and Devetsikiotis 2016; Zhang and Wen 2016). This allows for the control and trading of physical objects or services using smart contracts. For example, by using smart devices embedded in automobiles, drivers could negotiate with other cars to reserve a lane by paying a small compensation (Swan 2015a). In addition, peer-to-peer accommodation rental services can be created when both a service vendor and a customer agree on a smart contract. The vendor can then issue a digital key that is installed in the customer's smartphone to unlock the facility (Hancock and Vaizey 2016). Blockchain and associated smart contract technologies could advance society toward a more automated, flexile, and efficient lifestyle. Although blockchain systems have evolved from the infrastructure for peer-to-peer digital currency trading to much broader applications, they currently do not have accounting-specific modules, which leaves large room for researchers to imagine and propose ideas of incorporating the existing accounting information systems such as ERP and blockchain technologies.

1.4.2. Database, ERP and Blockchain

Comparing blockchain with existing approaches could help illustrate the advantages of this emerging technology. Databases are the best-explored and most widespread transaction recording and organizing applications. Distributed databases are more especially comparable with blockchain as both systems rely on multiple computers for operation and maintenance procedures. Peters and Panayi (2015) argued that blockchain helps to avoid the conflicts that occur when multiple modifications are made simultaneously by different computers within the distributed database system. They also mention other benefits of incorporating blockchain into such systems. These benefits include the ability to create self-enforcing contracts, as well as to ensure the security, confidentiality, and integrity of the data stored in its ledger.

ERP systems are among the most important innovations in corporate database usage (Davenport 1998). An ERP system is prepackaged business software that provides an integrated solution for the organization's information-processing needs (Nah, Lau, and Kuang 2001). ERPs are usually built upon core Relational Database Management Systems (RDBMS) to automatically process various business transactions (Kuhn and Sutton 2010). Besides process automation, ERP systems also distribute timely and accurate data, which provides the basis for real-time information analysis and management decision support (Hitt, Wu, and Zhou 2002). Using ERP systems, firms can integrate data from different business segments, reengineer business processes, improve financial controls, and increase information transparency and visibility (Grabski, Leech, and Schmidt 2011; Morris and Laksmana 2010; O'Leary 2004; Robey, Ross, and Boudreau 2002).

Blockchain is considered a new type of database that has the potential to either play the role of the accounting module in an ERP or be used in conjunction with the existing accounting information system. Unlike a regular ERP that is usually organized in a centralized architecture, blockchain distributes the power of transaction verification, storage, and organization to a group of computers. This mechanism can largely reduce the risk of a single point of failure (Peters and Panayi 2015), and make it more difficult for management to override the system. Blockchain is able to prevent any unauthorized data changes, which can help protect the integrity of data from cyber attacks. Generally, blockchain is an append-only, linear transactional database. It has a relatively simple data-organizing scheme as compared to an ERP, which is usually based on a relational database and allows many data operations (e.g., insertion, update, and deletion). Blockchain's structure can facilitate the tracing of tokenized objects (e.g., inventory items, accounting documents, etc.). Unlike an ERP system that requires intensive human effort, blockchain is designed to operate automatously with little human intervention (Peters and Panayi 2015; Swan 2015b). The ability to create smart contracts allows accountants to design and deploy various controls on blockchain systems. Also the decentralized nature of blockchain can help to prevent the manipulation of the control mechanism. Current blockchain systems do not have the accounting-specific modules present in ERP systems. The comparison between ERP and blockchain systems is summarized in Table 1.

Table 1: Differences between ERP and Blockchain

ERP	Blockchain
• Centralized • High tampering risk • Many data operations • Relational database • Human labor-intensive • Currently do not have self-enforcing contracts • Controls are specially designed and in place • Accounting-specific modules	• Decentralized and distributed • Low tampering risk • Append only • Linear transactional database • Non labor-intensive • Easier to create self-enforcing smart contracts • Controls could be set through smart contracts- smart controls • Currently no accounting-specific modules

1.5. Audit Apps

1.5.1. Definition and Classification

The term “app” refers to a software application running on computing devices, such as computers, tablets, and smart phones. Apps have long been used for general productivity and information retrieval purposes (Izhar and Malhotra 2014), but developers have hastened the trend toward specialization in areas like auditing. Audit apps are generally defined as “formalized audit procedures that can be performed by a computerized tool” (Vasarhelyi, Warren Jr., Teeter, and Titera 2014). They are typically a set of software packages that automate certain auditing procedures with limited need of human intervention (Dai and Li 2016), and can be reused to conduct targeted audit tasks on a frequent basis. Each app may perform a single audit task, or a combination of several related tests. Apps could also be customized to accomplish firm-specific audit tasks (Dai and Li 2016).

Many software providers have made efforts in creating audit apps in the recent years. CaseWare International Inc., a large company providing software solutions for auditing and accounting professions, started to develop audit apps in the recent years. It built a marketplace[4] selling audit apps that can only operate on its own platform. About 23 audit apps are on the marketplace as of this writing, covering various accounting accounts and ledgers such as general ledgers, account receivable, accounts payable, inventory, fixed assets, and payroll. ACL Services Ltd., another large audit software company, created 15 pre-built analytical apps that automate the standard financial controls over four business cycles, including purchase-to-pay, order-to-cash, general journal and fixed assets, and human resources management[5]. Ernst & Young created around 20 insight apps[6], several of which are audit-oriented. For example, the "Forensics App"[7] presents the latest fraud, bribery and corruption trends. KPMG launched the "U.S. Audit App"[8] on Apple store that delivers the latest information regarding revenue recognition, regulatory compliance, and the Financial Accounting Standards Board (FASB) to auditors. Qlik is a software provider specializing in business intelligence and visualization. It launched a new product called "Qlik Sense Enterprise"[9] that allows users to develop their own audit apps. Auditors can create a

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[4] https://us.marketplace.audicon.net

[5] https://www.acl.com/products/acl-essentials/?utm_source=ACL.com&utm_medium=News_Release&utm_campaign=2016-08-acl-launches-new-suite-of-pre-built-analysis-apps-to-monitor-erp-process-risk&utm_content=news-release&mrkto_source=

[6] http://www.ey.com/gl/en/home/ey-insights

[7] https://itunes.apple.com/us/app/ey-forensics/id1123943152?ls=1&mt=8

[8] http://www.kpmg-institutes.com/institutes/aci/articles/pubs/introducing-the-kpmg-u-s--audit-app-for-ipad.html

[9] https://community.qlik.com/docs/DOC-9106

customized dashboard with their preferred tables, graphs, and charts, to visualize audit-related data in order to discover abnormal patterns and capture potential errors or frauds in time. Since this app is not particularly designed for audit purpose, it has no built-in audit-specific functions. However, after creating customized apps, auditors can reuse the functions and metrics to perform audit analytics on a frequent basis. Many other companies have also developed "app like" products, which have similar purposes as audit apps but with different names. AuditNet, an organization that provides global resource for internal auditors and CPAs, also launched library of collected sections of data analytics scripts[10]. Those scripts function the same as audit apps since they also perform a set of data analysis procedures for audit purposes, but without friendly user interfaces. Forestpin Corporation is a company that develops enterprise data analytics applications. Its product, "Forestpin Enterprise"[11], automatically runs pre-programed analytics tests and shows results of all analyses on a dashboard using "tiles". Each tile can be viewed as an audit app that performs a specific analytical audit test and produce results with little user interaction. TeamMate Analytics[12] is software that has a collection of 10 "app like" modules to support analytical audit functions. As it runs on top of Excel, users without sophisticated IT skills are still be able to use those analytics tools. Table 2 summarizes the vendors and their app-related products.

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[10] http://www.auditnet.org/tools/script-library-for-data-analytics

[11] https://www.forestpin.com

[12] https://www.teammatesolutions.com/data-analytics.aspx

Table 2: Summary of app vendors and their products

Company	App Product
CaseWare International Inc.	Twenty-three audit apps that cover various accounting accounts and ledgers such as general ledgers, account receivable, accounts payable, inventory, fixed assets, and payroll
ACL Services Ltd.	Fifteen pre-built analytical apps that automate the standard financial controls over purchase-to-pay, order-to-cash, general journal and fixed assets, and human resources management
Ernst & Young	Twenty insight apps, with several audit-oriented apps
KPMG	U.S. Audit App that deliver information regarding revenue recognition, regulatory compliance, and the FASB
Qlik	Qlik Sense that allow creating customized visualization app
AuditNet	A library of data analytics scripts
Forestpin Corporation	Forestpin Enterprise software that runs pre-determined data analytics tests and shows the results on the tiles of a dashboard
TeamMate Analytics	Ten “app like” modules to perform analytics

Audit apps can be divided into three categories basic on their functions:

Analytical audit apps are computerized analytical routines (Dai and Li 2016). The functions of analytical audit apps can range from simple query to identify abnormal accounting records, such as transactions posted on weekends, to advanced data analysis such as process mining to analyze companies' business activities[13]. Examples of analytical audit apps are the Caseware and ACL apps.

Presentation audit apps: they are mainly used to visualize audit-related data. In general, presentation audit apps only need simple user interaction, such as "drag and drop" activities. The Qliksense app falls into this category.

News audit apps collect audit-related information and deliver the latest news, trends, and changes in regulations, audit approaches, etc., to auditors. Examples of information audit apps include the KPMG U.S. Audit App and the EY Forensics App.

Initially, the majority of audit apps are being developed by software vendors, but as audit apps become widely adopted and their development tools become more popular, some of the best ideas for new applications may be wiki-like and non-proprietary (Zhang, Pawlicki, McQuilken, and Titera 2012). This trend will increase the volume of available apps, while diminishing auditors' ability to manually seek the right audit apps.

The biggest challenge of using apps to perform audit does not lie in the tool itself, but the understanding of the underlying knowledge. Apps, especially analytical apps, may perform functions that involve data mining, machine learning, advanced data analytics models. As auditors generally have limited knowledge and training on those models, they may not be able to effectively use the apps. To solve this problem, Byrnes (2015) suggested a "super app", with which "many of the historically manual decision points within the process can be eliminated, thus making it a more user friendly task".

[13] https://us.marketplace.audicon.net/us_en/apps/process-mining-p2p.html

1.5.2. Apps vs. Traditional Audit Software

Compared with traditional audit software, the most important benefits of audit apps are their ease of use. Audit apps simplify and automate audit procedures, and thereby enable auditors to efficiently perform audit tests. They usually require little user interaction, i.e., after having data loaded into audit apps, they will automatically analyze the data based on pre-programmed algorithms (Dai and Li 2016). In contrast, large audit software usually requires users to conduct complicated operations in order to obtain the results. Thus, auditors should be specially trained before using the software. Compared to traditional software with standardized packages, audit apps are more customizable (Dai and Li 2016). Auditors can create customized audit apps that accomplish special audit tasks using professional SDKs provided by vendors (Dai and Li 2016). Unlike traditional audit software that can only be used on computers, apps can operate on various computing devices, including computers, tablets, and smart phones, which increase the flexibility of auditors' working environment. Small computing tools, such as tables and smart phones, are more convenient to use when performing audit examination away from the office, such as field inventory audit. The comparison between audit apps with traditional audit software is summarized in Table 3.

Table 3: The comparison of audit app and traditional audit software

Audit App	Traditional Audit Software
• Easy to use • Can be customized to meet special demands of auditors • Can operate on various computing devices, such as computers, tables, and smart phones	• Require technical training to use the software • Usually standard packages • Usually operate on computers

1.6. Audit Data Standards

Although audit apps are rapidly growing in number and variety, it is still challenging to use them efficiently. One of the challenges is "obtaining accurate data in a usable format following a repeatable process"[14]. Every company may define its own data formats, names, and structures. As a result, in each new engagement auditors have to spend much time understanding their client's data model, and transforming the data into the formats that can be recognized by audit apps (Dai and Li 2016). Such data preparation processes complicate the use of apps. To alleviate the data preparation effort, audit app providers may develop several audit apps that perform the same audit test but using different data formats to accommodate each company's data model, or create "bridge apps" mapping different data models to the one audit apps can recognize. However, either duplicated audit apps or "bridge apps" are not only a waste of resources, but will bring extra costs to auditors when performing audit for different companies. Therefore, a standardized set of universally

[14] https://www.aicpa.org/interestareas/frc/assuranceadvisoryservices/pages/assuranceandadvisory.aspx

extractable data would not only reduce audit app duplication (Zhang et al. 2012), but also simplify the process of using apps.

To reduce effort and cost, industry associations have undertaken initiatives to promote data standardization. In 2013, the AICPA's Assurance Services Executive Committee (ASEC) Emerging Assurance Technologies Task Force issued three Audit Data Standards (ADS): a Base Standard, a General Ledger Standard, and an Accounts Receivable Subledger Standard, which describe the set of essential data that would be extracted from an audit client's accounting information system in "a standardized format of either flat files or XBRL-GL" (Alles, Vasarhelyi, and Issa 2013). These standards provide uniform data models that stipulate the key data fields, field names, and data formats in those ledgers. In 2015 and 2017, the AICPA updated the Base Standard and the General Ledger Standard, and released three new standards: the Procure to Pay Subledger Standard, the Order to Cash Subledger Standard, and the Inventory Subledger Standard[15]. Those ADSs provide a foundation for data transmission and efficient analysis. If both companies and audit app developers follow ADSs to build their data models, the transmission of data from companies' ERP systems to audit apps will become seamless (Dai and Li 2016). This trend will simplify data preparation process, and thereby propel the growth of audit apps. To achieve such efficient app using paradigm, efforts need to be made to all vendors to adopt the ADS, or any common standards.

1.7. Recommender Systems

The studies of recommender systems have risen since the nineties along with the ecommerce market (Hill, Stead, Rosenstein, and Furnas 1995; Resnick, Iacovou,

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[15]https://www.aicpa.org/interestareas/frc/assuranceadvisoryservices/pages/auditdatastandardworkinggroup.aspx

Suchak, Bergstrom, and Riedl 1994; Shardanand and Maes 1995). As the number and variety of online products gradually increased, companies started to seek a tool to accurately present customers with those products they are most likely to purchase, rather than letting irrelevant goods overwhelm the potential consumers. Recommender systems can fulfill this task. This technology aims to predict the preference a user would give to a certain item based on the features of the product or the user's social environment (Ricci and Shapira 2011). Recommender systems collect customers' preferences in the past, demographic information of users, or the attributes of items, and make suggestions based on those data. Such information can be obtained explicitly (by collecting user ratings, comments, etc.) or implicitly (by monitoring user behavior, such as web sites visited and goods purchased) (Choi, Yoo, Kim, and Suh 2012; Lee, Cho, and Kim 2010). A well-developed recommender system should be able to balance factors like accuracy and stability in the recommendations (Bobadilla, Ortega, Hernando, and Gutiérrez 2013).

Based on the type of underlying filtering algorithms, recommender systems generally can be divided into four categories: 1) demographic, 2) content-based, 3) collaborative, and 4) hybrid (Adomavicius and Tuzhilin 2005; Bobadilla et al. 2013). Demographic filtering recommender systems (Krulwich 1997; Pazzani 1999) predict customers' preferences from the opinions of people who have similar demographic characteristics. The assumption of this algorithm is that, in general, individuals with certain common personal attributes (gender, age, educational level, region, etc.) will also have similar tastes. This early-stage approach, while it is relatively simple, relies on this one strong assumption and ignores much other useful information.

Content-based Filtering (CBF) recommender systems choose products for customers that are similar to those they preferred in the past (Lang 1995; Mooney and

Roy 2000). They usually generate recommendations using the contents of the items, such as category, production date, or even more complex information like textual descriptions. By analyzing those data, the systems could identify the similarity of the goods to those that a user has viewed, bought, or positively ranked in the past, and recommend such items to the customers. One major limitation of using this algorithm is the difficulty of analyzing multimedia data, e.g., graphical images, audio and video streams (Adomavicius and Tuzhilin 2005). In addition, this type of recommender system can hardly differentiate items by quality, since it does not capture users' opinions of the items.

Unlike CBF systems, Collaborative Filtering (CF) recommender systems analyze customer ratings and suggest the items that are preferred by people with similar tastes. GroupLens (Resnick et al. 1994) and Ringo (Shardanand and Maes 1995) are early recommendation systems that use the CF algorithm. GroupLens uses customer ratings to estimate their preferences, and clusters users with similar preferences into groups. Ringo provides music recommendations using a "word of mouth" recommendation mechanism. It determines user similarity based on their rating profiles. Nakamura and Abe (1998) created a variety of weighted majority prediction algorithms to predict user preferences on information contents. Kim and Yum (2005) proposed an iterative principal component analysis approach to avoid maintaining the entire dataset and analyzing repeatedly. Sarwar, Karypis, Konstan, and Riedl (2001) conducted experiments to evaluate the performances of different CF algorithms. Traditional CF algorithms are usually associated with several well-known problems, i.e., data sparseness, cold-start, and non-transitive association (Leung, Chan, and Chung 2007). Data sparseness means that the set of products with ratings is usually relatively small compared to the huge volume of online merchandises. As a result, the recommendations could be incomplete. The cold-start problem arises when new products just enter the market, which have no or very few ratings, such that no recommendations can be generated from them. The non-transitive association problem occurs when the correlation between two similar items (e.g., two accounting books from different publishers) is hard to calculate because the products are not likely to have been rated by the same user.

Several recommendation systems use hybrid approaches, which combine collaborative and content-based methods, to avoid the drawbacks of each method and increase overall performance (Balabanović and Shoham 1997; Burke 1999). The hybrid recommender systems can be classified as: (1) first using CBF and CF methods independently to predict customers' preferences and then combining their results, (2) incorporating some CBF characteristics into a CF system, (3) incorporating some CF characteristics into a CBF system, and (4) creating a system with both CBF and CF characteristics (Adomavicius and Tuzhilin 2005).

1.8. Research Questions

Industry 4.0, blockchain, and apps are expected to change the current business model. The audit profession would have to adjust the existing paradigm in order to adapt to the rapidly changing environment. Moreover, new audit approaches relying on the advanced technologies could be created to improve assurance quality.

This dissertation intends to introduce these emerging technologies to the accounting and auditing literature. Specifically, this dissertation focuses on addressing the following research questions:

- How could these emerging technologies improve assurance quality and speed?
- How could these technologies promote the transformation of the current audit

model towards next generation?

- What are the impediments to technology adoption and use in accounting and auditing practices?

Chapter 2. Imagineering Audit 4.0[1]

2.1. Introduction

This chapter aims to imagineer the effects and usage of the technologies that encompass Industry 4.0 upon the audit process, prior to their widespread implementation in business. The adoption of technology in the audit profession has substantially lagged behind the development and utilization by management (Kim, Mannino, and Nieschwietz 2009; Curtis and Payne 2010; Bierstaker, Janvrin, and Lowe 2014; Cangemi 2015; Cangemi 2016; Li, Dai, Gershberg, and Vasarhelyi 2016). The consideration of technology by standard-setting bodies lags even further, hampered by an extant codification based on the facts and economics of obsolete measurement methods, practices, and technologies.

Acceleration of changes may occur when management needs/technological changes force accounting methods to adapt and these, by their turn, pressure changes in assurance (Krahel and Titera 2015). For example, the adoption of large databases and cloud technology prompted the development of software and application layers for performance measurement, naturally leading to a demand for assurance.

Originating in Europe and spreading to the US, Industry 4.0 emphasizes six major principles in its design and implementation: Interoperability, Virtualization, Decentralization, Real-time capability, Service orientation, and Modularity (Hermann, et al. 2015). Furthermore, it promotes the use of remote devices to identify: Location, Identification, Temperature, Pressure, Movement, Company (who was with whom),

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[1] This chapter is based on the paper that is published in Journal of Emerging Technologies in Accounting (Dai and Vasarhelyi 2016).

Speed, Intentions, Face recognition, Defect detection, etc.

As industry moves toward the next generation, auditing should also adapt to the new environment. Auditors can leverage new technologies to collect a large range of real-time, audit-related data, automate repetitive processes involving few or simple judgments, and eventually achieve comprehensive, timely, and accurate assurance. For example, since RFID tags are embedded into products for tracking their product codes, the collected geographic information could also be used to examine inventory quantities (Krahel and Titera 2015). Business processes can likewise be monitored for internal control defects through event log analysis (Jans, Alles, and Vasarhelyi 2014). With the increase of the digitalization of business processes across the entire enterprise, auditors can continuously monitor business operations and identify abnormal behaviors in real time.

This chapter foresees the impact of the fourth industrial revolution on the auditing profession, imagineers the use of new schemata promoted by Industry 4.0 for audit purposes, and identifies challenges in the transformation towards the new generation of auditing: “Audit 4.0”. The remainder of this chapter proceeds as follows: Section 2.2 provides a discussion on Audit 4.0 from the perspectives of definition, auditing history, and essential elements. Section 2.3 imagines how auditing schema could be changed toward the new generation. Section 2.4 identifies new challenges faced by Audit 4.0. Discussion of the evolution of auditing profession is provided in section 2.5. The last section concludes this chapter.

2.2. Audit 4.0

2.2.1. Definition of Audit 4.0

Audit 4.0 will piggyback on technology promoted by Industry 4.0, especially the Internet of Things (IoT), Internet of Service (IoS), Cyber-Physical Systems (CPS), and smart factories, to collect financial and operational information, as well as other audit-related data from an organization and its associated parties. It analyzes, models, and visualizes data in order to discover patterns, identify anomalies, and extract other useful information for the purpose of providing effective, efficient, and real-time assurance. It is typically an overlay of Industry 4.0 business management processes and uses a similar infrastructure, but for assurance purposes.

2.2.2. Evolution of Auditing: From 1.0 to 4.0

Traditional manual audits (Audit 1.0) have existed for centuries fulfilling many needs. Although the IT audit (Audit 2.0) emerged in the 1970s, and most all businesses are currently computer-based, only about 15% of auditors are IT-enabled (Protiviti 2015). This delay of IT adoption can be partially attributed to conservatism and rigidity of the profession as well as the calcifying effect of increasingly obsolete regulation (Liu and Vasarhelyi 2014), but also to the lack of quality tools that would allow traditional auditors (i.e. those without IT and analytics training) to automate the functions that they currently perform manually (Brown-Liburd, Issa, and Lombardi 2015). The key characteristics of these audit generations are presented in Table 4.

Table 4: The generations of the audit

Audit 1.0	Audit 2.0	Audit 3.0	Audit 4.0
• Manual audit • Tools: pencils, calculators	• IT audit • Tools: Excel, CAATT software	• Inclusion of big data in audit analytics • Tools: analytical apps	• Semi- and progressive automation of audit • Tools: sensors, CPS, IoT/S, RFID, GPS

It is questionable that Audit 3.0 will emerge much faster than the previous generations as it may be impossible to assure modern big-data systems with the tools of the past. Anachronistic regulation, where for example a population of millions of transactions is examined with an extract of 70 transactions, may contribute to delays that reduce the relevance of external assurance.

2.2.3. Elements of Audit 4.0

Audit 4.0 will significantly change the auditing profession by automating current procedures, enlarging their scope, shortening timing, and eventually improve the overall assurance quality. This section illustrates the impacts of Audit 4.0 on auditing profession from four perspectives: standards, principles, technology, and auditors.

2.2.3.1. Standards

Krahel (2012) discussed the formalization of auditing standards arguing that most standards should be embedded into software as their implementation, in modern systems, tends to be done by computers. Consequently, the ambiguity in current auditing standards should be replaced by formal representation to allow for near-real-time assurance. Assurance, in the world of Industry 4.0, will be largely dominated by formal inter-object protocols, the technical capabilities of “things”, and the objective functions of the interlinked objects.

Standards could be programmed into machines, production lines, and products to enable real-time measurement, processing, and communication of financial information. For example, inventory measurement would be automated by tracking the current values of purchases (Krahel and Titera 2015). Manufactured inventory can also be constantly measured by collecting real-time data regarding energy consumptions of production lines and labor costs. Many items that were overhead allocation will be measured directly. In addition, products will autonomously issue alerts if they are obsolete, slow moving, or damaged, to prevent including or overstating the value of obsolete inventory. Such automation could reduce auditor effort vis a vis physical observation and manual inventory pricing, additionally providing precise performance and risk information in real time.

2.2.3.2. Principles

Industry 4.0 consists of six main technological principles: Interoperability, Virtualization, Decentralization, Real-time capability, Service orientation, and Modularity. Similar to Industry 4.0, Audit 4.0 relies on those six principles to increase data availability, enable continuous data monitoring and validation, and improve the automation of audit procedures.

Interoperability: Interoperability is both an important enabler of Industry 4.0 and a key design concept of future lifestyle. An intuitive example is the interoperation among traffic lights and vehicles (Drath and Horch 2014). Traffic lights in the future would connect to a network and provide information regarding their colors and time schedules. Cars would then receive this information from the network and adjust speed accordingly to reduce gas consumption and minimize emissions. The cars could also send their geo-location information and speeds to the network to adjust the schedules of traffic lights for an optimal traffic flow. In Industry 4.0, field devices, machines, plants, factories, and even products will be all connected and communicate through a global network (Drath and Horch 2014), which enable interoperation within enterprises and across entire value chains. Through communication and interoperation, new business models could become more intelligent and informative, achieving a higher level of optimization.

