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Invited Article

Blockchain: From Bitcoin to the Internet of Value and beyond

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Abstract

Information Systems (IS) scholars have made significant contributions to blockchain knowledge since blockchain technologies were first implemented in 2009 with the launch of Bitcoin. The overarching espoused aim of blockchain technologies is the decentralization of power over the Internet. Peer-to-peer payments were the first applications, followed by platforms for decentralized applications, decentralized autonomous organizations, and, more recently, self-sovereign identity, decentralized finance, nonfungible tokens, and metaverses. JIT invited Mary Lacity, director of the Blockchain Center of Excellence at the University of Arkansas, to provide an overview of the major innovations, explain how early enterprise adopters are using these innovations, and where these technologies might be headed. This paper, formatted as a conversation, hopes to inspire more IS scholars to engage in this rapidly evolving area.

In conversation with Leslie Willcocks, Joint Editor, JIT

Leslie Willcocks: In her role as Walton Professor of Information Systems and director of the Blockchain Center of Excellence at the University of Arkansas, Mary and her colleagues have deeply researched blockchain applications in industry, and much more. She has produced two books and many highly regarded papers on this ever-expanding area. Her conclusion: blockchain use by enterprises is a slow train, but it is coming. As joint editor-in-chief of JIT, I was intrigued as to the substance behind this conclusion, the challenges she was witnessing, the insights she has been getting, and what she was working on to take our knowledge further. As well as being a first-class academic, Mary has always had a strong rapport with practitioners, and I was fascinated to discover what she has been finding out about progress and direction. The COVID-19 questions also had to be asked.

Mary, we can begin with the basics. What is blockchain?

Mary Lacity: The term blockchain is a meta-concept that refers to several concepts and technologies, including distributed ledgers, consensus algorithms, cryptoassets, and smart contracts, to name a few. Before getting into the technical details, it is best to begin with what blockchains intend to facilitate. Fundamentally, blockchains aim to enable peer-to-peer transactions without relying on trusted third parties. It is the idea that we can evolve from an "Internet of information" that allows us to seamlessly share *information* to an "Internet of Value" where people transact *value*—that is, money and other assets—directly with each other (Tapscott and Tapscott, 2016). The pivot to an Internet of Value requires solutions to some very old problems—like double-spending, identity, credentials, bookkeeping, and a medium of exchange (i.e., money)—as well as to newer problems like cybercrime. Before blockchains, we relied on institutions to solve these problems; now, we rely on distributed technologies and incentivized communities to solve these problems (Lacity, 2020).

Leslie Willcocks: Let us get into the evolution. Many people associate blockchains with Bitcoin. As a trained historian, I know it is folly to identify a single person or event as the true beginning of an idea, but everyone seems to credit Satoshi Nakamoto as the creator of blockchain.

Mary Lacity: Yes, Nakamoto (2008) is the bellwether reference, but Nakamoto never uses the term "blockchain" in the Bitcoin white paper. Nakamoto (2008) did refer to a "chain of blocks". A blockchain is a database structure where recently approved transactions are sequenced and cryptographically locked in a time-stamped block and added to the top of the database.[1] The blockchain gets

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bigger and bigger over time, and transactions are immutable and tamper resistant.[2]

The timing of Bitcoin was no accident. After the 2008 Global Financial Crisis, people became increasingly distrustful of financial institutions. Movements like Occupy Wall Street ranted against wealth inequality and the influence of large financial institutions on government policy. People rallied against the government's power to control money. Bitcoin has its roots in Libertarian and Cypherpunk values, which aim to create social and political change by circumventing governments and large financial institutions through privacy-enhancing technologies (Lacity 2020).

Leslie Willcocks: How does Bitcoin process payments without banks and governments?

Mary Lacity: Bitcoin shifted payment processing from party-level record keeping to shared record keeping on a public distributed ledger, thus eliminating the need for reconciliations. Bitcoin shifted from government-issued currencies to a cryptocurrency (called bitcoin) that is guaranteed to be scarce, as the program locked the maximum number of bitcoins to be 21 million. Bitcoin moved away from trusted third parties (TTPs) like large banks to automated and community-driven, counter-party risk mitigation. Bitcoin (like many blockchain applications that followed) relies on cryptographic private–public key pairs to verify account ownership; whoever is in possession of the private key is assumed to be the legitimate owner of the "address," which is analogous to an "account." Preventing a double spend was a bit trickier to solve. Senders cannot be trusted to verify that they have enough cryptocurrency in their accounts to fund their transactions; therefore, an independent verifier is needed. Nakamoto's brilliant solution was to reward other people in the network (called "miners"[3]) with newly issued bitcoins to validate recently submitted transactions. The economic incentives of the Bitcoin network motivate validators to play by the rules.[4]

Leslie Willcocks: What is Bitcoin's significance today?

Mary Lacity: Bitcoin is important because it is the most visible ongoing proof that an open, public, decentralized, non-TTP-reliant application is secure and beyond government control—at least for one type of blockchain application, which is peer-to-peer payments. Other than a breach in August of 2010, Bitcoin's ledger has remained immutable (Shrem, 2019). All are welcome to participate. Millions of people use it—more than 100 million Bitcoin wallets have been created (Mitchell, 2020). Thousands of people help secure it by being miners. Bitcoin proves that the Internet of Value is technically feasible and that a shared digital ledger is highly secure.

Leslie Willcocks: Can you highlight some of the major innovations since Bitcoin?

Mary Lacity: Bitcoin, like all innovations, has limitations, and there is room for improvement. Bitcoin has limited functionality—it is just a payment system to send and receive bitcoins; it cannot do much else. Bitcoin has a greater price volatility than other major fiat currencies.[5] It is rather pokey, only capable of processing about two to six transactions per second (TPS), and it only creates a new block of transactions, on average, every 10 min[6] It is not yet user friendly, so most people end up relying on a trusted third party, or exchange, to buy and sell bitcoins. The miners who operate computers to secure the Bitcoin network consume *a lot* of electricity. Digiconomist tracks Bitcoin's energy consumption and reports that a single Bitcoin transaction consumes as much energy as 1,180,481 Visa transactions.[7]

Blockchain innovations since Bitcoin have aimed to improve upon it, depart from it, or extend beyond it. Figure 1 highlights some major innovations.

Altcoins

Some early innovations were new coins created by downloading the Bitcoin Core and altering the programming code. These are called "altcoins" because they are alternative coins to Bitcoin. A couple of early examples are Namecoin, launched in 2011, and Dogecoin, launched in 2013. Charlie Lee created Litecoin in 2011 to improve Bitcoin's settlement times by a factor of four; Litecoin creates a new block every 2.5 min instead of every 10 min like Bitcoin.

Enhanced Privacy

Although Bitcoin transactions are anonymous in that no personal identities are revealed on the public ledger, meta patterns can emerge that allow identities to be deduced.[8] Bitcoin is thus considered to be "pseudonymous" rather than "anonymous."[9] Privacy coins like Monero[10] (launched in 2015) and Zcash[11] (launched in 2016) were invented to overcome this limitation. Zcash uses zero-knowledge proofs to mask addresses. These innovations create complete anonymity, but in a way that prevents a double spend.

Platforms for Building dApps

Bitcoin is just a payment system to send and receive bitcoins; it cannot do much else. One reason is because Bitcoin does not have a Turing-complete[12] programming language, only a scripting language with limited functionality. Ethereum, launched in 2015, was invented, in part, to overcome this limitation; it is a platform for deploying other decentralized applications (dApps) and comes with a Turing-complete programming language called Solidity. Other dApp platforms include Cardano (launched in 2017), EOS and Tezos (launched in 2018), and Algorand (launched in 2019).

