The Promises and Perils of Blockchain in Auditing

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Chapter One: Purpose of Paper

This paper discusses the promises and perils of blockchain in auditing. By synthesizing available literature and data, this paper provides a comprehensive summary of blockchain technology, technological pitfalls, and how it could change auditing. This paper argues that blockchain could provide solutions to issues in auditing, such as the intensity of labor, high time consumption, and navigating complex regulatory standards.[1] This paper finds that the necessity for professional judgement throughout the auditing processes is paramount to the service itself and cannot be fully eliminated by blockchain. The value of an audit is derived from certified public auditors who provide financial advice, and the reputation of auditing firms relies on the trust that firms who hire auditors have with the quality of service they are provided.

Auditing is the attestation of numbers or amounts reported in financial statements of publicly listed or private companies. The purpose of financial statement auditing is ensuring that the standards applicable to the company were followed, to identify any material misstatements in the numbers reported by management and provide reasonable assurance with identifying fraud. Because auditing is an assurance service that relies on human interaction, when introducing new blockchain technology to the audit process, security and efficiency standards must be questioned. While this paper does not fully cover the issues of trust and ethical considerations of using blockchain, further research into the application would be useful.

The major promises of blockchain are embedded in its inherent characteristics which are decentralization, transparency, automaticity, and immutability. By automating certain steps in the auditing process, it will not decrease the value or profit of an auditing firm. Rather, it would increase efficiency and accuracy of the audit process. The external auditor's value is derived

[1] Cryptoeconomics, 2018

from the opinion made on a company's financials and their determination if the financial statements followed all standards applicable to the company in all material respects. These auditing processes take intense labor, along with a high volume of time, and require navigating intricate auditing standards.

Chapter Two: Background on Blockchain

Blockchain Technology

In this section, a detailed technical description of blockchain is provided to allow for understanding of how the technology operates. Starting with its definition, this section breaks down the essential characteristics of blockchain and its components which are significant to grasping the technology in coordination with the topic of this paper.

Blockchain was first described in Satoshi Nakamoto's white paper for Bitcoin.[2] Bitcoin is the first cryptocurrency and use of blockchain technology. According to Nakamoto, blockchain is a database, or distributed ledger, of all transactions in which each participating computer (node) of the network has a copy of; as nodes extend the blockchain by making transactions, they receive rewards, mainly in the form of cryptocurrency.[3] Bitcoin is intended to represent information that exists as electronic cash attached to an address on the digital network.[4] Users on the Bitcoin blockchain can exchange their digital assets by signing and transferring ownership rights to another network user.[5] And during this time, the blockchain publicly records the transaction took place which then allows all nodes of the network to independently validate the transaction.[6] Blockchain enables the usage of cryptocurrencies, like Bitcoin, but the two are not

[2] Werbach, 2018, p. 498
[3] Nakamoto, 2019
[4] Yaga, 2019, p. iv
[5] Yaga, 2019, p. iv
[6] Yaga, 2019, p. iv

synonymous. Due to the popularity of Bitcoin, alternative uses of blockchain were promoted because its distributed nature promises that no single party had complete control over the network.

In its simplest definition, blockchain is a distributed ledger that records every transaction that has ever taken place in an ordered pattern. Blockchain is a new type of distributed ledger technology (DLT) that splits the transaction into blocks that are validated by the network entirely through encryption.[7] DLT is a type of organized database that exists within multiple locations and parties and is decentralized to eliminate the necessity of a central intermediary who validates, and processes transactions made.[8] Once a transaction is verified, it is hashed to the chain of all prior transactions. The key advantages that popularized blockchain are transparency, efficiency, and security.[9] DLT simultaneously processes and authenticates the ledger and uses consensus to ensure that all participants of the network are updated on changes.[10] The public DLT allows multiple parties to view the same data, which was intended by the design of the platform. The most popular form of DLT is blockchain which is unique as it organizes the information into blocks that are linked together to form a chain.[11]

The major benefits of blockchain are decentralization of the network, transparent transaction history, immutability of the ledger, and security. Blockchain networks are not controlled by any central authority, rather they rely on consensus of every node on the network and therefore do not have a central point of failure for the entire network.[12] As no central agency is needed to operate blockchain, trust is transferred from humans to trusting code, but users must

[7] Ducas, 2017
[8] The Difference between Blockchain and Distributed Ledger Technology, 2018
[9] Collomb, 2016, p. 94
[10] The Difference between Blockchain and Distributed Ledger Technology, 2018
[11] The Difference between Blockchain and Distributed Ledger Technology, 2018
[12] Nguyen, 2019, p. 2

remain cautious as all technology is dependent on human actors to an extent. For example, human actors are responsible for coding the blockchain responsible for maintaining the secured transactions and may be required to update the code as the volume of users and transactions increase.

Using blockchain will also increase transparency of transactions as every participant of the blockchain is able to see the transaction history.[13] Blockchain is an immutable and persistent technology as no modifications can be done to the transactions recorded and falsification of transactions cannot be made without major computational power, which would be unfeasible in practice.[14] Additionally, the security and privacy that blockchain provides transactions is another major benefit to this technology. Users of the blockchain network use a pair of assigned public and private keys that is unique to them and are used for identification and verification.[15] The digital signature that is used after every transaction by a user is easily verified by the technology utilized on the blockchain network but is unfeasible to forge.[16]

Major applications of blockchain technology are cryptocurrency, smart contracts and Distributed Autonomous Organizations, or DAO. Cryptocurrency such as Bitcoin, Ethereum, and Cardano are increasing in value and daily trading volume rapidly as their uses internationally vary greatly. Throughout the boom in financial markets during the COVID-19 pandemic, interest in cryptocurrencies have increased and has led to further development within the blockchain space. Cryptocurrencies are used today for a variety of financial applications such as digital wallets and for online retail purchases.[17]

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[13] Nguyen, 2019, p. 2
[14] The Difference between Blockchain and Distributed Ledger Technology, 2018
[15] Nguyen, 2019, p. 2
[16] Nguyen, 2019, p. 2
[17] Nguyen, 2019, p. 2

Smart contracts allow distributed ledgers to become a distributed computer that can authorize particular contract conditions and trigger consequences which are programmable using the actual rules written within the contract.[18] Smart contracts can facilitate exchanges in digital or physical assets without using an intermediary while also enforcing rules around the agreement set into the smart contract. Obligations and coordinating penalties that were originally agreed upon by legal participants to the contract, can automatically be carried through the smart contract.[19] When analyzing the platforms that can be used to execute smart contracts, such as Bitcoin, NXT, and Ethereum, none of the scripting language can altered or modified without using an exorbitant amount of energy.[20] Using blockchain allows coders to eliminate the intermediaries that were necessary to make transactions and agreements, therefore utilizing smart contracts will allow audit firms to mitigate the risks resulting from the increased complexity.[21]

A DAO is a type of decentralized application that seeks to eliminate human input in transactions. It is an organization that utilizes a complex network of smart contracts and code that are used for automating specific legal obligations.[22] As a cost-effective solution to simplifying complex business models today, the sole interest of a DAO is the firm utilizing the coding language and ensuring its success.[23] Fast scalability and maintaining a high quality of service are highly valuable and sought after by many modern businesses.[24]

Blockchain Characteristics. This section identifies the essential characteristics of blockchain and how it is differentiated as a technology.