As interoperability continues to change the current business model, it could further impact the audit profession. In Audit 4.0, interoperation among suppliers, customers, banks, and other business entities could enable near-real-time examination of transaction-level occurrence and completeness assertions. A secure network is established to facilitate communications across different business entities. If a transaction involves two business entities, the two ERP systems will share the related accounting information. The entities will receive the information, match with the corresponding data in their systems, and issue warnings if they cannot be matched. Such interoperation could automate the examination of transactions, and highlight suspicious transactions for auditors and management. Within a company, transactions from different business processes could be utilized jointly to verify the continuity of the processes (Kogan, Alles, Vasarhelyi, and Wu 2014). By creating continuity equations over metrics generated from related business processes, auditors will be able to discover anomalies that significantly different from the predicted value of the metrics.

Virtualization: In Industry 4.0, as objects are connected to networks, their information about location, conditions, surrounding environment, etc., can be shared and integrated, and become searchable, explorable, and analyzable (Drath and Horch 2014). Using such information, a virtual copy of the physical world could be created that represents all objects in business with their relations and activities. In this world, each physical "thing" has a digital representation with a unique identifier (e.g., the Legal Entity Identifier [LEI][2] of a corporate entity), and its information would be continuously updated and transmitted to related parties. Virtualization enables transparency throughout the value chain, with all business processes and their performance presented in detail (Schuh, Potente, Wesch-Potente, Weber, and Prote 2014). Management can detect problems and bottlenecks in real-time through virtual process monitoring. R&D departments will also benefit from discovering and eliminating shortcomings of new products through virtual reproduction and simulation (Schuh et al. 2014).

Technologies have been developed to create a virtual copy of the physical world. Smart, Cascio, and Paffendorf (2007) described a scenario of virtual life called "mirror worlds", similar to virtualization in Industry 4.0. The mirror worlds are defined as "informationally-enhanced virtual models or reflections of the physical world" (Smart et al. 2007). Google Earth is a well-known example of the mirror worlds, within which contextual information on objects are captured, stored, and managed (Smart et al. 2007). The mirror worlds map each individual physical object to its virtual representation, can record its conditions over time using sensors, and create models to simulate object behavior[3]. Based on the concept of mirror worlds, either individual business processes or the entire value chain can be digitally

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[2]https://www.treasury.gov/initiatives/wsr/ofr/Documents/LEI_FAQs_August2012_FINAL.pdf

[3] For example predictive auditing (Kuenkaikaew 2013) would use predictions of the value of objects and relationship and compare with actual measured in the real and mirror worlds.

represented to facilitate control and analysis.

Information recorded in mirror worlds could dramatically reduce auditors' fieldwork and serve as an independent party to facilitate accounting information evaluation. As all relevant "things" in a business process will be virtualized and have representations in mirror worlds, auditors could perform most of the onsite examination remotely and continuously. For example, mirror worlds can record the time when a physical inventory item arrives and leaves the company, as well as its locations and conditions over time. Auditors can use this information as a substitute for physical inventory examination, and can likewise examine the occurrence and completeness of transactions by comparing the transactions in the mirror worlds with those in the company's ERP system. Mirror worlds can also be used to link non-financial processes (e.g. personnel, production, web-clicks) to the accounting records providing sequential integrity assurance.

Decentralization: Corporate IT is increasingly dependent on cloud systems with virtual machines. In the near future, these systems will extend to a larger and larger network of progressively more intelligent "things" where the current capabilities of RFID chips will be replaced by self-contained computers performing a large number of enhanced functions.

The increasing demand for customized products complicates today's manufacturing systems, and thus, it is difficult to centrally control machines (Hermann et al. 2015). For example, there are over 15 billion possible configurations of the Ford Fusion in the German market (Schleich, Schaffer, and Scavarda 2007). Such massive customization demands require the operation of production and assembly lines to be decentralized so that each machine or production line can make individual decisions and adjustments (Schuh et al. 2014). As the business environment becomes more complex and dynamic, the trend of decentralization will extend to the auditing profession. Internal control mechanisms could be embedded in each individual machine or device in order to continuously monitor accounting data and detect abnormal transactions that exceed expected thresholds. Such systems will be able to adjust thresholds on their own based on the changing environment and inputs from auditors, and submit failures and complex decisions to auditors for further investigations. These systems would be substantive enhancements to the continuous audit process envisaged by Vasarhelyi and Halper (1991).

Real-Time Capability: Factories in the Industry 4.0 will continuously monitor the conditions of physical objects and manufacturing activities, in order to discover system faults, adjust production, and make decisions in real time. For example, if a machine failure is detected, the factory will immediately react to the fault and reroute production to other machines (Shrouf, Ordieres, and Miragliotta 2014). In the long-term horizon, factories will have the capability to adapt to changing market demands, technology options, and regulations in real time (Schlick, Stephan, Loskyll, and Lappe 2014).

Vasarhelyi and Halper (1991) argued for an "audit by exception" where metrics would measure systems, standards would serve as benchmarks, and analytics would encompass the rules guiding issuing alarms to trigger actual audits. Audit 4.0 would expand these concepts to have diagnostics activated, self-correcting data algorithms (Kogan et al. 2014) fix errors, and self-aware devices alerting to the need for human intervention. Researchers and practice have made several attempts to achieve this goal. For example, Siemens Corporation developed and adopted an efficient model to enable real-time controls monitoring (Alles et al. 2006). This model analyzed transactional data and provides real-time identification of high-risk transactions that exceed expected limits and parameters. Another example is that Kim and Vasarhelyi (2012) built a model to continuously detect fraudulent transactions in the wire transfer payment process. By examining each transaction with pre-defined fraud indicators and estimating overall fraud risk, the model can identify potential fraud immediately and alert auditors for further investigation.

Service Orientation: The service-oriented feature of Industry 4.0 is described as "the services of companies, CPSs, and humans are available over the IoS and can be utilized by other participants" (Hermann et al. 2015). This service-oriented architecture is evolving as an important business model in the era of Industry 4.0. Any resource, such as production lines, assembly lines, storage, computation, labor, expert knowledge, etc., can be offered via network, and companies could pay per service. This business model can dramatically reduce manufacturing costs and bring extra profits by increasing cooperation between related parties, especially in those industries that have an increasing demand for customized products.

Audit 4.0 can adopt the service-oriented architecture to facilitate cooperation between auditors and other related-service providers. For example, data analytics is a useful and powerful technology that has been acknowledged by the audit profession, but its use is below expectation (Li et al. 2015). An important reason is that the inherent complexity of data analytics techniques may be beyond auditors' knowledge (Schneider et al. 2015). To circumvent this barrier, auditors can outsource the workload to professional data analytics companies or analytics software providers. Using the services from experts, auditors could be free from analysis work and focus on essential decisions. In a similar vein, audit software service could become cloud-enabled. Instead of selling audit software to individual audit firms or companies, the providers offer their software on a secure cloud and charge based on usage. This service-oriented model reduces both the upfront cost of audit software and later maintenance expenses.

Modularity: Modular systems gain prominence in Industry 4.0 as they can easily adapt to changing environments or requirements (Hermann et al. 2015). For example, production assembly lines can be broken into modules and each assembly station can individually compose the required processes based on customer-specific configuration. This model is flexible enough to produce new configurations and adjust to seasonal fluctuations (Hermann et al. 2015).

Vasarhelyi et al. (2014) imagined how modularity could facilitate auditors to perform analytics flexibly and efficiently. They proposed the use of audit apps as modules, assembling them together to perform complete analytics procedures. Auditors can choose and deploy appropriate audit apps based on the individual audit plan, and audit by exceptions. A new set of apps is chosen and used for each different audit client sensitive to specific risks, client capabilities, business environment, and auditor competencies.

2.2.3.3. Technology

Sensors, CPS, IoT, IoS, and smart factories are the core technologies that enable the intelligence, flexibility, interconnectivity, and corporation of Industry 4.0 and Audit 4.0. Other technology, such as RFID, GPS, and data analytics can support the next generation of auditing.

Sensors: The advance in micro-electro-mechanical systems technology and digital electronics at the beginning of 21st century enabled low-cost, low-power, multifunctional sensors (Akyildiz, Su, Subramaniam, and Cayirci 2002). These sensors, with the functions of data acquisition, processing, and communication, would be widely used in Industry 4.0 and could completely replace humans' role in data collection. Sensors could include pacemakers, location identifiers (e.g., GPS), individual identification devices (e.g., RFID tags), etc. (O'Leary 2013). Applications using sensor data and spatial information serve as examples that form the basis for smart homes, smart factories and smart cities (Paelke 2014). A recent project launched by the Boston's Mayor's Office[4] demonstrated how sensors collect real-time data to facilitate city improvements. The "Street Bump" project aims to monitor Boston's streets by collecting road condition data through sensors in volunteers' mobile phones while they drive. A mobile app can capture bumps on the road via built-in balance sensors of the phone, along with their locations and geo-tagged pictures of the environment. Such data provides governments with real-time street condition information, helping to fix bumps and plan long-term investments.

The acquisition of accounting data is increasingly automated (Alles et al. 2013). Sensors can hasten data acquisition to a real-time level with a much broader scope of data. An efficient way to capture accounting data is to use the sensors that are already built into manufacturing systems, logistics systems, or products. For example, smart refrigerators in the future can be embedded with sensors, cameras, and computers for the purpose of tracking food, expiration dates, and conditions. Similar devices could be used to capture accounting data throughout the business process with small extra cost. Vasarhelyi (2015) defined such utilization of devices and infrastructures built in business or manufacturing processes for auditing purpose as

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[4] http://www.cityofboston.gov/DoIT/apps/streetbump.asp

"piggybacking[5]". Using this strategy, auditors could obtain real-time accounting information that reflects current performance, such as quantity and quality of inventory, working hours of employees, energy consumption, etc., and discover system faults in time.

Cyber Physical System: Another equipment that would play an essential role in Audit 4.0 is Cyber Physical System (CPS), a new technology that embeds computers, sensors and actuators into an integrated platform. CPSs merge the physical world and its digital copy by tracking and documenting physical processes of production, analyzing data, and building an integrated virtual model that also links with other CPSs to enable real-time monitoring and decision-making. An example of CPS is smart preventive maintenance (Lasi, Fettke, Kemper, Feld, and Hoffmann 2014) in which a machine's sensors capture process parameters, such as stress, temperature, operating hours, etc., and the embedded computer records wear and tear. By combining the information of the physical object and its digital process parameters, the real condition of the machine could be measured.

In the context of Audit 4.0, CPSs could be employed to monitor and analyze accounting data flow, recognizing behavior patterns of different business sectors, discover irregularities or anomalies, and taking in-time actions. Since future machines, devices, and products will possess CPSs, they can trigger the company's ERP system to record accounting transactions and business events without human intervention. In addition, since CPSs independently store the history of business activities, or the movement and condition of physical objects, such data could serve as

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[5] Progressively hardware and software are built cumulatively and undergo multiple uses. For example chips and other hardware elements are the basis for computers and their operating systems. These are the bases for accounting systems, etc. This cumulative usage of overlapping technologies is called piggybacking.

a validation of companies' financial information. By automating the comparison between information stored in CPSs and the corresponding accounting data in the company's ERP system, auditors and management could obtain real-time alerts if a transaction record violates accounting standards.

Internet of Things (IoT): IoT is an essential element that enables factories moving forward to the new industry generation. IoT is a paradigm where physical objects are equipped with RFID tags, sensors, or CPSs and linked through a network that offers connectivity among devices, systems, and human (Chui, Loffler, and Roberts 2010; O'leary 2013; Pisching, Junqueira, Santos Filho, and Miyagi 2015; Shrouf et al. 2014). The main purpose of IoT infrastructure is to integrate everything in the business world into the network where those "things" can communicate their status, surrounding environment, production processes, and maintenance schedules. (Pisching et al. 2015; Shrouf et al. 2014). This infrastructure collects and shares information through the value chain, and further facilitates real-time decision-making and business automation.

Auditors can utilize the IoT infrastructure to enable real-time, comprehensive assurance. Recent studies promoted the use of a much broader scope of data (i.e., "big data") than the traditionally defined accounting data when monitoring and auditing transaction information (Brown-Liburd and Vasarhelyi 2015; Moffitt and Vasarhelyi 2013; Vasarhelyi et al. 2015). For example, blogs, message boards, and social media could be integrated in the analysis of financial information (O'Leary 2012; O'Leary 2013). Photo, video, and GPS location could also be used as evidence to verify transactions (Moffitt and Vasarhelyi 2013). Auditors can rely on IoT technology to capture the high volume, different structures of information from a large variety of resources in real time. In addition, IoT can facilitate real-time supervision of expense and performance of business processes. For example, with the help of IoT, companies can remotely monitor energy consumption from individual machines and production lines (Shrouf et al. 2014). Internal auditors could detect wasteful energy usage by comparing production plans and real-time energy consumption.

Internet of Services (IoS): With the increasing digitalization of services, people are able to obtain computational resources, electronic storage, or even expert knowledge through Internet. The main idea of IoS is to provide companies a platform that they can offer such services remotely to various customers. A good example of IoS is the project THESEUS (Buxmann et al. 2009). THESEUS deals with technology that facilitates services to be much more easily and precisely found, combined, used, and paid for via a network. It also attempts to establish a complete open platform on a cloud for developers and market participants to build applications, services, and new business models (Kagermann 2014). The platform increases the transparency of the availability of services, enables the collaboration between various partners, and facilitates participants to provide web-based services.

Auditing is a service industry that provides examination of an organization's financial statements. This profession is moving gradually towards online, digitalized services with the development of ERP system technology and the digitalization of accounting information. Vasarhelyi and Halper (1991) proposed a new model of audit that continuously monitors and analyzes accounting data flow of an organization, and anomalies or exceptions will trigger alarms to call auditors' attention. This continuous auditing and monitoring may be offer as on-line service by audit firms. Companies will request services over the Internet, and such requests will then be matched with the services that audit firms can provide. Audit firms will deploy their continuous auditing and monitoring models over a cloud-based infrastructure or in the company's accounting information system to analyze the data flowing through the organization. Anomalies as well as relating information will be sent to auditors to perform further investigation.

Smart Factories and Smart Products: The advance in sensors, CPSs, IoT, and IoS ushers in the fourth industrial revolution, and promotes a new intelligent, flexible, and secure factory: the "smart factory". Hermann et al. (2015) imagined that smart factories would employ a completely new approach to production, in which smart products are identifiable and traceable with the capability of self-awareness and optimization, and the whole manufacturing systems are connected vertically with other business processes and horizontally with related parties outside of the factory. Shrouf et al. (2014) visualized the main components and processes in a typical smart factory (Figure 3).

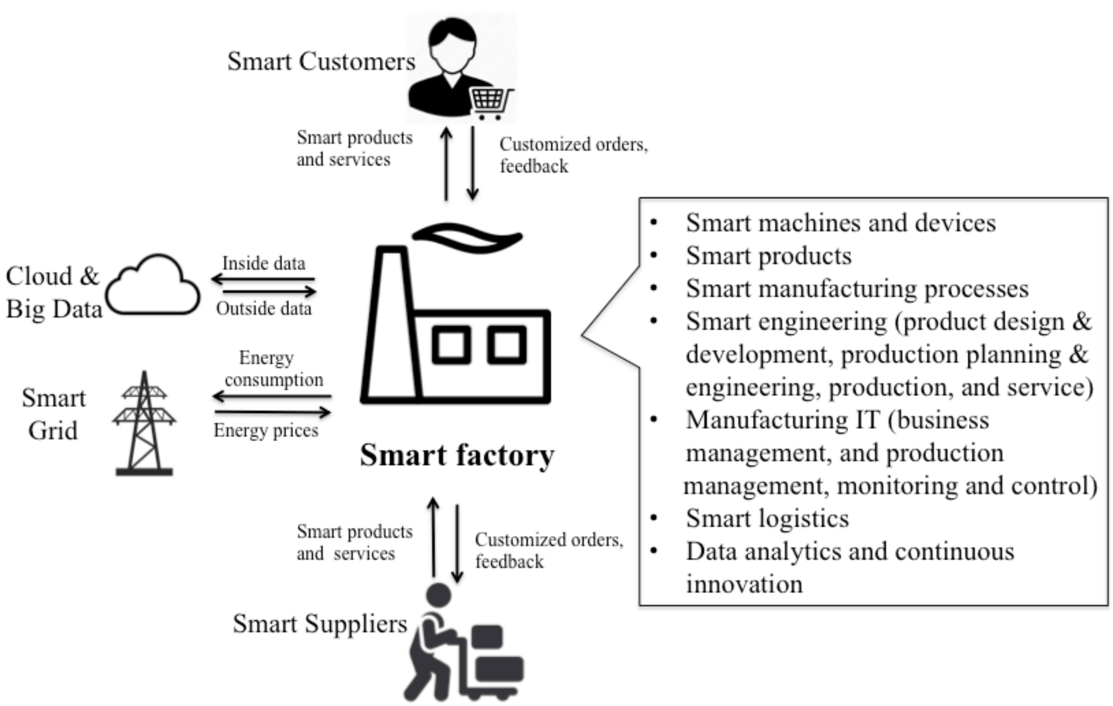

Figure 3: Smart factory architecture (Adapted from Shrouf et al. 2014)

In a smart factory, production is initiated by receiving orders with customized requirements via a network that connects the entire factory and outside related parties. The smart factory then generates a manufacturing plan based on machines' capabilities and status collected from the network, and autonomously guides raw materials and products throughout the production lines. The smart factory produces smart products that integrate the functions of data processing, storage, and analysis. The smart products record and transfer their conditions and status, as well as customers' behaviors and demands to the factory to facilitate quality control and product design. The smart factory is also connected to suppliers to enable just-in-time inventory. Compared to traditional manufacturing industry, smart factories improve the flexibility of manufacturing, increase the automation of operations, enable mass customization and proactive maintenance, and connect all sectors in the value chain (Shrouf et al. 2014). Therefore, smart factories are becoming the core of Industry 4.0.

As smart factories collect and integrate accounting and other audit-relevant information throughout the entire value chain, auditors could utilize those data and functions to facilitate monitoring and controls of accounting data flows in an organization, sharing accounting information among related parties, performing predictive and preventive audits, and eventually achieving close to real-time assurance, enlarging audit scope, and improving quality.

Some existing audit procedures could be automated under the context of smart factories, such as the automation of inventory valuation and measurement through tracking locations and conditions of smart products, and automatic validation of transactions using the corresponding accounting records from related parties. Moreover, auditors are able to analyze even larger volumes of data from various resources to provide precise "predictive assurance" (Kuenkaikaew 2013). Examples could be predictions of sales based on customers' comments and feedbacks, estimations of energy expense by collecting real-time consumption of each production line, or prevention of bad debts and preparation of allowances according to customers' profiles and ongoing behaviors. The same type of reorganization and utilization of analytics that enables the smart factory could create a continually updated "smart audit".

Other techniques that support Audit 4.0: RFID can identify an object in the virtualized world and report product status. GPS can be used to track products. In additions, workers' location in a factory could also be tracked using smart ID cards in order to provide them with guidance and instructions on-site (Gorecky, Schmitt, Loskyll, and Zuhlke 2014). Data analytics will continue playing an important role in Audit 4.0 by discovering patterns, detecting anomalies, identifying relations, and obtaining other useful audit-related information.

2.2.3.4. Auditors

In a world of intense automation and process scrutiny, the skillset of auditors is to change dramatically. Appelbaum, Kogan, and Vasarhelyi (2016) and Kozlowski (2016) discuss these needs. Auditors in the future must be much more technically trained, but processes must also be built with untrained users in mind. For example, Byrnes (2015) developed a "super-app" to supplement auditor usage of clustering. This tool not only performs clusterization but also applies statistical knowledge to complement auditor knowledge.

2.3. Imagineering Audit 4.0

With the intense use of sensors, CPSs, IoT/S, and smart factories, the business world is moving forward towards a highly automated, highly flexible[6], and highly interconnected environment[7] with real-time capability of corporation, fault detection[8], prediction[9], and decision-making. The auditing profession should adapt to this wave of changes, and leverage the emerging technology to enlarge the scope of auditing, shorten timing, improve accuracy, and eventually enhance the assurance level of the whole business world. This section imagines how auditing could be changed in the new environment of Audit 4.0. A summary of the Audit 4.0 structures is shown in Appendix A.

2.3.1. Mirror World in Audit 4.0

Since everything will be connected to the network, and potentially equipped with a CPS that allows data collection, processing, storage, and transmission, a virtual representation of the physical world, the "mirror world", can be created. Each object in the physical world will have a representation in the mirror world, and continuously update the information about conditions, locations, surrounding environment, history, etc., to the virtual representation. The mirror world will be established in a large, integrated cloud, which serves as an independent third party. Using data from various

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[6] Auditing standards and the PCAOB review process likely preclude flexibility in the auditing domain.

[7] Interconnectivity of processes as well of business partners would pose serious challenges for assurance standards but could substantially reduce risks to population and value integrity.

[8] Systems are most often set up sequentially; consequently, upstream fault-detection is downstream fault prevention.

[9] Audits are not inherently retroactive, but were forced into a "looking backwards" role by technological limitations. Modern big data and analytic methods allow for assurance that can be predictive or at least very close to the event.

resources, the mirror world will enable automatic confirmation between related business entities, automation of inventory and cash balance evaluation, real-time energy measurement and management, real-time faults and irregularity detection, remote continuous auditing/ monitoring, and remote audit- facilitating service. Figure 4 visualizes the basic structure and functions in Audit 4.0.

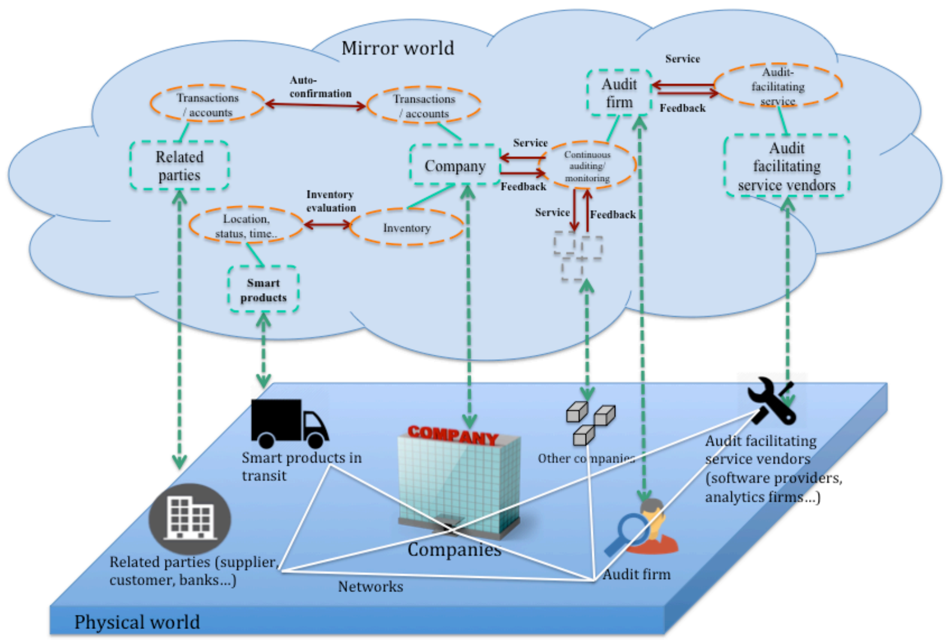

Figure 4: Basic structure and functions of Audit 4.0

Figure 4 shows the four major parties in Audit 4.0, including companies, related business parties (such as suppliers, customers, banks), audit firms, and vendors that offer audit-facilitating services (such as audit software, audit data analytics, etc.). Those four parties are interconnected, communicating in real time, and cooperating with each other. All objects will be traceable and able to store their conditions, status, and history locally, which can facilitate the validation of accounting information in an organization. In Audit 4.0, the changes of auditing profession will be mainly from three aspects: 1) inter-business parties, 2) intra-business, and 3) audit service. Figure 5, Figure 6, and Figure 7 show the new audit model from these three aspects.

2.3.2. Interlinked Organizations

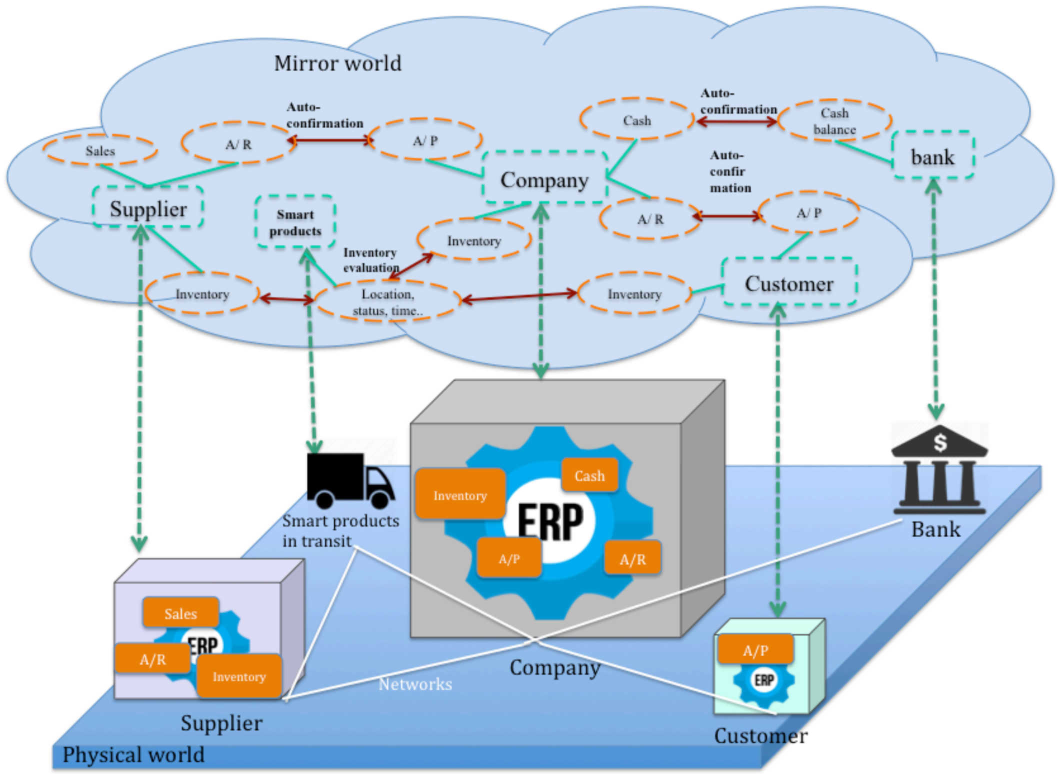

Figure 5: Audit 4.0 of inter-business parties

Figure 5 shows how Audit 4.0 can virtualize the physical examination and automate the confirmation process by allowing connections and corporations between related business entities. Due to its labor-intensive nature, physical examination can only be performed on a limited basis. Audit 4.0 makes products traceable and as a result enables real-time inventory examination. Confirmations are a highly regarded type of evidence, but they are historically costly to obtain. Audit 4.0 can minimize the cost by autonomously matching related accounts and transaction records from different parties, issuing alerts only if the information cannot be matched. Furthermore, organizations can opt to create autonomous storage of their joint transactions.