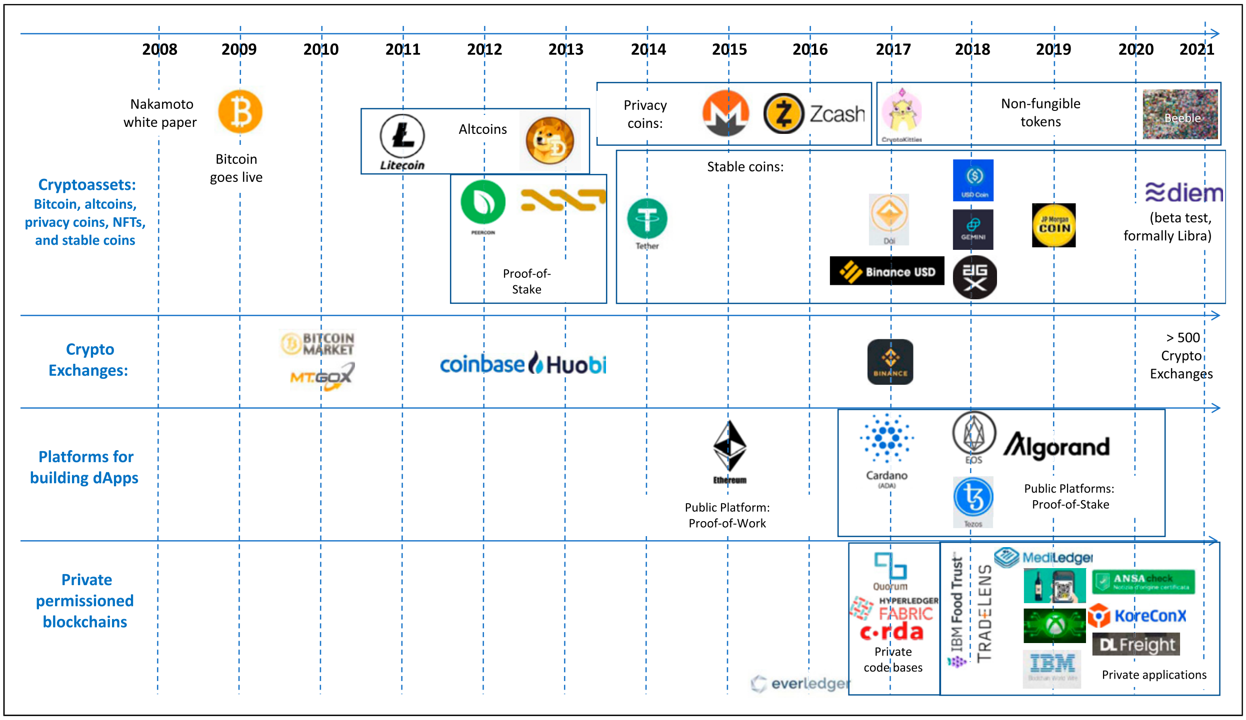

Figure 1. Timeline of major blockchain innovations.

Decentralized Autonomous Organizations (DAOs) are a special kind of smart contract that runs an entire organization automatically based on codified rules. The idea of a DAO is to create a completely independent entity that is exclusively governed by the rules a user programs into it and "lives" on the chain. One can think of a DAO as a company that has investors but no managers or employees. For example, in 2021, a decentralized community of investors used a DAO to pool their crypto to make a bid on one of the 13 original copies of the US Constitution. Their smart contract, called ConstitutionDAO, was launched on Ethereum and raised more than $20 million. Unfortunately, the community lost the auction to a bidder who bought it for $43 million. After losing the bid, all the money was returned to investors.[13]

Stable Coins

Compared to many fiat currencies, a lot of cryptocurrencies have high price volatility. In 2020, for example, Bitcoin's price ranged from $24,000 to $50,000 per bitcoin.[14] Stable coins overcome this limitation. Stable coins peg a cryptocurrency to a stable asset outside of the network, such as pegging a digital coin to a fiat currency or to commodity like gold or a barrel of oil. Notable stablecoins pegged to fiat currencies include Tether (launched in 2014), USD Coin and Gemini (launched in 2018), JPM Coin (launched in 2019), and the proposed Diem coin, which is the rebranded Facebook-dominated Libra coin, which is supposed to launch in 2021 (Lacity, 2020).

Nonfungible Tokens

Cryptocurrencies and fiat currencies are fungible assets in which tokens of the same kind are interchangeable. Nonfungible tokens (NFTs) were created to represent a particular asset, such as a work of art or a plot of land. Anyone can create NFTs on Ethereum by following the ERC-721 Token Standard for nonfungible tokens. Cryptokitties, an NFT launched on Ethereum in 2017, popularized NFTs (Wong, 2017). To date, Mike Winklelman—the artist known as Beeble—has the highest price paid for an NFT at $69 million for a digital collage of this work (Kastrenakes, 2021). NFTs can also enable fractionalized ownership; imagine a time when a few million fans own a sports team or when everyday art lovers share ownership of a Manet painting!

Scaling Solutions

Distributed systems have slower settlement times than centralized systems because distributed systems must propagate the newest version of the ledger throughout a network, creating latency problems. They also process fewer transactions per second—that is, low throughput.

Some innovations directly improve Bitcoin's performance. For example, Segregated Witness (implemented in 2017) is designed to squeeze more transactions into each Bitcoin block, which is capped at 1 MB by the original protocol, by moving digital signatures from the sender's address to a new part of a Bitcoin block.

Some innovations are "layer 2" solutions that run on top of Bitcoin to help unclutter the Bitcoin network. For example, the Lightning Network was available in 2017 to process intermediate transactions off chain. Functionally, it is like opening a bar tab with a credit card, ordering several drinks, and then settling the final bill with one payment. There are also layer 2 solutions for Ethereum, including the Raiden Network, Plasma, and Polygon.

User Access and Experience

Initially, the only way to interact with Bitcoin was to become a miner or to manage one's own digital wallet, which requires significant technical skills. Many people saw the need for an exchange where users could easily buy and sell bitcoins and other cryptocurrencies with fiat currency. *Cryptocurrency exchanges* were created to overcome this limitation. The first bitcoin exchanges were Bitcoin Market and Mt. Gox, both launched in 2010. Today, there are more than 500 cryptocurrency exchanges, including Coinbase, founded in 2012 in the United States; Huobi, founded in China in 2013; and Binance, founded in China in 2017 but which has since moved to Malta (Cryptimi, 2021; Garg, 2018). Early exchanges operated under the radar of regulatory bodies, and many consumers were at risk for shams.[15] Many exchanges now comply with regulations, including Know Your Customer (KYC) and Anti-Money Laundering (AML) requirements (Adeyanju, 2019). Increased compliance means a loss of user anonymity. Also, exchanges are trusted third parties, which are counter to the Cypherpunk and Libertarian values of the initial Bitcoin adopters.

Alternative Consensus Protocols

Consensus protocols are rules for adding validated transactions and making sure that copies of the distributed ledger agree. Bitcoin uses a proof-of-work (PoW) algorithm that results in a tamper-resistant ledger.[16] While highly secure, Bitcoin's proof-of-work consensus algorithm is resource intensive. To successfully compete for new bitcoins, Bitcoin miners use specialized computer hardware that consumes a lot of electricity. All the miners are burning electricity, even though only one will ultimately create the next block. Other consensus algorithms, most notably proof-of-stake (PoS), are designed to overcome this limitation. PoS selects the next validator node based on the size or age of its stake, which is the cryptocurrency locked away to show good faith, thus eliminating the frenzied competition of PoW. Peercoin (launched in 2012) and NXT (launched in 2013) are two early cryptocurrencies that use PoS. Platforms also use PoS, including Cardano, EOS, Algorand, Tezos, and Polkadot. Ethereum is also planning to move from PoW to PoS, probably by late 2022. Beyond proof-of-stake, other consensus protocols now include proof-of-activity (which combines proof-of-stake with proof-of-work), proof-of-authority, proof-of-capacity, proof-of-listening, proof-of-elapsed time, and proof-of-luck—the list goes on.

Leslie Willcocks: That's a lot of complicated innovations! How long did it take you to master the intricacies?

Mary Lacity: In my opinion, other than Tapscott and Tapscott (2016), there was no single source to learn about the why, what, who, where, and how of blockchains when I began my learning journey. I spent a lot of time learning on my own by reading white papers, interviewing thought leaders, and poking around Bitcoin, Ethereum, Ripple, and Stellar, which were the primary live blockchains in 2016. I decided to write the book I wished for when I was learning. The first book was published in 2018, but the space evolves so fast that I completely rewrote it in 2020. I am rewriting the blockchain fundamentals book once again, this time with a partner—Steve Lupien, director of the Center for Blockchain and Digital Innovation at the University of Wyoming. So, to answer your question, I have not "mastered" blockchains; I must keep learning (Lacity, 2018a; Lacity, 2020; Lacity and Lupien, 2022).

Leslie Willcocks: When did the more traditional enterprises pick up on all this?

Mary Lacity: Enterprises in the financial services sector have been among the first traditional organizations to recognize the threats and opportunities afforded by Bitcoin and cryptocurrencies. Traditional enterprises, including banks like Barclays, Santander, State Street, and Wells Fargo, that have been in continuous operation for hundreds of years, were among the early explorers of blockchain technologies. Industry consortia like R3, founded in 2014, were started to help incumbent enterprises create standards, write code bases, and bring blockchain financial services applications to life.

