BUSHOR-1548; No. of Pages 8
ARTICLE IN PRESS
Business Horizons (2018) xxx, xxx—xxx

Available online at www.sciencedirect.com
ScienceDirect

KELLEY SCHOOL OF BUSINESS
INDIANA UNIVERSITY

www.elsevier.com/locate/bushor

Blockchain adoption: A value driver perspective

Jannis Angelis [a,b,*], Elias Ribeiro da Silva [c]

[a] *School of Industrial Engineering & Management, KTH - Royal Institute of Technology, Lindstedtsvagen 30, 114 28 Stockholm, Sweden*
[b] *Research Institute of Industrial Economics, Grevgatan 34, SE-10215 Stockholm, Sweden*
[c] *Pontifical Catholic University of Parana, R. Imaculada Conceição 1155, 80215-901 Curitiba, Brazil*

KEYWORDS
Blockchain;
Distributed ledger;
Value drivers;
Artificial intelligence;
Decision making

Abstract The ongoing discussion regarding blockchain technologies is focused primarily on cryptocurrencies, but blockchain features and functionalities have developed beyond financial instruments. As the technologies provide new functionalities, the associated value proposition changes as well. This study explores the relationship between blockchain technologies and their underlying value drivers. Four identified distinct blockchain stages of increased maturity are analyzed and discussed. This covers the evolutionary technology types focused on transactions, smart contracts, decentralized applications, and the introduction of artificial intelligence supporting decentralized decision making. In addition, we address management issues around appropriate blockchain adoption using a blockchain value driver-focused framework that gives decision makers actionable questions and recommendations. We provide practitioners with a method for assessing suitable blockchain adoption that addresses the specific value creation associated with a given organizational strategy. For academics, we critically identify and assess the characteristics of the blockchain stages and their strategy implications and provide a structured approach conceptualizing blockchain technology evolution.

1. Strategic blockchain view

Commonly discussed for being the technology behind Bitcoin, blockchain—or distributed ledger—technology is well known due to the current cryptocurrency hype. However, the technology has

* Corresponding author
E-mail addresses: jannis.angelis@indek.kth.se (J. Angelis), elias.hans@pucpr.edu.br (E. Ribeiro da Silva)

https://doi.org/10.1016/j.bushor.2018.12.001

applications well beyond financial markets. In its most fundamental form, a blockchain is essentially a distributed database of records or a public ledger of all transactions or digital events that have been executed and shared among the participants. Each transaction in the public ledger is verified by a consensus of the participants in the system, allowing for traceability and, in turn, security without the need of a central authority. In addition, since every block is connected to the previous one, as the number of participants and blocks grows it is very difficult to modify information without having a network consensus (Corea, 2019; Crosby, Nachiappan, Pattanayak, Verma, & Kalyanaraman, 2015).

According to a report by the consultancy Bain & Co. (Williams, Gunn, Roma, & Bansal, 2016), while distributed ledgers are a relatively new phenomenon, they typically combine a number of established technologies in novel ways:

- *Blockchain*: A secure record of historical transactions, collected into blocks, chained in chronological order, and distributed across a number of different servers to create reliable provenance.
- *Digital signatures*: Unique digital keys used to authorize and check transactions and positively identify the initiator.
- *Consensus mechanism*: Rules and techniques to ensure that participant recordings and processing transactions agree on which transactions are valid.
- *Digital currency*: A cryptographic token that represents actual value.

A distributed ledger has the potential to be highly transparent, secure, immutable, and decentralized. These features are useful for dealing with operational and business issues besides financial transactions, and the technology has already been used for interorganizational cooperation beyond the cryptocurrency aspect. Early adopters have set about applying blockchain technology to everything from supply chain management to hospital records, the workings of government through transparent voting, and the digital signatures of e-ID (Banker, 2018; IBM, 2016; Laaper, Fitzgerald, Quasney, Yeh, & Basir, 2017; Ølnes, Ubacht, & Janssen, 2017; Roehrs, da Costa, & da Rosa Righi, 2017; Sullivan & Burger, 2017; Sun, Yan, & Zhang, 2016).

