



Beyond Bitcoin: What blockchain and distributed ledger technologies mean for firms



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Abstract Blockchain technologies are benefiting from significant interest in both societal and business contexts. Cryptocurrencies like Bitcoin have grown rapidly in user adoption over the past 8 years. However, blockchain technologies, which fuel cryptocurrencies, have the potential to extend to other business applications even more profoundly. Blockchain can be leveraged to drive innovation and increase efficiencies in new domains—including digital arts management, supply chains, and healthcare—but there remain technical, organizational, and regulatory headwinds that must be overcome before mass adoption can occur. In this article, we provide a brief history of blockchain and identify some of the key features that have enabled its popular uptake in the world of cryptocurrencies. We discuss how blockchain technologies have evolved from traditional software and web technologies and then examine their underlying strengths and evaluate new, noncryptocurrency use cases. We conclude with a look at the limitations of blockchain and present several important factors for managers considering blockchain implementation within their organizations.

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1. The web's frontier and blockchain

In 2003, Jeff Bezos took the stage at a TED event to compare and contrast the digital zeitgeist with

other periods in American history (Bezos, 2003). He spoke of the California Gold Rush—the run on land and mines in California in 1848—which created a social frenzy around the notion of gold prospecting, business, escaping the rat race, and simply having a go at entrepreneurship. Bezos also observed how the origin and implementation of electricity started with one clear, small goal: to provide light within homes and streets. Remarkably, a number of cottage industries evolved into the consumer electronics industry, which currently contributes \$2.9 trillion to the global GDP (Persistence Market Research, 2017). Bezos used these comparisons to highlight his thinking in the context of the nascent internet and Amazon. He believed that society had only scratched the surface of the web's capabilities, and that the best was yet to come.

Bezos was clearly right. In the 16 years since his presentation, Amazon has grown and innovated its offering to a near trillion-dollar market cap, providing goods and services that have far exceeded the original scope of the Amazon vision to become “Earth’s biggest bookstore” (Cakebread, 2017). In other areas, too, technology has made dramatic strides toward integrating into social and organizational lives, providing the kind of utility that we had only previously imagined within science fiction. Artificial intelligence (Kietzmann, Paschen, & Treen, 2018), virtual reality (Farshid, Paschen, Eriksson, & Kietzmann, 2018), the Internet of Things (Robson, Pitt, & Kietzmann, 2016), and robotics (Wirtz et al., 2018), to name a few, are starting to become normative experiences, disrupting the ways in which we consider business challenges and retain our competitive advantage in the market. In the same way that Bezos saw the early development of electricity as the foundation for something with greater potential, we would like to append the same sentiment to the topic of blockchain and how it can provide exponential value to business operations.

The benefits and utility of cryptocurrency are relatively simple to explain and understand, as are their implications for the financial services industry. However, with the promise of lowering costs, increasing process efficiency, and the changing importance of intermediaries, the underlying blockchain technology has significant potential to disrupt all sorts of business operations. At this relatively early stage of blockchain applications, these changes and their organizational implications are far harder to analyze or predict and, as a result, blockchain technologies and their potential impact are difficult for managers to understand. This confusion has led to frustration within the business community over how and if firms should incorporate

blockchain developments in order to create or retain competitive advantages within their respective industries. In this article, we hope to dispel some of the confusion by first explaining blockchain principles and then outlining its benefits and some of its organizational applications and realities for mass adoption. We then discuss technical and societal challenges and managerial implications before we consider what the future might bring for blockchain.