Enterprises have different needs and values than those espoused by Cypherpunks. Enterprises need confidentiality, not anonymity, and must comply with regulations, including KYC, AML, and General Data Protection Regulation (EU GDPR). Many enterprises want to control who submits transactions and who is allowed to operate a validator node,[17] whereas Bitcoin, for example, is public (anyone may submit transactions) and permissionless (anyone may operate a validator node). Therefore, private, permissioned blockchain code bases were developed, in part, to ensure confidential transactions comply with all regulations. Three popular private, permissioned code bases were released as open-source software in 2017: Corda (developed by R3), Hyperledger Fabric (initially developed by IBM and donated as open-source software (OSS)), and Quorum (initially developed by JP Morgan and donated as OSS). Enterprises and their trading partners used these code bases to create private solutions. For example, the Spunta Banca DLT solution is built on Corda; the IBM Food Trust is built on Fabric; and Winechain is built on Quorum.

Leslie Willcocks: At this point, Bitcoin is 12 years old. How would you characterize the size and maturity of blockchain?

Mary Lacity: As far as size, there are several markets to follow. The cryptocurrency market on the day of this writing (January 2022) had more than 17,000 cryptocurrencies and was worth more than 1.7 trillion US dollars (https://Coinmarketcap.com). This market fluctuates considerably.

The investment market to fund startups and projects includes traditional venture capital, as well as new investment models like initial coin offerings (ICOs), security token offerings (STOs), initial exchange offerings (IEOs), and initial decentralized exchange offerings (IDOs). The investment market was between $32 billion and $45 billion by 2020 (Lacity, 2020).

The enterprise services market is the hardest to size, but it is considerably smaller (about $2 billion in 2019), although it is estimated to grow to $64 billion by 2027 (Fortune Business Insights, 2021).

On maturity, Marco Iansiti and Karim Lakhani, both from Harvard Business School, published an insightful prediction on how blockchains would mature based on how TCP/IP matured (Iansiti and Lakhani, 2017). They argued that phase 1 brought single-use applications (like bitcoins for payments); phase 2 would bring private networks for enterprises; phase 3 would bring substitution, such as retailer gift cards based on bitcoins; and phase 4 would bring transformation that is highly novel and complex. They correctly predicted what we saw in 2017 and beyond—namely, that many enterprises chose private blockchains.

Jumping ahead to 2022, we now realize that different blockchain *components* are in different stages of maturity. According to Gartner, cryptocurrencies, dApps, and digital wallets finally climbed out of the trough of disillusionment in 2021. Smart contracts, blockchain platforms, and consensus mechanisms were still in the trough. Nonfungible tokens, decentralized finance (Defi), decentralized identity, and stablecoins were at the peak of inflated expectations (Gartner, 2021). Gartner's hype cycle, despite its deficiencies, is a useful tool for discussing overall global trends, but industries and specific organizations within industries adopt technologies at different rates. For example, companies like EY, IBM, Microsoft, and Walmart had already reached the slope of enlightenment by 2019 based on our research.

We can also assess the maturity from a philosophy of science perspective.

Leslie Willcocks: Please do.

Mary Lacity: Blockchains are still in a pre-paradigm phase, characterized by *conceptual fuzziness* and *competition between distinct views* (Kuhn, 1970). Pertaining to conceptual fuzziness, academics have yet to formalize a universally accepted definition of blockchain. This is part of the reason I sidestepped your first question and tried to give the vision of what blockchains enable. Ostern (2020) aimed to derive a clear definition of blockchain based on a review of 2300 information systems (IS) research articles. She extracted 51 separate definitions and identified three reasons for this conceptual fuzziness: (1) terminological ambiguities, (2) concept proliferation and conceptual inconsistencies, and (3) technological determinism. Lacek (2021) extended Ostern's work on developing a coherent definition of blockchain by expanding the search outside of IS research. Based on 548 additional articles, Lacek reached the same conclusion as Ostern: there is no academic foundation for defining the blockchain construct.

Pertaining to distinct views, public and private blockchain applications demonstrate the competition between different views and values. Applying a Hegelian inquiry perspective, I think of public blockchains as the thesis, private blockchains as the antithesis, and ultimately confidential (but not anonymous) transactions on public blockchains as the likely synthesis. EY, Microsoft, and ConsenSys are proponents of such a synthesis. They released the Baseline Protocol, which uses zero-knowledge proofs, to provide confidential transactions on Ethereum (see: https://github.com/eea-oasis/baseline). It is an important step.

Leslie Willcocks: Let us turn to your research.

What have you studied, how has the work evolved, and what are your major findings?

Mary Lacity: I am primarily interested in enterprise adoption of blockchain-enabled digital ecosystems. By 2016, large financial institutions finally started to take notice of blockchains. They wanted to know, "Will this technology disrupt our business models? How can we use this technology to our advantage?" Early consortia of banks and other traditional enterprises began exploring use cases with proof-of-concepts (PoCs) around that time.

In 2017, I became a visiting scholar at MIT's Center for Information Systems Research (CISR) to lead a project to determine how enterprises are preparing for blockchain. We researched how enterprises were building blockchain PoCs and capabilities to prepare for, and to direct, the future of business services. By November 2017, we had interviewed senior managers in 21 organizations, primarily representing large global financial services, including JP Morgan, State Street, BNP Paribas, TD Bank, and the service providers that helped them with development, including Cap Gemini, Deloitte, KPMG, and Wipro (Lacity, 2018a, 2018b; Lacity et al., 2018). We identified 16 action principles[18] that were effective for building blockchain PoCs and enterprise capabilities. These included:

- Shift the C-suite mindset from command-and-control over solutions to shared governance with trading partners.
- Co-create blockchain applications with select customers to make sure the solution will be truly valued by customers.
- Create an independent spinoff if the solution will disrupt current business models.

From PoCs, our research evolved to studying live deployments of the first blockchain-enabled solutions for enterprises in 2018. Our study of early adopters came from our research activities supported by the Blockchain Center of Excellence (BCoE) at the University of Arkansas, where I serve as director. We work with member firms on blockchain research in closed workshops and follow-up interviews; those firms include Accenture, ArcBest, Ernst & Young (EY), FedEx, FIS, Golden State Foods, IBM, J.B. Hunt Transport, McKesson, Microsoft, Tyson Foods, and Walmart.

We've studied more than a dozen live applications, including DL Freight, to process freight invoices; TradeLens to track shipping containers; the IBM Food Trust to trace food from farm to retail stores; WeTrade for trade finance for small to mid-sized customers; KoreConX for private investment and reporting compliance; MediLedger to trace pharmaceuticals through the US supply chain; Santander for bond issuance and settlement; SmartResume for verified resume credentials; WineChain to authenticate wines; ANSAcheck to prevent imposter news; Rapid Medical Parts to convert sleep apnea machines to hospital-grade respirators during COVID-19 by 3-D printing of parts; Stellar as a payment platform to bank the unbanked; the UK's National Health Service for digital staff passports; and Xbox royalty payments to compensate content creators.

Leslie Willcocks: To get a sense of the research, can you provide a synopsis of one case study?

Mary Lacity: Remko Van Hoek, professor of supply chain management at the University of Arkansas, and I published a case study on how Walmart Canada used blockchain technology to reimagine freight invoice processing with their trading partners. Walmart Canada relies on up to 70 freight carriers to deliver more than 500,000 shipments per year. For Walmart Canada and its carriers, the processing of freight invoices for load shipments was not working well for anyone in the supply chain. Up to 70% of invoices were being disputed. Both sides were expending too much time and too many resources investigating and reconciling disputes, and, consequently, freight carriers were getting paid weeks or months late. The two root causes of invoice disputes were mismatched records that needed reconciling and the fact that an invoice was only created and shared with Walmart after final delivery, when, of course, Walmart had to make sure all excess charges on the invoices were legitimate. In 2018, Walmart Canada decided to work with one of its major freight carriers and with an IT technology provider (DLT Labs) to solve the problem. Together, they developed a solution called DL Freight (Lacity and Van Hoek, 2021a).

The partners re-engineered invoice processing; instead of freight carriers creating an invoice after final delivery, Walmart Canada and the carriers start building the invoice during the tender process and automatically update the invoice from Internet of Things (IoT) data feeds as charges are incurred during shipment. Walmart Canada and the freight carrier each have a copy of the invoice that is guaranteed to be identical, serving as a single version. The automation is enabled by smart contracts, a key feature of blockchains. The permissioned blockchain ensures that only authorized parties can read/write to an invoice.