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[18] Werbach, 2018, p. 505 and Lu, 2017, p. 22
[19] Rosic, 2019
[20] Alharby, M., & Van Moorsel, A., 2017, p.4
[21] Kim, H., & Laskowski, M., 2017, p. 2
[22] Liebkind, 2020
[23] Liebkind, 2020
[24] Liebkind, 2020

Access and Openness of the Blockchain. There are two categories of blockchain, permission-less (public) and permissioned (private) blockchains.[25] The distinction between permission-less and permissioned is necessary to understand how blockchain can be manipulated to create the best system for the purposes required of the technology, for example, permissioned ledgers are less transparent and limit the participants who are allowed to contribute to the network which would best suit the handling of sensitive financial information that is required of auditing applications.[26]

Permission-less (public) ledgers are open to any potential user on the network and participation is contingent on each node validating transactions in the network.[27] An example of this form of the ledger is Bitcoin, the first cryptocurrency built on blockchain, as it allows any participant to mine, exchange, or buy bitcoins. In permission-less blockchains, all network participants can publish blocks, have access to the blockchain digital ledger, and create new transactions.[28] Often in permission-less blockchains, participants will work via multiparty agreements.[29] Another example is R3's Corda blockchain platform. R3 is an enterprise blockchain software firm which built a platform that businesses can use to build blockchain based applications to better their infrastructure and commerce. The Corda platform is a permission-less ledger that applies a strict privacy model to protect their client's information while simultaneously allowing businesses to build their applications that can be shared with anyone.[30] Ideally, this example illustrates a model that can be utilized for all blockchain users.

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[25] Yaga, 2019, p. 5
[26] Chedrawi, 2018, p. 6
[27] Boillet, 2018, p. 6
[28] Yaga, 2019, p. 5
[29] Yaga, 2019, p. 5
[30] R3

Permissioned (private) blockchains are limited access ledgers that are only open to those who have been invited into the network via the agreed-upon administrators.[31] This type of blockchain system can be interpreted as an extra secure form of blockchain as limited access provides a control layer for participation. For example, Verady is a firm that conducts auditing and accounting services for cryptocurrency organizations and handles secure and sensitive data regarding personal transaction data. Therefore, the use of a permissioned blockchain allows them to best ensure that their client's information is secure.[32] To maintain a permissioned blockchain, a network user can be placed in charge or the permissioned blockchain can be programmed as an open source blockchain.[33] It is suggested that organizations requiring more control and protection of assets or information that is stored on a blockchain system, use a permissioned blockchain.

Blockchain Block and Ledger. A block "contains a timestamp, the hash value of the previous block, and a nonce, which is a random number for verifying the hash."[34] Every time a block is verified by the nodes of the network, it is added to the chain which further extends the ledger, or transaction history. A block header contains the metadata for the block while the block data is the collection of validated transactions that have been submitted to the blockchain network for authentication.[35] As a foundational piece of blockchain, the block holds the key information of every authenticated transaction. The blockchain ledger is a list of transactions that have ever occurred to present.[36] Due to the velocity and volume of information that must be

[31] Yaga, 2019, p. 5
[32] Verady
[33] Open-source refers to technology software in which the original source code is available and may be changed and redistributed
[34] Nofer, 2017, p. 184
[35] Yaga, 2019, p. 15
[36] Yu, 2018, p. 13

recorded for every transaction, the data and code must all be stored digitally in large databases.[37] This is a source of risk for a firm using blockchain as the database utilized is a paid third party that must be trusted by blockchain organizers.

Hash. Hashing is the process of adding a cryptographic hash function to a set of data which can calculate unique outputs and allows ease of identification for transactions.[38] For blockchain particularly, hashing is used for cryptography, which is the process of securing information using code to ensure that encrypted messages or data cannot be seen by unplanned parties.[39] Therefore the hash function serves as security for the data and transaction which is essential for cryptocurrency transactions, such as bitcoin, as it ensures the transaction data and code are encrypted. For example, during the bitcoin mining process, which is when valid transactions are added to the bitcoin blockchain, each node with several valid transactions will try to compute a cryptographic hash that must meet particular standards of the block before it is added to the chain.[40] This process of computing a hash is highly intensive and requires a massive volume of energy which is a disadvantage of the bitcoin mining process, but once a node wins a block, it receives a reward in the form of a fixed sum of new bitcoins.[41]

Transaction Types. From a business perspective, a transaction can simply be recording activities that happen to both digital and physical assets.[42] The transactions that are recorded on the blockchain for cryptocurrency represents an exchange of digital currency between the nodes of the given blockchain.[43] All transactions must include both inputs and outputs which are all

[37] Yaga, 2019, p. 13
[38] Nofer, 2017, p. 7
[39] Cryptography
[40] Vranken, 2017, 2
[41] Vranken, 2017, 2
[42] Yu, 2018, p. 9
[43] Yaga, 2019, p. 9

sources of information recorded into the blockchain ledger.[44] Blockchain transactions were intended to be digital events are executed and verified by consensus among participants in the blockchain system and cannot be altered or removed.

Synchronization. The distributed nature of blockchain means that the copy of the ledger is on every node, or computer, of the network, rather than having a master copy.[45] The network must ensure that it is maintaining synchronization across all nodes, or consensus, which is an energy-consuming process.[46] Consensus means that every participant of the blockchain network has trust and confidence in the accuracy of the ledger.[47] If a majority of the nodes, more than 50%, on the network agree via consensus on the transaction validity in a block, only then can the block be added to the chain.[48] A possible danger consensus power has is a 51% attack is a technique that adversaries utilize to create a fork in a blockchain in order to conduct double-spending which can only be done when the adversary has more than half of the total hashing power of the entire network.[49] On a large and established blockchain, the possibility of a 51% attack is limited compared to a new network with limited computational power as it is more vulnerable to a 51% attack.[50] Consensus is the key element of blockchain as it ensures that all nodes of the network have agreed on the present state of the ledger. Consensus involves correctly identifying the order of transaction history within the blockchain while validation is verifying that the transactions are legal under international exchange laws and laws that within the nation that the exchange took place.[51]

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[44] Yaga, 2019, p. 12
[45] Werbach, 2018, p. 500
[46] Werbach, 2018, p. 500
[47] Werbach, 2018, p. 501
[48] Nofer, 2017, p. 184
[49] Sayeed, 2019, p. 1
[50] Nguyen, 2019, p. 4
[51] Business and Leaders, 2019

Consensus Models. The consensus mechanism is the backbone of how blockchain networks operate and ensure that the nodes within the network agree with each other. Within a trustless environment, the consensus mechanism is responsible for adding transactions to the blockchain and incentivize the participants to behave according to the best interest of all blockchain participants.[52] The two main consensus models that are used for reaching agreement between all participating computers, or nodes, on the blockchain for accepting new blocks are proof-of-work and proof-of-stake. Both consensus models have a clearly defined block reward in exchange for updating the transaction history on the blockchain but unlike proof-of-work, proof-of-stake doesn't require a cost in order to have the authority or position of power to update the blockchain network.[53]

Proof-of-work (PoW) allows a network user to publish a block as a reward for solving an intense computational puzzle.[54] Nodes on a PoW blockchain compete in order to find a solution to a mathematical problem, but this method rewards the node with a higher hash rate, or larger computational power, than all other nodes on the blockchain network.[55] Increasing a node's computational power drastically increases the energy consumption used to operate a PoW blockchain network, which is the challenge for this type of consensus mechanism. As network participants with low computational power are less likely to find the solution before those with high hash rate, some decide to create mining pools to increase their chances at receiving rewards.[56] The solution is the "proof" of the puzzle which requires an extensive amount of time and resources to be able to decipher.[57] In an effort to mitigate the challenges that the PoW

[52] Nguyen, 2019, p. 3
[53] Saleh, 2021, p. 3
[54] Yaga, 2019, p. 19
[55] Nguyen, 2019, p. 3
[56] Nguyen, 2019, p. 4
[57] Yaga, 2019, p. 20

consensus mechanism created, proof-of-stake was created as a way to reduce environmental impact, make transaction adding a more fair process, and maintain the same level of security.