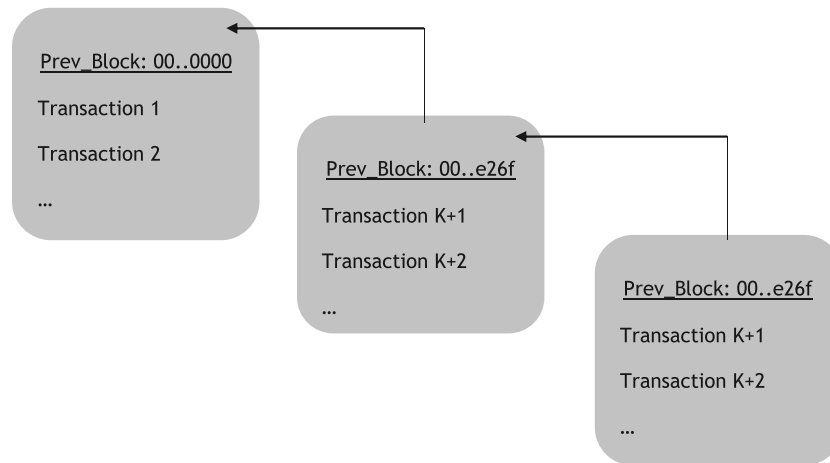
2. Blockchain principles

Between 2007 and 2008, the world was plunged into turmoil by the financial crisis—a man-made chain reaction of financial collapses built on bad debt and even worse administration, the likes of which had not been seen since The Great Depression. During a period of emergency mergers and bailouts, the world witnessed the fragility and instability of a tightly interwoven, highly leveraged, global financial system that appeared to be failing quickly. In response to these events, in October 2008, an unknown person identifying himself as Satoshi Nakamoto published a white paper to a cypherpunk¹ mailing list (Nakamoto, 2008), introducing the world to the topic of blockchains by outlining the benefits of an electronic cash system called Bitcoin. To date, Bitcoin and other cryptocurrencies are arguably the most commonly recognized use case of blockchain and, as such, are a suitable basis with which to explain the operating principles of the technology.

Blockchains have been described in various ways. The most generally accepted definitions are that they are distributed public ledgers (Kim & Laskowski, 2018; Zhao, Fan, & Yan, 2016) or a *metatechnology*: technologies made up of several technologies (Mougayar, 2016). Blockchains are exactly what their name suggests: a ledger of transactions, or blocks, that form to make a systematic, linear chain of all transactions ever made. While the blocks themselves are highly encrypted and anonymized, the transaction headers are made public and not owned or mediated by any specific person or entity. The headers are publicly available to those who would like to scrutinize transactions, as long as they have the wallet information details, also known as the *hash*, available. Every time a new transaction takes place on a blockchain, a new

¹ Activist advocating widespread use of strong cryptography and privacy-enhancing technologies as a route to social and political change.

Figure 1. Blockchain timestamps and immutability



Source: Kanig (2018)

block is resolved by a *miner*—an individual in the network whose job it is to verify each operation.

In the case of Bitcoin, miners create new blocks and add them to the chain on the network every 10 minutes by solving cryptographic puzzles; this process is known as *proof of work*. The new blocks include immutable timestamps, which provide a proof of work of what has happened before. Timestamps and immutability ensure that the chain of transactions cannot be tampered with as each sequential block references the prior block. Simply put, blockchains are tamper resistant since earlier blocks in the chain validate the transactions up to the present moment. If prior block information does not validate, the new blocks cannot form new parts of the existing chain and are rejected. As a result, a transparent and distributed accounting ledger of every transaction ever made on the network engenders trust (see Figure 1). Blockchains are extremely robust and less vulnerable than traditional IT infrastructures to malware and attacks from hackers.

3. Blockchain benefits

Since the release of the Nakamoto white paper and the subsequent launch of Bitcoin, it has evolved into a de facto blockchain currency (cryptocurrency) and trading instrument with a market cap of over \$100 billion. In this context, cryptocurrencies—the built-in currency of the blockchain payments and transactions—are native to the technology (Mougayar, 2016). However, not everything about the underlying blockchain is new, and many benefits are derived from established technologies.

3.1. Secure and transparent, distributed accounting ledgers

Blockchains are novel combinations of multiple computer engineering paradigms that have existed for decades. For example, a fundamental feature of a blockchain is secure transaction signing by each party that wants to send another party digital money, as in the case of cryptocurrencies. This mechanism relies on the interplay between hashing algorithms (e.g., SHA-256) and the provision of private and public software keys to each participant in the blockchain network. Private and public key modules (e.g., GPG, hashing algorithms) have existed for over 20 years.

Distributed databases have been a well-researched problem in computer science for several decades (Lake & Crowther, 2013). Even today, trusted databases with distribution capabilities like MongoDB and PostgreSQL suffer from lost data and inconsistent reads or writes due to network disruptions, power failures, data races, and more. While blockchains do not currently have the scaling capabilities of traditional distributed databases, they have proficiently addressed the issue of inconsistent data writes using artificial rate limiting through its consensus algorithms. Put another way, by insisting that parties who wish to write to the blockchain ledger spend resources and time to solve computationally intensive hash problems, the blockchain network buys itself time to properly order these parties before committing writes from any of them. The trade-off here is that writing to a blockchain is much more resource and time intensive than writing to a traditional database, but it is offset by the advantages in write consistency and uptime.