Uses are also broadening as the distributed ledger technology is being further developed and refined. But a common assumption made is that the business fundamentals remain unchanged regardless of which technology is selected. This may well be a mistaken assumption since maturing technology typically enables new types of product or service offerings and involves changes in the pursued and derived benefits. To explore this further, our study investigates the relationship between the use of blockchain technology and the underlying value drivers. The study approach addresses specific value creation aligned with a given organizational strategy. For academics, we identify the key characteristics of the blockchain stages and their implications for various business strategies. We also provide practitioners with a method for assessing their chosen business perspective on blockchain adoption going beyond the more simplistic singular blockchain stage.

2. Stages of blockchain maturity

The blockchain idea first proposed by Satoshi Nakamoto[1] has undergone rapid incremental evolutions over the past 10 years. Initially the technology was not programmable, as with Bitcoin, but blockchain technologies have emerged that do incorporate just such functionality. The idea of a programmable blockchain does not necessarily make it better than a nonprogrammable one, but it does fulfill a specific function and expands the scope for market decentralization in a general sense. The different kinds of blockchain technologies and uses are characterized by the following four stages (the first three are established and the fourth is the emerging AI-blockchain integration stage):

- *Blockchain 1.0* is focused on transactions, mainly on the deployment of cryptocurrencies in applications related to cash, such as currency transfer, remittance, and digital payment systems (Swan, 2015). Perhaps the most well-known example is Bitcoin, a decentralized digital currency in which encryption techniques are used to allow peer-to-peer transactions in a system that works without a central bank or single administrator.
- *Blockchain 2.0* is an extension of Blockchain 1.0. It encompasses privacy, smart contracts, and the emergence of non-native asset blockchain tokens and capabilities (Schuster, 2018). A well-known example of a platform that runs smart contract is Ethereum, but there are many other solutions such as the IBM-Maersk partnered

[1] A pseudonym

blockchain supporting global shipping (IBM, 2018) and the trade finance blockchain consortium we.trade (Wass, 2018).

- *Blockchain 3.0* expands the blockchain focus further to incorporate decentralized applications (dApp). A dApp consists of back-end code that runs on a decentralized peer-to-peer network connecting users and providers directly. This open-source software platform is implemented on decentralized blockchains using cryptographic tokens. For instance, an established distributed ledger may act as a platform for application developers to make their transactions possible. The dApps are designed to be flexible, transparent, distributed, resilient, and have a clear incentivized structure (Raval, 2016). The possibility of creating decentralized storage and decentralized computing enables greater scalability for dApps.

These three blockchain stages are not defined simply by the change or inclusion of specific features that, in turn, impact the given blockchain capabilities. The added features also enable the creation of new markets that otherwise would not be possible and increase the potential value of blockchain use as a whole.

The most recent, and just now emerging, blockchain iteration—Blockchain 4.0—similarly offers significant value opportunities. This involves the inclusion of artificial intelligence (AI) to blockchain technologies, two different sides of the technology spectrum. AI is based on probabilistic theory to express uncertainty. It is constantly changing, and the algorithms are projected to guess—or make assumptions of—reality. In contrast, blockchain uses a determinist hashing algorithm, which produces the same results when the inputs remain unchanged. The results are permanent and the algorithms and cryptography are projected to record reality. Although the technologies are different, their joint use helps solve complex problems. AI allows computers to learn from accessible data, while blockchain provides data accuracy, which is useful for feeding data into the AI system and for recording its outputs. A successful example of such combined technology use is CognitiveScale, an AI startup backed by IBM, Intel, Microsoft, and USAA that uses blockchain technology to store securely the results of AI applications built for regulatory compliance in financial markets (Harris, 2017). Generalizing it, a traceable path not only improves data trustworthiness and the construction of models but also creates a route back into the automated decision-making process.

Automated decision making in the form of algorithmic management (AM) consists of software algorithms that assume managerial functions and surrounding institutional devices that support algorithms. Efficiencies are gained as the optimizing algorithms analyze large data sets to better control processes and maximize predefined outputs such as costs or revenues. AM is best applied in stable environments wherein predefinitions are possible. AM can be given the freedom to take action based on poor performance, and corrective actions taken in real time to increase quality, assign appropriate work tasks, etc. Incorporating real-time information is also an option, with AM used to adjust parameters and conditions of smart contracts. In effect, AM is taking control over the decision making, albeit—at least, initially—within a predetermined range.