After DL Freight, disputed invoices fell to under 2%; invoices are now finalized within 24 h of final delivery; Walmart Canada achieved a positive ROI after one year; cash flows improved for freight carriers; relationships between Walmart Canada and freight carriers improved; and there were new opportunities for revenue generation and additional supply chain improvements. People may be skeptical of such positive results, but I suggest they read the case study. Walmart and DLT Labs made it cheap and easy for freight carriers to join DL Freight, and they now get paid a lot faster.

Leslie Willcocks: Could this have been done with a traditional database? Why was blockchain selected?

Mary Lacity: Yes, it could be implemented with other technologies, but Walmart Canada's objectives were well suited for a blockchain-enabled solution. In instances of multiple writers, blockchain is better than a traditional database because no company is the master. A blockchain solution keeps the independent copies of the invoice in sync—Walmart's copy is guaranteed to be identical to the freight carrier's copy. Moreover, blockchain creates a tamper-resistant, traceable history of events to simplify workflow and compliance; neither party can rewrite history (Lacity and Van Hoek, 2021a).

Leslie Willcocks: Why a permissioned blockchain instead of a public one?

Mary Lacity: Walmart Canada and the freight carriers did not want their invoices on a public blockchain; data about volumes and prices, for example, need to be confidential.

Leslie Willcocks: We did a lot of work together on action principles for effective automation. In the case of blockchain, what action principles explained the results you found at DL Freight and in other adoption examples?

Mary Lacity: Our work identified 20 action principles, which we organized along an adoption journey (see Figure 2). Action principles were associated with creating business and social value. For example, blockchain-enabled

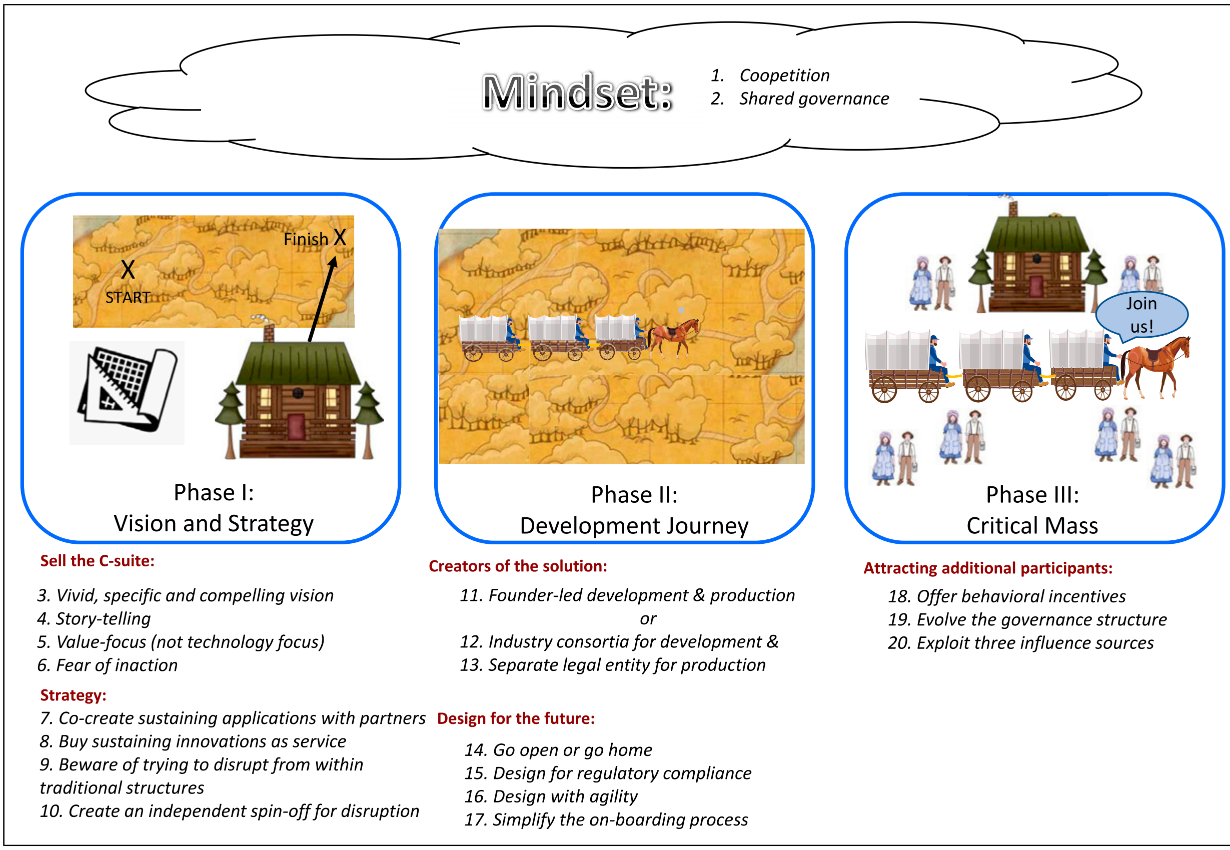

Figure 2. Action principles for blockchains used by enterprises (Lacity, 2020).

solutions created business value with more efficient supply chains (lower costs, better traceability) and social value with increased food safety (e.g., IBM Food Trust), increased drug safety (e.g., MediLedger), improved access to healthcare services (e.g., Rapid Medical Parts), and diminished imposter news (e.g., ANSAcheck).

Leslie Willcocks: Among these action principles, which are the *distinctive* practices needed to exploit these technologies?

Mary Lacity: The mindsets! For 60 or more years, senior business and IT leaders have controlled and deployed IT *within* the boundaries of the organization. The systems of record are completely governed at the enterprise level. For example, enterprises have used business process re-engineering (BPR), enterprise resource planning (ERP) and software-as-a-service (SaaS) to create fast, inexpensive, and accurate transaction-processing systems within their own boundaries. Blockchains promise similar results for inter-firm processes *if* senior business and IT leaders can embrace coopetition—the ability to work with trading partners, including competitors, on shared pain points—and agree to shared governance over software.

Leslie Willcocks: I see you have action principles associated with selling to the C-suite. CIOs have always had to be good at internal marketing. How should they explain to their CEOs and CFOs what blockchain is and why they should be getting into it?

Mary Lacity: From our case studies and interviews, we learned that CIOs should talk about the *why* rather than the *what* of blockchains. The why might be a vivid, specific, and compelling vision for a particular enterprise. For example, Col. Jas Allen Regenor (USAF ret.) was working for Moog Aircraft when he came up with a vision for moving Moog from centralized manufacturing to decentralized manufacturing, thereby allowing customers to print parts where and when they need them. It would be a complete pivot on their business models and operations. Because the US Department of Defense is one of Moog's biggest customers, the colonel explained the idea to them like this:

> "Imagine a scenario where lives depend upon a mission being flown off the deck of an aircraft carrier far out at sea. The only available aircraft has just been grounded with a failed critical part. There is no part inventory on the carrier. But we do have a 3-D printer and a stock of powder aboard. A technical data package is available for the part, and a replacement is quickly printed. You are the responsible person who needs to get this part quickly fitted to the aircraft and to sign the plane off as safe

> and ready to fly. How would you know if the newly printed additive manufacturing part you are holding in your hand is good for use?" (Small, 2018).

Notice also that the vision is specific to the company. Notice he did not even mention blockchain, but blockchain is a critical enabler to make sure the printing instructions are authentic—that is, not manipulated by a cyberattack. Blockchains also help with tracking parts through the supply chain, a situation where multiple parties are adding to the part's history—trading partners do not want one entity to control or own the end-to-end historical data.

Dale Chrystie, blockchain strategist for FedEx, extends this notion even further by suggesting that CIOs custom tailor the message to each C-suite executive. For a CFO, a CIO might ask, "What if we never needed to reconcile invoices again? What if cross-border payments required only micro-fees?" For a chief operating officer: "What if we could trace an asset's location, custody, authenticity and condition, and all of an asset's component parts from commissioning to decommissioning?" For a chief compliance officer: "What if we could automate compliance assurance and reporting?" You get the idea.

Leslie Willcocks: What are other ideas to consider when speaking to the C-suite?

Mary Lacity: Executives like to know what competitors are doing, so CIOs could use success stories from early adopters as powerful examples of value delivered in their industry or in an adjacent industry. The C-suite can also be convinced of blockchain's value by highlighting the consequences of inaction. No CEO wants to be blindsided by their company's "Kodak" or "blockbuster" moment. Many times, the price of inaction is extinction. John Whelan, managing director of digital investment banking for Santander, told his C-suite: "If we do not build it, somebody else will." He also said, "I think the banks realize that our competitors are not just other banks, but our competitors are also big tech, whether it is Facebook, Google, Alibaba, or TenCent. In many respects, money and value are just ones and zeros in a machine, and that's an engineering problem, not a financial problem." (Lacity, 2020)

Leslie Willcocks: If you had to give one or two high-level insights from your research findings, what would that be?