3.2. Decentralized networks

The combination of hash algorithms, private and public keys, and the decentralized ledger is what makes blockchains powerful in modern internet architecture. Parties that wish to take part in a transaction do not even need to know each other's identities but they can be assured that the intended party is the sender/receiver, since only the intended party has access to his/her own private key. These parties can also be reasonably assured that committed transactions will be written in the correct order. Moreover, the parties can be confident that their transaction histories will never be lost or corrupted, even if one party defects from the network, as long as the network has a large number of participants.

Blockchain technology is unique in that it does not require a large central server to store and maintain data. As long as the network achieves consensus regarding what transactions happened in the past, the network collectively acts as a server to host the data. If one rogue participant decides to modify previous data, the network majority will quickly outvote him/her. Even cloud computing is not truly decentralized, as servers for cloud computing providers like Digital Ocean, Linode, and Amazon host data placed in designated physical and central locations.

3.3. Trust, transaction time, and cost

To consumers, the specific promise of blockchain is manifold, mainly based on the fact that peer-to-peer systems do not require intermediaries or third parties; transactions can occur intelligently between sole parties. In the context of cryptocurrencies, tamper-resistant blockchain solutions can prevent 'double-spending' and ensure that transactions are debited from one account and credited to a different account without the risk of the same funds being allocated more than once; since monetary transactions are made between individual parties, they reduce concerns around trust placed on financial institutions. The resulting efficiencies mean that costs and transaction times can be reduced significantly.

Organizations also see the benefits of blockchain. In many parts of the world, hyperinflation has decimated local economies and digital currencies have been introduced to stabilize the economy; Ecuador, Senegal, and Venezuela are three such countries that have already adopted digital currencies, either wholly or in part (Heathman, 2017). In other parts of the world, Japan, Estonia, India, and Sweden are investigating methods by which they can adopt

digital currency given the decline in use of traditional notes and coins (Catalini & Gans, 2016; Mason, 2017). As of this writing, the Bank of England is researching ways in which a digital currency might be introduced into the existing banking system to complement the pound (Bank of England, 2018; Meakin, 2018).

It is important to note that, even with decentralization, blockchain is not immune to data corruption or network attacks. If the number of participants in a blockchain is low, a coordinated group of malicious parties can create enough nodes to produce a network majority, forcing mutated data upon the rest of the benign nodes. A participant who loses and inadvertently gives up his/her private key through a phishing scam, for example, hands full control of their stored digital assets to the hacker. However, the assumed benefits of the blockchain to consumers and organizations have created much excitement in business circles, far exceeding the specific context of cryptocurrencies. Blockchains can also be logic-based transaction platforms in which digital representations of items of value (e.g., car, house, holiday, code for unlocking a door) can be written into so-called *smart contracts*, as seen in the Ethereum blockchain. Here, transactions can be processed by code instead of simply being recorded and stored permanently within the blockchain, ensuring transparency for all transactions—all without the requirement of intermediaries. The potential applications seem limitless, as "any transaction, product life cycle, workflow, or supply chain could, in theory, use blockchains" (Takahashi, 2017).

4. Blockchain applications

There is no shortage of use cases for blockchain adoption that promise to protect firms' business dealings, manage assets differently, prevent theft, simplify and speed up organizational processes, reduce errors, and remove the necessity for third parties. Opportunities arise everywhere and, in this section, we point to some of the most compelling blockchain applications.

4.1. Blockchain and entrepreneurship

Exploitation of the technology is evident in a number of business communities, including startups and intrapreneurs, whereby the disruptive potential of blockchains is driving innovation within business modeling and value propositions (Magretta, 2002; Nowiński & Kozma, 2017). As a development platform, the blockchain provides a bedrock for new

sets of software applications that are decentralized and cryptographically secure. As open source software, most blockchains are open to development from everyone, which will encourage incremental innovation and further improve the robustness of the blockchain ecosystem. The removal of third-party intermediaries combined with convergent solutions such as IoT and AI is driving competition, driving down costs, and lowering barriers to entry.

4.2. Blockchain and governments

For governments, the potential for blockchain adoption is equally compelling, with a variety of use cases that could aid and protect democratic principles. Land titles in developing countries have long been an issue for citizens; a large number of registries were lost due to lack of ownership proof. In Honduras, blockchains are being used to guarantee that land rights are digitized, ensuring consecutive governments cannot strip land owners of what is rightfully theirs by successive dictatorships (Lemieux, 2016).

In the context of voting, individual citizens' details could be stored in blockchains to guarantee that voting is executed lawfully and foreign government influence could be mitigated since the potential for vote tampering would be marginal. A malicious party cannot cast a vote on behalf of another individual because each individual has a unique private key that only he/she can access.