Proof-of-stake (PoS) is a consensus model based on the stake a network user invests, often in the form of cryptocurrency, which depends on the success entire network to ensure that all network participants act to the communal benefit of the blockchain.[58] Simply put, PoS's blockchain is secured based on every node having a financial stake in the chain's success.[59] A signature distinguishment between PoW and PoS is generating consensus on the blockchain utilizing low block rewards.[60] PoS expands the value of native coins on their blockchain network and therefore, shifts the validator incentive to encourage the nodes to move towards consensus.[61] Investing energy into computational power is not utilized in the PoS blockchain network and blockchain leaders are based on the stake in the network that the individual participant has.[62]

Chapter Three: Background on Auditing

Traditional Accounting and Auditing. Starting in 13th century Italy, accounting originated from recording merchant transactions using the double-entry method.[63] As the language of business, accounting has facilitated the translation of information from the data that surrounds us into a language that converts the complexities of financial data into a concise summary.[64]

Auditing is the examination of a firm's financial reports by an independent party to form a professional perspective, via an audit report using auditing standards set by a governing

[58] Yaga, 2019, p. 21
[59] Larimer, 2013, p. 1
[60] Saleh, 2021, p. 4
[61] Saleh, 2021, p. 4
[62] Nguyen, 2019, p. 4
[63] Yu, 2018, p. 41
[64] Yu, 2018, p. 42

accounting standards board.[65] The purpose of auditing is obtaining a certified auditor to analyze a firm's financial statements prepared under the applicable financial standards reporting framework, and provide an educated opinion on the financial state of the organization.[66] Auditing standards exist to ensure that both private and public companies follow regulations and best practices created by regulatory and non-profit bodies that aid in determining the extent of procedures that must be completed to meet audit objectives.

It is the responsibility of the external auditor to monitor information management, identify what amounts in the financial statements would cause a material change in a financial statement user's decision-making process and provide an independent opinion on whether the client followed the applicable audit standards.[67] Monitoring information is necessary as an accountant to verify transaction symmetry and organize the vast amount of information provided by firms. Certified auditors divide the potential risk and limit a manager's liability exposure. As a certified auditor validates the information, there is an increase in the quality of the financial information that is used by stakeholders. It is an external auditor's responsibility to provide an independent opinion based on evaluating the financial statements based on the applicable auditing standards. As all individuals are susceptible to biases, it is necessary for auditors to remain completely independent from their clients, all while maintaining a positive communication and workflow.[68]

Auditing is performed for a variety of reasons but all involving requirements by stakeholders who rely on positive financial information for their incentives. Reasons include the following: public companies are required to conduct audits by the Security Exchange

[65] Pricewaterhouse Coopers, What is an Audit?
[66] Li, 2017, p. 296
[67] Chedrawi, 2018, p. 7 and 8
[68] Chedrawi, 2018, p. 8

Commission, investors requirement for non-public companies, companies accepting funds or grants from the government, companies accepting bank loans, or if a firm is looking to join a competitive list of firms, such as the Forbes 100.[69]

For an external party, a clean audit opinion indicates that the financial statements are credible from a material standpoint and given reasonable assurance by certified public accountants. To carry out a well-researched audit, an auditor will spend up to a month on a single client for a straightforward financial audit, depending on the needs of the client, the time frame of performing financial audits may vary from client to client.[70] According to the 10th Annual Audit Survey report, there are increasing audit fees that have persisted for the last decade and the reasons cited for the increases in costs are new standards created by Financial Accounting Standards Board (FASB), especially regarding revenue and lease reporting, high levels of mergers and acquisitions, and a focus on revenue recognition.[71] As accounting standards continue to evolve, an increase in the hourly pay of certified auditors is observed. On average, hourly fees have risen from $216 in 2009 to more than $283 per hour in 2019, the survey suggests that increases in auditing fees will continue to rise in the following years.[72]

Auditing Processes. The main tasks of auditing are the following: gathering financial materials pertinent to the audit, evaluating the level of compliance to accounting standards, reporting on risk management and internal controls of the firm, lastly audit engagement teams test accounts deemed material in the financial statements and investigate any material misstatements or alleged fraud.[73]

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[69] Keng, 2018
[70] Keng, 2018
[71] 10th Annual Audit Fee Survey Report
[72] 10th Annual Audit Fee Survey Report
[73] Kenton, 2020

Reconciliation is a vital auditing process in which multiple sets of transaction records are compared and checked for the same data. The reconciliation process inspects suspicious or unexplainable discrepancies in the accounts which can be done daily, monthly, semi-annually, or annually. This process is done to ensure that a firm's accounts in the general ledger are "consistent, accurate, and complete."[74] The time and money spent on reconciliations depend on the following factors: the size of the company, number of transactions, number of accounts, number of parties involved, number of bank accounts, etc.[75] For a small firm, reconciling accounts might take between two to three business days, but larger firms can take a week or more.[76]

Inefficiencies of Auditing. The current inefficiencies of the auditing system include the intensity of labor, high time consumption, and navigating complex regulatory standards.[77] Technical inadequacies of older auditing software have led to decreased billing realization rates on auditing engagements and other issues that are vital to conducting an efficient audit.[78] Computers, internet, and database advancements have facilitated the reduction of the inefficiencies identified above, but these issues are still elements that must be improved in the future.

Human Trust. A most important part of auditing is the human factor that is incorporated into the auditing processes. Open dialogue and trust are established early within the relationship between the auditor and the client.[79] This intangible element of auditing is the human and social interactions that are essential to carrying out a successful and well-done audit. Auditing is a

[74] Tuovila, 2020
[75] Q&A Forum
[76] Q&A Forum
[77] Cryptoeconomics, 2018
[78] Chang, 2018
[79] Auditing the Human Element, 2014

relational business that relies on the reputation of the audit firm to attract new clients. Within the independent business relationship between the client and the audit firm, there is a degree of reliance on the reasonable assurance provided by the auditors on the client's financials.[80] Although we expect that the high level of training and ethical guidelines that are expected of auditors is congruent to the client's values and ethical standards, the audit team cannot assume that the financial statements are clear of material misstatement.[81] It is essential for the audit team to approach their analysis from a perspective of risk and identify which accounts they should test based on the predicted level of material error.[82]