Mary Lacity: Based on our adoption studies, these first-generation enterprise applications are delivering business value by removing shared pain points, but they do not disrupt, transform, or obliterate existing structures. They are best characterized as *sustaining* innovations, not *disruptive* innovations—as predicted by Clayton Christensen's Theory of Disruptive Innovation (Christensen et al., 2015). Enterprises still rely on trusted third parties, but these TTPs take on different roles. Rather than verifying transaction data, TTPs in first-generation solutions manage services, such as operating network nodes, protecting digital wallets on behalf of clients, enforcing access rules set up by members, and managing software updates. Our finding is supported by a 2020 HFS Research survey of 318 respondents from Global 2000 companies; HFS Research found that only 6% of enterprise blockchain applications intend to remove intermediaries (Gupta et al., 2020).

Leslie Willcocks: That sounds rather tactical. Where is the disruption?

Mary Lacity: It is already here. As predicted by Christensen, startups are leading the disruption process. Decentralized finance (DeFi) is a perfect example. On public blockchains like Ethereum, people earn interest on their cryptoassets through lending, use cryptoassets for collateral to obtain loans, and place bets on the value of cryptoassets (buying derivatives). According to Statista (2021), the DeFi market was about $70 billion per month from November 2020 to May 2021. Compared to the $10 trillion in stocks traded globally per month, DeFi seems small; however, it is clearly a new business model that has real advantages, such as not needing to open an investment account—users just download a digital wallet, with no paperwork and no trusted third party. Top DeFi platforms include Aave, Avalanche, Solana, SushiSwap, and Uniswap. It is truly an opportunity for more inclusion in financial markets.

Leslie Willcocks: Let me now address COVID-19. Has the pandemic and related economic crisis delayed or accelerated blockchain applications?

Mary Lacity: Both. For certain applications, COVID-19 has obliterated the barriers to adoption because the use cases are too critical to delay adoption. Remko and I published an article in the *Harvard Business Review* on how COVID-19 accelerated blockchain adoption in some supply chains (Van Hoek and Lacity, 2021). Erran Carmel (American University) and I are studying digital health passes (DHP), many of which rely on blockchain technology (Lacity and Carmel, 2022). In some jurisdictions, new COVID-19-related laws accelerated adoption of DHPs, and in other jurisdictions, laws were passed against using DHPs.

As an example of accelerated adoption, one US state, New York (NY), adopted a DHP called Excelsior, which is built on IBM's digital health pass platform. The platform utilizes blockchain technology. As of fall 2021, the Excelsior pass verifies three types of healthcare credentials for NY residents: COVID-19 vaccination, PCR test, and antigen test. The Excelsior DHP is connected to the New York State Immunization Information System and to New York City's City-wide Immunization Registry. All New York healthcare providers must report COVID-19 vaccinations/test results to these registries as of January 2021 (New York Department of Health, 2021). In August, New York City (NYC) Mayor Bill de Blasio ordered that people must prove they have received at least one vaccination to enter indoor dining, fitness centers, and entertainment facilities (Caspani and Whitcomb, 2021). Employees at these facilities must also bind the health pass information to the individual by asking to see an identification card, such as a driver's license, or face fines. While I was in NYC in September, every business I entered complied with the law.

In contrast to NY, other US states—such as Alabama, Arizona, and Arkansas—banned vaccinations and digital health passes, thus preventing their adoption (Davis, 2021). As for the United Kingdom and Europe, your colleague at the London School of Economics, Edgar Whitley, is leading the research agenda (Whitley, 2020, 2021). Erran, Edgar, and I are also involved in public initiatives to help develop ethical standards for digital health passes and for other credential-sharing applications, such as the Good Health Pass Collaborative, the Ada Lovelace Institute, and the Trust Over IP Foundation. Academics are increasingly valued in community advocacy and standards-making bodies.

Leslie Willcocks: Looking into future developments, have you a sense of how all this will evolve over the next five to 10 years?

Mary Lacity: Yes. Iansiti and Lakhani (2017) were insightful when they compared the development of blockchains to TCP/IP. I concur with John Wolpert, group executive at ConsenSys, that blockchains will become boring. Blockchains will be the modest-yet-vital middleware layer that assures ecosystem partners that their data are synchronized. Many enterprises likely will move to public networks, where scalability in terms of number of participants and ease of onboarding reigns superior to private networks. However, enterprises will share very little data on public blockchains. Instead, cryptographic proofs will assure partners that they are working from the same data and sequence of events. EY, Microsoft, ConsenSys, and others are developing the Baseline protocol I mentioned that use zero-knowledge proofs to ensure data confidentiality on public networks. John Wolpert frequently says, "Blockchains are data nudist colonies: public blockchains are public beaches; private blockchains are private beaches." (Wolpert 2021) Blockchains are useful for syncing workflows for inter-firm transaction processing, but I no longer think that the majority of enterprises will post a lot of data to them.

If blockchains become boring, then it is the compound innovations that will be exciting. Just as the combination of mobile technology, Global Positioning System (GPS), and social media enabled apps to find quality restaurants or parking spaces nearby, the combination of public blockchain networks, consensus protocols, smart contracts, and the tokenization of assets gave rise to DeFi, fractionalized ownership of assets, and other economic models. Global communities and scholars are envisioning uses for sustainability (e.g., Saraji and Borowczak 2021), creating self-sovereign identity (Preukschat and Reed, 2021), colonizing Mars (Smith, 2020), creating the metaverse where physical, augmented, and virtual realities will converge (Christodoulou et al., 2022), and so much more. It is hard to anticipate all the use cases that will irrevocably alter the business, social, political, and economic landscape, but it is unfolding rapidly.

Leslie Willcocks: Concerning a research agenda, the JIT would very much like to receive research papers on blockchain and further developments. For example, I would suspect there will be a growing convergence of the major digital technologies. But, from your much more informed perspective, what are the worthwhile questions to ask?

Mary Lacity: Several blockchain literature reviews and research agendas have already been published (see Table 1), so I point readers to those sources. From my perspective, blockchains offer a bounty of research opportunities because they materialize at the level of an ecosystem rather than at the level of an individual or organization.

I am particularly interested in blockchain governance—who has decision rights? Although blockchain transactions are automated, there are network-level decisions to be made, such as: Who can operate a node? How do you agree on and coordinate software upgrades? Who decides what should happen if there is a crisis like a major hack? What governance should be on chain (such as voting rights managed by a smart contract) vs. off chain, such as by an open-source community? Our research uncovered eight governance models (see Figure 3). There are trade-offs between centralized and decentralized governance structures. We value blockchains for decentralizing power, but decentralization does not lend itself to rapid decision making (Lacity et al., 2019). We need more research on the antecedents, fit-to-decision to be made, and outcomes of governance structures.

Some of our most revered theories need to be revisited because of blockchain. For example, Lumineau et al. (2020) noted that transaction cost economics has theorized contractual and relational governance, but blockchain governance creates a third governance choice. The authors argue that contractual governance is regulated by law, relational governance is regulated by social norms, and blockchain governance is regulated by protocols and code-based rules. Blockchain governance is just beginning to be theorized and examined by IS scholars (e.g., Beck et al., 2018; Ziolkowski et al., 2020).

Clayton Christensen argued that the case method should be used to build modern business theories (Christensen 2005). Sarker et al. (2021) did a detailed case study on how the global shipping industry is using blockchain to combat corruption and made insightful extensions to theories on corruption controls. Cases such as this provide compelling evidence how blockchains can address ecosystem-level challenges. In addition to theory

Table 1. Blockchain Literature Reviews and Research Agendas.