4.3. Blockchain and digital rights management

The music industry has a long history of unfair practices and nefarious contract agreements that have always favored the labels (Gopal, Sanders, Bhattacharjee, Agrawal, & Wagner, 2004). Musical blockchains are disrupting this power by giving back the control, ownership, and distribution rights to the artists themselves (Dickson, 2016; Lyubareva, Benghozi, & Fidele, 2014). Since the digital revolution of the 1990s, consumers have also been able to reproduce and download albums and songs without moderation on a peer-to-peer basis, highlighting the issues and flaws in current IP, copyright, and licensing laws. This has given rise to a remix culture (Lessig, 2010), meaning modern technology and infrastructure have allowed consumers to copy, edit, and redistribute original digital content without any meaningful repercussion or with little regard to legal and moral considerations (Kietzmann & Angell, 2014).

On a musical blockchain, the balance of power would be given back to the artist; hash representations

of their music could be written into a block with a unique ID and metadata including ownership and licensing rights. This means that the content could not be misattributed easily unless the artist allowed it. Payments could be made using a digital currency and the artists could control the way that they distribute or sell music. Different rates could be given for different population segments (e.g., students and the elderly would receive huge discounts; Dickson, 2016; Tapscott & Tapscott, 2016).

4.4. Blockchain and supply chain management

Supply chain management is a \$16 trillion sector with large overhead in terms of costs, error handling, fraud, and administration (Boucher, 2017). Blockchain is ripe to disrupt this sector, especially when synthesized with an IoT strategy. The promise of a blockchain/IoT approach is that many of the issues associated with supply chain handling can be eliminated or drastically enhanced, thus reducing overhead significantly. This works by ensuring each party with a private key writes a confirmation to the blockchain that they have received a product. This secure chain of custody allows for high confidence verification of where and how a product was handled, and allows each member of the supply chain to identify and inspect where any mishandling might have occurred.

The granularity and information that IoT and blockchain promise has given rise to companies such as Provenance, Smartlog, and Everledger, which offer transparency services, tracking, and provenance of everyday goods (Montecchi, Plangger, & Etter, 2019). While this may seem overzealous, provenance can be crucial to certain industries that rely on evidencing the source of goods, and to consumers who want to ensure companies align with their personal values.

An example of this would be diamond supply, for which the provenance of stones is integral to the underlying value of the stones (Iansiti & Lakhani, 2017; Tapscott & Tapscott, 2016). Ordinary consumer goods such as clothing, meats, wine, seafood, and postal services are also affected by documentation issues; while proving the authenticity of goods is one aspect of their appeal, many companies are finding that blockchain gives them a competitive advantage with consumers who are increasingly concerned with the origin of goods sourced from around the world (Armstrong, 2016). The promise of this type of use case in driving the circular economy is significant because it provides consumers with information on the reused/recycled components in the products they buy.

Finally, blockchains can protect consumers from deceptive counterfeit fraud. By registering the initial purchase onto a blockchain, the authenticity of the product can be permanently stored and the ownership of the certificate can be passed along in a transaction that can be managed through smart contracts. By connecting the physical product with the blockchain via the use of an IoT device such as a sensor, the connection between the product and its authentication certificate is locked.

4.5. Blockchain and the energy sector

In the energy sector, companies are currently developing blockchain solutions to disrupt and diversify their operations models entirely. Prosumers who produce their own energy via solar can now sell any excess reserves of energy back to the market using blockchain-powered apps. This step provides value to consumers who care about the provenance of their energy source and supplemental income to prosumers.

4.6. Blockchain and healthcare

Our current healthcare system is plagued with information siloes and inefficient data interchanges between electronic health record vendors, providers, insurance companies, research organizations, and patients. The fax machine is still the primary mode of patient health data exchange due to factors like organizational bureaucracy, provider apathy, misaligned incentives, and inertia (Withers, 2018). Moreover, inconsistent and unsecure data storage has led to massive breaches of patient data from large healthcare entities globally (Pierson, 2017). This led to significant public backlash and mistrust in the way patients' data are stored, interpreted, and potentially sold without their knowledge. Because of inefficient data sharing, physicians have incomplete pictures of patients' health profiles, which leads to slower treatment and poorer health outcomes (Wicks et al., 2010).