When a supplier ships smart products (usually equipped with CPSs) to a company, the smart products will sense changes in location, and record their status (out for delivery) and time in the embedded systems. They can also communicate with a worker's smart personal tag and provide personnel identifiers or electronic signatures. Next they will trigger the supplier's ERP system to record sales and receivables, reduce the inventory, identify the employee that executed the transaction, and send all the information to the mirror world. Upon arrival, the smart products will verify their locations and change their status to "arrived". In addition, sensors embedded in the smart products can report their conditions to the warehouse personnel (also tag identified) who will decide whether to receive or return to the supplier. Those received products will trigger the purchasing company's ERP system to record inventory and payables, and change their status to "inventory". The products will also update their locations and status upon the departure from the company's warehouse to record sales and reduce in inventory. All the changes and new information will be updated continuously in the mirror world. To count inventory, auditors can simply check the locations and status of virtual products through the mirror world.

The mirror world enables a new model that automatically collects confirmation evidence (Li and Vasarhelyi 2016). Relating accounting information (receivables and corresponding payables, cash account and bank balance) from related companies will be located from the mirror world and matched. Such automatic confirmation can provide real-time, reliable, on-demand verification at both transaction and account levels through company collaboration. Moreover, as the mirror world records the details of business activities happening in the physical world, it can serve as an independent information resource to verify the accuracy of accounting records in the company's ERP system.

2.3.3. Connecting the Mirror and the Real Worlds

The dual worlds have their connections providing the key functionalities that the world of IoT and other technologies allow.

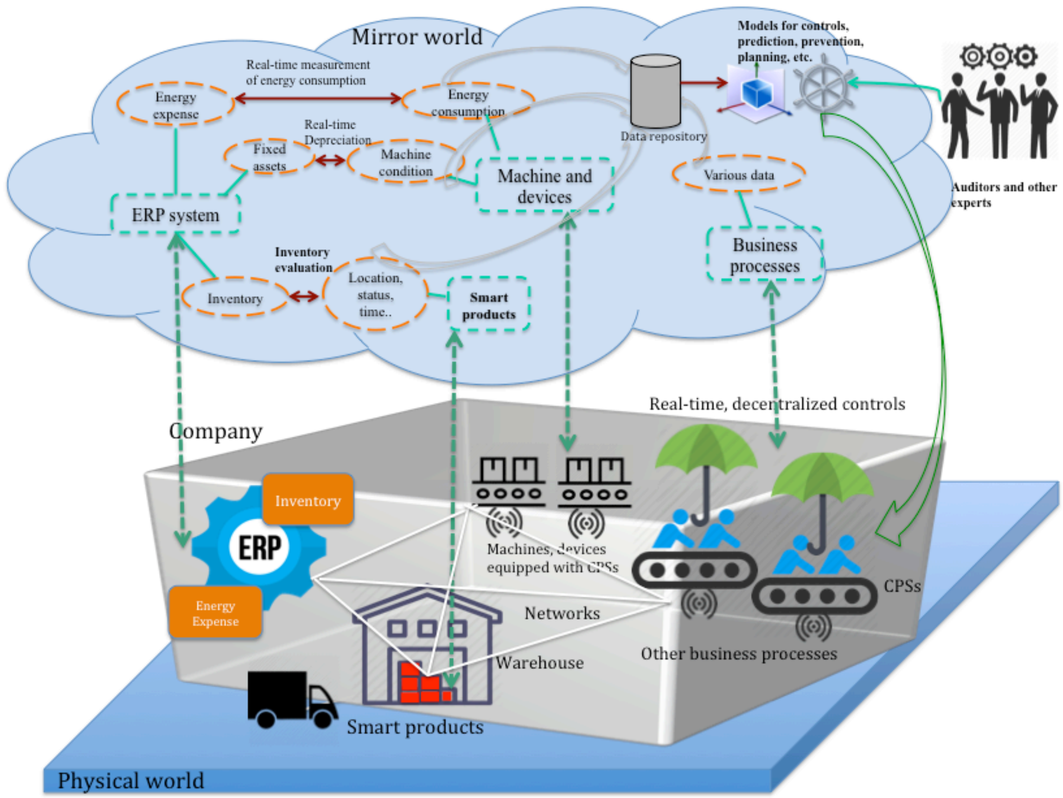

Figure 6: Audit 4.0 of intra-business

Figure 6 shows how Audit 4.0 can provide a comprehensive assurance to a company by gathering and analyzing accounting and other business data from the entire business. The mirror world will continuously capture data that reflect current status and performance of the organization. In addition, business processes will be monitored against pre-determined rules to detect violations of key controls, and cross-verified via certain continuity equations (Kogan et al. 2014). Employees' activities will also be captured by cameras and sensors to identify irregular or abnormal behaviors. Those data will all be linked to an organization's EPR system to enable real-time accounting.

The mirror world will integrate real-time data from the entire organization into a data repository in the cloud. Auditors and other experts can create analytics models on top of the data repository in order to continuously detect anomalies, discover system faults, identify control inefficiency, and manage resources. Once an anomaly or fault occurs, the corresponding model will send an alert to auditors or management who will promptly take action. Some control monitoring models can also be implemented in the individual equipment or facilities instead of the cloud, if they only monitor local data generated or flowing through the machines. Such decentralization may dramatically reduce the workload in the cloud and improve overall efficiency.

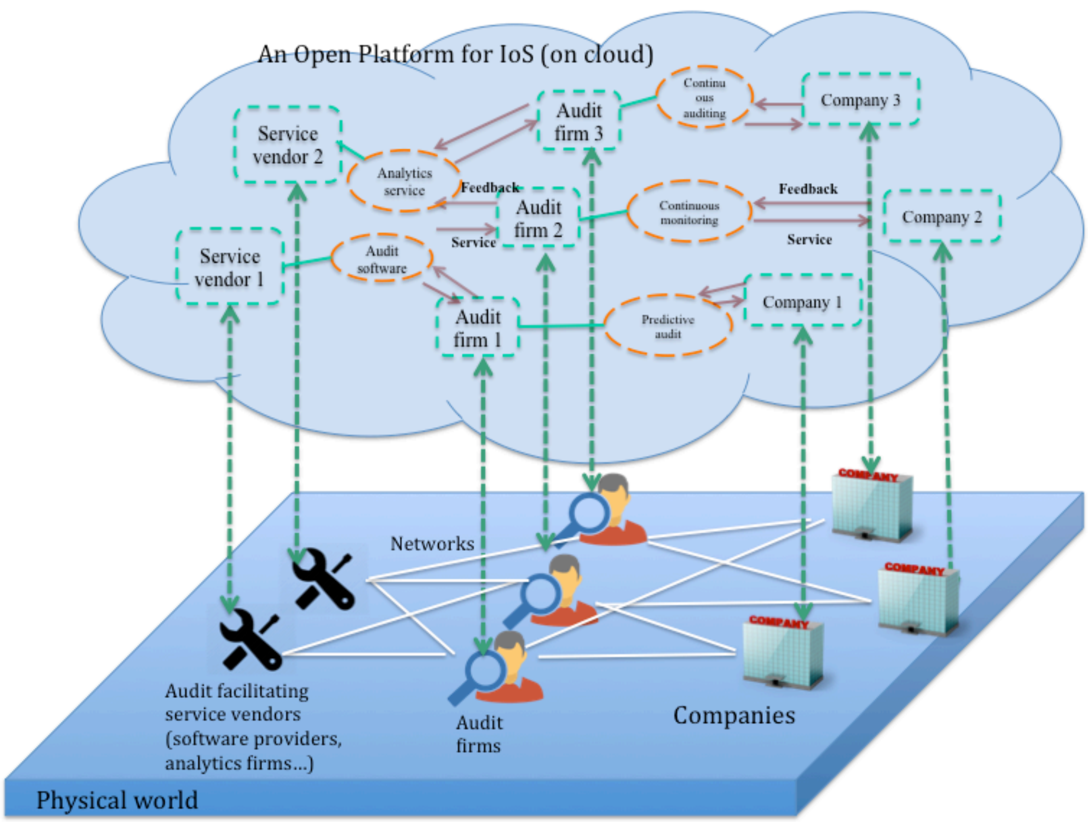

Figure 7: Audit 4.0 regarding Audit Service

Figure 7 shows how Audit 4.0 will enable flexible, low-cost, and high-quality audit service based on the concept of IoS. An open platform that is accessible by audit firms, companies, and audit-facilitating services vendors, will be established on a cloud. In the Audit 4.0 environment, audit firms are able to provide digitalized services, such as continuous auditing and monitoring, anomaly detection, in a remote manner. Each audit firm can publish detailed descriptions of their services and availability on the platform. Companies can also announce their requests for service along with requirements. The platform will autonomously match the services offered by audit firms with the demands from companies, and recommend the most appropriate audit service to the companies based on the service matching, timing, and quality. A company will be able to use services from various audit firms. Once the company accepts the service, the audit firm will then offer the service remotely over the platform. Clients' feedbacks will be then collected for service improvement as well as quality evaluation and controls.

Audit-facilitating service vendors could also use the platform to help perform audits with a relatively low cost. For example, vendors can deploy audit software on the cloud, and offer to multiple auditors or audit firms at the same time. Auditors can pay per use instead of purchasing the software, and can obtain instant help from vendors as they can directly access the software from the cloud. Auditors can also use the platform to outsource technical work, such as data analysis, to a professional company. Similarly, the platform will match the services offered by the vendors and the needs from auditors, and suggest the suitable services.

Although the imagineering in this section is based on physical products, the same rationale and methods can be applied to digital goods (Vasarhelyi and Greenstein 2013) such as the sale of software, educational materials, banking services, insurance services, etc. In that case, sensors and other measurement software will be replaced by measurement modules, but by and large the methods will be similar.

2.4. Challenges

2.4.1. Digital Crime – "Technology Giveth, Technology also Taketh"

Technology has been developed to facilitate and enhance a wide spectrum of human activities, but in parallel with these benefits, it also allows for dysfunctional use. For example, Audit 4.0 allows for the usage of RFID chips to mark and count inventory but RFID chips can be piled in warehouses with no inventory attached. Remote access opens the door to unauthorized use. A highly integrated production system with an online audit layer can be a boon for industry but can also be used to integrate the facilities of an enemy or as an overbearing system of spying by a totalitarian regime. Of particular concern is the issue of cybersecurity as the power of technology can be used to steal massive amounts of information without obvious traces.

2.4.2. Security and Privacy Issues of Companies' Data

Emerging technology poses a significant threat to the security and privacy of organizational information (Shapiro and Baker 2002). For example, as firms upload their data to the cloud, their accounting information, as well as customers' sensitive data could be exposed to an untrusted environment. Besides, the increasing frequency of communication between different business parties and the share of financial information enhance the probability of data breach. To avoid potential damage and reputation loss due to security and privacy flaws, companies and audit firms should create strict policies to keep the data secure and private. Some effective approaches include encrypting sensitive information before transmitting to the cloud, using secure channels to commute with other entities, and hiring professionals to install secure products, detect and respond to attacks, and evaluate security and privacy risks over time.

2.4.3. Standardization of Data

Developing uniform data standards is vital for the exchange of information and data in the context of Audit 4.0. Data in Audit 4.0 may originate from a variety of sources, such as the sensors embedded in machines and devices, companies' ERP systems, databases of associated outside parties, and public resources (e.g., news, social media, and governments), and they will be analyzed by different parties with different models of data structure, format, and name rules. To facilitate information exchange and analyses in Audit 4.0, regulators and standardization agencies should create suitable standards that define the formats and naming rules of commonly used data. A recent initiative in auditing practice is the five voluntary, uniform Audit Data Standards (ADS)[10] issued by AICPA. Those ADSs provide an example of the efficient exchange of data from various companies. With standardization, interparty data transmission will become seamless, and various analytical tools can be directly employed upon the data without cumbersome data preparation processes.

2.5. Natural and Accelerated Evolution of the Audit Profession

The slow evolution of socio-technical systems discussed in this chapter creates serious discontinuities in functionalities and creates difficulties in the evolution of technological use. Some factors may serve to accelerate this process including visionary research followed by opportunistic business initiatives. The accelerating factors include pressure from different stakeholders, competitive costing pressures,

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[10] https://www.aicpa.org/interestareas/frc/assuranceadvisoryservices/pages/auditdatastandardworkinggroup.aspx

development of facilitating applications, and competitive international disadvantage by more progressive legislation in other countries, etc.

Conceptually, many questions arise as it could be argued that a layer of automated assurance is not an audit but a set of controls. This issue will be raised with predictive audits (Kuenkaikaew 2013), prescriptive audits[11], and continuous auditing (Vasarhelyi and Halper 1991). Although it has not been much discussed in the literature, layers of technology and the utilization of analytics will change the natural roles of the three lines of defense (management, internal audit, and external audit). Internal audit has in some instances taken a more aggressive role in the adoption of technology (Vasarhelyi, Alles, Kuenkaikaew, and Littley 2012). External audit has in instances relied on this more advanced work and in certain cases, under adverse economic incentives, adopted advanced analytics to decrease its risks although the traditional audit steps are still required by regulators. Management is increasingly utilizing advanced analytics in their processes and is starting to require their assurers to do the same, although Sarbanes-Oxley limits advisory services provided by external auditors.

2.6. Conclusions

Audit 4.0 utilizes data collection equipment such as sensors, embedded computers, and software modules to collect data across the entire company and its outside entities such as suppliers and customers, via a network in close to real time. Data analytics techniques are employed to build models upon this data for the purposes of monitoring product quality, identifying machine faults, saving costs, and

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[11] Prescriptive Analytics answers the question of what should be done given the descriptive and several predictive analytics results. To date it has been used predominantly in the geo-exploration and bio-medical industries, and in academic research (Applebaum et al. 2016).

facilitating decision-making. Audit by exception (Vasarhelyi and Halper, 1991) is used to bring attention to major issues in a largely automated audit. The audit process strongly relies on a mirror world representation of processes and a strong analytical interlinking of not only financial but especially non-financial to financial linkages. Finally the approach will substantially rebalance the concepts of lines-of-defense, will be applicable to many types of assurances (external, internal, specialized), and will be mainly automated.

Chapter 3. Towards Blockchain-based Accounting and Assurance[1]

3.1. Introduction

Blockchain is considered one of the most important and innovative technologies developed in recent years (Peters and Panayi 2015; Pilkington 2016; PwC 2015; Swan 2015a). Originally used for Bitcoin[2] trading, blockchain establishes a decentralized public ledger that provides a secure infrastructure for transactions among unfamiliar parties without a central authority. This technology is meant to reduce trading costs, increase transaction settlement speed, enable micropayments, reduce fraud risk, improve the auditability of transactions, and increase the effectiveness of monitoring (Swan 2015a; Fanning and Centers 2016; Pilkington 2016; Yermack 2017). Blockchain has evolved from a secure monetary transaction system into part of an ecosystem of emerging technologies that includes artificial intelligence, the Internet of Things (IoT)[3], robotics, and crowdsourcing. These technologies together represent the technical foundation of future commerce (Deloitte 2016; Dorri, Kanhere, and Jurdak 2016; Ferrer 2016; Omohundro 2014). Blockchain is obtaining increased attention from the accounting profession. PwC for example, views blockchain as the "next-generation business process improvement software to structurally alter shared practices between customers, competitors, and suppliers" (PwC 2016). Similarly, Deloitte expects that blockchain will dramatically improve collaboration among businesses and individuals, the transparency of business

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[1] This chapter is based on the paper that is published in Journal of Information Systems (Dai and Vasarhelyi 2017)

[2] Bitcoin is the most widely used crypto-currency.

[3] IoT is a novel paradigm in which of physical objects interact and cooperate with each other (Atzori, Iera, and Morabito 2010).

processes and data, and ultimately the productivity and sustainability of the economy (Deloitte 2016).

The applications of blockchain have been discussed and piloted in many domains including banking, trading, insurance, data protection, voting, intellectual property, identity authentication, leasing, and government service[4] (Atzori 2015; Cointelegraph 2015; De Meijer 2016; Liebenau and Elaluf-Calderwood 2016; Peters and Panayi 2015; Swan 2015a; Trautman 2016; WSJ 2015; Yermack 2017; Zyskind, Nathan, and Pentland 2015). However, the potential for blockchain to benefit the accounting and assurance domains is still under-explored. This chapter aims to fill the gap in the literature, and to generate insights for both practitioners and regulators on the acceptance and use of the emerging technology. It provides an initial discussion on how blockchain can change the accounting profession by enabling a real-time accounting ecosystem, and how it could shift the current auditing paradigm towards a more precise, timely, and automatic assurance system.

Blockchain enables companies to generate a new type of accounting information system that chronologically records validated transactions on public or semi-public ledgers. Those transactions will include not only monetary exchanges between two parties, such as payments collected from clients, cash deposited to banks, etc., but also the accounting data flow within a company. By incorporating other emerging technologies (e.g., IoT), blockchain could facilitate real-time tracking and monitoring of activities of physical objects, and automate the recording and measurement of business performance. Blockchain could enable near-real-time

[4] Sample applications include NASDAQ's use of blockchain in private market trading (WSJ 2015), and Citibank's creation of three blockchains and issuance of an internal cryptocurrency, the "Citicoin" (Cointelegraph 2015). Many solutions, such as Ethereum and Rubix, provide "Blockchain-as-a-Service" (BaaS), allowing users to develop their own blockchains.

disclosure by continuously broadcasting ledgers to interested parties (e.g., managers, auditors, creditors, stakeholders, etc.) at various aggregation levels based on users' roles and demands. Because of the dramatic decrease in the unit cost of processing, memory, and storage, as well as the emergence of distributed public ledgers like blockchain, external parties can access a company's real-time accounting information at low cost.

As blockchain can continuously share relevant accounting data to the interested parties, the role of providing assurance can be expanded from primarily auditors to a much broader scope of participants, including business partners (suppliers, clients), creditors, government bodies, etc. These parties may participate in the transaction verification process by providing reliable and independent information used for attesting to obligations and ownership. In addition, many state-of-the-art tools, such as analytical audit apps, continuous auditing and control monitoring mechanisms, and process mining models, can then be applied to the accounting records within the blockchain in order to provide effective, efficient, and timely assurance. Moreover, as more and more physical objects (e.g., machines, production lines, and inventory items) become Internet-ready, real-time business process monitoring could be embedded with the blockchain technology and executed by these physical objects.

The remainder of this chapter proceeds as follows: Section 3.2 discusses the literature on the use of blockchain in auditing domain. Section 3.3 illustrates the potential applications of blockchain in re-conceiving corporate accounting. Section 3.4 analyzes the utilization of blockchain technology to enable an efficient, effective, and timely assurance system. The challenges facing blockchain implementation are discussed in Section 3.5. The last section concludes this chapter.

3.2. Related Research

Although the literature within many other fields has proposed potential applications of blockchain, there is limited research examining the utilization of this technology within accounting and auditing practice. Yermack (2017) provided a brief discussion on using blockchain to enable real-time accounting. He imagined that with voluntary disclosure of a company's ordinary business transactions via blockchain, interested parties could obtain instant access to accurate financial information. From there, any information consumer could create personalized financial statements without relying on the judgment of auditors or the integrity of managers. While the detailed mechanisms and paradigms used to support real-time accounting were not designed, the concept is nevertheless noteworthy. Fanning and Centers (2016) suggested that blockchain technology could be of benefit to the auditing profession by making the comparison of corresponding accounting entries, present on the books of each of the trading parties, relatively easy. Explicit illustration on how to achieve such a goal is still missing, but this would reduce auditors' efforts relating to financial transaction testing. Kiviat (2015) illustrated the idea of blockchain-enabled "triple-entry accounting" using the example of bitcoin transactions. It described the mechanism for posting accounting entries of bitcoin trades to the blockchain in order to prevent transaction tampering. Unfortunately, this "triple-entry accounting" mechanism is specifically designed for the bitcoin system, and cannot be directly applied to general corporate accounting systems. Peters and Panayi (2015) discussed the utilization of blockchain to facilitate banking ledger processing. While they provide detailed illustration on how the new technology can automate accounting booking processes, the discussion only focuses on the banking context and not broader general accounting systems. Therefore, this chapter aims to extend the literature by proposing the utilization of blockchain in a generic accounting system. Specifically, this chapter illustrates:

1) How blockchain could create a real-time, reliable, and transparent accounting ecosystem, and

2) How blockchain could be used to develop an automatic assurance system, and help the extant auditing paradigm become more agile and precise.

3.3. Blockchain-based Accounting Ecosystem

As mentioned in section 3.1, accounting profession could largely benefit from blockchain, and its current paradigm may be eventually changed thanks to this emerging technology. Blockchain, as well as associated smart contracts, can be leveraged to securely store accounting data, to instantly share relevant information with interested parties, and to increase the verifiability of business data. Using blockchain technology, companies are able to generate new accounting information systems that record validated transactions on secure ledgers. Those transactions will include not only monetary exchanges between two parties, such as payments collected from clients, cash deposited to banks, etc., but also the accounting data flow within a company. Such systems would enable close to real-time reporting by instantly broadcasting accounting information to interested parties, such as managers, auditors, creditors, and stakeholders. Because of the dramatic decrease in the unit cost of processing, memory, and storage, as well as the emergence of distributed public ledgers like blockchain, external participants can access company's real-time accounting information at low cost. Smart contracts could serve as automatic controls that monitor accounting processes based on pre-determined rules. In addition, with the advancement and popularization of IoT, controls could be embedded into the blockchain. These IoT based controls could be incorporated into various physical objects, in order to monitor and enact business processes in real time. Moreover, data analytics can also be used conjunction with blockchain to discover anomalies and other useful information. In this system, managers, accountants, business partners, and investors could actively collaborate to verify transactions, as well as provide reliable evidence for cross-validation. These components should come together and comprise a real-time, verifiable, and transparent accounting ecosystem. Figure 8 provides an overview of the blockchain accounting ecosystem.

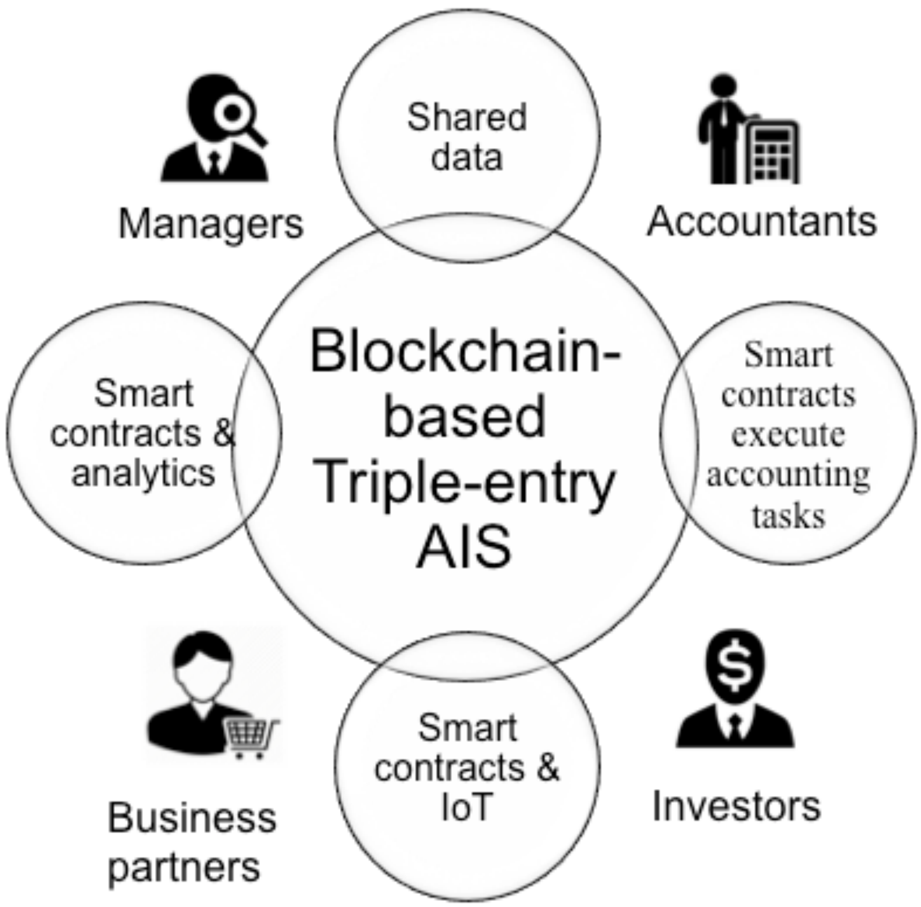

Figure 8: An overview of blockchain-based accounting ecosystem

3.3.1. Triple-entry Accounting

Triple-entry accounting[5] has been discussed for years by both academics and

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[5] Ijiri (1986) proposed a “triple-entry bookkeeping” system to measure “momentum accounting” that reflect how fast income or asset are changing. However, the triple-

professionals (Elias 2011; Grigg 2005, 2011; Kiviat 2015; Lazanis 2015; Tyra 2014). The primitive mechanism of transaction and business activity recording is the single-entry bookkeeping, in which each transaction is only recorded in one account (Sangster 2016). Although such a mechanism is simple and efficient, it is fraught with a high risk of errors and fraud, since such issues are difficult to track and repair. To improve the accuracy of the bookkeeping system, traditional financial accounting is based on a double-entry system (Pacioli 1514). This system enables rapid confirmation that the transaction has been correctly entered (Sangster 2016). The double-entry system can reduce the risk of human documentation error, such as accidental deletion of transactions, but it does not provide comprehensive assurance for companies' financial statements. Although auditors serve as third-party examiners who perform a series of tests on companies' accounting records and provide their opinions on the accuracy of the financial statements, improvements on the existing reporting and assurance system are still needed.