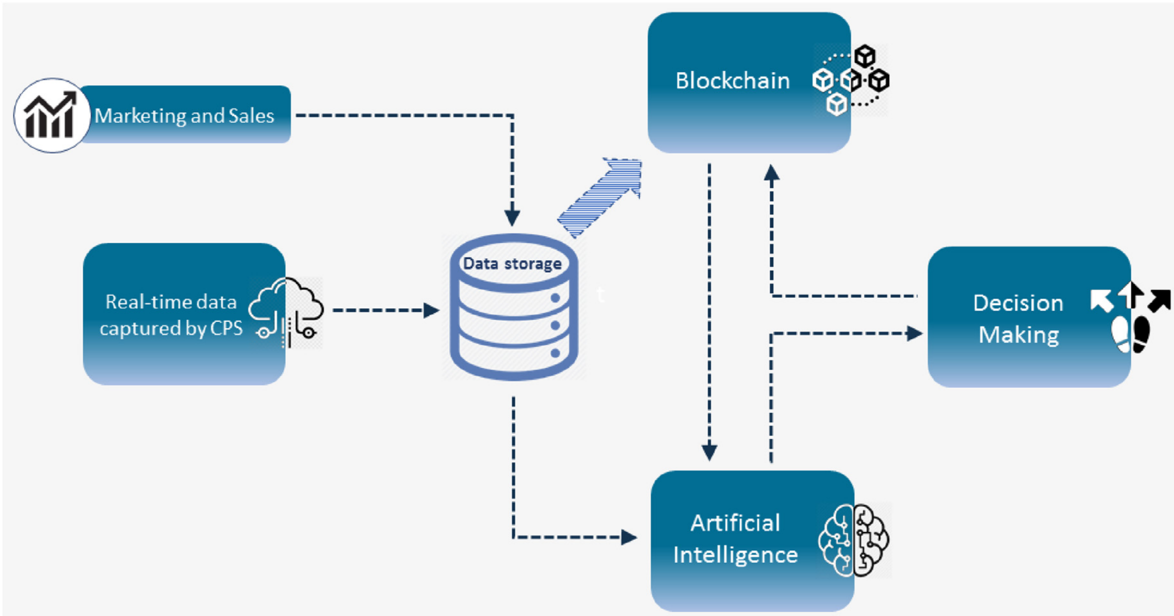
As the figure shows, the AI makes decisions that are stored in the blockchain. This is fed back to the AI to enable further analysis and to improve decision making. Depending on the degree of openness of the shared ledger, data storage and blockchain may, in practice, converge (see the striped arrow in Figure 1). In a public distributed ledger, the two will be identical, while in a hybrid public/private ledger it will be identical for some parties but not for all. In contrast, a private ledger may have strong firewalls between data storage and blockchain recording, only making public the decisions and not the actual data they are based upon. Note that Blockchain 4.0, in particular, is useful in environments in which traceability and immutability are highly valued. In other circumstances, the AI function may instead be directly linked with the decision making without the reliance on and use of a decentralized database.

3. Underlying logic of blockchain value drivers

Looking at the blockchain evolution, we can identify an underlying logic to how certain drivers create value. Blockchain 1.0 is directly related to a decrease in transaction cost. This is not only in a narrow financial sense but also with a broader idea of eliminating the need for a central authority to ensure secure transactions. Such decentralized consensus reduces costs, for instance by removing middlemen.

Blockchain 2.0 takes a further step forward by enabling the development and use of smart contracts. From these smart contracts, it is possible to operate knowing the rules of the game, and parties that are not well known can trust each other without the need for middlemen acting as guarantors.

Figure 1. Algorithm management process



This also means that the blockchain is no longer limited to financial relations only. Beside enabling the elimination of many middlemen, the transparent and autonomous nature of smart contracts mitigates risks of manipulation and error.

Blockchain 3.0 introduces the concept of decentralized applications and computing. This provision of offerings requires the sharing or partial outsourcing of activities that otherwise would be handled by the focal organization. It changes the more traditional type of transaction structure and typically requires governance modifications since services provided and the underlying required support functions fall outside the focal organization's direct control. This supports a network approach that incorporates new parties, which may have several positive effects such as increased learning and access to new capabilities or technologies. The change of organizational boundaries allows for different constellations tailored to generate value in a preferred way. For instance, it may enhance the service innovativeness or speed to market of new products.