Blockchains have the potential to revolutionize the way health data is stored, handled, and efficiently exchanged between healthcare entities while maintaining these entities' incentives. For example, after a patient receives a lab result, the data—instead of being stored centrally on the lab's servers—can be stored encrypted on the blockchain network.² The data itself can be tagged

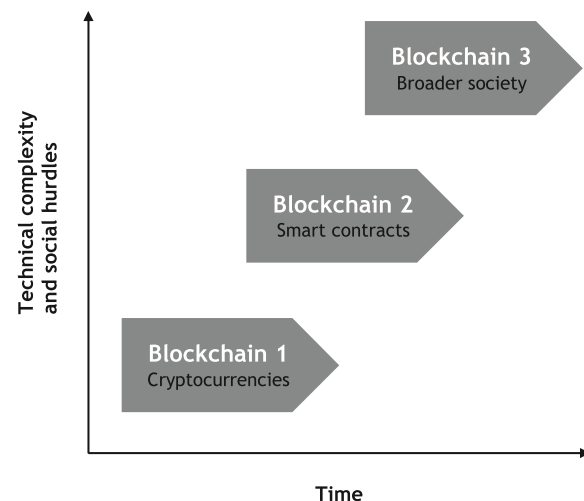
with the creator of the data (i.e., the lab) so any parties who access data in the future can see who generated it. This allows for the preservation of commercial incentives for the lab as they will still be able to bill insurance companies and receive funding based on their work. However, the control of the data is now given to the patient, who can actively decide to share it with a new family doctor or send it to a university for research purposes. This reduces concerns surrounding lost or corrupt data, slow exchange of data, and unknown reselling of data. Many blockchain-based healthcare startups like Doc.ai and Encrypgen have already developed decentralized health data solutions.

5. The realities of mass adoption

There is little doubt that businesses, governments, and central banks are all considering the broader implications of absorbing blockchain technology into their respective operations, but the future of blockchain and cryptocurrencies is contentious as of this writing (Kietzmann & Archer-Brown, 2019). Many academics and observers agree that they have much potential (Pazaitis, De Filippi, & Kostakis, 2017; Takahashi, 2017) but the scope of their usefulness is still moot.

Comparisons about the roadmap to full maturity have been aligned with the developments of the early web; many academics (Swan, 2015; Zhao et al., 2016) see the evolution of blockchain in three decade-long iterations in which each iteration faces its own unique technical and business challenges to larger adoption (Figure 2). For example, in the case of cryptocurrencies, we are seeing wild fluctuations in market value as users are more

Figure 2. Roadmap of blockchain adoption



² Or, to comply with privacy laws, stored off-chain with a referent to the data on the blockchain.

interested in exploiting market returns than using them as a medium of value exchange. We have entered the age of smart contracts in which blockchain is being used as a decentralized, programmable logic platform. However, most smart contracts are still comprised of programs to create new cryptocurrencies. Regulation and organizational acceptance are still in its infancy and will need to open up dramatically before blockchain is used more broadly in any application. We have not yet come close to this stage. Despite the feature-based merits of blockchain, it still faces many technical and societal barriers.

6. Technical and societal challenges

We are currently living through the first iteration of blockchain: cryptocurrencies. However, it is the second and third iterations that offer the most promise for disrupting business paradigms, processes, and economic impact (Swan, 2015; Zhao et al., 2016).

In order to advance the progress of developing blockchain adoption toward future iterations of development, various obstacles need to be overcome. First and foremost, there are a wealth of technical challenges to consider that mostly involve developing and nurturing the ecosystem required to support maturity and wider adoption (Wang, Chen, & Xu, 2016). The issues are various and require research and input from developers, startups, software engineers, venture capitalists, and users to solve issues such as secure transactions, interoperability between blockchains, and endless scalability (Mougayar, 2016).

Moreover, a large proportion of society does not yet understand what blockchains or cryptocurrencies are or how they can use them. This means that there will be an impetus on the blockchain community to lobby for the technology within their own communities and beyond. If blockchains or currencies are going to be adopted within business operations and society generally, then there is a lot of work to be done to simplify and demystify these concepts and usage for colleagues, consumers, and critics. This will clearly take time and evangelists within the technology space will need to provide leadership and vision in order to produce the next generation of killer apps to whet consumer appetite.