In studying blockchain, trust is an essential element that should be highlighted as it must be created through technology and therefore, users of the blockchain should also be knowledgeable of how the trust treated impacts transactions.[83] In a human sense, trust is created within interpersonal relationships where people rely on one another for a purpose and can be created through friendships, written or verbal agreements, etc. On the other hand, blockchain does not inherently create trust as it is not organically formed and requires programmers to create the traits of trust blockchain users rely on, such as transparency, accessibility, and security.[84] In order to provide the best service to clients, understanding trust and how it is perceived, in a technical sense, among users is essential in order for programmers to meet the characteristics of trust in blockchain that users are looking for.[85] The idea that blockchain is a trustless environment comes from its anonymous peer-to-peer based transactions that is at the foundation of why blockchain was originally created as no trust is needed when transactions are seen by

[80] Auditing the Human Element, 2014
[81] Acca
[82] Acca
[83] Shin, 2020 (p. 1-2)
[84] Shin, 2020 (p. 4)
[85] Shin, 2020 (p. 15)

every user.[86] Although blockchain is a dynamic technology, this notion does not recognize the human trust that is still required for the operations and programming of the blockchain on a regular basis.[87]

Chapter Four: Blockchain's Application in Auditing

Automating steps within auditing processes will not take the value or profit of a firm away from it, the application of blockchain into accounting services, such as auditing, will allow auditors to utilize the visibility of transparent transactions on a secure forum. As cryptocurrency and new financial applications are emerging, it is vital for auditors to be well equipped to effectively provide their services. Auditing processes take intense labor, a high volume of time, and require navigating intricate accounting standards. The major promises of blockchain are embedded in its inherent characteristics which are decentralization, transparency, automaticity, and immutability, each of which are discussed in more detail below.

Promises of Blockchain in Auditing. In this section, the possible advantages that blockchain can provide the auditing industry will be discussed and assumes that both the client and the auditor utilize blockchain technology. The current issues regarding assurance that can be remedied by blockchain are large time-consumption of auditing, reliability issues, and security concerns. To minimize the costs of an audit, it is evident that the easier it is to gather financial records that have been properly reported under appropriate accounting standards, the less time auditors will have to spend conducting tests to ensure that all transactions are correct and presented fairly.[88] A majority of the time spent during an audit is spent conducting data-entry and clerical work that would not need to be done with appropriate use of electronic accounting

[86] Craggs, 2019 (p. 3)
[87] Craggs, 2019 (p. 10)
[88] Keng, 2018

systems or proper bookkeeping.[89] In applying blockchain to auditing services, auditors can use the distributed ledger technology as a basis to verify reported transactions and eliminate the need to manually extract data that is normally done by auditors.

Data Base. The biggest client complaint of auditing is the lag between the transaction and verification dates in financial reports as well as the sheer amount of time it takes to manually extract relevant information from the firm's accounting records needed to create the report. Using blockchain, the transactions that are chronologically reported on the distributed ledger can more easily be organized and seen by the auditor. Due to the inherent organization of blockchain, audit time should be greatly reduced and allow for less time spent on verifying transactions and more time for the certified auditor to create a well-educated report on the firm based on the statements provided by the blockchain-based audit.[90]

Permanent Ledger. A common benefit of blockchain is the irreversibility of the transaction record, which would provide reliable financial statements to clients.[91] Since all transaction data is recorded on the nodes of the network and not centrally located to one source, and each block in the blockchain is hashed together referencing previous blocks, double-sending, deletion, and reversing transactions risks are dramatically reduced.[92] Yet there are instances, such as the DAO fork[93], in which Ethereum's development team decided to create a hard fork in the existing blockchain and created a new path for clients on the network to jump over to.[94] Developers located the point in the blockchain ledger where the attack occurred and split the

[89] Keng, 2018
[90] Li, 2017, p. 296
[91] Boillet, 2018
[92] Blockchain Technology and its Potential Impact on the Audit and Assurance Profession, AICPA
[93] A hard fork in blockchain is the change in the protocol of the network which invalidates blocks and transactions that were valid or validates blocks and transactions that were invalid. This requires all nodes to jump to the new version of the blockchain. Frankenfield, 2019
[94] Orcutt

chain; the new blockchain is now referred to as Ethereum and the original chain is Ethereum Classic.[95] This decision has greatly impacted the very nature of blockchain as the developers of Ethereum rewrote history and essentially defeated the purpose of blockchain. How can the irreversibility of blockchain be trusted if the coders of the blockchain itself can change the course of the transaction history?

Transparency. Transparency and traceability techniques can be greatly improved with blockchain as the probability of fraud being found increases with the use of a permanent digital transaction ledger.[96] For example, the use of digital signatures, which utilizes cryptography and mathematics to prove one's identity, facilitates increased security and anti-fraud system implementation for auditors.[97] It is essential to auditing firms to maintain a reputation of integrity and accountability as all businesses entrust them to provide reliable advice on vital matters to a firm's financial security. Anti-counterfeiting efforts will also be improved as blockchain's ledger and anti-tampering methods will allow auditors to trace transactions and prevent bad actors from changing the ledger. Recording transactions at the same time they occur will allow auditors quick access to transaction data and further increase transparency.[98]

Efficiency. Many firms should experience a reduction in the need for financial statement reconciliation with a centralized and single ledger because transaction information is being reported in one ledger rather than multiple, as it is traditionally. This increases the efficiency of firms and allows services to be performed promptly for clients. And lastly, blockchain uses encryption to validate the transactions made, so by its very coding, blockchain ensures that fake transactions are not hashed onto the previous transactions. According to EY's figures, using

[95] Siegel
[96] Chedrawi, 2018
[97] Boillet, 2018
[98] Cryptoeconomics, 2018

blockchain rather than centralized databases for information storage and processing is potentially 90 to 95% cheaper than what firms are paying today.[99] Simply as a database, blockchain can significantly reduce the cost of storing and organizing information in a way that makes data easier to find and store in a secure space.

Smart Contracts. As described in the section above, smart contracts are a set of agreements written in code that are self-executing and exist in the blockchain.[100] These coded scripts allow multi-step processes, such as reconciliations, to become automated.[101] An application that is being explored is utilizing smart contracts to automatically regulate accounting guidelines onto financial statements.[102] If the Generally Accepted Accounting Principles (GAAP) and the Financial Accounting Standards Board (FASB) were regulated via automatic smart contract functions, it may decrease the operational risks and errors of financial statements which would increase the efficiency and effectiveness of the audit process.[103]

Trust and Regulation. Understanding trust in blockchain is significant to the usage of the technology itself as uncertain outcomes and vulnerable information are at stake.[104] The use of private or public oversight is necessary during the transition of trust from human to computers. The power behind an individual's trust is what gives blockchain and cryptocurrency its power because they both do not exist in a physical sense, rather individuals must believe that they exist and trust its capability to protect their money and information.

Blockchain can supplement law by acting as another level of regulation for firms to be responsible for.[105] Blockchain can also complement law by working in coordination with

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[99] Karajovic, 2019, p. 324
[100] Frankenfield, 2020
[101] Christidis, 2016, p. 2292
[102] Yu, 2018, p. 42
[103] Yu, 2018, p. 42
[104] Werbach, 2018, p. 494
[105] Werbach, 2018, p. 534

regulations already set-in stone. DLTs can be integrated into existing trust frameworks, such as banking software, so that regulations will be more scalable.[106] Accounting standards are enforced by FASB and the International Accounting Standards Board (IASB), but their system relies on the ethical and moral values of every individual auditor. With the help of blockchain, these standards can be automated and monitored continuously.