Finally, Blockchain 4.0 is the result of the joint use of blockchain and artificial intelligence. This allows systems to make decisions and act on them without the need for direct human interference. Indirectly, management may manage by either (tightly) setting parameters or (loosely) dictating areas in which the blockchains then operate. There is a degree of management control and decision making retained, but it is focused on defining directions rather than executions. The latter may even include setting or adjusting targets and assessments, activities that traditionally are well within the management's responsibilities. This ability to perform a management function by setting parameters, making judgments, and then executing on them independently from management supervision is its main value driver.

Note that while the blockchain stages have developed on each other, this does not mean that an organization building a blockchain capability must implement the technologies in a similar order. There is also no requirement to use all stages. The specific functionalities needed, and hence stage of blockchain technology to use, is dependent on the underlying value that is being pursued. Figure 2 summarizes the enablers and value drivers of each blockchain type.

4. Value creation implications

Although the various blockchain stages are built upon each other, each has a different purpose. For value creation, it matters more what functionalities are required for the given service than the technology used. Each stage of blockchain technology provides certain enablers that are capable of generating value but for each specific case, the value generated at the various stages may differ.

The decentralized consensus functionality, which underpins the creation of Blockchain 1.0, has provided a new way to gain security, transparency, and transactional advantages in the financial transaction process. But for Blockchain 2.0, which includes smart contracts in the business processes,

Figure 2. Enablers and value drivers of blockchain

	ENABLERS	VALUE DRIVER
1 Blockchain 1.0	Decentralized consensus	Transaction cost
2 Blockchain 2.0	Smart contracts	Added services
3 Blockchain 3.0	Decentralized applications, storage and computing	Organization boundaries
4 Blockchain 4.0	Decentralized artificial intelligence	Autonomous decision-making

there are broader possibilities available. This includes developing additional services as well as providing incremental value to existing services. In addition to financial transactions, several other services may be offered. For every new functionality implemented, there is an increased possibility to deliver added value while maintaining the intrinsic benefits of using blockchain. This is observable in comparisons between the four blockchain stages.

Despite the evolutionary element of the four stages, it does not mean that the highest value necessarily is gained from pursuing and implementing the higher stages. Instead, value captured is primarily related to the specific proposal and service offering and not to the blockchain functionalities. This follows the complexity-novelty framework by Iansiti and Lakhani (2017) that identified stages of technology development and their capability implications. Therefore, comparisons related to the added value of a given initiative must be made within the same blockchain stage rather than between stages. Emphasis is put on intra- rather than inter-comparisons. It is the set purpose and strategy that determines which blockchain technology stage is the most appropriate and will generate the highest value for the organization.

This last observation needs highlighting. Blockchain adoption does not evolve in the same way as many other maturity-based technologies. It is not about maturity levels. Each blockchain stage comprises a set of functionalities that are necessary to meet certain service needs. An organization does not have to start with the employment of Blockchain 1.0 and then mature in its technology applications by later implementing stages 2.0 through to 4.0 in a serial sequence. Instead, as long as the technological capability is manageable, the appropriate technology stage can be adopted from start or anytime. This has three distinct but related implications. First, it is more important to implement and use the appropriate stage of blockchain technology than pursuing higher technology levels. Second, the technology stage does not by itself mean it generates more value. It is how the technology is employed that determines its generated value and not its functionality. Finally, using different stages of technology should not be compared directly in terms of their value creation.

5. Structured decision making against the hype

Perhaps due to the technology hype, many digital enthusiasts seek solutions through blockchain-based applications when dealing with data transparency and immutability issues. While using a blockchain in many instances is both suitable and appropriate, there are technology-induced features that require careful feasibility and viability considerations prior to any blockchain adoption. In support of this, we provide a structured framework for managers to evaluate the blockchain options for adoption and deployment. In the next sections 5.1–5.4, we discuss four key questions that help identify the appropriate blockchain technologies. They cover value drivers and opportunities (Q1), feasibility and viability of adopting blockchain (Q2), and technology selection (Q3 and Q4).