The development of a killer app would clearly expedite the route to wider adoption if it caught the imagination of the public at large. One such development that aligns with this idea is the recent announcement by Facebook CEO Mark Zuckerberg that Facebook will begin to research decentralization

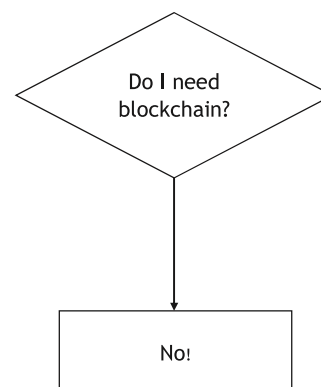
and cryptocurrencies for the company as part of his personal challenge: “I’m interested to go deeper and study the positive and negative aspects of these technologies, and how best to use them in our services” (Zuckerberg, 2018).

Other challenges facing blockchain adoption are questions relating to legal issues and regulation (Boucher, 2017). While the pace of technology is fast moving, regulation and lawmaking are slow-moving processes. This has been evidenced within the fintech industries, which have taken a progressive approach to evolving technologies such as distributed ledger technologies, algorithmic trading, and the potential of peer-to-peer transactions. The Financial Conduct Authority in the UK currently holds a technology-neutral stance on the adoption of blockchains in finance and considers their future usage acceptable “as long as risks are acknowledged and mitigated” (Clarke, 2018). In the U.S., Jay Clayton, Chairman of the Securities and Exchange Commission, has taken a hardline stance that all cryptocurrencies are securities and should be regulated as such, imposing stringent oversight on new blockchain projects (Higgins, 2018).

7. Managerial implications

Hopefully, we have adequately illustrated the potential of blockchains and digital currencies to add utility to business, society, and the web. It is a lot to consider and, for managers wondering about implementation, there are potential risks as well as benefits to acknowledge. In terms of guidance as to whether a blockchain solution is suitable for the business, there are a number of decision models available. Each offer differing guidance about the appropriate conditions for implementation, including Meunier’s (2018) tongue-in-cheek model (see Figure 3).

Figure 3. Managerial bias toward blockchain



Source: Meunier (2018)

Clearly, Figure 3 is not a serious illustration of whether an organization should think about adopting blockchain; however, it is an illustration of many managers' current thinking and bias against blockchain. A more appropriate way to think about adopting blockchain is to consider organizational problems in need of solutions and how these solutions could be found in blockchain technologies.

For managers thinking about using a blockchain solution, several important considerations should serve as the bedrock of their decision-making processes.

- **Trust:** Resolving a lack of trust between parties in an ecosystem is arguably the most important benefit of the blockchain. Notions of trust operate along a broad spectrum and there are a number of ways in which blockchains solicit trust between stakeholders in various exchanges. Most notably are the removal of intermediaries between cash transactions, which is the current model of digital currencies but could be adapted within any intermediary business model (e.g., peer-to-peer auctions, insurance, banking). Because of the implementation of consensus algorithms and cryptography, parties in a network can interact and transact with each other relatively safely and with assurances that their transactions and identities will not be stolen or corrupted.
- **High uptime requirements:** The decentralized nature of blockchains ensures high uptime since they do not have a single point of failure.
- **Immutability:** If a business requires an immutable, chained log of transactions, then a blockchain may be a suitable solution for future auditing purposes.
- **Transaction speed variability:** The speed of transactions can vary depending on which blockchain is used. If slow transaction times are reductive to the stakeholder experience, then a blockchain solution should be evaluated more carefully, since different blockchains operate at different velocities. Examples of currency blockchain times vary from between seven transactions per second (TPS) in the case of Bitcoin to nearly 3,000 TPS, in the case of EOS (Williams, 2018).

Managers wear many hats within their role, and part of that role includes nurturing innovation and finding operational efficiencies that benefit the business. In this context, there is an argument for managers to think about blockchain beyond the realms of the decision model and to take a position of innovation

and creativity that contributes to the evolution of the company via process and business modeling innovation (Morkunas, Paschen, & Boon, 2019).

8. Looking ahead

It is clear that blockchain technologies are still in their infancy and a lot of their promise still lies within speculation and hyperbole. Much of this speculation appears to be fueled by the ongoing and polarizing debate that questions the utility and value of cryptocurrencies and how they could complement existing fiat currencies.

Clearly, blockchain has a long way to go before it matures to become an integral societal product, though there are pockets of implementation within various areas of business. The use cases detailed in this article speak to the potential of the technology and give a view of what a blockchain future could look like. Just like the early web, it appears that the success of blockchains and digital currencies will depend upon the business communities' appetite to disrupt and embrace the way that we transact value. Furthermore, it will require a lot of heavy lifting by the blockchain community to develop the tools and infrastructure required to nurture a vision of the web that advances society, culture, technology, and business, just as Jeff Bezos did.

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