The "triple-entry system" was recently proposed as an independent, transparent, and secure paradigm in order to improve the reliability of companies' financial statements. The triple-entry system originally required transaction-processing authorization from a neutral intermediary, with each party (the two parties involved in the transaction and the intermediary) creating a record for the transaction, resulting in three entries total (Grigg 2005). However, this mechanism requires an independent and reliable intermediary to verify each individual transaction placing a heavy burden on such an intermediary. In addition, entries stored by the intermediary are also exposed to the risk of loss or unauthorized changes due to cyber attacks.

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entry accounting in this paper refers to documenting accounting entries in blockchain or with a third party.

Blockchain technology has the potential to improve this mechanism and mitigate these problems. Blockchain could play the role of the intermediary by automating the storage and verification process, providing a secure foundation that prevents tampering and enables close to real-time auditing (Kiviat 2015). Because of the nature of blockchain, once an accounting entry is confirmed and added to the chain, it can never be altered or destroyed. Moreover, smart contract technology could enable rapid verification of transaction records following accounting standards or pre-specified business rules. By encoding the third accounting entry into blockchain, companies can generate a transparent, cryptographically secure, and self-verifying accounting information system, which could facilitate reliable data sharing between business parties and continuous reporting for shareholders.

One potential design of the simplified triple-entry accounting information system is shown in Figure 9.

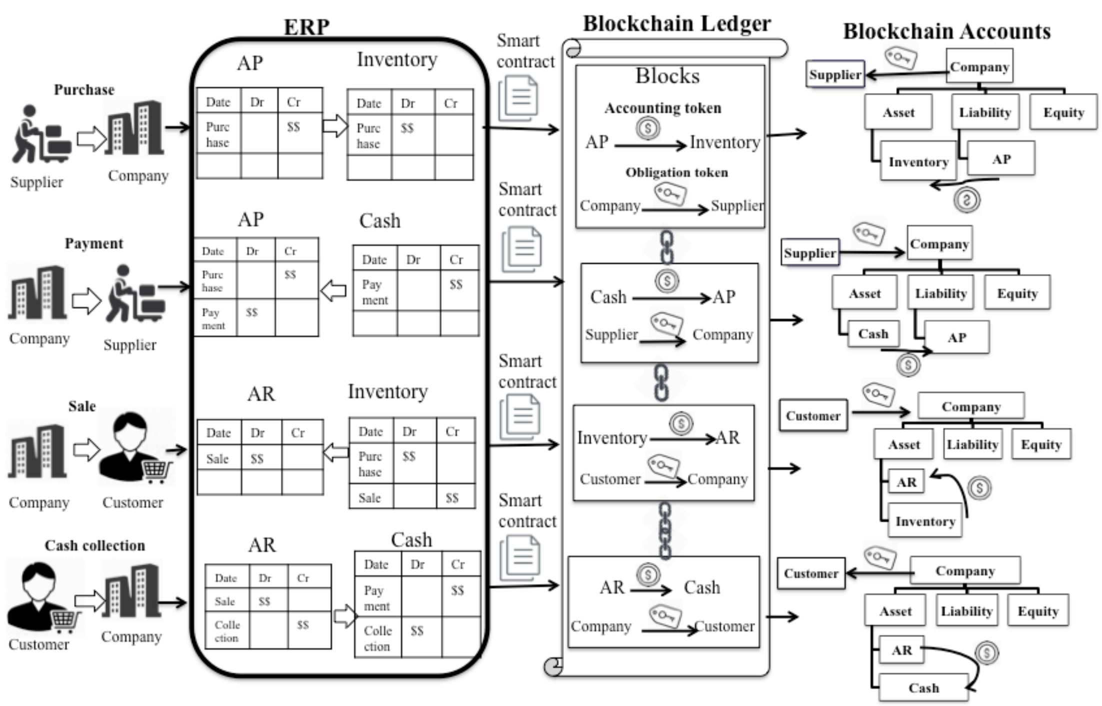

Figure 9: A triple-entry accounting information system

This system would record information regarding both transactions between business parties and data flows within an organization. In the system, every transaction would store a record in the blockchain ledger in addition to the entries that have been included in the traditional double-entry system. To reflect data flows within an organization, the entries in the blockchain ledger would be recorded in the form of transfers between accounts, which together comprise an interlocking system of enduring accounting records. Accounts in the blockchain ledger would be organized in a hierarchical structure to aggregate data at various levels, which enables both instant balancing of the accounting equation and different views of information for different users. Tokens in the blockchain ledger would also be used as certificates to attest to obligation or ownership of assets among business parties. Blockchain technology allows for timely examination of potential errors or fraud within accounting entries (e.g., duplicate payments) and enables the automation of transaction verification from business partners. Moreover, smart contracts encoded with accounting and business rules could play an important role in the efficient control of the recording process.

Figure 9 displays the working process of the system, using a simple purchase-sale business cycle as an example. When a company purchases goods from its supplier by credit, it will record Accounts Payable and Inventory in its ERP system. It will simultaneously submit this event in the form of a transfer of digital tokens between two blockchain accounts, to the blockchain ledger. Each account in the modern double-booking system would have a corresponding blockchain account. A blockchain account is equivalent to a Bitcoin wallet[6], which contains an account's

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[6] A Bitcoin wallet is a software package that allows users to make transactions on the Bitcoin network.

unique identifier[7], related transactions, current balance, and cryptographical keys[8] for verification. Blockchain accounts would be formed in a hierarchical structure that aggregates accounting records at three levels: individual accounts at the bottom, total assets, liabilities and equity in the middle, and the company as a whole at the top. This structure can automatically confirm the balance sheet equation using smart contracts. For example, if the balance in the company account is set as the balance in the assets account less the total balance of liabilities and equities account, a smart contract could be created to monitor the balance of the company account, which issues alerts when the balance does not equal to zero. Another benefit of the hierarchical structure of accounts is that it allows data views at various levels. Various consumers of information, such as managers, investors, creditors, and business partners, have different demands and restrictions on accounting data acquisition; thus, different data views should be granted based on user roles.

The digital tokens in the blockchain ledger can be simply viewed as a symbol for recording and tracking purposes. As on-credit inventory purchases involve an obligation to an outside party, an obligation token would be involved. This token is a certificate that attests to the obligation and ownership of an asset, as well as its amount and timing, and is undeletable and undeniable once issued. The obligation token mechanism can facilitate the implementation of automatic confirmation (Li and Vasarhelyi 2016) by automatically matching the total token value with the supplier's account receivable balance. The obligation token could also be embedded in a smart

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[7] Rather than creating a Bitcoin-like random wallet identifier, the account's unique identifier could be assigned by a trusted third party such as the SEC in order to prevent abuse.

[8] Cryptographical keys are a pair of public and private keys used in the public-key cryptography system (Diffie 1988). They aim to verify the authenticity of the sender of a transaction, and ensure that the sender cannot repudiate a transaction after its occurrence.

contract that encodes the interparty relationship and can execute payment once certain conditions are realized (e.g., due date arrives). Other business rules, such as issuing discounts for early payments, could also be easily encoded into the smart contract, which allows autonomous execution of pre-specified terms based on future conditions and activities.

After a token transaction is submitted to the blockchain network, the computers in the network would perform several procedures to verify the transaction, including the verification of:

1) Recording by the company's ERP system,

2) Posting of the transaction,

3) Asset transfer,

4) Correct amounts and accounts, and

5) Posting party validity (e.g., the company's ERP system or AP clerks).

Although the verification process will be automated by blockchain technology, this process should be restricted to certain parties, such as accountants, management, auditors, etc. Therefore, the blockchain ledger in this scenario falls into the permissioned blockchain category. In addition, each party would have a specific role in the verification process, and their actions and concerns might be addressed differently. For example, if an auditor doubts a transaction, it might be paused for confirmation by accountants, while the CFO could decide to cancel it entirely. These rules could also be programed in to blockchain to enable automatic controls. After verification, valid transactions would be grouped into blocks and appended to the main chain, and then users who have authorizations can view and explore them. Due to the nature of blockchain, confirmed and uploaded transactions cannot be manipulated. To protect the privacy of a company's sensitive data, the transactions could be encrypted before being uploaded to the blockchain ledger, and only users who have the decryption key should be able to view the content of transactions.

Following the same procedure, the company would record accounting data generated in the procurement, sale, and cash collection business processes. Tokens would be transferred from the cash account to the payable account when the company processes a payment. Meanwhile, the supplier would send the obligation token back to the company to attest the clearance of obligation. Similarly, the company could collect an obligation token when its customer makes a purchase by credit, and clear the token as soon as payment is received. As discussed earlier, all the processes operate automatically, and since the entries are cryptographically assured by blockchain technology, falsifying or destroying them to conceal fraud is practically impossible.

With the increasing automation of accounting information in the modern business world, most accounting standards should be embedded into the software and systems that implement and execute the recording process (Krahel 2012). Smart contracts could play an important role in the encoding of accounting rules and the autonomous recording of transactions that are in compliance with certain accounting standards. For example, after programming the rule of "sales should be recorded after shipment of goods" into smart contracts, such program could examine the shipment date before inserting a sales record into the blockchain ledger, and pause transaction updates until goods are shipped. Smart contracts which have accounting rules encoded could serve as effective internal controls that monitor the recording of accounting activities and therefore provide automatic assurance on processes such as posting, classification, and cutoff. For this reason, it is imperative for companies, auditors, and standard setters to collaborate in the design and implementation of smart contracts as this can facilitate the execution, automation and self-monitoring of such contracts. Libraries of the templates of these smart contracts would progressively be developed and contribute to decrease the cost of their creation. Furthermore, independent certification authorities could vouch for their validity and integrity.

3.3.2. Enabling the Accounting Ecosystem

The functions of automatic information verification, processing, storing, and reporting in the triple-entry accounting information system could be combined to form a self-sufficient accounting ecosystem. In such an ecosystem, smart contracts would operate as autonomous software agents[9] on blockchain technology for verification, control, fraud prevention, etc. To enable intelligent and instant verification, smart contracts could be combined with IoT technologies that can capture the actual conditions and activities of physical objects in order to monitor the recording process. For example, smart contracts might only post a sales record to the blockchain ledger if an inventory item is known to be departing the company based on information transmitted via the IoT. As discussed in chapter 2, future devices will be equipped with sensors, intelligent chips, and accessible to networks; they therefore may be able to self-report any inventory damage, non-delivery, or delays. These reports could trigger smart contracts to record such transactions in the blockchain ledger.

Many accounting processes could be automated using smart contracts by encoding business rules or agreements into software. Examples include automatically processing and recording payments using invoicing through self-enforcing smart contracts, and monitoring employees' performance and paying dynamic salaries using

[9] A software agent is a software component that acts autonomously to meet pre-set objectives (Briscoe and De Wilde 2009; Vasarhelyi and Hoitash 2005).

smart employment (Peters and Panayi 2015). Automation of tax filings in the form of smart contracts could provide continuous updates to government agencies. By programming tax rules into smart contracts, the tax system could become substantially simpler and less controversial (Allison 2015)[10]. Besides automation, smart contracts could add intelligence to the accounting process by integrating big data and predictive analysis. By encoding a default- or a credit rating-prediction model into a smart contract, a company will be able to offer loans with dynamic interest rates, which change based on the debtors' financial status and purchase behaviors. Such contracts could also adjust bad debt estimations according to debtors' likelihood of default.

Ideally, blockchain-based financial information could be made visible immediately to shareholders, creditors, business partners, government agencies, or other interested parties (Yermack 2017). Each information consumer has unique interests and objectives that lead to different needs of accounting data, e.g., CFO and auditors require full access to all accounting data, AP clerks need to review accounts payable entries, and investors only use highly aggregated information. Therefore, specialized access authorizations should be granted to each type of information consumer based on their role and demands. As discussed in the previous section, the blockchain-based accounting information system could allow users to view data at various aggregation levels set based on pre-determined roles. Such an increase in transparency, coupled with the verifiable nature of the blockchain, has the potential to

[10] It must be noted that the laws and regulations to be automated must be clearly "rule-based" in current technology, with very clear comprehensive contingencies. "Principle-based" rules are difficult to automate (Krahel 2012). Many rules will not be uniform, but rather diverse according to companies' special situations. Smart contract designers (management, auditors, lawyers, or regulators) can determine the terms or rules that are most suitable for their

increase shareholder trust by reducing opportunities for management earnings manipulation (Yermack 2017). Since the recording and presentation process is shifting from manual operation to progressive automation, the accountant's role is changing from collector and aggregator to interpreter and analyst.

One important issue that is worth careful consideration is the scope of participants in the blockchain-based accounting ecosystem. This is especially the case with regard to the processes of transaction verification and smart contract creation and validation. The blockchain-based accounting system is proposed as a permissioned blockchain in which only entities inside a company (e.g., its ERP system or accountants) can submit a transaction record to the blockchain ledger, with the verification function being restricted to accountants, management, and auditors. The design and performance of smart contracts may involve a large range of participants, such as management, representatives from business partners, creditors, auditors, service vendors (such as big data analysis firms), etc., as long as they can devote their competencies to create effective and efficient smart contracts. However, the validation of smart contracts' compliance with regulations and legislations should be performed by relevant professionals, such as auditors, lawyers, and regulators.

3.4. Applying Blockchain to Continuous Assurance

3.4.1. Using Blockchain to Increase Information Auditability

As blockchain technology and associated smart contracts become increasingly adopted for use in creating a verifiable and tamper-proof system, the current assurance paradigm may be fundamentally changed. One essential benefit of the blockchain infrastructure is the increased auditability of information. Since a blockchain ledger secures the data that is posted on it, it could also lend veracity to many audit related documents. For example, if each individual inventory item is registered in the blockchain upon its arrival at the company's warehouse, and its location and condition are continuously updated, a complete track and history of inventory items could be generated. This would enable remote, real-time inventory examination. Even audit trails could be documented on blockchain to facilitate tracing and review in the future. Similarly, information in electronic invoices, bills of lading, letters of credit, receipts, etc., could also be documented in the blockchain (EY 2015), on which all documents are traceable, permanently accessible, and unchangeable, allowing auditors to test the completeness of financial information. Those documents could also be shared among related parties for cross-validation. For example, missing invoices at the customer side may indicate a fictitious sale. To enable this mechanism, new standards might be implemented which enforce the incorporation of blockchain technology into the documentation of accounting information. Requiring certain types of documents to be filed on blockchain would mean that the absence of any records might indicate false transactions or fraud. Placing blockchain technology in the hands of managers, auditors, business partners, and creditors can achieve a new level of assurance. The collaboration of these individuals could provide trusted real-time assurance through the "proof of transaction" mechanism.

3.4.2. Smart Controls

While traditional auditing is centered around the audit of paper-based income statements on an annual or quarterly basis, this is no longer the world in which businesses operate. Increases in the speed and scope of business activity mean that any advancement enabling auditors to provide assurance closer to the transaction date would be meaningful. The traditional audit cannot provide near- real time assurance due to the manual nature of its procedures and the lack of tools to effectively analyze and monitor large amounts of transactional data (Alles, Kogan, and Vasarhelyi 2002; Vasarhelyi and Halper 1991). Since 1990s, there have been discussions on how paper-based auditing techniques would be dramatically augmented by, and eventually integrated into, smart contracts (Szabo 1997). With the integration of blockchain technology, smart contracts can operate with the supervision of multiple parties. A smart contract-enabled, control-based assurance paradigm could play an essential role in the new business world. Managers and auditors would program the firm-specific control protocols into smart contracts, which in turn could monitor accounting records or business processes. The protocols could implement not only general accounting rules, but also more intelligent controls, especially when combined with other state-of-the-art techniques, such as big data, data analytics, and continuous auditing/monitoring models. For example, smart controls could automatically monitor the delinquency risk in credit cards by following a risk prediction model tailored to each customer. They could also revoke a transaction if the company's process mining model (Jans, Alles, and Vasarhelyi 2014) detects that its underlying processes are disobeying certain internal business rules. One of the advantages of smart controls is their ability to self-adjust based on environmental changes (Szabo 1997). Therefore, smart contracts could execute complex controls to support an intelligent, flexible, and timely assurance paradigm.

The assignment of authority to change the accounting and business rules pertaining to smart controls could be critically important, as companies may manipulate these rules to gain illicit benefits. Ultimately smart controls must rely on a governance process[11] through which users agree to certain requirements for changing underlying code, as well as provisions for dispute resolution (Yermack 2017). Since the mechanism of blockchain technology ensures the integrity of posted data, it would also be utilized for protecting the code embedded in smart contracts. By posting (and probably encrypting) codes of smart controls on blockchain, managers and auditors could continuously verify the integrity of those programs.

Blockchain-based continuous assurance has been associated with the debate on the role of the auditing profession in this autonomous, self-regulating paradigm (Peters and Panayi 2015; Yermack 2017). Although auditors' accuracy verification roles may be diminished, their judgment, oversight, and insight should become even more necessary. The focus of auditing would change from record tracing and verification to more complex analysis such as systemic evaluation, risk assessment, predictive audits, and fraud detection. Another essential role that auditors would play is that of an evaluator and examiner over the execution of smart controls. Auditors should understand the codes in smart controls, and investigate the accuracy of program operation. To be qualified to perform such roles, auditors should be technically trained, and have the assistance systems that are designed for auditors to understand, operate, and analyze blockchain and associated technologies (Tschakert, Kokina, Kozlowski, and Vasarhelyi 2016).

3.4.3. Linking Blockchain to Audit 4.0

Chapter 2 proposed a vision of a new audit paradigm called Audit 4.0. It

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[11] Today's legal and regulatory system is a governance system of this type for extant data and processes. However, rules and regulations will have to be re-written to reduce the ambiguity in their interpretation.

utilizes emerging technologies to enlarge the scope of auditing and enhance assurance automation. An important component of Audit 4.0 is the mirror world, a virtual model that reflects business activities and conditions of objects in the physical world. Storing and securing the data in the mirror world is critical for Audit 4.0 operation. Blockchain technology is optimal for this and can provide cryptographical integrity to information transmitted into the mirror world. Moreover, auditors and other service providers could create smart contracts running on top of blockchains that perform effective controls and advanced analyses. The vision of blockchain-enabled Audit 4.0 is shown in Figure 10.

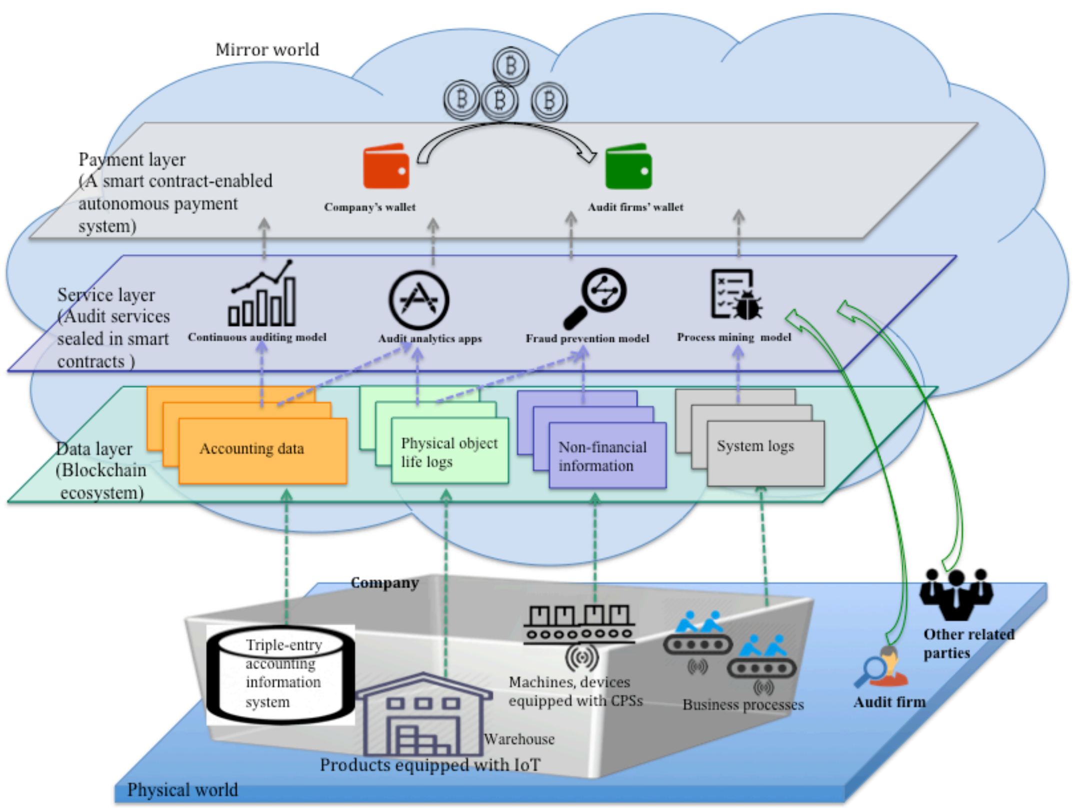

Figure 10: The vision of a blockchain-based Audit 4.0 assurance environment

A blockchain-enabled Audit 4.0 would consist of two components: the physical world and the mirror world. Each relevant object in the physical world would have a virtual representation in the mirror world, with the conditions, locations, surrounding environment, history, and activities continuously updated. The mirror world is comprised of three layers: data, service, and payment.

The data layer is an ecosystem of blockchains, each of which would record a type of data that is needed for audits. Examples of such data include:

1) companies' financial data, which could be stored in the triple entry accounting information system,

2) life-logs of physical objects (such as inventory, machines, buildings) recorded and transmitted by IoT,

3) non-financial information that would be captured from CPSs embedded in various business processes or from outside information resources (such as news, social media), and

4) system logs that record real business processes as used in process mining (Jans, Alles, and Vasarhelyi 2014).

Since the integrity of those data is protected by blockchain, the audit could rely on these data when performing advanced analyses.

The service layer allows auditors or other experts to provide digitized services using smart contracts. Many audit services, such as continuous auditing (Vasarhelyi and Halper 1991; Vasarhelyi, Alles, and Williams 2010), continuous controls monitoring (CCM) (Alles et al. 2006), audit data analytics (AICPA 2015), etc., have been digitized and could be offered remotely. Besides, associating blockchain data integrity with process logs in ERPs (e.g., through process mining and real time exception analysis) could substantially improve the integrity and reliability of business systems. Those services could be quantified into small tests or analytical apps and sealed into smart contracts. Those smart contracts would autonomously operate on top of the blockchain ecosystem and analyze the data to preemptively identify significant risks, prevent frauds, and support decisions.

The top layer is an automatic payment system that will send a payment to auditors once the pre-agreed audit services are provided. Smart contracts could monitor the progress of service providing, and initiate payments once the services have been accomplished. As the use of cryptocurrencies increases in the real business world, companies might use such cryptocurrency to make payments. Consequently, smart contracts can directly control the digital wallet of a company, and send pre-agreed cryptocurrency amounts to its audit firm's wallet. With cryptocurrency and smart contract controls, the payment process can become completely automated. Such a system could protect and benefit both companies and audit firms, as payments would be issued only if services are completed.

3.5. Challenges

Although this chapter proposes potential applications of blockchain, the challenges of acceptance and full utilization of this technology in the accounting and auditing sphere cannot be neglected. In the past decades, many disruptive technologies, such as ERP (Enterprise Resource Planning systems) and EDI (Electronic Data Interchange), have generated great contributions toward improving a firm's productivity and reducing operational costs. However, the technical complexity of the solutions, the requirement of substantial investments of financial and time resources, the difficulty to expand the technologies to business partners, and the demand for business and process changes could all hinder the adoption of those technologies (Davenport 1998; Iacovou, Benbasat, and Dexter 1995; Kuan and Chau 2001; Law and Ngai 2007; Pan and Jang 2008). Since blockchain shares many of these challenges with ERP or EDI, lessons learned from their implementations could serve as object lessons in this context.