5.1. Value drivers and value opportunities

- *Question 1: What kind of value is sought?*

The first step is to identify exactly what kind of value opportunity is being pursued and its enabling blockchain technologies. Blockchain adoption should occur when there is a need that a specific blockchain technology meets, such as providing transparency, immutability, ledger privacy, reliability, and safety. Value drivers enable reductions in transaction-based costs, the addition of new services, the delineation of organizational boundaries, and the automation and decentralization of decision making. As discussed in section 3, drivers for value creation are intrinsically linked to the features and functionalities gained through blockchain use. For instance, data immutability for property registration or personal identification cannot be guaranteed by centralized systems as well as in decentralized and shared ledger systems because participants in the latter case can track changes made. On the other hand, when tracking supply chain data from a noncritical service provider, the actual value proposition is based on the tracking itself and not on the immutability of the tracked data. A technology that offers immutability is then not a value driver. Hence, value gained from centralized and decentralized systems will differ.

Note that the identification of need and value proposition behind each initiative is important, but not sufficient to justify blockchain adoption. That also requires identification of an appropriate technology, which is discussed next.

5.2. Feasibility and viability

- *Question 2: Is it a feasible and viable option to adopt the technology?*

Given the emerging nature of blockchain technologies, to construct and maintain a blockchain-based application from scratch can easily become a rather arduous and expensive endeavor, and there are still relatively few options of prebuilt solutions for specific applications. Therefore, blockchain should be pursued when there is a strong expected benefit to using it. As for viability, considerations are required on acquisition or development and the capabilities required to actually use the technology. This may involve access to skilled programmers to continuously maintain the blockchain software or data, or managers to deal with legal obligations arising from its use. A range of challenges around application scope, counterparties, process, data, technology, people, regulation, performance, and security must be settled. Preferably this is based on a pre-established set of appropriate questions for deciding if the application of a blockchain is both feasible and viable, as suggested by Seibold and Samman (2016).

5.3. Appropriate selection of technology

- *Question 3: Why is a blockchain preferable to a centralized ledger?*

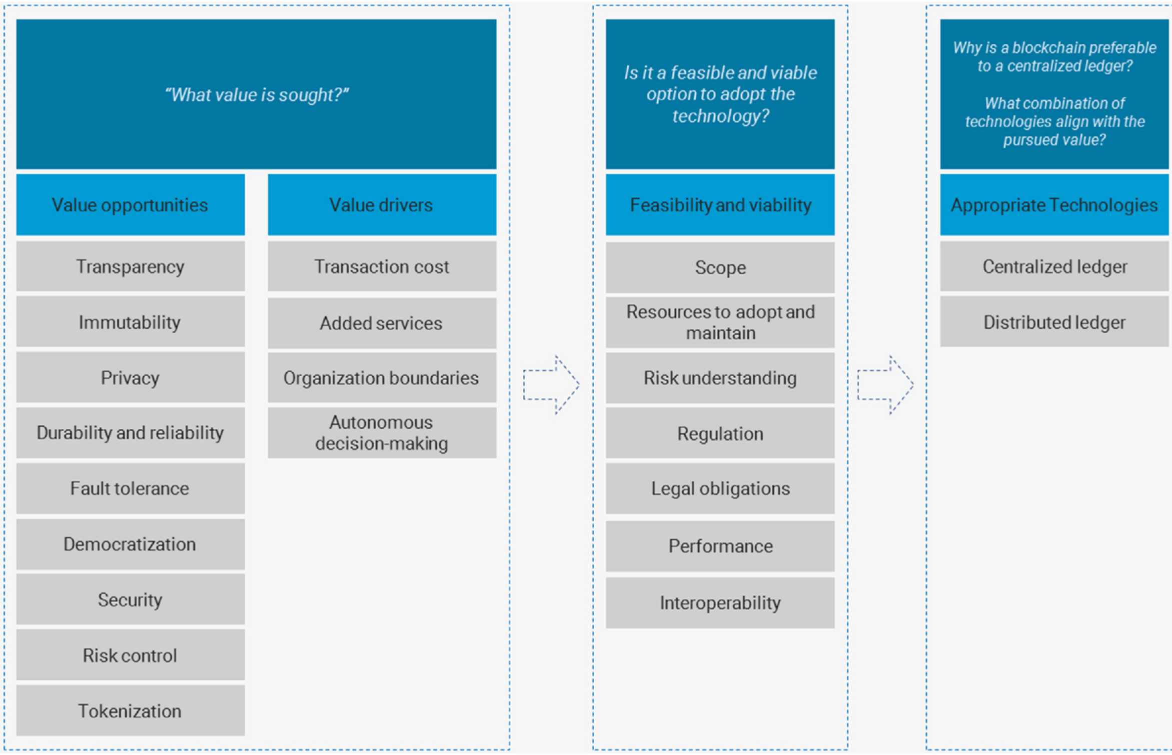
Blockchain initiatives are becoming more numerous. For instance, data from the CoinSchedule shows that in 12 months, 372 Initial Coin Offering (ICOs) were launched, raising approximately $9.9 billion (Chong, 2018). In addition, according to a study by the company Juniper Research (2017), 57% of large firms sampled are considering incorporating blockchain to their business processes, and expect the technology to be integrated into their existing systems by the end of 2018. However, the surge in blockchain interest does not in itself lead to actual new or improved solutions to offerings or business processes, nor does it mean that using a blockchain is the best option. Such considerations lead to the critical issue of technology uniqueness.