The possible solutions that are necessary to explore are adapting the law to encounter the challenges that blockchain presents, further integration of smart contracts into enforcing laws, and embedding DLT into legal enforcement.[107] Using smart contracts and blockchain will provide accounting standard setters a way to ensure their regulations are being followed as decisions are recorded and saved within the ledger. Another important factor that must be considered moving forward are the implications of too little or too much law on the blockchain. Either direction might lead to too little law that Blockchain grows uncontrolled or too much where blockchain is driven underground.[108]

Regulation as we know it today is government mandated and organized but new versions of regulation are derived from market incentives and technological architecture. Regarding the research at hand, blockchain is created by code and operates on the rules that it is coded on. Code requires stability and manifestation as a physical rule-maker which is what regulation can provide.[109] To be recognized legally and compared as an equal to current laws, code must work in coordination with regulations that are trusted by the general population. As individuals put their trust into code, auditors are ensured that their clients will trust the data that they provide

[106] Werbach, 2018, p. 537
[107] Werbach, 2018, p. 539 and 543
[108] Werbach, 2018, p. 550
[109] Finck, 2018, p. 44

using blockchain technology. Using blockchain in auditing firms will be able to enforce the efficiency of their services while also providing a level of trust from auditors.

Perils of Blockchain in Auditing. As a maturing technology, blockchain has failures that need to be addressed before implementing it into the process of auditing.

Synchronization. As explained in the 'Blockchain Components' section, the first problem introduced by DLTs is ensuring that all participants of the network are synchronized, as all ledgers must not fall out of synch with each other because it opens the opportunity for double spending the same assets.[110] Because the synchronization process requires a large amount of computing power to verify transactions in coordination with every node on the network, questions have been raised regarding the impact of blockchain on the environment.

Node Failure. Node failure is a common issue related to blockchain technology. Nodes can drop off the network or leave autonomously, but there may be internal computer issues or external physical damage to the node, or computer, as well. It has been proposed that self-detection or self-configuration factors may be required to keep nodes from failing during transactions.[111]

Environmental Externality. For example, Bitcoin's annual total carbon footprint is estimated to be 36.91 Mt CO2 which is equivalent to the carbon footprint of New Zealand. Bitcoin also has an electrical energy consumption of 77.72 TWh which is comparable to Chile, and 10.76 kt of electronic waste which is around the amount of Luxembourg.[112] One suggested solution is shifting the proof-of-work process of verifying transactions and transitioning to a proof-of-stake process that uses less energy by allocating mining power based on the percentage

[110] Blockchain and the Future of Accountancy ICAEW thought leadership, IT Faculty
[111] Li, 2018, p. 180
[112] Bitcoin Energy Consumption Index

of coins held by the miner.[113] Proof-of-stake is also found to have a smaller potential for an attack as the economic incentives structure is less advantageous for the miner.[114]

Human Involvement. Another common risk is the over-reliance of these technological innovations for automation that still require, to a large degree, human oversight.[115] The vast human element that is required to create a blockchain-based system is worrisome as humans must code the blockchain to create reliable solutions, but due to the human influence on the technology, human errors must be taken into consideration.[116] Another factor to consider as a blockchain user would be, what motives do coders have and what incentivizes them to code the programs in a mutually beneficial way for every participant?

Regarding auditing, human involvement is a pivotal requirement to the value of an auditing firm. Without establishing a reputation of trust and commitment, accounting firms would not be able to form a loyal customer base. An auditor's high-level training and ethical standards provide their blockchain platforms the trust needed for the client to feel reassured.

Legal Jurisdiction. As the nodes of the blockchain network can be disbursed all around the world, establishing jurisdiction for handling disputes is difficult to identify. Jurisdiction refers to the court authority or regulatory body that has the legal right to make decisions on disputes regarding the laws or regulations set in place.[117] While in permissioned blockchains, a preestablished dispute resolution process can be set into place, a public blockchain could be subject to every jurisdiction that each node resides.[118] Regarding the usage of accounting standards, there is little research on how bookkeeping should be done for firms with

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[113] Finck, 2018, p. 20
[114] Frankenfield, 2020
[115] Boillet, 2018
[116] Chedrawi, 2018, p. 7
[117] JURISDICTION: meaning in the Cambridge English Dictionary
[118] Salmon, 2019, p. 2

cryptocurrency assets. For auditing to be simplified, increased research and regulations must be established by FASB and the International Accounting Standards Board (IASB).

Regulation. Because trust is no longer placed in the intermediaries of transactions, blockchain must make up for the trust no longer instilled into the intermediaries. The distributed nature, shared transaction history, cryptography usage, and overriding capabilities provide the technology with trustworthy characteristics.[119] But from the blockchain scandals that have occurred such as the DAO attack, Mt. Gox[120], and others, it is evident that blockchain technology is far from perfect.

Technology always renders regulation outdated as regulatory bodies cannot evolve at such a high pace.[121] But the constant necessity for the legal and regulatory framework of both private and public institutions is crucial for continued high-tech adoption. Regulations within blockchain are necessary because they provide an ethical framework that can be followed by network participants to protect those who are vulnerable, such as new users of the blockchain.[122] The current system is deemed inadequate to handle regulation of blockchain because current laws and regulations enforced by federal level government are geared towards centralized firms with a particular body of authority, to which blockchain organizations do not fit.[123]

Accounting Standards. FASB has yet to release any framework for how cryptocurrencies should be handled concerning financial reporting.[124] Defining the location of a network on cyberspace is an under-developed territory of research that requires more attention as disputes

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[119] Yaga, 2019, p. 2
[120] Mt. Gox was a Bitcoin exchange in Tokyo that launched in 2010 and in 2014 the exchange closed and filed for bankruptcy. They announced that over 850,000 customer and company bitcoins were stolen from the exchange.
[121] Borg, 2019, p. 188
[122] Borg, 2019, p.188
[123] Salmon, 2019, p. 1
[124] Board Room of the FASB Offices- 401 Merritt 7 (2019)

rise and all potential risks remain unknown.[125] This issue has been brought up in FASB meetings in which many respondents find that blockchain has not grown to the point of great concern for altering any International Financial Reporting Standards as of now.[126] But regulatory powers need to understand that blockchain technology is not an advancement that will go away, it will just advance further.

Chapter Five: Real World Audit Applications

The following applications of blockchain in the accounting field have proven successful in their services utilizing distributed ledger technology. All applications have illustrated how blockchain technology can be effectively used in the accounting field as well as shown solutions to the inadequacies that accounting firm clients have introduced. While a failed auditing blockchain platform was sought after for this paper, the application is so new that all companies utilizing their versions of accounting software on blockchain platforms have not published or openly reported scandals or even minor issues.

Factom. As an innovative blockchain company, Factom blockchain is an open-source, fully decentralized platform that provides a blockchain-as-a-service for its clients.[127] Their systems aid clients in creating business-ready apps that preserve evidence, demonstrate compliance, increase process transparency, streamline audits, reduce costs, and automate transactions, all doing so without costly infrastructure or cryptocurrency exposure. [128] Their company's foundation is based upon complete security of data on the blockchain and providing their clients with an immutable record.[129] Factom technology can specifically aid in the auditing

[125] Salmon, 2019, p. 8
[126] Board Room of the FASB Offices- 401 Merritt 7 (2019)
[127] Factom
[128] Factom
[129] Saul Schwartzbach, 2020, Private Messaging via LinkedIn

process by cutting down time analyzing financial documents so that auditors have the most correct statements to date to present their clients.