The acceptance of ERP and EDI technologies has been well studied in the literature. The Technology-Organization-Environment (TOE) framework (Tornatzk, Fleischer, and Chakrabarti 1990) has been used to examine the factors that have significant influence on ERP or EDI adoption (Kuan and Chau 2001; Pan and Jang 2008; Schniederjans and Yadav 2013). This framework examines the three aspects that drive or impede the adoption and use of technological innovations at firm level: the technological context, the organizational context, and the environmental context. This section provides a comparative discussion on the challenges in the adoption and implementation of blockchain for accounting purpose with those of ERP or EDI from the three perspectives in the TOE framework.

3.5.1. Technological Context

Many studies have identified the significant impacts of technology readiness and capability in EDI or ERP adoption (Kuan and Chau 2001; Pan and Jang 2008; Schniederjans and Yadav 2013). Since the operation of blockchain usually needs substantial storage and computation resources, the adoption of blockchain technology in large corporate systems will depend on the projected development of larger storage systems, wider bandwidth for data transmission, and substantial expansion of computational power. Meanwhile, management needs to consider the scope of accounting data and other information necessary to post to a blockchain system in order to provide sufficient transparency and accurate assurance while preventing the system from becoming overwhelmingly demanding for resources. In addition, sensitive information should be protected from irrelevant parties (Gal 2008).

Similar to EDI (Iacovou, Benbasat, and Dexter 1995), blockchain can only maximize the benefit to enterprises through the wide adoption of the technology, since sufficient participants are required to ensure the security of the ledger, provide reliable verification of transactions, and prevent illicit collusions. In addition, a large variety of reliable audit evidence could be provided through information shared by separate organizations (third party confirmation). Unfortunately however, while the data stream of transactions may not be terribly large, many mainstream blockchain mechanisms, such as Bitcoin, are highly demanding of storage and computational power in order to ensure the security of data. Placing volumes of corporate data into such a system would be extremely demanding and potentially expensive for current commercial computing. Such requirements of substantive resources could impede the popularization of this technology, especially among small and medium enterprises (SMEs). Solutions for alleviating such overhead costs include using permissioned blockchain instead of permissionless chains, creating less costly algorithms, etc. Although some light and scalable blockchains have been piloted (such as Ripple[12] and Litecoin[13]), the security models on which those mechanisms rely may not be suitable for accounting applications. Therefore, a special blockchain scheme is still needed to provide reliable and accurate accounting information at reasonable storage and computational cost. In addition to technical advancement, blockchain practitioners may learn lessons from the adoption of EDI. When this occurred, large organizations, industry associations, and governments promoted the popularization of the technology

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[12] https://ripple.com

[13] https://litecoin.org

through partner expansion plans (Iacovou, Benbasat, and Dexter 1995).

The impact of IT complexity has been well discussed in the adoption of ERP or EDI (Bradford and Florin 2003; Premkumar, Ramamurthy and Crum 1997). Lack of understanding of the technology is also a major challenge for blockchain popularization (Deloitte 2016). Blockchain's algorithms and operating paradigms require substantial system and security knowledge. As such, managers, accountants, and auditors should obtain necessary training and cooperation from IT professionals in using this technology correctly and efficiently. These parties also need special training in order to participate in the design and implementation of smart contracts. Moreover, the audit of smart contracts is an even more complex issue that requires solid understanding of this technology.

3.5.2. Organizational Context

Perceived benefits and costs have been considered one of the main predictors for the initial use of EDI and ERP (Kuan and Chau 2001; Premkumar, Ramamurthy, and Nilakanta 1994; Schniederjans and Yadav 2013). Christensen (2013) also argued that large established companies have difficulty adopting disruptive technologies (such as blockchain) until their traditional business model is seriously threatened. If blockchain technology is to be widely adopted, its beginning will be in the areas where security and data integrity are of paramount concern and the volume of data is not overwhelming, such as ecommerce businesses. Startups that intend to sell blockchain related products could provide a fertile testing ground. Corporate processes would have to be changed dramatically with a large initial investment in smart contracts[14], making firms rebalance their workforces, placing and trusting their data in the public domain (even if encrypted), and convincing business partners to participate in an open share environment. All of this should be implemented while conducting business in parallel with their traditional systems.

3.5.3. Environmental Context

The acceptance and use of ERP and EDI has proven to be significantly influenced by regulator pressure (Iacovou, Benbasat, and Dexter 1995; Kuan and Chau 2001; Schniederjans and Yadav 2013). Therefore, regulators are expected to play an essential role in the adoption stage of blockchain within the accounting sphere. Regulators should have a deep understanding of the technology and its impact on businesses, and provide appropriate guidance and supervision to prevent misuse and abuse of blockchain and smart contracts. They should also think about how the existing accounting standards can be adapted to the increasingly reliable and transparent accounting ecosystem. Moreover, the auditors' role in the new accounting system should be rethought, and the current audit paradigm may need reengineering.

3.6. Conclusions

This chapter proposes a radically different measurement and assurance paradigm utilizing modern blockchain and smart contract technology. Although the technological world has provided business with computers, Internet, cloud computing, and advanced analytic methods, the essence of the accounting measurement model has remained the late medieval model of double entry (Pacioli 1514). Furthermore,

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[14] As in many of modern computer processes, smart contracts will entail large initial investment in development and validation but very small incremental costs in their usage. This will imply also in the progressive layering of smart contracts with increasing degrees of interaction and aggregate complexity.

auditing's (Montgomery 1919) basic approach has been very slowly evolving for a century, making use of technologies limited at best. The fear is that basing modern accounting and auditing in these old technologies will make the processes redundant, non-flexible, defenseless against modern cyber attacks, and dependent on anachronistic rules.

Consequently, after drawing on multiple disciplines and thought pieces from the accounting profession, this chapter argues for a blockchain-based accounting and assurance methodology that would provide real-time, reliable information disclosure and progressively automated assurance. However, the difficulties of both the development and implementation of such a radically different technology cannot be ignored.

Chapter 4. Towards App-based Auditing

4.1. Introduction

The recent advance in technology has created increased analytic opportunities for the auditing profession. Auditors are beginning to use an emerging technology called "Audit Data Analytics" (ADA) to use new evidence from various sources. It could enable risk identification and evidence collection from the whole population of companies' data or even public information, and change the frequency of performing audit from annually or quarterly to close to real time. Following this trend, ADA is expected to "fully replace traditional procedures in areas where assessment of completion, existence, accuracy and valuation can be assessed without specific organizational knowledge beyond account mapping to the financial statement captions" (AICPA 2013).

Although auditors are increasingly aware of the importance and value of data analytics, surveys from both academia and practice (EY 2014; KPMG 2015; Li et al. 2015) indicated that the use of analytics is below expectation. The most significant challenge when performing analytics is the choice of the right tools (EY 2014). In order to perform effective ADA, auditors should use professional judgment to determine issues such as which audit assertions can be supported by analytic technology, what data are needed, and which analytical tools are suitable to accomplish the tasks. However, since auditors generally have limited training in ADA, they may not be able to use it in an effective manner. Choosing appropriate tools would be important to perform useful ADA (Brown-Liburd, Issa, and Lombardi 2015). Since paltry guidance or standards have been issued regarding how to perform ADA in the current audit procedures, auditors may only examine portions of available data, execute partial analyses, and concentrate on issues they specialize in while ignoring other critical ones (O'Leary 2015). In addition, tool developers may have difficulties in discovering potential demand for ADA. Therefore, guidance of integrating the emerging ADA technology into the exiting audit procedures could benefit both auditors and tool developers. Such guidance should provide a synopsis of the process to employ ADA tools on audit tasks, including but not limited to assessing business risks, identifying misstatement, detecting frauds and errors, and capturing inefficient processes. It should also allow for flexibility and experimentation. Furthermore, this guidance should establish a foundation for tool developers to discover the demands of ADA tools that can identify emerging risks, handle new types of data, apply new analytical models, and complement skills of auditors (Byrnes 2015). Finally, the guidance may help further develop the discipline so that students can learn the approach of investigating audit issues through the view of ADA.

Analytical audit apps, a set of formalized analytical tests that can be performed by computerized tools, may serve to popularize ADA. The ease of use, user-friendly interface, and flexibility in operational environment make audit apps potentially popular tools to perform ADA. Although audit apps are quickly growing in popularity, there is limited research and practice in integrating audit apps into current audit procedures through a systematical way. In addition, the increase in number and variety of audit apps, as well as the fact that each vendor has its own audit data standard, would complicate the app selection process. The AICPA has already taken notice; its Audit Data Analysis Enablement Working Group focuses on guidance for external auditors on how to apply data analytics tools to risk assessment and substantive tests (AICPA 2013). While this framework can provide general ADA guidance, it does not facilitate specific app recommendation. Auditors are still left with the considerable problem of choosing the right ADA approaches and the appropriate apps to accomplish the tasks. In addition, the working group's recommendations still do not incorporate differing client needs. Audit apps needed by auditors vary based on client industry, size, risk profile, etc. Individual preference and judgment are also relevant; auditors may choose different audit apps to accomplish the same task because of differences in background knowledge, previous experience, familiarity on technology, etc. Appropriate apps will be able to increase the efficiency and effectiveness of audit activities and facilitate providing timely opinions. It is therefore important to generate customized app recommendations for each particular auditor and client.

This chapter aims to propose a framework that links analytical audit apps to existing audit procedure in order to provide guidance on the use and creation of apps. Based on the framework, an ADA planning system should be designed to integrate apps into a new type of audit plan. An intelligent app recommender system is further designed to suggest the most appropriate analytical apps for auditors to deploy in a particular engagement. Finally, a new app-based audit paradigm is imagined which is composed of the ADA planning system, the app recommender system, and other intelligent audit-aid systems.

The remainder of this chapter proceeds as follows: Section 4.2 proposes a framework that provides guidance on the use and development of analytical audit apps. Section 4.3 presents a preliminary ADA planning system that embeds apps into audit plans. Section 4.4 improves the planning system by suggesting the most appropriate apps based on the recommender system technology. Illustrations on the ADA planning system and the app recommender system are provided in Section 4.5. A new app-based audit paradigm and a potential use case are demonstrated in Section 4.6. The last section concludes this chapter and proposes future research directions.

4.2. A Framework of Linking Analytical Apps to Audit Procedure

Although analytical audit apps are growing in popularity and becoming promising tools to perform effective audits, their adoption remains limited. One of the main challenges is teaching auditors how to incorporate apps into existing audit procedures. Auditors, especially those with less experience and analytics knowledge, will likely desire guidance of employing apps to accomplish audit tasks. However, no guidance has been issued to facilitate integration of audit apps into current audit procedures. In order to assist auditors to efficiently use apps, as well as facilitate the vendors to develop right apps that can fulfill auditors' demands, a framework is proposed to define the factors that should be considered when developing or using apps.

Dai and Li (2016) created a framework that provides guidance of designing and developing armchair audit apps. Although that framework could provide insights on the creation of apps, those apps are particularly designed for "armchair auditors." An armchair auditor may not be a professional auditor, but "anyone who has an interest in government spending, and usually uses technologies to perform analyses" (Dai and Li 2016). As a result, a framework geared toward armchair auditors would not be suitable to guide professional auditors. Therefore, a new framework that provides app use and creation guidance for profession auditors is developed in this section (shown in Figure 11).

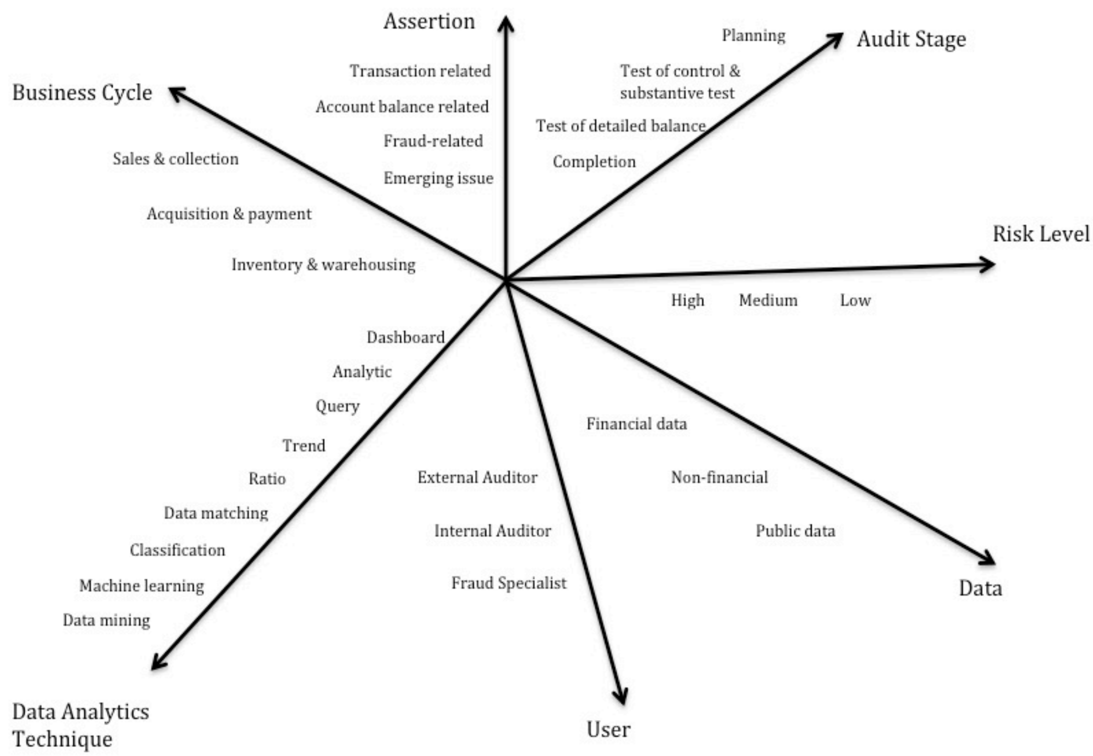

Figure 11: A framework of creating and using analytical audit apps

The framework is composed of seven dimensions: 1) assertion, 2) business cycle, 3) audit stage 4) risk level, 5) data, 6) data analytics technique, and 7) user. The first four dimensions follow the common procedures of performing audit. Since a successful use of data analytics application should embed tools into current processes (Siegel 2013), apps should be linked to existing audit procedure in order to facilitate performing efficient audit-oriented data analytics. In addition to the normal procedure in which auditors decide the assertions to test, they should also determine which assertions can be examined by apps, and which require manual work (Vasarhelyi et al. 2014). Existence, accuracy, and valuation are the main assertions on which apps could contribute to collect useful evidence (AICPA 2013). More importantly, assertions about emerging issues of a less traditional nature (Bumgarner and Vasarhelyi 2015) should be considered in addition to those that have been defined by international auditing standards and U.S. GAAS. An assertion is defined as “the concern of auditors of particular system faults” (Bumgarner and Vasarhelyi 2015). As the modern business model becomes increasingly complex, traditional assertions will no longer be enough to cover the whole set of auditors’ concerns. With the advance in data analytics and the increasing availability of data from a variety of resources, audit apps can facilitate auditors to discover more system faults than they used to do. Therefore, new assertions about emerging issues could be the key targets to consider when designing and using apps.

Auditors currently investigate financial statements by cycles (Arens, Elder, and Mark 2012). In order to facilitate auditors to use analytical audit apps, apps should be associated with the cycles in which they could perform the best investigations. Audit stage is another important factor that determines the appropriateness of apps. Each audit stage has different tasks and therefore has unique demands of apps. For example, at the planning stage auditors may use apps to identify high-risk business processes, while to perform substantive tests auditors choose apps that can test particular assertions. App developers should suggest the audit stage in which an app is specialized to help auditors understand and use this tool.

At the beginning of an audit, auditors should assess client risks in order to determine the nature and extent of further audit tests (Arens, Elder, and Mark 2012). In the analytics based audit, risk assessment remains critical because it provides a foundation for deciding the number and functions of apps to be used in the remainder of the audit. High-risk business processes would need apps with more sophisticated functions, and required much more analytical tests than less risky areas. Therefore, associating apps with the risk levels of the conditions in which they could provide the best analyses could help auditors choose the right apps in the investigation of different areas.

The fifth and sixth dimensions focus on the technology perspective. Auditing big data has proven challenging for auditors (Brown et al. 2015; Dai and Li 2016; O'leary 2015). Modem ERP systems gather and generate large quantities of financial data as well as non-financial information regarding business operations. In addition, more complex data that are not recorded by ERP systems, such as customer telephone recordings, customers' comments from online forums, and surveillance videos are now collected to facilitate governance and predictions (Vasarhelyi, Kogan, and Tuttle 2015). Auditors also have access to a vast amount of public data outside of the organization. News and articles, social media postings, and even government open data (O'Leary 2015), could contribute to identify suspicious transactions and support investigations. A recent survey revealed that data quality and availability are the biggest barriers of using data analytics (KPMG 2015). Therefore, auditors need first to carefully examine data quality and integrity, and then select apps that perform effective analyses on the high-quality and relevant data. App developers could also obtain insights and create apps to analyze new types of data.

Big data creates many analytic opportunities for auditors. However, performing efficient and effective analyses is always challenging. As the volume and variety of data are rapidly growing, auditors seek state-of-the-art analytical techniques to obtain accurate results as well as save time. Vasarhelyi et al. (2014) proposed a list of commonly used data analytics techniques:

"Dashboard—provides a quick snapshot of a data state;
Analytic—statistical or summary procedure;
Query—pulls records matching specific criteria;
Trend—evaluates values over time;
Ratio—compares relationships of data;
Data matching—used to find duplicate or missing data;
Classification—groups data elements on similar attributes."

In addition to the above basic data analytics, researchers are exploring the use of more sophisticated techniques in audit, e.g., utilizing data mining or machine learning models in fraud or anomaly detection. For example, clustering models could be used to detect fraudulent life insurance claims, or identify inefficiency of discount offering processes (Dai, Byrnes, and Vasarhelyi 2013; Thiprungsri and Vasarhelyi 2011). Processing mining techniques could be applied to monitor internal controls (Jan, Alles, and Vasarhelyi 2014). Although those advanced technologies have not been widely used in audit practice, they are expected to eventually play an important role in identifying risks, predicting loss, and improving assurance.

The last dimension considers the role of users that could affect app selection. External auditors, internal auditors, and fraud specialists play different roles in financial investigation and thereby have special demands on app functions. As external auditors mainly focus on financial statements, they would desire apps that can detect material misstatements. Internal auditors are more interested in internal control and operational risks, and they usually have relatively frequent access to various companies' internal data (Li et al. 2017). Therefore, internal auditors are likely to favor apps that can handle large volume transactional or business process data. To detect fraudulent transactions, fraud specialists could have the demand of the apps that analyze complex business processes and uncover unusual behaviors that fraudsters intend to hide. To sum up, the role of users need to be considered when designing audit apps, and different apps should be developed to meet the special demands of each type of users.

Appendix B uses a matrix to show a collection of existing analytical audit apps and how they can be linked to the framework using. The matrix lists selected apps[1] from the Caseware app marketplace. Each app is associated with the assertion the app can support, the business cycle and audit stage in which the app are specialized, the risk level of the area the app can perform the best analyses, the data the app need to perform analysis, the technique that app uses, and the users for whom the app is designed. On current market, more apps are designed for substantive testing than other audit stages. Data required by apps are typical financial, rather than alternative data such as customer comments or data from news or reports. Mainly basic data analytics techniques have been employed through apps, which leave a large space for developers to create more sophisticated apps. Few fraud-related apps have been released, probably because economics of scale of those apps do not justify their development.

4.3. A Preliminary Audit Data Analytics (ADA) Planning System

Section 4.2 demonstrates a framework that links apps with the existing audit procedure. Based on the framework, this section proposes a preliminary planning system that embeds apps into a new type of audit plan, the Audit Data Analytics (ADA) plan, to provide guidance on performing analytical audits. The system would maintain a matrix that contains the latest audit apps on market and relevant information. Auditors would use their professional judgment to determine the audit stages in which apps could be used, the business cycles that require analytical work, and which assertions can be supported by

[1] There are 57 analytical apps in the Caseware Financial App package.

technology. Auditors could then choose the apps that only need the data they can access and use analytics techniques they are comfortable with. Based on those inputs from auditors, as well as the assessed risks of clients and the type of users, the system would generate an audit plan that suggests a list of apps to be used in the engagement. The design of the system is shown in Figure 12.

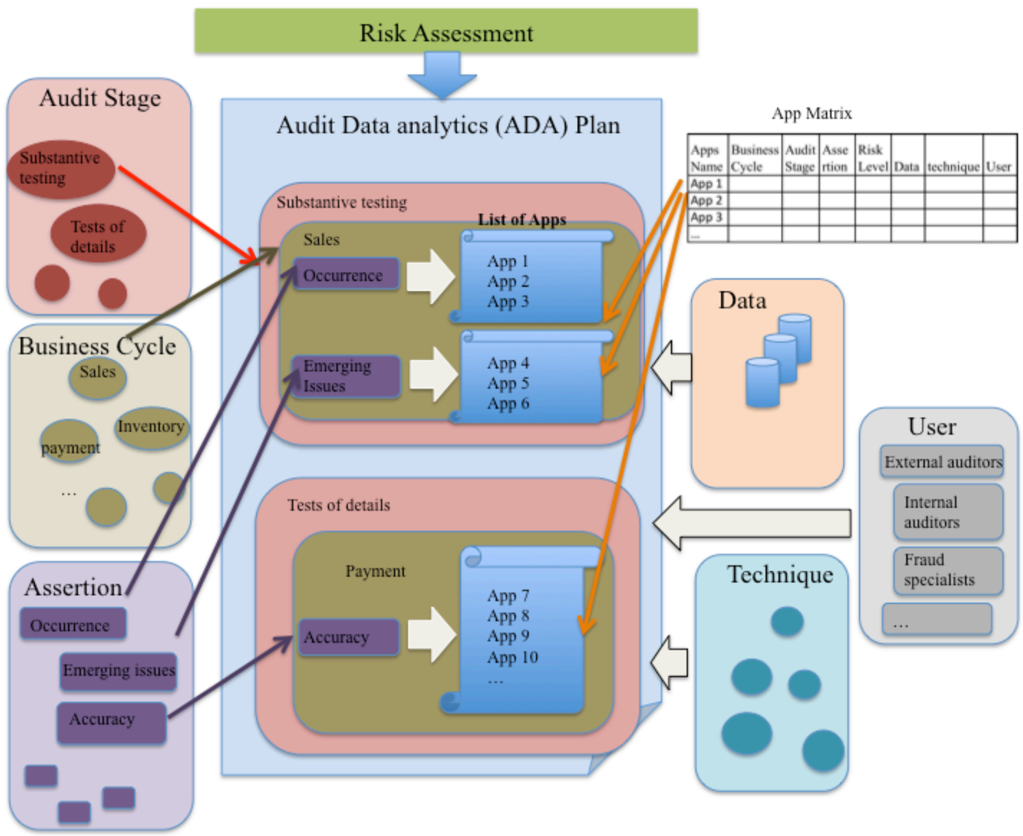

Figure 12: A preliminary planning system for audit apps

Compliant with the framework of developing and using analytical audit apps, the system would select appropriate apps from six key perspectives: audit stage, business cycle, assertion, risk level, data source, technique, and user. The matrix would record the information of each audit app available on market, and would be updated periodically to capture newly released apps. When using the system, an auditor would first choose audit stages, business cycles, and assertions they would like to perform analytical work. This step is critical because the auditor needs professional judgment to decide the scope of necessary analytics (Vasarhelyi et al. 2014). Failure to determine the appropriate scope may weaken the efficiency or effectiveness of the analytical audit. For example, a smaller scope may leads to insufficient analytical tests and ignorance on high-risk transactions, while using analytics in every area could result in a large waste of effort and money. Assessed risks of the audit client would also be used to guarantee that sufficient and appropriate apps are chosen.

For each combination of selected stages, cycles, and assertions, the system would search the matrix and collect apps that meet the criteria, and generate a sub-matrix of apps. The system would further scan the sub-matrix and present to the auditor the options of 1) the data that should be prepared in order to perform analyses, and 2) the techniques that are available to analyze the data. Based on data availability and quality, as well as the knowledge level, the auditor would then select the data that have already been collected, and the techniques with which they are comfortable. The auditor could also specify his/her role as an external auditor, an internal auditor, or a fraud specialist.

After collecting inputs from the auditor, the system would screen the sub-matrix for the apps that only require available data, use the techniques the auditors can understand, and are specifically designed for that type of auditor. The system would then generate an ADA plan by organizing and grouping those apps based on their audit stage, business cycles, and assertions. The required data, techniques would also be clearly listed aside of each app. The auditor could review the ADA plan and discard apps that are not suitable for the engagement. The auditor could also add new apps, which may not be included in the system, to the ADA plan. The system would store the final version of the ADA plan for documentation and future use.

When new apps are added to an ADA plan, the system would note the new apps suggested by the auditor, as well as the associated information. The system administrator would periodically survey new apps. If a new app can be found on the market and proved to perform effective analytics, the system would then add it to the matrix for future app suggestion.

4.4. An Intelligent App Recommender System (ARS)

A potential problem of the preliminary ADA planning system is its heavy reliance on auditor judgment. Since data analytics and audit apps are emerging technology, auditors may not have sufficient knowledge and experience to make proper choices. Another problem is that the system does not consider the nature of audit clients and auditors' preferences. As a result, the system would generate a uniform ADA plan if auditors select the same audit stages, business cycles, assertions, risk levels, data, techniques and user type. However, different audit clients may require different apps, while the same data analytics routines may be applied to audit clients in similar situations. Therefore, to help less experienced auditors to effectively use apps and to enhance the quality of the ADA plan, the planning system must be able to provide intelligent app recommendation.