Organizations that choose to use blockchain in their operations need to rely on the technology to solve a problem that realistically otherwise would remain unresolved. There is an issue on how it adds value that other technologies do not. This has two aspects. The first relates to the use of a distributed rather than centralized ledger, such as an ERP system. The second aspect deals with data ownership. It covers the expected benefit of having more than one database owner and sharing all data on, for instance, sales or monetary transactions.

A Juniper Research (2017) report warned against using blockchain without first considering other alternatives since, in many cases, systemic rather than technological change might be both a better and cheaper solution. In addition to costs, unnecessary blockchain introduction may cause significant internal and external disruptions; there are clearly risks associated with blockchain adoption. For instance, the example of property registration or personal identification presented in section 5.1 may not be feasible due to the implicit risks. A study by Suberg (2018) showed that blockchain related majority attacks, or so-called 51% attacks, in which a group of miners control the network mining hash rate, is both a credible and significant threat. Another risk is that a user with a compromised private key cannot recover it, unlike in a centralized system wherein reissue typically is possible. In this way, personal identity preservation is also nowhere near a guarantee. The expected benefits of blockchain adoption must outweigh such risks compared with more centralized technologies.

- *Question 4: What combination of technologies align with the pursued value?*

Figure 3. Framework for value analysis in blockchain adoption



As blockchain technologies have evolved, the functionalities have increased as well. Hence, once management has decided that using blockchain is an appropriate element in the digital strategy, the next step in the decision-making process is to establish the features that the selected technology must provide. This requires defining parameters on conditions such as scalability, level of privacy, latency, and degree and form of autonomous decision making.

5.4. Blockchain value driver framework

Building on these issues, we suggest using the blockchain value driver framework (Figure 3) to capture the technology feasibility and viability as it provides a strong indication of technology appropriateness. It also gives insights on particular features the blockchain needs to have, and in which context and product or service offerings to apply the technology.

For each step, the framework provides actionable questions and recommendations. It covers the respective questions managers need to ask, considerations for adoption, and their underlying dimensions.

6. A broader view of blockchain adoption

The potential of blockchain is currently receiving significant attention, but actual practical applications are still being developed. Emphasis has been on blockchain technology itself rather than on the issues around selection and adoption. What management needs to decide is how to position their companies in the stages of blockchain technology as a way to increase the degree of service innovation and value creation. But, as also noted by Michelman and Catalini (2017), architectural changes in how value is created and appropriated within a given market do not happen overnight. We suggest managers think carefully about the risks associated with blockchain adoption and preferably start small when it comes to actual assimilation of technology to existing or new processes and offerings. However, there is not a definite need to start with the decentralized consensus of Blockchain 1.0. Instead, an organization should directly pursue the type of blockchain technology that most fits with its business needs, and not move linearly from Blockchain 1.0 to 4.0 since such shifts may not create the desired value. After all, it is having the appropriate technology functionalities that generates the greater value. This may, for instance, mean that when only seeking smart contracts Blockchain 2.0 is preferable to Blockchain 3.0 technologies since the latter provides additional functionality that is superfluous and perhaps even a poor fit with the purpose of the provided service.

Organizations with relatively limited resources or experience in digital technology adoption should not underestimate the difficulties associated with the implementation of more complex technology, despite the many best-practice cases found on technologically sophisticated early adopters. In the end, it is up to management to define the appropriate technology adoption path, and not by default follow the hype around the benefits of every emerging technology. Instead, the key is to ensure the value provided by the chosen technology is the one that best fits with the overall strategy.