	Type	Scope	Findings/Suggestions
Alkhuary et al. (2020)	Literature review and future research directions	47 articles published in Thomson Reuters list of academic journals	Authors analyzed publication outlets, researchers' country, research method, theories used, and identified three clusters (law, economic, and innovation). Authors call for more research on BC-based applications and competitive advantage; BC-based applications quality standards; implementations; financial services and poverty; economic policies; social structures; supply chain management; and trust in offline versus digital transactions.
Beck et al. (2018)	Research agenda	Research case study and agenda for blockchain governance	Authors identify research questions pertaining to decision rights, accountability, and incentives.
Cao et al. (2017)	Literature review	188 articles from journals listed by the Chinese Academy of Sciences	The authors found the most articles in economics journals (139 articles) and the fewest in management journals (three articles) at the time of this study. The most popular topics were digital currencies, Internet finance, and banking.
Da Cunha et al. (2020)	Literature review	35 articles across multiple databases focused on blockchains and economic and social development	Authors analyzed the uses of blockchain for development, the most common of which were money transfers, financial services, cryptocurrencies and payments, money-laundering prevention, and transaction records. The authors also analyzed the regions targeted for economic/social development, which were global (35 countries listed).
Karger (2020)	Literature review	32 articles on BC and artificial intelligence (AI)	The authors identified three ways that AI and BC intersect: 1. BCs can support AI methods, such as making AI more transparent. 2. AIs can support BCs by making them more intelligent. 3. AI and BC combined to create new types of applications.
Kohli and Liang (2021)	Research framework	65 submissions to the *JMIS* special issue on blockchains	Framework includes research themes, research methods, underlying theories, application domains, outcomes, and key constructs.
Rossi et al. (2019)	Research agenda	Research agenda	Authors call for rigorous empirical and theory-driven information systems (IS) research. Authors identify research questions at the protocol level, application level, and interactions between protocol and application levels.
Shahid and Jungpil (2020)	Literature review	2125 articles published in ACM Digital Library, IEEE Xplore, JSTOR, Science Direct, Scopus, and Web of Science	The authors identify eight topic areas: finance, protocol, energy/markets, economics, incentives, business, social/privacy/trust, and computing/security. They also looked at disciplines, including computer science, law, economics, business, and engineering.

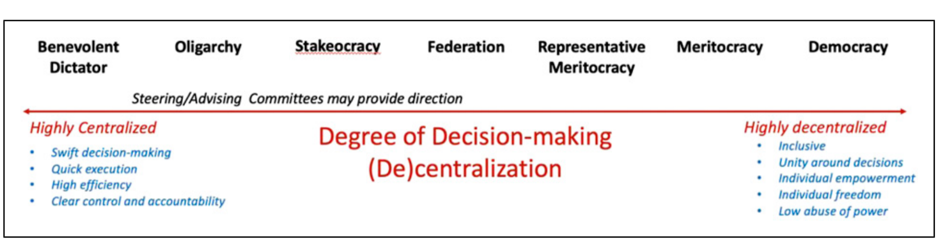

Figure 3. Blockchain governance models.

development, we need more detailed case studies of enterprise blockchain adopters to understand the implementation challenges and action principles to overcome them (Lacity et al., 2021). The action principles in Figure 2 will evolve.

Beyond empirically observing these new worlds, researchers are also helping to build it. Design scientists, for example, are actively building IT artifacts to improve technical components and create new user applications. For example, Carvalho (2021) designed a loot box application used in video games to purchase items with real money, based on blockchains. Zavolokina et al. (2020) convened a consortium of trading partners in a used-car ecosystem to inform the unanswered questions on how to govern blockchain ecosystems. Researchers are also active in helping define global blockchain data and processing standards, which is key to interoperability since current blockchain networks operate as isolated islands. Academic contributors are welcomed by the communities, and this type of work has immediate impact. Roman Beck, in my opinion, is the epitome of academic leadership in the blockchain standards domain. Beck is convenor of ISO TC 307/WG 5 Blockchain Governance standardization group, appointed representative of Denmark at the European Blockchain Partnership Technical Steering Group to develop the European Blockchain Services Infrastructure, and convenor of the EU Commission Blockchain Ethical Guidelines working group. He does this important work while still maintaining a traditional research pipeline (e.g., Beck et al., 2018, 2020; Pedersen et al., 2019;). As business school professors will increasingly be expected to produce innovative and influential work (i.e., Shapiro et al., 2017), I view participation in global standards-making bodies as worthwhile.

Academics also need to influence ethical uses of technology. The metaverses are coming fast, combining many of the technologies we've talked about. The negative consequences of addiction, bullying, and threats to our humanness from two-dimensional social media and digital games will be escalated in three-dimensional metaverses (Porra et al., 2019). The Deloitte Foundation is working with the University of Arkansas, Duquesne University, University of Virginia, and Notre Dame University on tech ethics curricula. We hope to make a difference, but we need many more academics to influence policy makers, tech giants, developers, and users.

Leslie Willcocks: Well, let us end there, Mary. This has been a tour de force. The long-term impact of blockchain for the Internet of Value has clearly been all too easy to underestimate. The short-term picture has been blurred by the paradox of massive hype fueled by the cryptocurrency narrative, coupled with the all-too-painfully slow adoption of other kinds of blockchain applications. It also struck me that, beyond Bitcoin etc., you do need to partner a lot more with external agencies to develop and harness the business potential of these technologies. With technology, as we know, this is rarely easy. Personally, and on behalf of our readership, thank you so much for your time and insights.

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Notes

1. Each block contains header information, such as the number of transactions included in the block, the timestamp when the block was created, the computer that created the block (called a miner), and, most importantly, the block number that precedes it, thus creating a linked chain of blocks.
2. Readers who want an accessible overview of Bitcoin and how it works can visit https://www.youtube.com/watch?v=L-Qhv8kLESY. Before Bitcoin, there were other digital cash ideas and experiments. Nick Szabo, inventor of smart contracts, conceived of decentralized digital cash in 1998 as Bit Gold (Szabo, 1998), but it was not implemented. David Chaum launched DigiCash in 1990—the first live cryptocurrency of significance. While an important breakthrough, DigiCash was centrally controlled in that the company's system performed the validations (Chaum, 1982). Nakamoto (2008) synthesized several innovations, such as the idea of a public ledger (Dai, 1998); timestamping (Massias et al., 1999; Haber and Stornetta, 1991; Bayer et al., 1993); cryptographic Merkle trees for security (Merkle, 1980); digital currencies like Hashcash (Back, 2002); and proof-of-work consensus to keep copies of the public ledger in sync (Dwork and Naor, 1993). Nakamoto brought these prior inventions together to create a peer-to-peer payment application. The Bitcoin blockchain is distributed over a public network, making it highly resistant to hacks. The Bitcoin network went live on 3 January 2009.
3. The Bitcoin protocol is based on a gold-mining metaphor. Just as gold miners *work* using physical resources to excavate gold from mines, bitcoin miners *work* using computer resources to release new bitcoins; Bitcoin, like gold, has a limited supply, making it a rare commodity. Just as it gets harder to find gold as a mine is depleted, Bitcoin releases fewer new digital coins over time.

4. Nakamoto (2008) wrote this about the economic incentives to motivative miners to behave honestly: "If a greedy attacker is able to assemble more CPU power than all the honest nodes, he would have to choose between using it to defraud people by stealing back his payments, or using it to generate new coins. He ought to find it more profitable to play by the rules, such rules that favor him with more new coins than everyone else combined, than to undermine the system and the validity of his own wealth." p. 4.
5. Price volatility indices calculate the standard deviation of a price from its mean during a certain time period. Bitcoin's 2021 average 30-day price volatility index measured in US dollars was 4.56%; the 60-day volatility was 3.40% on 17 December 2021 (https://www.buybitcoinworldwide.com/volatility-index/). For comparison, the 60-day volatility of major fiat currencies against the US dollar averaged between 0.008 (against the Japanese yen) and 1.08 percent for the Swiss franc (exchange-rates.org).
6. However, Bitcoin transactions are not considered to be truly settled for at least an hour because settlement is probabilistic rather than deterministic. Although a new block is created on average every 10 min, the actual settlement time is longer due to the possibility of a temporary divergence of the network. Sometimes, two nodes in a distributed blockchain network create the next block at the same time, resulting in two versions of the top of the ledger called a "soft fork." For a short while, different nodes in the network work off of different branches of the ledger until one branch is established as the longest and, therefore, the valid branch. To confidently consider a Bitcoin transaction to be settled, it is generally recommended to wait until the transaction is six blocks deep, which on average takes an hour.
7. The comparison of Bitcoin to Visa is more nuanced, as Bitcoin is a complete end-to-end payment system. Estimates of Bitcoin's consumption does not consider all the electricity of the banks, cardholders and merchants who burn electricity. https://digiconomist.net/bitcoin-energy-consumption/
8. For example, if two parties to an exchange know each other's identities, each can trace subsequent transactions in or out of those addresses. Moreover, many transactions are funded with multiple addresses, allowing a party to tie an identity to even more addresses.
9. "Bitcoin Anonymity-Is Bitcoin Anonymous?" https://www.buybitcoinworldwide.com/anonymity/
10. Monero uses "ring signatures" and a "key image" to hide the sender's address; a "stealth address" to hide the recipient's address; and "ring confidential transactions" to mask amounts ring signatures take the sender's digital signature and a number of decoy signatures to make a key image. Miners and the public see only the key image. The Monero protocol requires that key images may only be used once. To prevent a double spend, miners need only to make sure that the key image appears nowhere else in the blockchain. Thus, the key image is the main way Monero makes sure the private key was not used before to spend the amount. Monero uses ring confidential transactions, or RingCT, to mask amounts by using a "range proof" to prove to miners that the inputs of a transaction are equal to the outputs, but miners do not know the value of either.
11. Zero-knowledge proofs are a method for one party (or node) to verify possession of a piece of information to other parties (or nodes) without revealing the information (Bellare and Goldwasser, 1989).
12. A term that refers to a computer programming language that has a full set of commands to execute every algorithm that another Turing-complete programming language can execute. For example, a simple calculator with basic arithmetic functions is not Turing complete because it cannot execute if-then-else or loop logic.
13. To see the ConstitutionDAO on the Ethereum network, go to: https://etherscan.io/address/0x4f7ebf67b662bee6a764a2b79a3291f93d4be2df#readContract
14. https://www.coinbase.com/price/bitcoin
15. How do you spot a scam? For the casual investor, Techcrunch contributor Deep Patel identified these red flags to detect scams: the early release of coins goes primarily to the founders, not investors or miners; the founders are anonymous or have little credible experience; the project's white paper is missing details; the project has no clear timelines; the project claims the programming code will be open sourced but it does not exist on GitHub, the de facto repository for open-sourced blockchain source code (Patel, 2017).
16. Blockchains are tamper resistant, in part, because of the linked cryptographic hashes. A hash is an algorithm for transforming one input into a different output. A good hashing algorithm makes it practically impossible to determine the input value based on the output value, but the same input will always produce the identical output, making verification quick and easy. Blockchains use hashes in many places to add layers of security. Public keys are hashed into addresses; addresses and amounts within a transaction are hashed to create a unique and secure transaction ID; transaction IDs within a block are hashed together multiple times to produce a Merkle root that resides in a block header; and the data in the block header, including the Merkle root and previous block ID, are hashed to create a unique and secure block ID. With a PoW, the miners are using their computers to compete to be the first to find a legitimate block ID for the next block. It is not easy to find an acceptable number; it takes a lot of computing power to perform the brute force guesses to find a hash number that is less than the current mining difficulty. The mining difficulty is a number that the software adjusts to keep the average rate of new block generation at 10 min. Once a block is added to the blockchain, it is nearly impossible for anyone to rewrite a transaction and recompute all the necessary hashes, not only for the block where the transaction resides, but for all the blocks on top of it.