A recommender system could serve as a valuable tool to identify the most appropriate apps to be used in a specific engagement and filter out irrelevant ones. This technology is superior to other information filtering applications (e.g. search engines, spam filters, etc.) because of their ability to provide personalized and meaningful recommendations (Zhou, Xu, Li, Josang, and Cox 2012). Unlike standard search engines that provide the same results for the same queries from different users, recommender systems are able to use personal characteristics and behaviors to provide personalized, relevant results to each individual user. Because of this advantage, recommender systems can suggest the best apps by analyzing the audit standards, audit clients and auditors' historical preferences.

This section proposes an audit app recommender system (ARS), which can help auditors select appropriate apps for a particular engagement. This framework is vendor-independent; collecting and making recommendations among all audit apps on the market without bias. The framework of the app recommender system is shown in Figure 13. The proposed system would make app recommendations via three components: audit standards, audit clients, and auditor preferences. Recommendations based on audit standards would be generated by creating a structure that categorizes audit apps by industry, business cycle, account, audit assertion, and audit objective. These recommendations would create a narrowed initial selection of audit apps that would be then refined by client and by auditor preference. Recommendations based on audit clients would be created using a two-stage Collaborate Filtering (CF) approach to estimate the suitability of an audit app for a particular client. Recommendations based on auditors' preferences would be also performed using the CF approach to predict the rating that a particular auditor will give to an audit app. The system would create a final score for each audit app by combining the results from these two filtrations, recommending apps with high scores to the auditor.

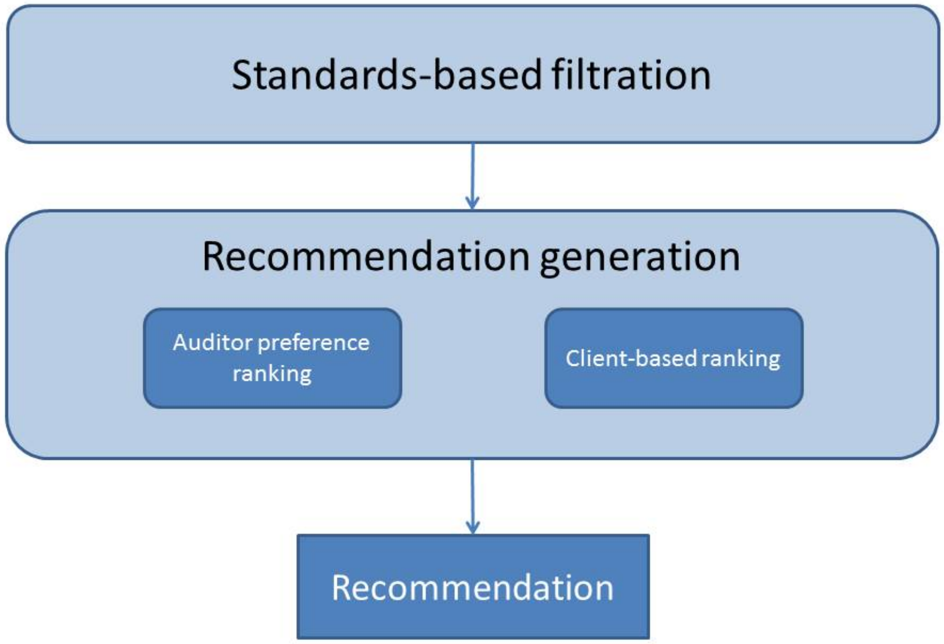

Figure 13: Design of the audit app recommendation system

4.4.1. Recommendations based on Audit Standards

When conducting financial statement audits, auditors may follow five key steps to develop audit objectives: understanding objectives and responsibilities, dividing financial statements into cycles, knowing management assertions, knowing general audit objectives, and knowing specific audit objectives (Arens, Elder, and Mark 2012). After identifying specific objectives, auditors can perform corresponding procedures on transactions, account balances, and related disclosures. The app selection process must follow this procedure, additionally controlling for client industry. Client industry is an important factor that would drive the choice of audit apps to use in particular engagements. Each industry has special business processes and risks, in which auditors would need different analytics and data to collect evidence. For example, finance and insurance companies do not purchase or produce physical products, so inventory-testing apps should be filtered out for those client types. Finance and insurance industry-specific apps should likewise be filtered out when dealing with retail clients. Similarly, water pollution would be considered as a significant risk for beverage companies, but may have a moderate impact on other industries. The AICPA (2014) has provided guidance and delivered “how-to” advice for handling auditing issues in different industries. Within a specific industry, auditors must also identify cycle (e.g. sales and collection, procurement and payment, etc.) and individual accounts within that cycle. Each account is associated with several management assertions. Auditors choose a specific audit objective based on such an assertion so that the audit apps that can test such audit objective will be recommended.

A proper app recommender system must fit into this process. The proposed system is shown in Figure 14. The system would filter audit apps by industry, business cycle, account, assertion, and audit objective before producing a final set of recommendations. Industry selection would generate a list of industries that covers all possible industry categories. Business cycle selection would link each industry with all possible business cycles for clients in that industry. Account selection would associate each business cycle with all possible related accounts. Assertion selection would link assertions with corresponding accounts. Objectives would be linked to corresponding assertions during objectives selection. Finally, the system would link all available audit apps with the audit objectives they can test. Each audit app may investigate one or more audit objectives, while each audit objective may also be linked to many audit apps, since those audit apps cooperate to accomplish that audit objective. Using the system, an auditor could choose the client’s industry and the relevant business cycle, account, assertion, and audit objective, and finally obtain a narrowed initial array of objective-appropriate audit apps.

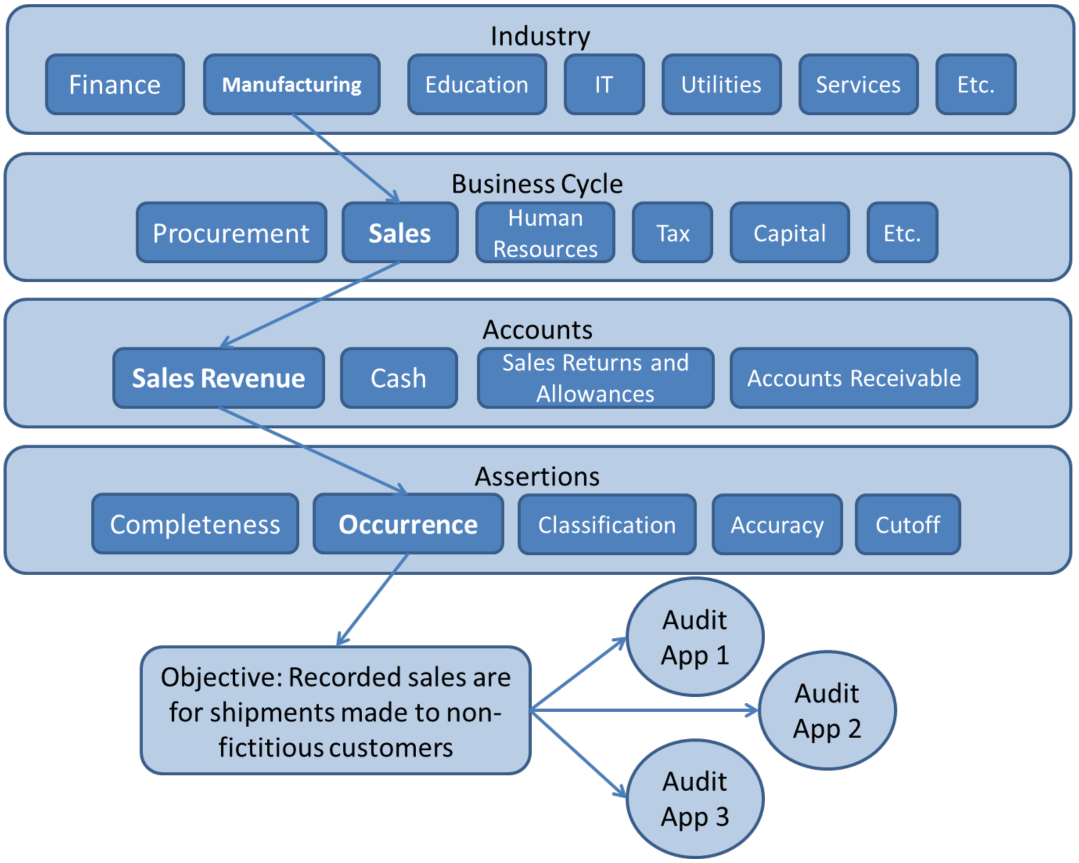

Figure 14: Recommendations based on audit standards

As the use of audit apps grows, apps will be developed with increasing frequency, hampering manual classification of new apps within the system. One solution is to encourage app vendors to link new apps to related objectives at the time of launch. Vendors will be motivated to classify their apps into the system in order to increase visibility and use. An alternative is to apply text-mining techniques to automate the process of classifying new apps. This section uses the first solution, which lets app vendors link new audit apps to related audit objectives.

4.4.2. Recommendations based on Audit Clients

Since the number of audit apps is expected to increase dramatically, it is possible that a narrowed initial selection of audit apps may still contain dozens of apps, leading to a time-consuming search process even after the initial filtration. Therefore, the results of standards-based filtration should be further refined. Since audit problems usually have a large number of solutions and it is difficult to choose the best one, such problems often are solved using heuristic approaches (O'Leary and Watkins 1989). The ARS uses the heuristics approach. Specifically, if an app has been frequently used by auditors for similar clients (e.g., The Target Corporation), that app is likely to be appropriate for the next such client (e.g., Wal-Mart Inc.). A mechanism to identify such apps could further refine and prioritize recommendation results.

To generate client-based recommendations, a CF recommendation approach (derived from Zhang, Dai, Li, Li and Luo [2011]) is used to predict the suitability of an app to be used for an audit client. The underlying assumption is that the more the audit app has been used for similar audit clients in the past, the more suitable that app is to be used in a given instance. As shown in Figure 15, the approach has two clustering-based phases: 1) preparation, which would group audit clients based on an app usage matrix, and 2) recommendation, which would make predictions based on the nearest cluster to a given client.

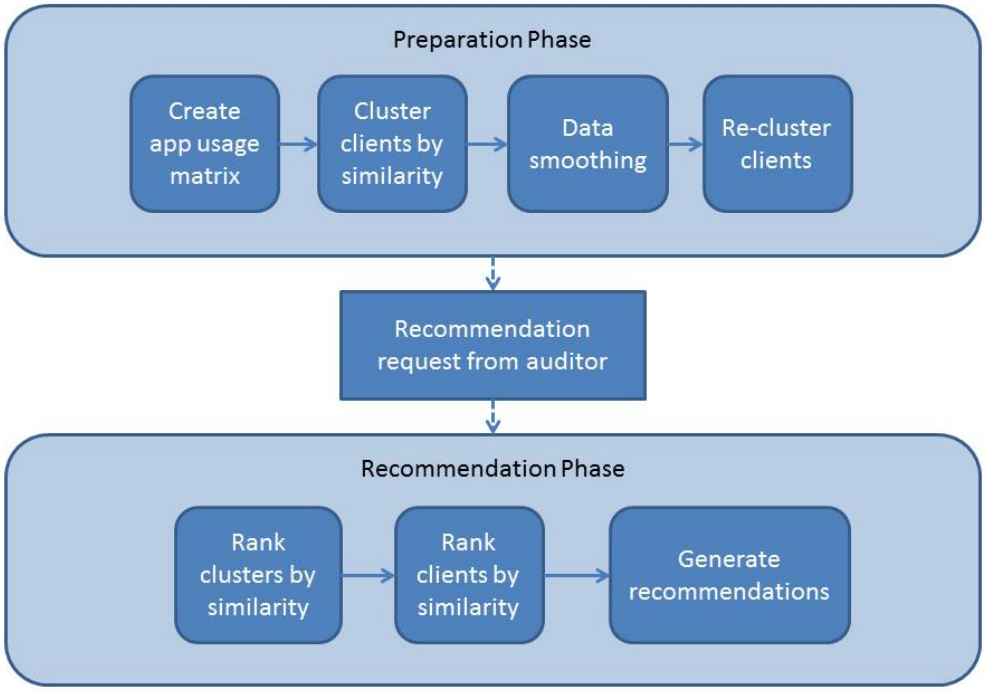

Figure 15:Two-phase clustering-based recommendation

The details of the proposed approach are as follows. In the preparation phase, an app-usage matrix (shown in Table 5) would be first created to record the usage frequency of each audit app for each audit client. The usage frequency could be captured by analyzing system log, or simply asking users to provide such information. This matrix would be used as the basic data source to generate recommendation. Each row represents as audit client, and each column represents an app. Each cell, at the intersection of a row and a column, represents how many times a specific app has been used for a specific client in the past one year. The reason to choose a one-year window for calculating audit app usage is that in a dynamic environment, audit app commonly gain or lose popularity due to updates or competition from other apps. One potential problem of the matrix is that it may be too sparse to be used for providing accurate recommendation. Apps, especially at the adoption phase, could be familiar to few auditors, and the use of them in audit engagements would be rare. To solve this problem, app-usage matrix could be extended by adding clients' information, such as firm size, risk profile, etc. Such information could weaken the sparseness of the matrix, and thereby improve the recommendation accuracy.

Table 5: App-usage matrix

	Audit App 1	Audit App 2	Audit App 3	…	Firm Size	Risk profile
Client 1	U_1	U_3		…	…	…
Client 2	U_2		U_5	…	…	…
Client 3		U_4		…	…	…
…	…	…	…	…	…	…

Based on the app-usage matrix, audit clients would be then clustered into groups, using classic clustering methods, such as k-medoids (Han, Kamber, and Pei 2006). The main objective of the clustering is to accelerate the recommendation phase. Another benefit of the client clusters is to facilitate further mitigation of the sparseness problem. The ARS could estimate the missing values in the app-usage matrix based on the information from the clients in the same cluster. This method is based on the assumption that the usage frequency of a certain audit app should be similar for the audit clients in the same clusters, due to the fact that those audit clients share similar features with each other. Thus, it is reasonable to utilize the usage frequency of an audit app for audit clients to estimate the missing usage of the app for clients in the same cluster. For the audit client i in cluster k, the missing usage for audit app j can be smoothed as:

$$\mathrm{U}_{\mathrm{i,j}} = \delta(\overline{\mathrm{U}}_{\mathrm{k,j}}) \tag{1}$$

where $\overline{\mathrm{U}}_{\mathrm{k,j}}$ is the average instances of use of audit app j for all audit clients in cluster k, and δ is a coefficient that allows adjustment in the contribution of the data smoothing.

Next, the ARS would re-cluster the clients using the smoothed app-usage matrix. After obtaining new audit client groups, the preparation phase would end. This step could be performed on a continual basis without any human intervention.

When an auditor requests app recommendation for a particular client, the recommendation phase would begin. In this phase, the ARS would predict the usage frequency of an audit app for the target client using the average usage frequency for similar audit clients in the past. To speed up the selection of similar audit clients, the ARS would first find the top N similar client clusters for the target client, and choose the top M similar clients from those similar clusters.

In order to find the top N similar client clusters, the similarity between the target client and the centroid of each client cluster should be measured. The similarity could be calculated using the Pearson Correlation Coefficient (Sarwar et al. 2001):

$$\mathrm{s}(\mathrm{x},\mathrm{y}) = \frac{\Sigma_{\mathrm{j}=1}^{|\mathrm{x}\cap\mathrm{y}|}(\mathrm{U}_{\mathrm{x,j}}-\overline{\mathrm{U}}_{\mathrm{x}})(\mathrm{U}_{\mathrm{y,j}}-\overline{\mathrm{U}}_{\mathrm{y}})}{\sqrt{\Sigma_{\mathrm{j}=1}^{|\mathrm{x}\cap\mathrm{y}|}(\mathrm{U}_{\mathrm{x,j}}-\overline{\mathrm{U}}_{\mathrm{x}})^2}\sqrt{\Sigma_{\mathrm{j}=1}^{|\mathrm{x}\cap\mathrm{y}|}(\mathrm{U}_{\mathrm{y,j}}-\overline{\mathrm{U}}_{\mathrm{y}})^2}} \tag{2}$$

where $\mathrm{s}(\mathrm{x},\mathrm{y})$ denotes the similarity between client x and y (in this case, x is the target client, and y is the centroid client in an cluster); |x∩y| is the number of apps that have been used for the both clients; $\overline{U}_x$ and $\overline{U}_y$ are the average app usage frequency for client x and y; and $U_{x,j}$ and $U_{y,j}$ denote the usage frequency of app j for client x and y.

Using the same formula, the similarity between the target client and each client in the top N similar clusters could be calculated, which would then be used to select the top M target clients. With the top M similar audit clients, the usage frequency of an app for the target client could be predicted by taking the weighted average of deviations from the mean usage frequency of the audit app for similar audit clients. The weighted sum (Sarwar et al. 2001) would be used to predict the usage frequency of audit app j for audit client i:

$$P_{i,j} = \frac{\sum_{k=1}^{m} s(i,k) \times U_{k,j}}{\sum_{k=1}^{m} |(s(i,k)|} \tag{3}$$

$P_{i.j}$, represents the predicted usage frequency of app j for client i; m denotes the top M similar clients of the target client i; $s(i, k)$ measures the similarity between client i and each similar client; and $U_{k,j}$ represents the usage frequency of app j for client k (which is one of the similar clients). Using this formula, the potential usage frequency of each audit app for the target client could be predicted by capturing how similar clients use the app.

4.4.3. Recommendations based on Auditors' Preferences on Apps

Auditors' own familiarity with the technique would also drive the choice of technique(s) to use in particular environments (Murthy and Groomer 2003); therefore, auditors' preferences can be used to further refine audit app recommendations. Auditors may have specific preferences regarding app vendors, versions, underlying analytical models, user interfaces, etc. Some auditors like apps developed by large vendors rather than small vendors or individuals; some auditors prefer older, stable versions of audit apps, while others prefer the latest versions; some favor apps with fancy user interface such as those allowing hand gestures, while others prefer more conventional operation. An effective recommendation system could incorporate these preferences to enhance result accuracy.

The ARS would incorporate auditors' preference into recommendation using a similar approach as used for the client-based recommendation. This approach is based on the assumption that auditors often choose apps that are consistent with their historical preferences, as well as the experiences and knowledge gained from their colleagues. Two auditors who have chosen the same apps in the past are likely to have similar preferences on apps in the future. The ratings of the first should influence the recommendations for the second. The preference-based approach also has two phases: preparation and recommendation. In the preparation phase, auditors would be clustered based on preference similarity; in the recommendation phase, the system would generate a list of apps for a specific auditor based on the app ratings from similar auditors.

The details of the proposed approach are as follows. In preparation phase, an auditor-rating matrix (shown in Table 6) would be created. Each row and column represents an auditor and an app, respectively. Each cell represents the rating that the auditor in the row has given to an audit app in the past. This matrix may have the same data sparseness problem as that in the app-usage matrix, as one auditor is likely to use and rate only a few apps. To address this problem, the matrix could also be extended by adding demographical information of auditors, such as their position levels, the accounting firms they work for, etc. Such information could facilitate the clustering of auditors and identifying those who have similar preferences on apps.

Using the auditor-rating matrix, the ARS would cluster similar auditors into groups, and smooth missing ratings using the formula (1). Then, auditors would be re-clustered, and the preparation phase would end.

Table 6: Auditor-rating matrix

	Audit App 1	Audit App2	Audit App 3	…	Position level	Audit Firm
Auditor 1	R_1	R_4	R_5	…	…	…
Auditor 2	R_2		R_6	…	…	…
Auditor 3	R_3			…	…	…
…	…	…	…	…	…	…

In the recommendation phase, the ARS would predict the rating of an audit app using the average of ratings that similar auditors have given to the audit app in the past. Specifically, the ARS would first identify the top N similar auditor clusters to the target auditor, and then select the top M similar auditors within those similar clusters. The similarity between the target auditor and the centroid of each auditor cluster could also be measured using the formula (2). After obtaining M most similar auditors, the ARS would predict the rating of an audit app given by the target auditor by using the weighted sum (formula (3)) of the ratings that the similar auditors have given to the app.

4.4.4. Scores of Audit Apps and Final Recommendation

The two predictions from the client-based and preference-based approaches would be combined to generate a final, client- and auditor-specific recommendation score for an app using a weighted linear model. The final recommendation score for the app would be calculated as:

$$Score = \delta P_u + (1- \delta) P_r$$

Where P_u represents the predicted usage frequency of the audit app for the target client, P_r represents the predicted rating that the target auditor will give to the app, and δ is the coefficient to adjust the contribution of each component. Finally, apps with high scores will be recommended to the auditor.

One of the potential problems when using the app recommender system is that typically a set of apps can only operate on certain software but not on others. As a result, the software that auditors have will constrain their choice of apps. To solve this problem, efforts could be made by industry associations such as AICPA to create common standards that all vendors should follow to develop apps. The apps compliant with the common standards would be able to operate on different platforms and environments, which would allow the full use of the available apps, as well as eliminate the waste of duplicated tools. However, even without common standards, the recommender system will still be useful for recommending apps from a single vendor, if the number of apps outstrip auditors' ability to manually review each app and choose the most appropriate ones.

4.5. Illustration

This section provides two illustrations on the ADA planning system and the intelligent app recommender system[2], respectively. The first illustration shows the process of using the preliminary ADA planning system to embed audit apps into existing

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[2] Microsoft Access 2013 is used to perform the illustrations.

audit procedure. The second one demonstrates how the app recommender system can suggest appropriate apps based on the app usage and rating history.

The ADA planning system is first illustrated. The first step is to let auditors put in the scope and nature of the analytical work they decide to perform. Figure 16 presents the input dialog that auditors will use to select apps and generate the ADA plan.

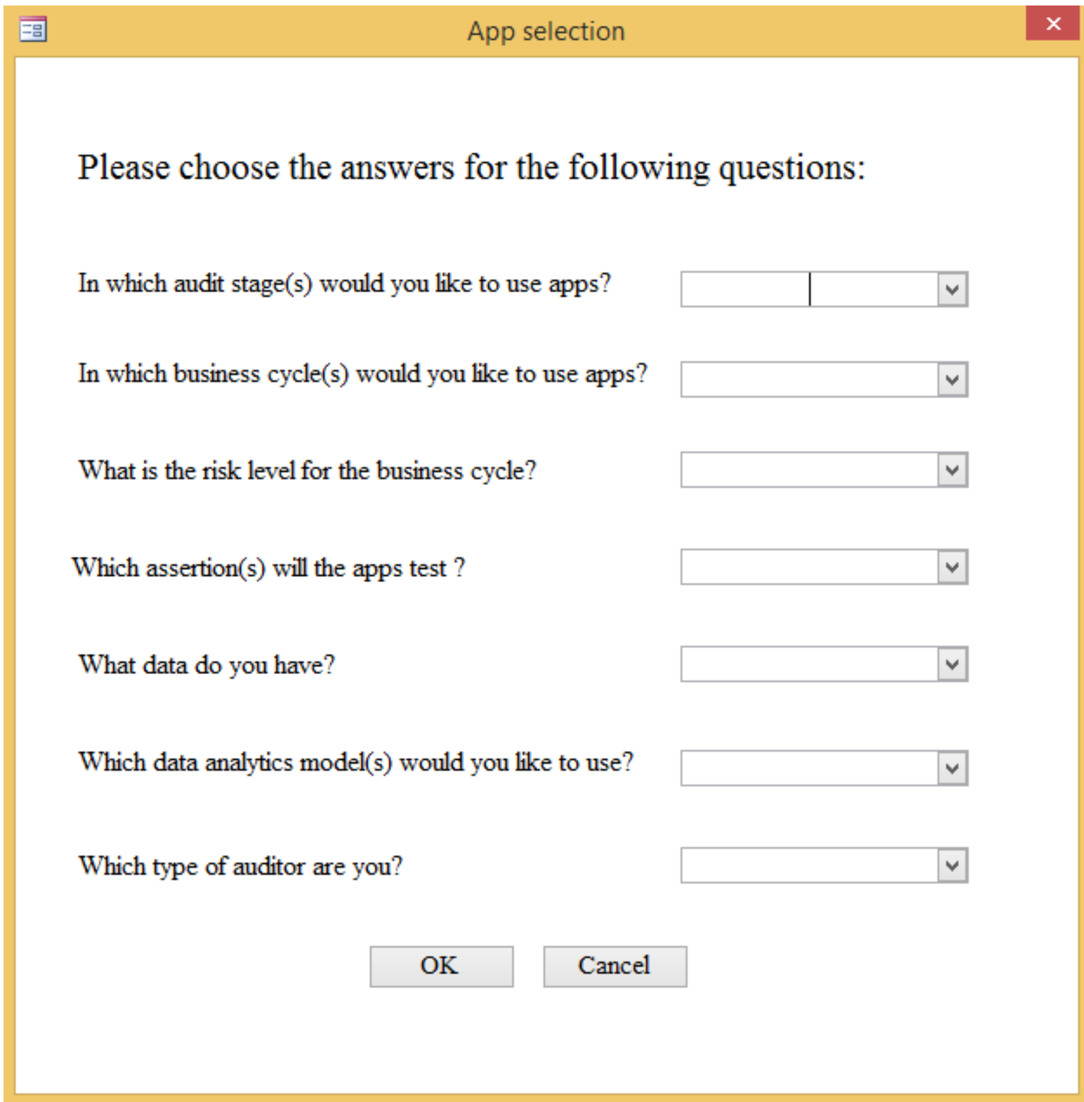
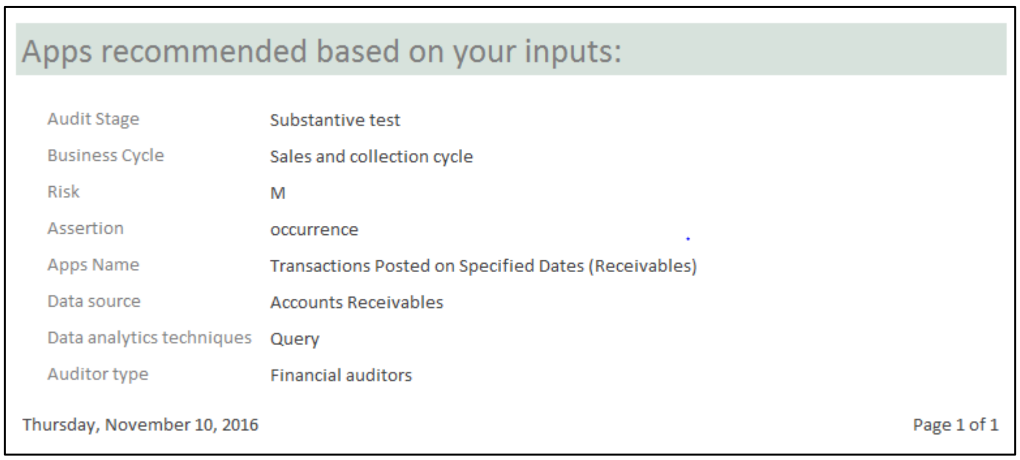


Figure 16: Auditors' inputs to the ADA planning system

Auditors will choose from the dropdown menu to answer each question. After obtain auditors' inputs, the planning system will screen its app matrix to identify those apps that fulfill all the criteria. In this illustration, the table in Appendix B (which includes 57 audit apps from the Caseware Financial App package) is used as the app matrix. Figure 17 shows the app recommendation when the auditor select “substantive test” as the audit stage, “sales and collection” as the business cycle, “occurrence” as the assertion, “M” as the risk level, “accounts receivable” as the data source, “query” as the data analytics technique, and “financial auditors” as the audit type.