Some examples of Factom's real world usage are the following cases. Equator, a company in the mortgage industry, leverages Factom blockchain in order to track individual loans via blockchain.[130] Equator then has access to an immutable record of data, their documents, and the vital audit reports pertinent to decision making.[131] Another company, Vodii, also leverages Factom's blockchain for the same uses in the title and escrow industry.[132] On a larger scale, a Chinese legal court in Hangzhou city utilized Factom's technology in order to organize evidence in a copyright infringement lawsuit.[133]

Unlike other public blockchains, Factom's distributed ledger facilitates the chronological linkage of related transactions to minimize storage usage and retrieval times more efficiently for data.[134] The peer-to-peer network is governed by a system whose membership is contingent on performance and community support, which means that request submissions and entries can be made at a cost based on the chain and entry size.[135]

Factom's Authority Node Operator, Saul Schwartzbach, noted several setbacks recently experienced by Factom and other decentralized public blockchains, especially in regard to regulations of the United States government. Schwartzbach stated that Factom has been using a conservative approach when integrating cryptocurrency into their business model which has recently resulted in a strain of their resources due to lack of customer awareness. Another decision that Factom consciously made during the process of creating their blockchain platform

[130] Altisource Portfolio Solutions, 2018
[131] Equator, 2020
[132] Vodii, 2020
[133] Saul Schwartzbach, 2020, Private Messaging via LinkedIn
[134] Factom
[135] Factom

was not introducing an initial coin offering for their platform and Schwartzbach finds that it will be beneficial for Factom in the long run.[136]

Verady. As a cryptocurrency tax, accounting, and audit technology company, Verady provides its services to customers via the VeraNet asset assurance network.[137] Their systems improve how financial statements are prepared for blockchain networks by allowing a firm to view all digital assets in a singular setting that is constantly up-to-date and can integrate with the top blockchains and cryptocurrency exchanges available.[138] Bridging the gap between the modern cryptocurrency world and traditional financial needs is essential to providing the financial statements needed for auditing processes.[139]

Auditing services provide both essential management suggestions as well as quantitative financial information based on the financial statements provided by the firm to the auditor.[140] Verady's blockchain technology has enabled them to manage cryptocurrency transaction data to produce traditional financial verification and standardized reports. This would aid auditors by allowing them to have their client's cryptocurrency transaction history in a concise and reportable statement. Their platform, Legible, can be integrated into some common accounting platforms, such as Xero, QuickBooks, and Netsuite, which allows users to synchronize their cryptocurrency assets with the rest of their finances.[141] Ledgible generally provides clients with financial reports, capital gains and losses report, and a streamlined way for them to view their cryptocurrency portfolio. Verady is an example of how blockchain has the power to verify cryptocurrency transactions to provide tax filing, accounting, and auditing services.

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[136] Saul Schwartzbach, 2020, Private Messaging via LinkedIn
[137] Verady
[138] Verady
[139] Ledgible adds Multiple Foreign Currencies Support, 2019
[140] Ledgible adds Multiple Foreign Currencies Support, 2019
[141] FAQ, Ledgible

R3. As an enterprise blockchain software firm, R3, is collaborating with a wide ecosystem of industries, both in the private and public sectors. The company launched Corda, which is an open-source blockchain platform that meets the needs of network infrastructure requirements of highly regulated industries by conducting business on a strict privacy model as a permission-less blockchain platform.[142] All available data is shared with the parties involved in each business transaction and Corda allows firms to make transactions securely and efficiently. R3 can specifically aid in the auditing process by organizing sensitive financial information in a platform that is easily accessible to both the auditor and their client.

R3 has developed two interoperable distributions of the Corda platform, Corda and Corda Enterprise.[143] Corda is a free download-based platform on GitHub while Corda Enterprise is a commercial directed platform that allows firms with high volumes of data and currency to require a modified blockchain platform that can organize and manage the volume of data.

R3's newest platform, Conclave, gives businesses the power to organize and process sensitive data from multiple parties in a confidential manner which allows companies to collaborate in a secure way. Data misuse is protected against in Conclave using confidential computing and Intel SGX which is assurance for data and allows users to feel confident about the safety of their information.[144]

R3's usage of the permission-less distributed ledger while also applying a strict privacy model is a unique use of the ledger system to protect privacy, but more research needs to be done on the advantage and disadvantages of this application and whether it would be beneficial to use the same model for auditing systems.

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[142] R3
[143] Corda Enterprise
[144] Conclave

Chapter Six: The Future Application of Blockchain in Auditing

Due to the reason financial auditing exists, either legal requirements for publicly listed companies in the United States or demand from company stakeholders, agency problems are formed between the owner and employees.[145] As an analytical process to ensure the financial statements are reported fairly and according to auditing standards, financial audits can mitigate agency problems, and using blockchain in auditing can provide the needed transparency between the agent and principle to reduce asymmetric information and increase accuracy in the certified public accountant's opinion. [146]

As stated above, the integration of blockchain technology will increase the audit process, as they take intense labor, a high volume of time, and require navigating intricate accounting standards. By integrating blockchain into the audit process, it may help mitigate the risks that audit standards try to control. By automating certain steps in the auditing process, it will not decrease the value or profit of an auditing firm. Rather, it would increase efficiency and accuracy of the audit process. The external auditor's value is derived from the opinion made on a company's financials and their determination if the financial statements followed all standards applicable to the company.

This paper discusses the promises and perils of blockchain in auditing. By combining available literature and data, the contribution of this paper is to provide a comprehensive summary of blockchain technology and how it will change auditing. This paper argues that the necessity for human opinion in auditing processes, such as creating reports, cannot be removed as the value of the service is not derived from the audit itself. The value of the audit rests in the certified auditors who provide financial advice and the relationship created with the entire firm.

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[145] Chedrawi, 2018, p. 9
[146] Chedrawi, 2018, p. 11

This paper also argues that blockchain will provide solutions to issues in auditing, such as the intensity of labor, high time consumption, and navigating complex regulatory standards.[147]

[147] Cryptoeconomics, 2018

References

"Confidential Computing Platform for Next-Gen Data Sharing." *Conclave*, 11 Feb. 2021, conclave.net/why-conclave/.

"FAQ." *Ledgible*, 17 Oct. 2019, ledgible.io/faq/.

10th Annual Audit Fee Survey Report. (n.d.). Retrieved from https://www.financialexecutives.org/Research/Publications/2020/10th-Annual-Audit-Fee-Survey-Report.aspx

Abreu, P. W., Aparicio, M., & Costa, C. J. (2018, June). Blockchain technology in the auditing environment. In *2018 13th Iberian Conference on Information Systems and Technologies (CISTI)* (pp. 1-6). IEEE.

Acca. (n.d.). Why the value of audit is more crucial than ever. Retrieved from https://www.accaglobal.com/my/en/member/member/accounting-business/2018/02/practice/audit-crucial.html

Alharby, M., & Van Moorsel, A. (2017). Blockchain-based smart contracts: A systematic mapping study. *arXiv preprint arXiv:1710.06372*.