17. Rights of participation define who is allowed to submit transactions to the blockchain network. At a very high level, rights of participation are either open to the public or private. Rights of validation define who is allowed to run validator nodes in the blockchain network. Rights of validation are either permissionless (anyone may operate a validator node) or permissioned (an individual or institution needs permission or must be selected/voted upon to run a validator node). There are nuances; EOS, for example, distinguishes between node validators, which anyone may run (permissionless), and block producers, which must be voted upon by the community (permissioned) (Lacity, 2020).
18. An action principle attributes an action to an outcome in a real-life implementation of an emerging technology or practice. A set of action principles is created by researchers after engaging in a dialog with practitioners to learn about the associations they make between actions and results (Lacity et al., 2021).

References

Adeyanju C. (2019) *What Crypto Exchanges Do to Comply with KYC, AML and CFT Regulations*; CoinTelegraph. Available at: https://perma.cc/KDN8-JYTJ.(Retrieved from September 1, 2021).

Alkhuary R., Brusset X., and Fenies P. (2020) Blockchain in general management and economics: a systematic literature review. *European Business Review*. 32(4):765-783.

Back A. (2002) *Hashcash - a denial of service counter-measure*. http://www.hashcash.org/papers/hashcash.pdf.

Bayer D., Haber S., and Stornetta W.S. (1993) Improving the efficiency and reliability of digital time-stamping In: *Sequences II: Methods in Communication, Security and Computer Science*: 329-334.

Beck R., Kildetoft M., and Radonic N. (2020) *Using Blockchain to Sustainably Manage Containers in International Shipping*. Aisnet. ICIS 2020 Proceedings https://aisel.aisnet.org/icis2020/blockchain_fintech/blockchain_fintech/5/

Beck R., Müller-Bloch C., and King J. (2018) Governance in the blockchain economy: a framework and research agenda. *Journal of the Association for Information Systems*. 19(10): 1020–1034.

Bellare M., and Goldwasser S. (1989) New paradigms for digital signatures and message authentication based on non-interactive zero knowledge proofs. *Advances in Cryptology — CRYPTO'*. 89:194–211.

Cao S., Cao Y., Wang X., et al. (2017) A review of researches on blockchain In *Wuhan International Conference on e-Business Proceedings*, 57; Available at: http://aisel.aisnet.org/whiceb2017/57.(Retrieved from September 18, 2021).

Carvalho A. (2021) Bringing transparency and trustworthiness to loot boxes with blockchain and smart contracts. *Decision Support Systems*. 144:1-13. https://doi.org/10.1016/j.dss.2021.113508.

Caspani M., and Whitcomb D., (2021) *New York becomes first U.S. city to order COVID vaccines for restaurants, gyms, Reuters*. Available at: https://www.reuters.com/world/us/nyc-require-proof-vaccination-indoor-activities-mayor-2021-08-03/. (Retrieved September 18, 2021)

Chaum D. (1982) *Computer Systems Established, Maintained and Trusted by Mutually Suspicious Groups*. Berkeley: University of California.

Christensen C., Raynor M., and McDonald R. (2015) What Is Disruptive Innovation? *Harvard Business Review*. 87(12): 44–53.

Christensen C. (2005) The Ongoing Process of Building a Theory of Disruption. *Journal of Production Innovation Management*. 23(1):39–55.

Christodoulou K., Katelaris L., Themistocleous M., et al. (2022). NFTs and the Metaverse Revolution: Research perspectives and open challenges. In: Treiblmaier H and Lacity M (eds) *Blockchain and the Token Economy*, Houndmills: Palgrave MacMillan, forthcoming.

Cryptimi. (2021) *How many cryptocurrency exchanges are there?* Cryptimi. Available at: https://www.cryptimi.com/guides/how-many-cryptocurrency-exchanges-are-there. (Retrieved from August 2, 2021)

da Cunha P., Soja P. and Themistocleous M. (2020) Blockchain for Development: Preliminary Insights from a Literature Review. In *AMCIS 2020 Proceedings. 10*. Available at: https://aisel.aisnet.org/amcis2020/adv_info_systems_research/adv_info_systems_research/10. (Retrieved from September 18, 2021).

Dai W. (1998) *b-money*. http://www.weidai.com/bmoney.txt. http://www.weidai.com/bmoney.txt.

Davis E. (n.d.) *These States Have Banned Vaccine Passports*. U.S. News. Available at: https://www.usnews.com/news/best-states/articles/which-states-have-banned-vaccine-passports.(Retrieved from September 18, 2021)

Dune Analytics. (2020) *Contract Deployments per Month*. Dune Analytics. Available at: https://explore.duneanalytics.com/embed/query/329/visualization/515?api_key=RqqCse8wDeW3MZKeZFOab2Ju8QA5Q8Itnr1cbLgk (Retrieved from September 18, 2021).

Dwork C., and Naor M. (1993) *Pricing via processing: Combatting Junk Mail*. Available at: http://www.hashcash.org/papers/pvp.pdf.(Retrieved from September 18, 2021).

Feller W. (1957) *An introduction to probability theory and its applications*. John Wiley & Sons.

Fortune Business Insights. (2021) *Blockchain Market*Size, Fortune Business Insights. Available at: https://www.fortunebusinessinsights.com/industry-reports/blockchain-market-100072 (Retrieved from August 3, 2021).

Garg P., (2018) *Binance Set to Move to Malta with Their Prime Minister Welcoming*, Blockonomi. Available at: https://blockonomi.com/binance-malta/.(Retrieved from September 2, 2021)

Gartner. (2021) *Hype Cycle for Blockchain 2021; More Action than Hype*. Gartner. Available at: https://blogs.gartner.com/avivah-litan/2021/07/14/hype-cycle-for-blockchain-2021-more-action-than-hype/ (Retrieved from August 2, 2021).

Gupta S., Duncan S., Mondal T., et al. (2020) *HfS Top Enterprise Blockchain Services*. HFS Research.

Haber S., and Stornetta W. (1991) How to time-stamp a digital document. *Journal of Cryptology*. 3(2):99–111.

Haber S., and Stornetta W. (1997) Secure names for bit-strings. In *Proceedings of the 4th ACM Conference on Computer and Communications Security*. 28–35.