Apps recommended based on your inputs:

Audit Stage	Substantive test
Business Cycle	Sales and collection cycle
Risk	M
Assertion	occurrence
Apps Name	Transactions Posted on Specified Dates (Receivables)
Data source	Accounts Receivables
Data analytics techniques	Query
Auditor type	Financial auditors

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Figure 17: A sample results of the ADA planning system

As the app matrix in Appendix B has only one app (the app “Transactions Posted on Specified Dates (Receivables)”) that meets all the requirements, the planning system will suggest this app to the auditor. The results could include more than one app if there are multiple apps in the matrix that fulfill the criteria. This process will be rerun if the auditor needs to change the input. Finally, the system will embed the all the selected apps into the ADA plan. An example of the ADA plan is shown in Figure 18[3].

[3] This ADA plan is generated for a financial auditor who decides to use apps to perform substantive test in the acquisition and payment cycle that is identified as high risk, and to use the “query” technique to perform analysis on the data in payable account.

RUTGERS
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Newark and New Brunswick

Audit Data Analytics Plan

Friday, February 10, 2017

This audit data analytics plan is designed for ABC company and generate based on the requirements of auditor XYZ

Apps Name	Creditors with Total Invoice Amount Greater than Approved Limit
Audit Stage	Substantive test
Business Cycle	Acquisition and payment cycle
Risk	H
Assertion	accuracy
Data source	Accounts Payables
Data analytics techniques	Query
Auditor type	Financial auditors

Apps Name	Creditors with Net Debit Balance
Audit Stage	Substantive test
Business Cycle	Acquisition and payment cycle
Risk	H
Assertion	accuracy
Data source	Accounts Payables
Data analytics techniques	Query
Auditor type	Financial auditors

Apps Name	Creditors with Balances Greater than Approved Limit
Audit Stage	Substantive test
Business Cycle	Acquisition and payment cycle
Risk	H
Assertion	accuracy
Data source	Accounts Payables
Data analytics techniques	Query
Auditor type	Financial auditors

Page 1 of 1

Figure 18: A sample ADA plan

The second illustration is on the intelligent app recommender system. The first step is to perform an initial filtering on apps by the specific industry, business cycle, account, and assertion that an app is designed for. An auditor will use the input dialog (shown in Figure 19) to provide that information.

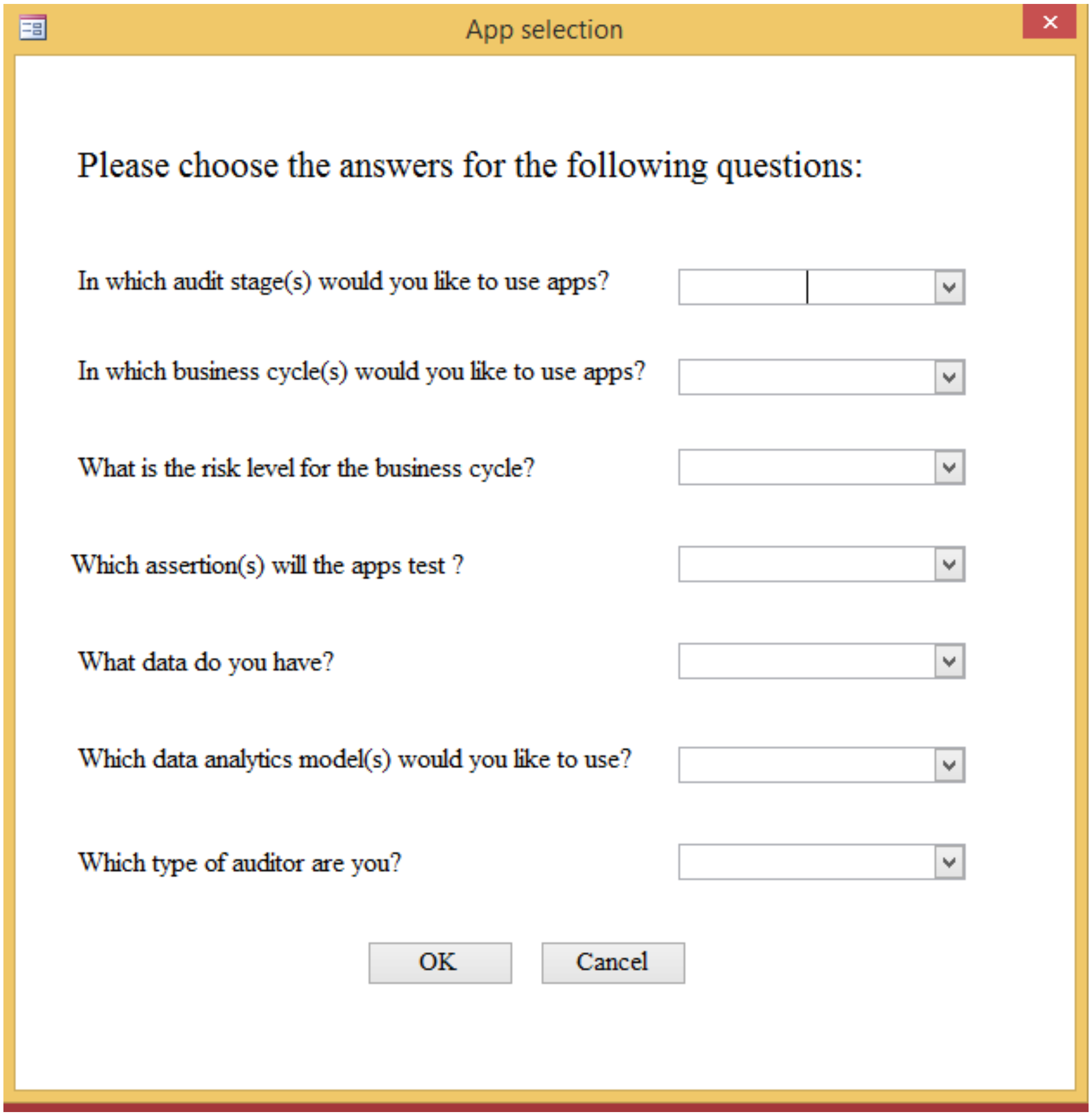

Figure 19: The initial screen of the intelligent app recommender system

With auditors' inputs, the app recommender will filter out the apps that do not meet all the criteria, paring down to a group of candidate apps. Table 7 shows the examples of app candidates used in this illustration.

Table 7: Examples of app candidates

Apps Name	Industry	Business Cycle	Account	Assertion
Aging by Receipt Date and Unit Cost	General	Inventory and warehousing cycle	Inventory	occurrence
Zero and Negative Unit Cost	General	Inventory and warehousing cycle	Inventory	accuracy
Recalculate Inventory Balance	General	Inventory and warehousing cycle	Inventory	accuracy
Negative Quantity on Hand	General	Inventory and warehousing cycle	Inventory	completeness
Last Sales Price Lower than Unit Cost	General	Inventory and warehousing cycle	Inventory	accuracy
Large Inventory Amounts	General	Inventory and warehousing cycle	Inventory	occurrence
Inventory Received Around Specified Date	General	Inventory and warehousing cycle	Inventory	cutoff

After obtaining the app candidates, the app recommender system will screen the auditor-rating matrix in the system and create a narrowed rating matrix that will only include the information on the app candidates. Table 8 shows the narrowed rating matrix that only has the ratings for the app candidates in Table 7.

Table 8: An example of the narrowed auditor-rating matrix

	Aging by Receipt Date and Unit Cost	Zero and Negative Unit Cost	Recalculate Inventory Balance	Negative Quantity on Hand	Last Sales Price Lower than Unit Cost	Large Inventory Amounts	Inventory Received Around Specified Date
Auditor 1	1	4	1	5	4	5	1
Auditor 2	5		4	3		2	
Auditor 3	1	5		4	5	4	1
Target auditor	1						

Based on the ratings in Table 8, the app recommender system will calculate the similarity of each pair of auditors, and group auditors with similar app preferences into clusters. Clearly, auditors 1 and 3 gave similar ratings to apps in the past, and the ratings are far different from what auditor 2 gave. Therefore, auditors 1 and 2 will be grouped together.

Since the auditor-rating matrix could be sparse, the recommender system will also capture the demographical information on auditors in order to facilitate the clustering of similar auditors. Figure 20 presents the input dialogs that auditors will use to provide such information.

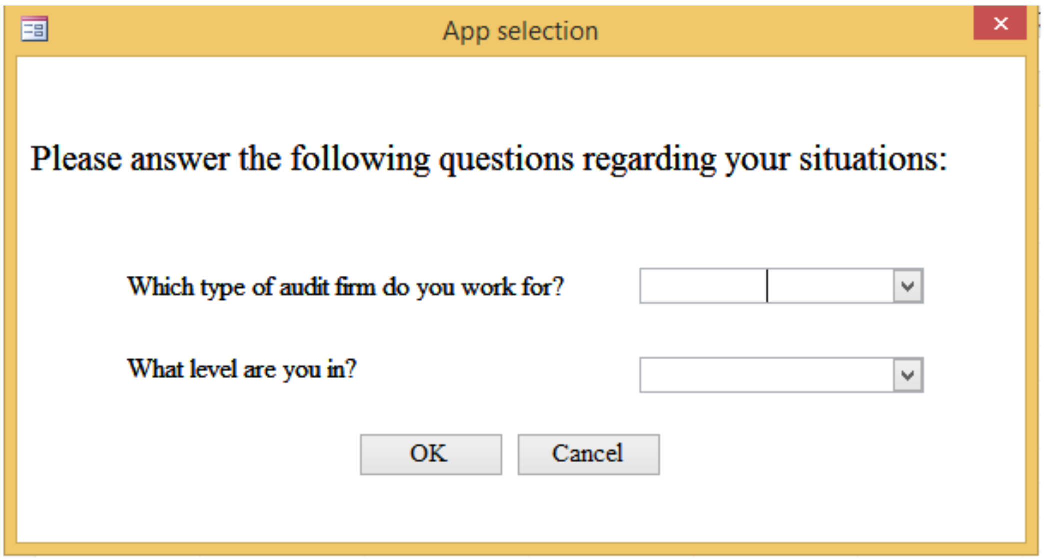

Figure 20: The input dialog for auditors' information

After capturing the demographic information of auditors, the app recommender system will extend the rating matrix by adding information regarding auditors' position level and employing firm. Table 9 demonstrates the extended auditor-rating matrix used in this illustration.

Table 9: An example of the extended auditor-rating matrix

	Aging by Receipt Date and Unit Cost	Zero and Negative Unit Cost	Recalculate Inventory Balance	Negative Quantity on Hand	Last Sales Price Lower than Unit Cost	Large Inventory Amounts	Inventory Received Around Specified Date	Position level	Audit Firm
Auditor 1	1	5	5	5	5	5	1	Senior	EY
Auditor 2	5		4	3		2		Junior	PwC
Auditor 3	1	5		4	5	4	1	Manager	EY
Target auditor	1							Senior	EY

Based on the information in Table 9, auditor 1 and 3 should still be clustered together as they have similar preference on apps, and both work for EY. The main difference is their position level: auditor 1 is a senior auditor while auditor 3 is at the manager level. The system will then choose the auditor clusters that have the similar characteristics and app preferences as the target auditor. The cluster with auditor 1 and 3 is similar to the target auditor, because they all gave the app “Aging by Receipt Date and Unit Cost” a low rating (which is 1) in the past, and all of them work for EY. However, as auditor 1 and the target auditor are both at senior level, which is different from auditor 3, auditor 1 will be considered as the most similar one, and his ratings of apps will be used to predict the opinion of the target auditor. As auditor 1 gave a rating of 5 to five apps, including the Zero and Negative Unit Cost app, the Recalculate Inventory Balance app, the Negative Quantity on Hand app, the Last Sales Price Lower than Unit Cost app, and the Large Inventory Amounts app, the system will give “5” as the predicted rating of those apps for the target auditor.

Following a similar procedure, the app recommender system will further predict the usage frequency of apps for the target client. The first step is to create a narrowed app-usage matrix with only app candidates. Table 10 shows the narrowed matrix with the information of usage frequency for only the app candidates in Table 7.

Table 10: An example of the narrowed app-usage matrix

	Aging by Receipt Date and Unit Cost	Zero and Negative Unit Cost	Recalculate Inventory Balance	Negative Quantity on Hand	Last Sales Price Lower than Unit Cost	Large Inventory Amounts	Inventory Received Around Specified Date
Client 1	0	2		2	2	2	0
Client 2	0	2	0	2	2	2	0
Client 3	1	0		0	0	0	1
Target Client							

The system will also capture the attributes of the companies, such as firm size and risk profile, for the clustering of similar clients, and add such information to the app-usage matrix. Figure 21 shows the input dialogs to provide the client's information. Table 11 demonstrates the extended app-usage matrix with information on client's size and risk profile.

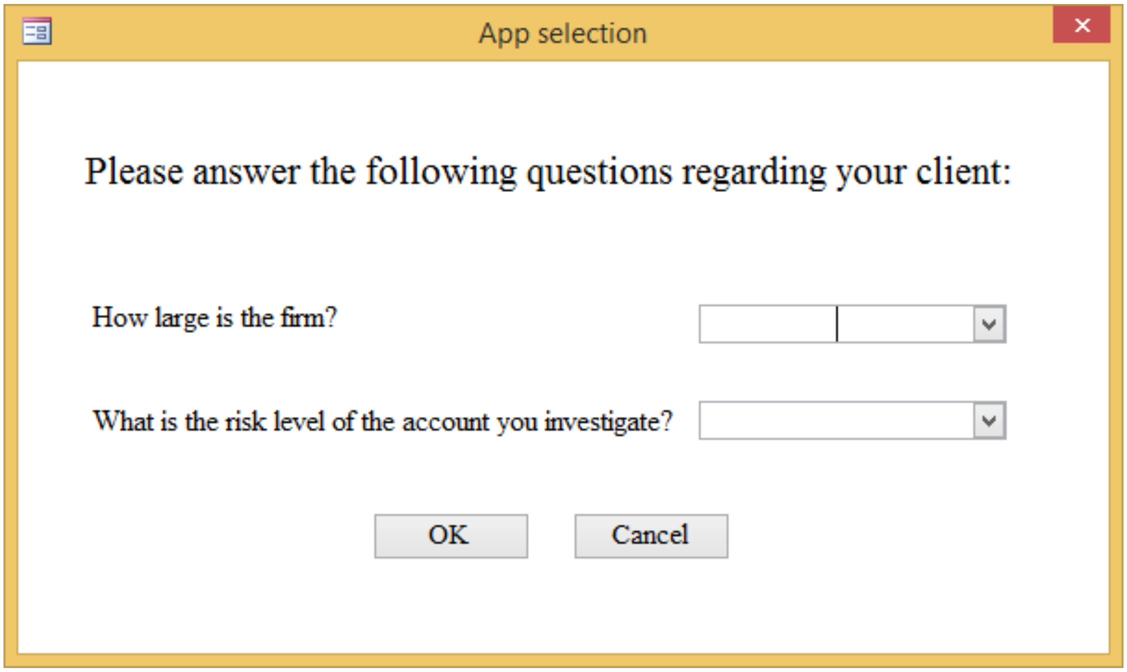

Figure 21: The input dialog for audit clients' attributes

Table 11: An example of extended app-usage matrix

	Aging by Receipt Date and Unit Cost	Zero and Negative Unit Cost	Recalculate Inventory Balance	Negative Quantity on Hand	Last Sales Price Lower than Unit Cost	Large Inventory Amounts	Inventory Received Around Specified Date	Firm size	Risk profile
Client 1	0	2		2	2	2	0	L	L
Client 2	0	2	0	2	2	2	2	L	M
Client 3	1	0		0	0	0	1	S	H
Target Client								L	M

Based on the data in Table 11, clients 1 and 2 will be grouped into a cluster as they are both large firms and similar apps have been employed to audit them in the past. Client 3 will be screened out because its attributes and app usage history are different from clients 1 and 2. The system will then search the matrix and find that the target client has similar attributes as the cluster with clients 1 and 2 because they are all large firms. It will further identify client 2 as more similar one to the target client, because they both have medium risk in the inventory cycle. Thus, the frequency of usage of apps for client 2 will be used to predict the potential app usage for the target client. As five apps (the Zero and Negative Unit Cost app, the Negative Quantity on Hand app, the Last Sales Price Lower than Unit Cost app, the Large Inventory Amounts app, and the Inventory Received Around Specified Date app) have been most frequently used for client 2 (all of them have been used twice in the past year), the system will assign “2” as the potential usage frequency of those apps for the target client.

Finally, the system will then calculate the recommendation score of each app by combining its predicted rating and potential usage frequency. Apps with high scores will be suggested to auditors. In this illustration, four apps, including the Zero and Negative Unit Cost app, the Negative Quantity on Hand app, the Last Sales Price Lower than Unit Cost app, and the Large Inventory Amounts app, have higher scores than others’, and thereby will be recommended to the auditor. A final recommendation report is shown in Figure 22.

RUTGERS
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Newark and New Brunswick

Friday, February 10, 2017

App Recommendation Report

This report recomemds apps for auditor to use in the audit engagement of company ABC.

Apps Name	Zero and Negative Unit Cost
Industry	General
Business Cycle	Inventory and warehousing cycle
Account	Inventory
Assertion	accuracy
Apps Name	Negative Quantity on Hand
Industry	General
Business Cycle	Inventory and warehousing cycle
Account	Inventory
Assertion	accuracy
Apps Name	Last Sales Price Lower than Unit Cost
Industry	General
Business Cycle	Inventory and warehousing cycle
Account	Inventory
Assertion	accuracy
Apps Name	Large Inventory Amounts
Industry	General
Business Cycle	Inventory and warehousing cycle
Account	Inventory
Assertion	accuracy

Page 1 of 1

Figure 22: A sample app recommendation report

4.6. Towards an App-based Audit Paradigm

Vasarhelyi et al. (2014) proposed an automated audit paradigm and imagined a procedure that could facilitate to progressively achieve such audit automation. In this procedure, a common data repository should be first created, and analytical apps should be developed and deployed to perform effective analyses upon those data. The ADA planning system and the app recommender system proposed in this chapter could largely increase the feasibility of the audit automation procedure by facilitating the creation of app-embedded audit plans, as well as enabling automated suggestions on the appropriate apps to be deployed. Kozlowski (2016) extended the audit paradigm to a complete audit ecosystem in which various agents automatically execute functions such as importing client data into a standardized form, selecting appropriate audit apps to execute, feedback loop for unresolved results and search for resolutions, etc. As details of the components in the ecosystem have not been clearly addressed in that study, this section aims to enrich the ecosystem by proposing an app-based audit paradigm that automates the audit planning, testing, and results analyzing processes with the ADA planning system, the app recommender system, as well as several other intelligent mechanisms.

The proposed app-based audit paradigm is shown in Figure 23. Thanks to the recent technological innovations, auditors in this paradigm would gather data from a variety of sources, and employ effective and easy-to-use apps suggested by audit plans to collect sufficient audit evidence in time. Specifically, the paradigm would be composed of a risk assessment system, an audit planning system, an app recommender system and a result analysis system with several intelligent modules, as well as the process of generating internal and external audit reports. The risk assessment system would assist to locate the business cycles and processes with high inherent risks. Such system could be realized by deriving senior level auditors' knowledge on information evaluation and judgment with respect to risks (Brown-Liburd, Mock, Rozario, and Vasarhelyi 2016) and integrating them into an expert system. Based on assessed business risks and auditors' judgment, the audit planning system would list a set of assertions that can be supported by technology, the corresponding analytical tasks, as well as the frequency of their operations in order to identify anomalies and collect evidence in time. The system could also recommend a list of audit procedures that require manual work. Next, auditors would gather relevant data that have been formalized by the Audit Data Standards, from businesses' ERP systems and other database, as well as public websites. The recommender system would then choose the most appropriate apps to be used in the engagement according to auditors' preferences and the client's attributes. Auditors would use the suggested apps to conduct analyses upon those data. Later on, outcomes from the apps would be demonstrated and further investigated by the result interpretation module, the exception prioritization module, and the exception investigation module. The result interpretation module would explain the analytical results to facilitate auditors' decision-making. A "super-app" (Byrnes 2015) could serve as such a module by providing complementary knowledge (such as statistics, data mining, etc.) to auditors. The exception prioritization module would rank risky transactions by severity to avoid extremely heavy information load caused by big data. Li, Chan, and Kogan (2015) proposed a framework for exception prioritization in the continuous auditing context, which could provide insights for the design of this module. The exception investigation module would integrate auditors' knowledge and generate a list of exceptional exceptions that require further investigation. Issa (2013) designed a weighting system that utilizes experts' knowledge to identify and stratify irregularities. Finally, auditors would use their professional judgment to determine whether sufficient evidence has been collected, and then either operating the process to generate final reports or retrieve to the planning stage in order to collect useful evidence.

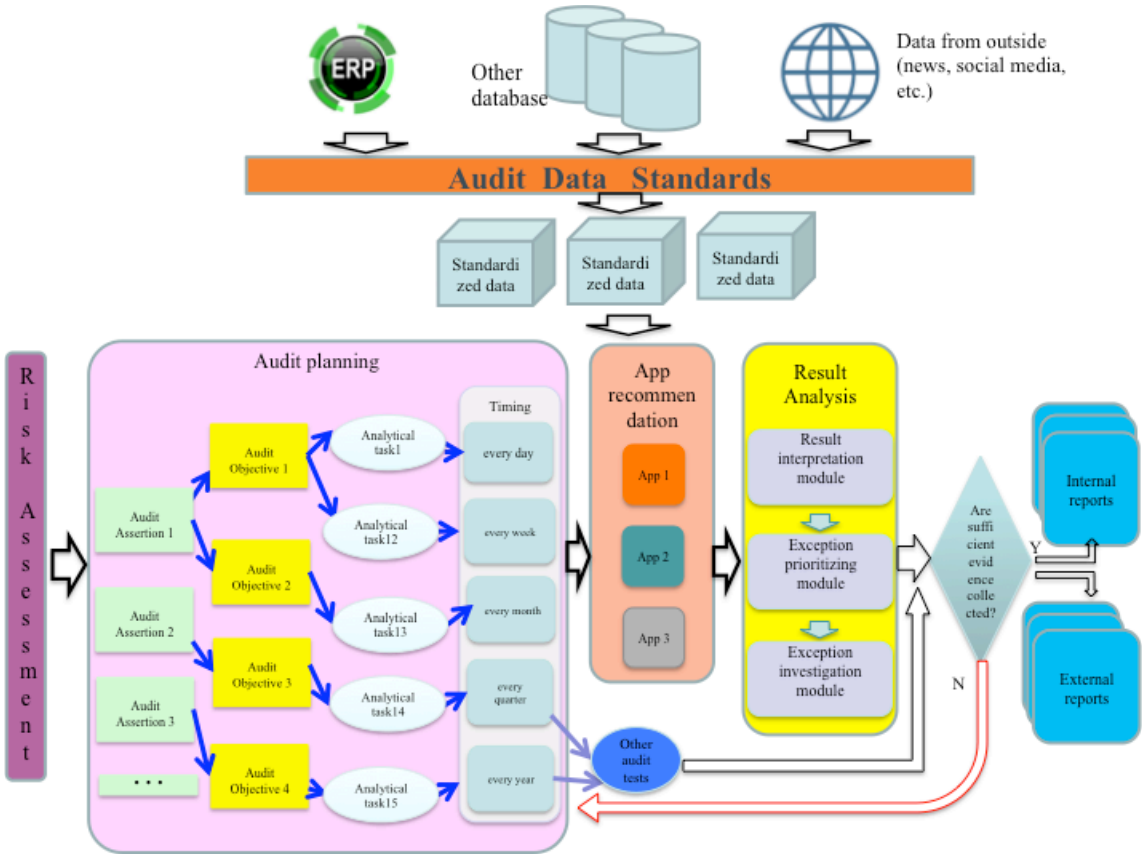

Figure 23: The vision of the app-based audit paradigm

4.6.1. A Potential Application: App-enabled Key Audit Matters

The app-based audit paradigm is not just in Utopia. In fact, researchers and app vendors have been devoting efforts toward studying and experimenting with some portions of the paradigm, which provides a solid technical foundation for its realization. However, fundamental changes in auditing standards would still be necessary to impel the enormous transformation from the manual or semi-manual audit procedure toward an intelligent and progressively automated paradigm.