Altisource Portfolio Solutions S.A. (2018, November 13). Equator Launches Mortgage Servicing Blockchain Solution. Retrieved from https://www.globenewswire.com/news-release/2018/11/13/1650572/0/en/Equator-Launches-Mortgage-Servicing-Blockchain-Solution.html

Audit innovation. (n.d.). Retrieved from https://www.ey.com/en_gl/audit/innovation

Auditing the human element. (2014, May 6). Retrieved from https://transform.iema.net/article/auditing-human-element

Bentov, I., Lee, C., Mizrahi, A., & Rosenfeld, M. (2014). Proof of activity: Extending bitcoin's proof of work via proof of stake [extended abstract] y. *ACM SIGMETRICS Performance Evaluation Review*, *42*(3), 34-37.

Bible, W., Raphael, J., Taylor, P., & Valiente, I. O. (2017). Blockchain technology and its potential impact on the audit and assurance profession. *Aicpa. org*.

Bitcoin Energy Consumption Index. (n.d.). Retrieved from https://digiconomist.net/bitcoin-energy-consumption

Bloomenthal, A. (2020, January 29). An Uneven Playing Field: Asymmetric Information. Retrieved from https://www.investopedia.com/terms/a/asymmetricinformation.asp

Board Room of the FASB Offices- 401 Merritt 7. (n.d.). Retrieved from https://www.fasb.org/jsp/FASB/Document_C/DocumentPage&cid=1176173849557

Boillet, J. (2018, September 28). How can you build trust when emerging technologies bring new risks? Retrieved from https://www.ey.com/en_gl/digital/how-can-you-build-trust-when-emerging-technologies-bring-new-risks

Borg, F. J., & Schembri, T. (2019) Blockchain & Cryptocurrency Regulation: The Regulation of Blockchain Technology. *Global Legal Insight,* (188-192).

Business and Leaders. (2019, March 6). Focus: Blockchain Validation vs Consensus, Explained by BitSong. Retrieved from https://businessandleaders.it/2019/02/27/blockchain-validation-vs-consensus/

Cachin, C., Sorniotti, M. V., & Weigold, T. (2016). Blockchain, cryptography, and consensus. *IBM Res., Zürich, Switzerland, Tech. Rep*, *2016*.

CGMA, C. (2018). Blockchain augmented audit–Benefits and challenges for accounting professionals. *The Journal of Theoretical Accounting Research*, *14*(1), 117-137.

Chang, H., Kao, Y.-C., Mashruwala, R., & Sorensen, S. M. (2018). Technical Inefficiency, Allocative Inefficiency, and Audit Pricing. *Journal of Accounting, Auditing & Finance*, *33*(4), 580–600. https://doi.org/10.1177/0148558X17696760

Chedrawi, C., & Howayeck, P. (2018). Audit in the Blockchain era within a principal-agent approach. *Information and Communication Technologies in Organizations and Society (ICTO 2018):"Information and Communications Technologies for an Inclusive World*.

Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the internet of things. *Ieee Access*, *4*, 2292-2303.

Collomb, A., & Sok, K. (2016). Blockchain/distributed ledger technology (DLT): What impact on the financial sector?. *Digiworld Economic Journal*, (103).

Corda Enterprise - Blockchain Platform for Business. (n.d.). Retrieved from https://www.r3.com/corda-platform/

Craggs, B., & Rashid, A. (2019, May). Trust beyond computation alone: Human aspects of trust in blockchain technologies. In *2019 IEEE/ACM 41st International Conference on Software Engineering: Software Engineering in Society (ICSE-SEIS)* (pp. 21-30). IEEE.

Cruz, R. D. L. (2019). Privacy Laws in the Blockchain Environment. *Annals of Emerging Technologies in Computing (AETiC)*, *3*(5), 34-44.

Cryptoeconomics. (2018, December 11). The Future of Blockchain-based Auditing is Called "Multi-chain Reconciliation through Blockchain... Retrieved from https://medium.com/@cryptoeconomics/the-future-of-blockchain-based-auditing-is-called-multi-chain-reconciliation-through-blockchain-d909ee41f89d

Cryptography. (n.d.). Retrieved from https://techterms.com/definition/cryptography

Deloitte named world's most valuable professional services brand: Deloitte Malta: Press release. (2019, August 26). Retrieved from https://www2.deloitte.com/mt/en/pages/about-deloitte/articles/mt-pr2019-002-deloitte-named-worlds-most-valuable-professional-services-brand.html

Ducas, E., & Wilner, A. (2017). The security and financial implications of blockchain technologies: Regulating emerging technologies in Canada. *International Journal*, *72*(4), 538-562.

Equator. (2020, February 27). Retrieved from https://www.equator.com/company/

Factom. (n.d.). Retrieved from https://www.factom.com/

Finck, M. (2018). *Blockchain regulation and governance in Europe*. Cambridge University Press.

Frankenfield, J. (2020, January 29). Proof of Stake (PoS). Retrieved from https://www.investopedia.com/terms/p/proof-stake-pos.asp

Frankenfield, J. (2020, January 29). Smart Contracts: What You Need to Know. Retrieved from https://www.investopedia.com/terms/s/smart-contracts.asp\

Gao, Y., & Nobuhara, H. (2017). A proof of stake sharding protocol for scalable blockchains. *Proceedings of the Asia-Pacific Advanced Network*, *44*, 13-16.

Gomaa, A., Gomaa, M., & Farag, M. (2019). The Creation of One Truth: Single-Ledger Entries for Multiple Stakeholders Using Blockchain Technology to Address the Reconciliation Problem. *Available at SSRN 3397684*.

Grand, A., Wilkinson, C., Bultitude, K., & Winfield, A. F. (2012). Open science: a new "trust technology"?. *Science Communication*, *34*(5), 679-689.

Haseebrabbani. (2017, October 12). What is Hashing & Digital Signature in The Blockchain? Retrieved from https://blockgeeks.com/what-is-hashing-digital-signature-in-the-blockchain/

Hawlitschek, F., Notheisen, B., & Teubner, T. (2018). The limits of trust-free systems: A literature review on blockchain technology and trust in the sharing economy. *Electronic commerce research and applications*, *29*, 50-63.

Herbsleb, J. D., & Grinter, R. E. (1999, May). Splitting the organization and integrating the code: Conway's law revisited. In *Proceedings of the 21st international conference on Software engineering* (pp. 85-95).

Holland, D., Kiseleva, K., & Grigoryan, V. (2020). *U.S. Patent Application No. 16/038,680*.

Hu, D., Lin, S., & Zhang, J. (2019). *U.S. Patent Application No. 16/424,750*.

Huang, L., Zhang, G., Yu, S., Fu, A., & Yearwood, J. (2019). SeShare: Secure cloud data sharing based on blockchain and public auditing. *Concurrency and Computation: Practice and Experience*, *31*(22), e4359.

ICAEW. (2017). Blockchain and the future of accountancy.

Insights, D. (2019). Deloitte's 2019 Global Blockchain Survey. *Blockchain Gets Down to Business. Deloitte*.

Karajovic, M., Kim, H. M., & Laskowski, M. (2019). Thinking outside the block: Projected phases of blockchain integration in the accounting industry. *Australian Accounting Review*, *29*(2), 319-330.