References

Banker, S. (2018, February 22). The growing maturity of blockchain for supply chain management. *Forbes*. Available at https://www.forbes.com/sites/stevebanker/2018/02/22/the-growing-maturity-of-blockchain-for-supply-chain-management/#7d0dba9b11da

Chong, N. (2018, June 2). ICOs raise over $9 billion six months into 2018, surpassing 2017 figures. *News BTC*. Available at https://www.newsbtc.com/2018/06/02/icos-raise-over-9-billion-six-months-into-2018-surpassing-2017-figures/

Corea, F. (2019). The convergence of AI and blockchain. In F. Corea (Ed.), *Applied artificial intelligence: Where AI can be used in business* (pp. 19–26). Cham, Switzerland: Springer.

Crosby, M., Nachiappan, Pattanayak, P., Verma, S., & Kalyanaraman, V. (2015). *Blockchain technology: Beyond Bitcoin*. Berkeley, CA: Sutardja Center for Entrepreneurship & Technology.

Harris, P. (2017, December 7). What blockchain technology means for artificial intelligence. *NASDAQ*. Available at https://www.nasdaq.com/article/analysis-what-blockchain-technology-means-for-artificial-intelligence-cm888540

Iansiti, M., & Lakhani, K. (2017). The truth about blockchain. *Harvard Business Review, 95*(1), 118–127.

IBM. (2016, October 19). *Walmart, IBM, and Tsinghua University explore the use of blockchain to help bring safer food to dinner tables across China*. Available at https://www-03.ibm.com/press/us/en/pressrelease/50816.wss#release

IBM. (2018, January 16). *Maersk and IBM to form joint venture applying blockchain to improve global trade and digitize supply chains*. Available at https://www-03.ibm.com/press/us/en/pressrelease/53602.wss

Juniper Research (2017). *Blockchain enterprise survey: Deployments, benefits, and attitudes*. Hampshire, UK: Jupiter Research.

Laaper, S., Fitzgerald, J., Quasney, E., Yeh, W., & Basir, M. (2017). *Using blockchain to drive supply chain innovation*. New York, NY: Deloitte Development LLC.

Michelman, P., & Catalini, C. (2017). Seeing beyond the blockchain hype. *MIT Sloan Management Review, 58*(4), 17–19.

Ølnes, S., Ubacht, J., & Janssen, M. (2017). Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. *Government Information Quarterly, 34*(3), 355–364.

Raval, S. (2016). *Decentralized applications* (1st ed.). Sebastopol, CA: O'Reilly Media.

Roehrs, A., da Costa, C. A., & da Rosa Righi, R. (2017). OmniPHR: A distributed architecture model to integrate personal health records. *Journal of Biomedical Informatics, 71*, 70–81.

Schuster, B. (2018, January 26). What is the third generation of blockchain technology? *HackerNoon*. Available at https://hackernoon.com/what-is-the-third-generation-of-blockchain-technology-36a46af5ccbc

Seibold, S., & Samman, G. (2016). *Consensus immutable agreement for the internet of value*. Amstelveen, Netherlands: KPMG.

Suberg, W. (2018, May 25). Ethereum Classic 51% attack would cost just $55 million, result in $1 billion profit: Research. *CoinTelegraph*. Available at https://cointelegraph.com/news/ethereum-classic-51-attack-would-cost-just-55-mln-result-in-1-bln-profit-research

Sullivan, C., & Burger, E. (2017). E-residency and blockchain. *Computer Law and Security Review, 33*(4), 470–481.

Sun, J., Yan, J., & Zhang, K. (2016). Blockchain-based sharing services: What blockchain technology can contribute to smart cities. *Financial Innovation, 2*(26), 1–9.

Swan, M. (2015). *Blockchain: Blueprint for a new economy* (1st ed.). Sebastopol, CA: O'Reilly Media.

Wass, S. (2018) Trade finance blockchain platform soon available to clients of nine European banks. Available at https://www.gtreview.com/news.fintech/trade-finance-blockchain-platform-soon-available-to-clients-of-nine-european-banks/.

Williams, G., Gunn, D., Roma, E., & Bansal, B. (2016). *Distributed ledgers in payments: Beyond the Bitcoin hype*. London, UK: Bain & Company.