In January 2015, the International Auditing and Assurance Standards Board (IAASB) issued a new Auditor Reporting Standard, the ISA 701 (ISA-701 2016), in which a particular focus is the requirement of including a new section in the auditor's report, called "Key Audit Matters" (KAM) (EY 2016). The KAM aim to deliver the most significant factors or risks that impact the auditor's professional judgment when performing audit upon a company to its investors. The KAM is required to be reported for audits of financial statements for periods ending on or after 15 December 2016. A similar concept, the "Critical Audit Matters" (CAM)[4], have been adopted by the Public Company Accounting Oversight Board (PCAOB) in 2017 to enhance the informativeness of auditor's reports. Those critical changes in the standards require auditors to disclose more information regarding how they make judgments. The app-based audit paradigm may assist auditors to provide such information in an automatic manner, and provide valid explanation on why those matters are critical to auditors.

The ISA 701 requires auditors to describe the KAM in an audit report, as well as a succinct explanation on why the matters are determined to be KAM. Auditors may explain the reason by "describing the audit approach in relation to a matter, in particular when the audit approach required significant tailoring to the facts and circumstances of the entity" (ISA-701 2016). In the app-based audit paradigm, auditors could clearly document their logic and procedures of performing audits using the risk assessment system and the planning system. In addition, as the app recommender system would suggest firm-specific analyses to auditors, this mechanism could also be used to further explain the audit approaches that are tailored to audit clients.

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[4] https://pcaobus.org/Rulemaking/Docket034/2017-001-auditors-report-final-rule.pdf

Auditors could also explain the KAM by providing "an indication of the outcome of the auditor's procedures with respect to the matter" (ISA-701 2016). The result interpretation module and the exception investigation module in the app-based audit paradigm could provide a clearly explanation on why a certain area or a business process should be considered high-risk, as well as the key insights from the investigation. Moreover, since "the greater the number of key audit matters, the less useful the auditor's communication of key audit matters may be" (ISA-701 2016), the exception prioritization module could identify the most significant matters in an audit out of a long list of them, and provide explanation on why they are more critical than others.

4.7. Conclusions

The inherent complexity of data analytics may hinder their adoption and full use by auditing profession. Apps simplify analytics procedures and provide easy-to-use interfaces, and thereby become valuable tools that enable auditors to perform analytical investigations in an easy and effective manner. However, auditors with less knowledge and experience in analytics still desire guidance on integrating apps into existing audit procedures, as well as selecting the most appropriate ones from hundreds of others to conduct investigation upon a specific client. To meet this need, as well as provide insights to vendors on the potential demands of apps, this chapter first proposes a framework that identifies the factors that should be considered when using or developing apps. Based on the framework, an ADA planning system is then proposed to assist mapping apps to audit plans. An intelligent app recommender system is further designed to provide personalized suggestions for a particular auditor, enabling the selection of appropriate apps. Armed with the right tools, auditors would be able to efficiently perform audit activities and provide timely opinions. The ADA planning system, the app recommender system, as well as other intelligent mechanisms would together comprise an automatic app-based audit paradigm, which could facilitate the progressive transformation towards audit automation.

In future work, experiments could be conducted to investigate how the ADA planning system and audit app recommender system could improve auditors' ability in performing analytical audit. Their feedback could also be collected to improve the design of those systems. Another research question could be how to automate the process of classification upon new apps using text-mining techniques. By analyzing the descriptions of a new audit app, the industry, business cycle, assertion, and audit objective that the new app can test could be identified. This solution could help minimize the time and labor in the process of classifying a new app; however, the accuracy of app classification should be periodically tested and monitored. Finally, some dimensions of the app use and development framework, such as the business cycle and the audit stage, may need rethinking in the future audit world like the continuous auditing or Audit 4.0 environment. As those advanced audit paradigms would change the current procedure of performing audit, new dimensions would be necessary to substitute for old ones in order to adapt to the rapid-changing environment.

Chapter 5. Conclusion and Future Research

5.1. Summary

Adopting emerging technologies to improve assurance quality and reduce the time-consuming work of auditors, as well as adapting existing audit procedures to rapidly changing business models, are long-time missions of auditing researchers and practitioners. Because of the nature of this profession, the adoption of technology has been substantively lagged by management and standard-setting bodies (Bierstaker, Janvrin, and Lowe 2014; Curtis and Payne 2010; Li, et al. 2016; Mahzan and Lymer. 2008). As a result, academic research can play a critical role in developing and driving technology innovations in auditing practice, because it is able to explore the potential applications and experiment with various implementations without the need to achieve an immediate ROI (Alles, Kogan, and Vasarhelyi 2008). Researchers should also provide guidance and insights for the practice by developing conceptual paradigms that turn the technological applications into real audit methodologies (Alles et al. 2008).

This dissertation explores the potential utilization of three recently emerging technologies, i.e., industry 4.0, blockchain, and audit app, in the auditing and accounting domain, and discusses the process of reengineering the current audit paradigm. Industry 4.0 relies on a set of state-of-the-art technologies, such as IoT/S, CPS, and smart factories, to link physical processes to a virtual world by continuously collecting data about physical object movements, surrounding environment, machine conditions, and human activities, in order to facilitate optimal resource management, process monitoring and control, as well as decision-making. Auditors could piggyback on the existing devices and infrastructure that have been implemented by the companies that adopt industry 4.0, and use them for assurance purposes. Blockchain is a mechanism that decentralizes the power of a network of computers using a public ledger in order to enable trading among untrusted parties. Recently, blockchain has broadened its technical foundation to support various businesses. Accounting is among the professions to which blockchain can bring great benefits and fundamentally change the current paradigm. Blockchain's functions of protecting data integrity, instant sharing of necessary information, as well as programmable and automatic controls of processes could facilitate the development of a real-time, reliable, and transparent accounting ecosystem. Blockchain could also serve as a foundation to enable automatic assurance, and help the current auditing paradigm become more agile and precise. Audit apps are easy-to-use tools that allow auditors to perform efficient and effective analytical investigations. Compared to traditional audit software, apps have several advantages that encourage auditors to use them in daily work, such as requiring less data analytics background, allowing for simple human interaction, and possessing a flexible operating environment. Providing suggestions on the use of apps in a particular engagement rather than general guidance could further facilitate auditors to make the full use of apps in order to examine the whole population of available data, execute complete analyses, and identify critical issues.

The first essay proposes the vision of "Audit 4.0", which is typically an overlay of Industry 4.0 business management processes and uses a similar infrastructure, but for assurance purposes. This essay provides the first definition of Audit 4.0, as well as a thorough discussion on the four main elements (standards, principles, technologies, and auditors) that together comprise the future audit paradigm. The essay further illustrates how the Audit 4.0 could operate with the assistance of the technologies promoted by Industry 4.0 from four perspectives: the mirror world, the collaboration among different organizations, the operation within a company, and the new audit service model, "audit as a service". With the vision of the new auditing paradigm, this essay provides insights to both academic and practice on the potential benefits of using new technologies to capture business data and physical objects' information in real time, as well as leveraging various analytical models and devices to continuously monitor business processes. However, obstacles to transformation should not be underestimated. One important challenge is digital crime. As Audit 4.0 would heavily rely on technologies to automatically capture and store data, data integrity would become a critical issue. Ineffectiveness in protecting data from malicious changes would cause inaccuracy in monitoring and anomaly detection, and thereby the failure of the Audit 4.0 paradigm. Thanks to blockchain, this concern could be dramatically mitigated, because this technology provides a cryptographical guarantee on data integrity.

Following the above discussion, the second essay explores how blockchain could be leveraged to securely store accounting data, to instantly share relevant information with interested parties, and to increase the auditability of business data. This essay first proposes a blockchain-enabled, real-time, reliable, and transparent accounting ecosystem. In the ecosystem, blockchain would play the role of the accounting information system, which distributes the power of transaction verification, storage, and management to a group of computers in order to prevent any unauthorized data changes. This mechanism would facilitate close to real-time reporting of reliable accounting information to interested parties. Blockchain is also proposed in this essay as a tool to authenticate any audit related information, such as the data captured in the Audit 4.0 paradigm. Since blockchain provides security of the data that are posted on it, auditors could trust the integrity of those data and perform various analyses. Moreover, automatic and agile assurance could be further enabled by smart contracts that would operate on blockchain to automatically control business processes against pre-determined rules. Since the original design of blockchain is to enable peer-to-peer digital currency trading, how to adapt the existing blockchain mechanisms to accounting and auditing sphere is worth careful thought.

A major component of Audit 4.0 is data analytics. Audit 4.0 relies on various analytical methods to model and visualize data in order to identify anomalies and thereby achieve the effective, efficient, and real-time assurance. In addition, the blockchain-based assurance paradigm could also be powered up by data analytics to detect invalid transactions and violation of business rules. Analytical audit apps could serve as an efficient and effective tool to facilitate analytics-based investigation. However, as auditors generally lack familiarity with data analytics, they will likely desire guidance or assistance to select the most appropriate apps for auditing specific clients. To meet this need, and provide insights for regulators, the third essay of this dissertation provides a synopsis of the processes to employ apps in accomplishing audit tasks. To provide guidance on the use and developing of apps, this essay creates a framework that links analytical audit apps to existing audit procedures. A planning system is then used to integrate apps into audit plans. An app recommender system is further employed to suggest the most appropriate apps to be used in a particular engagement. Finally, this essay imagines an app-based audit paradigm that may facilitate the creation of new, more informative audit reports. The relationship of Audit 4.0, blockchain, and audit app is shown in Figure 24.

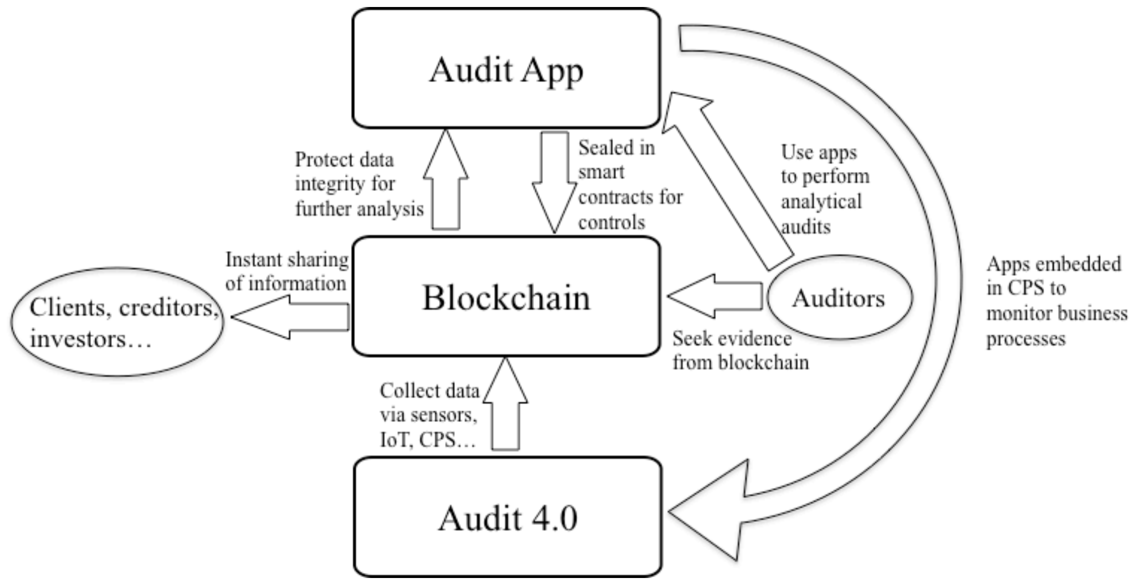

Figure 24: The relationship of Audit 4.0, blockchain, and audit app

The concept and illustration of audit 4.0 were reported in the Journal of Emerging Technologies in Accounting (Dai and Vasarhelyi 2016). The idea of blockchain-base accounting and assurance, as well as its challenges were discussed in the Journal of Information Systems (Dai and Vasarhelyi 2017). The framework of using a recommender system to choose audit apps was presented in the 2014 American Accounting Association Annual Meeting (Dai, Krahel, and Vasarhelyi 2014).

5.2. Contributions

The main contributions of this dissertation are threefold. First, it is among the first studies to introduce several emerging technologies, i.e., industry 4.0, blockchain, and audit app, to the accounting and auditing literature. Second, it explores the potential applications and utilization of those technologies in the accounting and auditing profession. The discussions and illustrations provide insights to auditors, regulators, and technology vendors, to facilitate the incorporation of the technologies into the existing audit procedures, as well as promote the transformation of the current audit model towards next generation. Third, it provides a thorough discussion on the challenges in the adoption and use of those technologies, as well as potential solutions that could mitigate those concerns.

5.3. Limitations

While the goal of this dissertation is to discuss and provide insights on how the technologies of industry 4.0, blockchain, and audit app could impact the accounting and assurance profession, it has some limitations. First, those technologies are emerging and rapidly developing. As new algorithms and approaches are introduced, their accounting and assurance applications may need to be expanded and reconsidered. Second, this dissertation only provides a general discussion of the role the technologies could play in the accounting and assurance environment, but their applications and challenges in specific areas, such as government auditing, need further studies. Third, some concepts in the dissertation, e.g., triple-entry accounting, may be just an adaptation to the extant world and not advanced enough to use going forward in a rapidly changing world.

5.4. Future Research

A large number of issues arise from the adoption and utilization of the new technologies in accounting and auditing practice. This section lists research questions regarding the use of the three technologies.

5.4.1. Audit 4.0

1. What new types of audit evidence can be generated and collected in the context of Audit 4.0?
2. As more data will be collected in Audit 4.0, how can auditors avoid information overload and find relevant auditing information?
3. How should auditing standards be changed to adapt to the next auditing environment?
4. What are new audit procedures to be developed/ created in Audit 4.0?
5. What new knowledge should auditors obtain to perform audits in Audit 4.0?
6. What should be done to protect the security and privacy of companies' sensitive information in Audit 4.0?
7. How should external and internal auditors cooperate to enable Audit 4.0?
8. Will the current audit model be changed in Audit 4.0?
9. How can predictive and prescriptive audits be used in Audit 4.0?
10. How will the cost reductions that will likely accompany Audit 4.0 change the depth of examination, the procedures used, and their frequency of usage?
11. As many emerging technologies/systems are used in Audit 4.0, what are new controls that should take place to examine whether the technologies/systems operate as they are supposed to do?

5.4.2. Blockchain

1. Would corporate blockchain streams quickly expand to an unmanageable size?
2. What accounting data should be recorded in blockchain? What other information (such as IoT data) should be loaded to blockchain in order to provide better

assurance?

3. How can existing blockchain mechanisms be changed to be more applicable for accounting applications, especially in SMEs?
4. How can blockchain mechanisms be less costly while remaining secure?
5. Should large enterprise and governments play the role of the main promoters in the acceptance phase? How could they help SMEs to adopt and use this emerging technology?
6. What knowledge should managers, accountants, and auditors acquire to be ready to use the blockchain-base accounting information system?
7. What training should be provided to managers, accountants, and auditors, respectively, in order to help them understand, design, and audit smart contracts?
8. How could a triple-entry system work and interface with evolving traditional systems?
9. What markets could receive the most benefits from the adoption of the blockchain-based accounting information system?
10. How can the original blockchain model be adjusted for real-time reporting and assurance?
11. How should accounting standards be changed? Should there be parallel standards created for this transformation?
12. What standards should be created to enforce the audit of smart contracts?
13. Would auditing be needed/ necessary with a secure blockchain data stream? In which areas? Which areas should be abandoned, and what new audit assertions must be created?

5.4.3. Audit App

1. What other dimensions should be considered in the use and development of apps?
2. Besides the methods mentioned in chapter 4, what are other ways to automate the process of classification of new apps?
3. What audit clients' characteristics other than firm size and risk profile could be used to find similar clients?
4. What auditor characteristics other than position levels and employing firms could be used to find peers?
5. How can content-based algorithms be incorporated to the app recommender system in order to suggest apps based on their similarity?
6. What other components should be added into the app-based audit paradigm?
7. What are the value of audit apps to the new, more informative audit report?

Technologies have driven the development of the audit profession for decades, and will continue to do so for the foreseeable future. With the recent emerging of numerous technologies, auditing profession is entering a more rapid-changing era than ever. The question is no longer "whether" or "when", but "how" technologies will facilitate the auditing profession and "what" we, as researchers, should contribute to the transition of this domain to the next generation. This dissertation is only a first attempt to propose a new audit paradigm, the "Audit 4.0", and illustrate how blockchain and audit apps could be utilized to improve audit quality and efficiency. Future studies on understanding the connection between those technologies and the auditing profession, as well as exploring their applications in the audit processes are in urgent need for the development of this domain.

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Appendix A: Audit 4.0 Structures

Inventory Item $_{(u,l,d)}$ == Inventory Item $_{(u,l,d)}$	comparing two locations / times allows for determining inventory status changes Variation on this process allows for monitoring digital goods Similar process attaching information to work badges can be used for service oriented companies

u-> Universal Product Code (UPC)

l-> location

d-> date

Interlocking of processes where equations (Kogan et al. 2014) are created that verify the continuity of processes including timing differences

Interlocking of similar processes across organization boundary lines for confirming transactions and bank deposits as well as account balances

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A large number of analytics can be developed out of printed press, social media utterances, etc. to predict / correlate to/ support the values of the balance sheet and income statement.

Same approach can be applied to utilization of items connected through the Internet of Things (IoT), such as track items' locations and conditions to perform remotely inventory evaluation, measure and evaluate of assets' conditions and qualities using sensors, as well as monitor real-time energy expense

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An open platform can be established to allow remote auditing/monitoring services and audit-facilitating services offered over Internet or on cloud.

Appendix B: Matrix of Audit Apps on Market

Apps Name	Business Cycle	Audit Stage	Assertion	Data sour-ce	Data analytics technique	Auditor type	Risk
Transactions Posted on Specified Dates /Receivables	Sales and collection cycle	ST	occurrence	AR	Query	Financial auditors	M
Transactions Around a Specified Date /Receivables	Sales and collection cycle	ST	cutoff	AR	Query	Financial auditors	M
Duplicate Field Search /Receivables	Sales and collection cycle	ST	occurrence	AR	Data matching	Financial auditors	M
Debtors with Total Amount Greater than Credit Limit	Sales and collection cycle	ST	accuracy	AR	Query	Financial auditors	H
Debtors with Net Credit Balances	Sales and collection cycle	ST	accuracy	AR	Query	Financial auditors	H
Debtors with Balances Greater than Credit Limit	Sales and collection cycle	ST	accuracy	AR	Query	Financial auditors	H
Debtor Transaction Summary	Sales and collection cycle	ST	NA	AR	Analytic-Summari zation	Financial auditors	L
Aging by Invoice Date /Receivables	Sales and collection cycle	ST	occurrence	AR	Analytic-Summari zation	Financial auditors	L
Transactions Posted on Weekends (Payables)	Acquisiti on and payment cycle	ST	occurrence	AP	Query	IT auditors	M

Transactions Posted on Specified Dates (Payables)	Acquisition and payment cycle	ST	occurrence	AP	Query	Financial auditors	M
Transactions Posted at Specified Times (Payables)	Acquisition and payment cycle	ST	occurrence	AP	Query	IT auditors	M
Transactions by User ID	Acquisition and payment cycle	ST	NA	AP	Query	Internal auditors	L
Transactions Around a Specified Date (Payables)	Acquisition and payment cycle	ST	cutoff	AP	Query	Financial auditors	M
Invoices without Purchase Order Numbers	Acquisition and payment cycle	ST	occurrence	AP	Query	Financial auditors	H
Duplicate Invoices or Payments	Acquisition and payment cycle	ST	occurrence	AP	Data matching	Financial auditors	M
Duplicate Field Search (Payables)	Acquisition and payment cycle	ST	occurrence	AP	Data matching	Financial auditors	M
Creditors with Total Invoice Amount Greater than Approved Limit	Acquisition and payment cycle	ST	accuracy	AP	Query	Financial auditors	H

Creditors with Net Debit Balance	Acquisition and payment cycle	ST	accuracy	AP	Query	Financial auditors	H
Creditors with Balances Greater than Approved Limit	Acquisition and payment cycle	ST	accuracy	AP	Query	Financial auditors	H
Creditor Transaction Summary	Acquisition and payment cycle	RA	NA	AP	Analytic-Summarization	Financial auditors	L
Aging by Invoice Date (Payables)	Acquisition and payment cycle	ST	occurrence	AP	Analytic-statistic	Financial auditors	L
Aging by Receipt Date and Unit Cost	Inventory and warehousing cycle	ST	occurrence	IV	Analytic-statistic	Financial auditors	L
Zero and Negative Unit Cost	Inventory and warehousing cycle	ST	accuracy	IV	Query	Financial auditors	M
Recalculate Inventory Balance	Inventory and warehousing cycle	ST	accuracy	IV	Recalculation	Financial auditors	L
Negative Quantity on Hand	Inventory and warehousing cycle	ST	completeness	IV	Query	Financial auditors	M
Last Sales Price Lower than Unit Cost	Inventory and warehousing cycle	ST	accuracy	IV	Query	Financial auditors	M

Large Inventory Amounts	Inventory and warehousing cycle	ST	occurrence	IV	Query	Financial auditors	M
Inventory Received Around Specified Date	Inventory and warehousing cycle	ST	cutoff	IV	Query	Financial auditors	M
Inventory Location Summary	Inventory and warehousing cycle	PL	NA	IV	Analytic-Summarization	Financial auditors	L
Duplicate Field Search (Inventory)	Inventory and warehousing cycle	ST	occurrence	IV	Query	Financial auditors	M
Compare Sales Price with Unit Cost	Inventory and warehousing cycle	ST	accuracy	IV	Query	Financial auditors	L
Calculate Unit Turnover Ratio	Inventory and warehousing cycle	RA	NA	IV	Ratio	Financial auditors	M
Calculate Inventory Turnover Ratio	Inventory and warehousing cycle	RA	NA	IV	Ratio	Financial auditors	M
Aging by Receipt Date and Ending Inventory Balance	Inventory and warehousing cycle	ST	occurrence	IV	Analytic-statistic	Financial auditors	L
Summary by Account Number	General	RA	NA	GL	Analytic-Summarization	Financial auditors	L

Summary by Account Combination	General	RA	NA	GL	Analytic-Summarization	Financial auditors	L
Out of Balance Journal Entries	General	ST	accuracy	GL	Query	Financial auditors	M
Missing Journal Entries	General	ST	occurrence	GL	Data matching	Financial auditors	M
Journal Entries with Specific Comments	General	ST	occurrence	GL	Query	Financial auditors	H
Journal Entries with Rounded Amounts	General	ST	occurrence	GL	Query	Financial auditors	M
Journal Entries with Large Amounts	General	ST	occurrence	GL	Query	Financial auditors	M
Journal Entries with Amounts that End in 999	General	ST	occurrence	GL	Query	Financial auditors	M
Journal Entries Posted on Weekends	General	ST	occurrence	GL	Query	IT auditors	M
Journal Entries Posted on Specific Dates	General	ST	cutoff	GL	Query	Financial auditors	M

Journal Entries Posted at Specific Times	General	ST	occurrence	GL	Query	Financial auditors	M
Journal Entries by User	General	RA	NA	GL	Query	Internal auditors	L
Journal Entries by Period and Journal Source	General	RA	NA	GL	Query	Internal auditors	L
Journal Entries by Period	General	RA	NA	GL	Query	Financial auditors	L
Duplicate Journal Entries	General	ST	occurrence	GL	Data matching	Financial auditors	M
Account Balances by Period	General	RA	accuracy	GL	Analytic-Summarization	Financial auditors	L
Account Balances by Journal Source	General	ST	accuracy	GL	Query	Financial auditors	L
Recalculate Straight Line Depreciation	Acquisition and payment cycle	ST	Valuation and allocation	FA	Recalculation	Financial auditors	L
Recalculate Declining Balance Depreciation	Acquisition and payment cycle	ST	Valuation and allocation	FA	Recalculation	Financial auditors	L
Fixed Assets Additions	Acquisition & payment cycle	ST	Valuation and allocation	FA	Query	Financial auditors	M

Duplicate Field Search (Fixed Assets)	Acquisition and payment cycle	ST	occurrence	FA	Data matching	Financial auditors	M
Depreciation Exceeding Cost	Acquisition and payment cycle	ST	Valuation and allocation	FA	Query	Financial auditors	M
Asset Category Summary	Acquisition and payment cycle	RA	NA	FA	Analytic-Summarization	Financial auditors	L

Note: ST-Substantive Test, RA-Risk Assessment, PL-Planning, AR-Accounts Receivable, AP-Accounts Payable, IV-Inventory, GL-General Ledger, FA-Fixed Asset, L-Low, M-Medium, H-High.