Iansiti M., and Lakhani K. (2017) *The Truth about Blockchain*. Harvard Business Review:118–127.

Karger E. (2020) *Combining Blockchain and Artificial Intelligence, ICIS 2020 Proceedings*. https://aisel.aisnet.org/icis2020/blockchain_fintech/blockchain_fintech/6/.Paper Number 1722.

Kastrenakes J. (2021) *Beeple sold an NFT for $69 million through a first-of-its-kind auction at Christie's, the Verge*. Available at: https://www.theverge.com/2021/3/11/22325054/beeple-christies-nft-sale-cost-everydays-69-million. (Retrieved from August 2, 2021).

Kohli R. and Liang T.P. (2021) Special section: strategic integration of blockchain technology into organizations. *Journal of Management Information Systems* 38(2): 282–287.

Kuhn T. (1970) *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Lacek D. (2021) *Blockchain Essays – Contrasts in the Business Landscape*. University of Denver.

Lacity M. (2018a) *A Manager's Guide to Blockchains for Business*. UK: SB Publishing, Stratford-upon-Avon.

Lacity M. (2018b) *Addressing Key Challenges to Making Enterprise Blockchain Applications a Reality*, 17. MIS Quarterly Executive:(pp. 201–222).

Lacity M., Zach S., and Paul C. (2019) *Blockchain Governance Models: Insights for Enterprises, Blockchain Center of Excellence*. University of Arkansas Research Paper Series.

Lacity M. (2020) *Blockchain Foundations for the Internet of Value*. Fayetteville Arkansas: Epic Books/University of Arkansas Press.

Lacity M., and Carmel E. (2022) Verifiable Credentials in the Token Economy. In: *Blockchain and the Token EconomyHorst Treiblmaier*. Houndmills: Palgrave MacMillan. Forthcoming.

Lacity M., and Lupien S. (2022) *Blockchain Foundations for Web 3.0*. University of Arkansas Press. Forthcoming.

Lacity M. C., Moloney K. and Ross J. (2018) *Blockchains: How to position your company for the inevitable*. MIT Sloan School of Management, Center for Information Systems Research.

Lacity M., Willcocks L., and Gozman D. (2021) Influencing information systems practice: the action principles approach applied to robotic process and cognitive automation. *Journal of Information Technology*. 36(3):201–240.

Lacity M., and Van Hoek R. (2021a) How walmart canada used blockchain technology to reimagine freight invoice processing. *MIS Quarterly Executive*. 20(3):1–15.

Lacity M., and Van Hoek R. (2021b) What We've Learned So Far About Blockchain for Business, *Sloan Management Review* 63(3):48–54.

Lumineau F., Wang W., and Schilke O. (2020) Blockchain governance—a new way of organizing collaborations? *Organization Science*. 32(2):500–521. https://doi.org/10.1287/orsc.2020.1379.

Massias H., Avila X., and Quisquater J.-J. (1999) Design of a secure timestamping service with minimal trust requirements. In: *20th Symposium on Information Theory in the Benelux*.

Merkle R. (1980) Protocols for public key cryptosystems. In *Proc. 1980 Symposium on Security and Privacy*. IEEE Computer Society:122–133.

Mitchell E. (2020) *How Many People Use Bitcoin in 2021?* Bitcoin Market Journal. Available at: https://www.bitcoinmarketjournal.com/how-many-people-use-bitcoin/.(Retrieved from August 2, 2021).

Nakamoto S. (2008) Bitcoin: a peer-to-peer electronic cash system https://bitcoin.org/bitcoin.pdf

Ostern N. (2020) Blockchain in the IS research discipline: a discussion of terminology and concepts. *Electronic Markets*. 30:195–210.

Patel D. (2017) *Six red flags of an ICO scam*. Techncrunch. Available at: https://techcrunch.com/2017/12/07/6-red-flags-of-an-ico-scam/.(Retrieved from January 29, 2022).

Pedersen A., Risius M., and Beck R. (2019) A ten-step decision path to determine when to use blockchain technologies. *MIS Quarterly Executive*. 18(2):99–115.

Porra J., Lacity M., and Parks M. (2019) *Can Computer-Based Human-Likeness Endanger Humanness? - A Philosophical and Ethical Perspective on Digital Assistants Expressing Feelings They Can't Have*. Information Systems Frontiers. (pp. 533–547).

Preukschat A., and Reed D. (2021) *Self-Sovereign Identity: Decentralized digital identity and verifiable credentials*. Shelter Island: Manning Publications.

Rossi M., Mueller-Bloch C., Thatcher J., et al. (2019) Blockchain research in information systems: current trends and an inclusive future research agenda. *Journal of the Association for Information Systems*. 20(9):1388–1403.

Saraji S., and Borowczak M. (2021) *A Blockchain-based Carbon Credit Ecosystem*. University of Wyoming white paper. Available at: https://www.uwyo.edu/research/advancing-research-and-scholarship/a-blockchain-based-carbon-credit-ecosystem.pdf.(Retrieved from September 18, 2021).

Shahid M., and Jungpil H. (2020) A cross-disciplinary review of blockchain research trends and methodologies: topic modeling approach. Proceedings of the 53rd Hawaii International Conference on System Sciences. 4053–4059.

Sarker S., Henningsson S., Jensen T., et al. (2021) The use of blockchain as a resource for combating corruption in global shipping: an interpretive case study. *Journal of Management Information Systems*. 38(2):338–373. https://doi.org/10.1080/07421222.2021.1912919

Shapiro D., Kirkman B., and Courtney H. (2017) Perceived causes and solutions of the translation problem in management research. *Academy of Management Journal*. 50(2): 249–266.

Shrem C. (2019) *Bitcoin's Biggest Hack in History: 184.4 Billion Bitcoin from Thin Air*. Hackernoon. https://hackernoon.com/bitcoins-biggest-hack-in-history-184-4-ded46310d4ef.

Small G. (2018) *Additive Manufacturing Reshaping Logistics*. Available at: http://www.moog.com/news/blog-new/IntroducingVeripart_Issue3.html.(Retrieved from October 1, 2018).

Smith K. (2020) *Elon Musk details Mars colonization plans*. BraveNewCoin. Available at: https://bravenewcoin.com/insights/elon-musk-details-mars-colonization-plans.(Retrieved from September 18, 2021).

Statista. (2021a) *Amount of cryptocurrency held in decentralized finance, or DeFi, worldwide from August 2017 to May 28, 2021*. Statista. Available at: https://www.statista.com/statistics/1237821/defi-market-size-value-crypto-locked-usd/ (Retrieved from August 14, 2021).

Statista. (2021b) *Value of global equity trading worldwide from. 1st quarter 2017 to 4th quarter 2020(in trillion U.S. dollars)*. Statista. Available at: https://www.statista.com/statistics/242745/volume-of-global-equity-trading/.(Retrieved from August 14, 2021).

Szabo N. (1998) *Secure Property Titles with Owner Authority*. Available at: https://nakamotoinstitute.org/secure-property-titles/.(Retrieved from August 14, 2021).

Tapscott D., and Tapscott A. (2016) *Blockchain Revolution: How the technology behind Bitcoin and other cryptocurrencies is changing the world*. New York, NY: Penguin Random House.

Van Hoek R., and Lacity M. (2021). *How the Pandemic Is Pushing Blockchain Forward*, Harvard Business Review, (p, 52–53).

Whitley E. (2020) *Using apps for contact tracing in response to Covid-19: the controversies*. LSE Business Review. http://eprints.lse.ac.uk/105927/1/businessreview_2020_07_14_using_apps_for_contact_tracing_in_response.pdf.

Whitley E. (2021) *How would COVID status certificates work – and who would be eligible?* LSE Business Review. http://eprints.lse.ac.uk/109051/1/covid19_2021_02_26_how_would_covid_status_certificates_work_and_who.pdf.

Wolpert J. (2021) *How Syncing Workflows with Counterparties Transforms Cash Management, EY Global Blockchain NYC 2021*. Available at: https://www.youtube.com/watch?v=-uvuKe8gmQ4.(Retrieved from September 14, 2021).

Wong B. (2017) *The Ethereum network is getting jammed up because people are rushing to buy cartoon cats on its blockchain*. https://qz.com/1145833/cryptokitties-is-causing-ethereum-network-congestion/.

Zavolokina L., Ziolkowski R., Ingrid B., et al. Management, governance, and value creation in a blockchain consortium. *MIS Quarterly Executive*. 2020;19(1).

Ziolkowski R., Miscione M., and Schwabe G. Decision problems in blockchain governance: old wine in new bottles or walking in someone else's shoes? *Journal of Management Information Systems*. 2020;37(2):316–348.