Keng, C. (2018, May 31). How Much Do Financial Audits Cost? At Least $10,000 Dollars. Retrieved from https://www.forbes.com/sites/cameronkeng/2018/05/31/how-much-do-financial-audits-cost-at-least-10000-dollars/

Kenton, W. (2020, January 29). Audit Department. Retrieved from https://www.investopedia.com/terms/a/audit-department.asp

Kim, H., & Laskowski, M. (2017, July). A perspective on blockchain smart contracts: Reducing uncertainty and complexity in value exchange. In *2017 26th International Conference on Computer Communication and Networks (ICCCN)* (pp. 1-6). IEEE.

Kosba, A., Miller, A., Shi, E., Wen, Z., & Papamanthou, C. (2016, May). Hawk: The blockchain model of cryptography and privacy-preserving smart contracts. In *2016 IEEE symposium on security and privacy (SP)* (pp. 839-858). IEEE.

Larimer, D. (2013). Transactions as proof-of-stake. *Nov-2013*.

Ledgible adds Multiple Foreign Currencies Support. (2019, November 4). Retrieved from https://verady.com/news/developing-bank-statements-for-blockchains/

Lessig, L. (1999). Code is law. *The Industry Standard*, *18*.

Lessig, L. (2003). Law regulating code regulating law. *Loy. U. Chi. LJ*, *35*, 1.

Li, Jiao. "Data transmission scheme considering node failure for blockchain." *Wireless Personal Communications* 103.1 (2018): 179-194.

Li, Z. (2017). Will blockchain change the audit?. *China-USA Business Review*, *16*(6), 294-298.

Liang, X., Zhao, J., Shetty, S., & Li, D. (2017, October). Towards data assurance and resilience in IoT using blockchain. In *MILCOM 2017-2017 IEEE Military Communications Conference (MILCOM)* (pp. 261-266). IEEE.

Libra: A New Global Payment System. (n.d.). Retrieved from https://libra.org/en-US/

Liebkind, J. (2020, January 29). DAOs, Blockchain, and the Potential of Ownerless Business. Retrieved from https://www.investopedia.com/news/daos-and-potential-ownerless-business/

Lu, Q., & Xu, X. (2017). Adaptable blockchain-based systems: A case study for product traceability. *IEEE Software*, *34*(6), 21-27.

Nakamoto, S. (2019). *Bitcoin: A peer-to-peer electronic cash system*. Manubot.

Nguyen, C. T., Hoang, D. T., Nguyen, D. N., Niyato, D., Nguyen, H. T., & Dutkiewicz, E. (2019). Proof-of-stake consensus mechanisms for future blockchain networks: fundamentals, applications and opportunities. *IEEE Access*, *7*, 85727-85745.

Nofer, M., Gomber, P., Hinz, O., & Schiereck, D. (2017). Blockchain. *Business & Information Systems Engineering*, *59*(3), 183-187.

Orcutt, M. (2019, May 2). Once hailed as unhackable, blockchains are now getting hacked. Retrieved from https://www.technologyreview.com/s/612974/once-hailed-as-unhackable-blockchains-are-now-getting-hacked/

Pouwelse, J., de Kok, A., Fleuren, J., Hoogendoorn, P., Vliegendhart, R., & de Vos, M. (2017). Laws for creating trust in the blockchain age. *European Property Law Journal*, *6*(3), 321-356.

PricewaterhouseCoopers. (n.d.). Malta's new regulatory framework built for blockchain technology. Retrieved from https://www.pwc.com/mt/en/publications/technology/pwc-malta-blockchain-alert.html

PricewaterhouseCoopers. (n.d.). What is an audit? Retrieved from https://www.pwc.com/m1/en/services/assurance/what-is-an-audit.html

Q&A Forum. (n.d.). Retrieved from https://www.proformative.com/questions/account-reconcilliation-tools-and-time-requirements

Rosic, A., & Blockgeeks. (2019, August 16). What Are Smart Contracts? [Ultimate Beginner's Guide to Smart Contracts]. Retrieved from https://blockgeeks.com/guides/smart-contracts/

Saleh, F. (2021). Blockchain without waste: Proof-of-stake. *The Review of financial studies*, *34*(3), 1156-1190.

Salmon, J., & Myers, G. (2019). Blockchain and associated legal issues for emerging markets.

Shin, D., & Bianco, W. T. (2020). In Blockchain We Trust: Does Blockchain Itself Generate Trust?. *Social Science Quarterly*, *101*(7), 2522-2538.

Siegel, D. (2016, June 27). Understanding The DAO Attack. Retrieved from https://www.coindesk.com/understanding-dao-hack-journalists

Somdip, D. (2018). *A proof of work: Securing majority-attack in blockchain using machine learning and algorithmic game theory* (Doctoral dissertation, Modern Education and Computer Science Press).

Taddeo, M. (2010). Trust in technology: A distinctive and a problematic relation. *Knowledge, Technology & Policy*, *23*(3-4), 283-286.

The Difference Between Blockchain and Distributed Ledger Technology. (2018, March 19). Retrieved from https://tradeix.com/distributed-ledger-technology/

Tuovila, A. (2020, February 5). Reconciliation Definition. Retrieved from https://www.investopedia.com/terms/r/reconciliation.asp

Verady. (n.d.). Retrieved from https://verady.com/company/

Vincent, N. E., & Wilkins, A. M. (2020). Challenges when auditing cryptocurrencies. *Current Issues in Auditing*, *14*(1), A46-A58.

Vodii. (2020). Retrieved from https://vodii.co/

Vranken, H. (2017). Sustainability of bitcoin and blockchains. *Current opinion in environmental sustainability*, *28*, 1-9.

Wang, M., Duan, M., & Zhu, J. (2018, May). Research on the security criteria of hash functions in the blockchain. In *Proceedings of the 2nd ACM Workshop on Blockchains, Cryptocurrencies, and Contracts* (pp. 47-55).

Werbach, K. (2002). A layered model for Internet policy. *J. on Telecomm. & High Tech. L.*, *1*, 37.

Werbach, K. (2005). Breaking the ice: Rethinking telecommunications law for the digital age. *J. on Telecomm. & High Tech. L.*, *4*, 59.

Werbach, K. (2009). Higher standards regulation in the network age. *Harv. JL & Tech.*, *23*, 179.

Werbach, K. (2018). Trust, but verify: Why the blockchain needs the law. *Berkeley Tech. LJ*, *33*, 487.

Xue, J., Xu, C., Zhao, J., & Ma, J. (2019). Identity-based public auditing for cloud storage systems against malicious auditors via blockchain. *Science China Information Sciences*, *62*(3), 32104.

Yaga, D., Mell, P., Roby, N., & Scarfone, K. (2019). Blockchain technology overview. *arXiv preprint arXiv:1906.11078*.

Yu, T., Lin, Z., & Tang, Q. (2018). Blockchain: The introduction and its application in financial accounting. *Journal of Corporate Accounting & Finance*, *29*(4), 37-47.

Zhu, X., & Wang, D. (2019, April). Application of Blockchain in Document Certification, Asset Trading and Payment Reconciliation. In *Journal of Physics: Conference Series* (Vol. 1187, No. 5, p. 052080). IOP Publishing.