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The attached educational project, by Yehuda Kleinman, entitled The Implications of Blockchain Technology on Supply Chain Management and the Potential Benefits and Barriers to its Utilization in Procurement, when completed, is to be submitted to the Graduate Faculty of the University of Wisconsin- Platteville in partial fulfillment of the requirements for the (MASTER OF SCIENCE IN INTEGRATED SUPPLY CHAIN MANAGEMENT) degree.

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The Implications of Blockchain Technology on Supply Chain Management and the Potential Benefits and Barriers to its Utilization in Procurement

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Yehuda Kleinman

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Statement of the Problem

As supply chains have become both increasingly global and streamlined, they increasingly require advancements in their modes of information sharing. Just a couple short decades ago it was absurd to think a dock worker in the Port of Hong Kong could scan a pallet being loaded into a container, and a planner in Dubuque Iowa could be notified in just a matter of moments. It would be utterly preposterous to think that standard of technology would so soon after be considered insufficient. Yet, advancements in the field of supply chain and information systems technologies have businesses searching for new methods of information sharing, capable of easily and securely transmitting information to their ever-increasing number of business partners.

Further advancing the need for information sharing capabilities across organizational lines is the increasingly blurred line drawn between business partners in the modern-day supply chain. In an effort to streamline the supply chain and maximize value, supply chain partners have taken drastic steps in eliminating space between their companies, and now even go as far as to view supply chain partners as extensions of their own organizations. One such highly visible example was when Walmart and Proctor and Gamble famously took previous collaboration to a new level by embedding Proctor and Gamble offices within Wal-Mart facilities to eliminate degrees of separation, and even went as far as having Proctor and Gamble personnel play a large role in crafting the Wal-Mart forecast for Proctor and Gamble products (Attaran, Mohsen, & Sharmin 2002).

In the auto industry the blurred line is becoming nothing more than a faded imprint as companies that have traditionally been fierce competitors are more regularly partnering in joint ventures, sharing manufacturing facilities, and subcontracting work to one another (Atiyeh, 2019). While the operations are becoming increasingly intertwined, companies are struggling to share information with one another quickly, securely, and cost-effectively. The result of the informational bottleneck is an effective damper on the business partners gaining all the possible value of these newly innovative relationships.

Part and parcel of supply chain partners becoming inextricably linked is the inevitable result that each transaction holds greater importance to a larger number of stakeholders within the supply chain. The current information system platforms utilized by supply chains generally store data on database servers that are accessible only to those with access. In order to share the data with their supply chain partners, organizations commonly create portals that provide restricted access of relevant information pertaining to the specific supply chain partner. With the aforementioned blurred lines between organizations and proliferation of supply chain partners, the traditional methods are simply no longer adequate for providing the essential visibility by recording and securely transmitting transactional data linked to an activity being performed in a location on the opposite end of the globe for consumption of all interested parties in real-time (Lyall, Mercier, & Gstettner, 2018). The immediate result of which manifests itself as a lack of visibility and time delay in relaying transactional data, which creates the end result of waste generation which minimizes the overall value generated by the supply chain.

The Way of the Future?

Any supply chain professional skimming through their news feed is likely to have seen, and just as likely to have missed, the importance of recent, albeit somewhat muted headlines with the term blockchain bandied about. While it is true the term may hold some meaning to those enraptured with Bitcoin and the crypto currency explosion, it is likely the term holds just some linguistic familiarity but no more meaning than that.

Earlier in 2018, Samsung, the second largest tech company in the world (Stoller, 2018a) announced it would be investing in blockchain technology with the goal of reducing their supply chain costs by a whopping 20 percent. Meanwhile, the e-commerce behemoth Amazon whose foundation is formed by building the most advanced global supply chain has made its intentions clear that it no longer sees value in a long-term relationship with Oracle, the second largest software developer (Novet,2018) and tenth largest tech company in the world (Stoller, 2018b). So, after the great and mighty Amazon has declared their intentions, Oracle has responded with an investment in blockchain (Wood, 2018)? Meanwhile SAP and IBM have created a joint venture using blockchains and have created entire divisions dedicated to blockchain projects (SAP Ariba, 2017). While these industry leading companies are seemingly going about their business as status-quo, there is significant evidence foretelling of a drastic shift in the way these companies view information systems of the future, and blockchain technology seems to be of central importance to the shift in the undercurrent. But what is this all about? And what aspects of blockchains have they found so appealing that they are willing to invest so heavily in the technology? While the techy may not understand the inner-workings of blockchain technology, at this point one thing is for sure; the supply chain leaders are looking for innovative solutions to address the earlier stated problems of opaque visibility and security costs and are exploring blockchains as a potential way of the future.

Of utmost significance in the previous statement is the idea of security playing a pivotal role, both in its increasing costs to companies and its sensitive nature, inhibiting transitioning to a new technology platform (Gottlieb, 2011). It would be simple enough to create an open sourced ledger by which anyone can contribute, and supply chain partners would be able to share information, but that would leave supply chains open to those with nefarious intentions. Meanwhile, the current information system platforms have become increasingly costly and difficult to keep up with the ever-increasing security demands. The result of which has companies eager to explore methods of information sharing and storing that address these two significant concerns:

- Information visibility
- Cost-effective security

Purpose of the Study

The primary purpose of the study will be to understand the impacts blockchain technology will have on the operations of future procurement operations. The scope of study will include not only the impact to supply chains more generally but will dive deeper into the specifics of the implications on procurement. Prior studies have investigated the use of smart contracts (Stark, 2016) and the potential complications blockchain technology presents to the current legal systems (Mik, 2017). The study will build on previous studies and take a comprehensive look at the integrated procure-to-pay (P2P) process flows to assess the impacts to each node in the P2P process.

Significance and Implications of the Study

The vision of what a potential end-to-end supply chain with little human intervention is becoming clearer. "With a digital foundation in place, companies can capture, analyze, integrate, easily access, and interpret high quality, real-time data — data that fuels process automation, predictive analytics, artificial intelligence, and robotics, the technologies that will soon take over supply chain management." (Lyall et al., 2018). Increased automation, advancements in robotics, and the progress being made toward self-driving vehicles are contributing to the clarity what a future supply chain would look like, but until blockchain technology became a possibility no one was quite sure what the information sharing system to support such a supply chain would look like.

Currently, blockchains have made limited inroads into the world of supply chain management. However, the two industries that seem to have embraced the concept of blockchain technology within their supply chains in the early stages have been the food industry and the luxury goods industries (Gandhi, Majumdar, & Monahan 2018). The fully transparent system with live information is exactly what the food industry required, and they were quick to adopt the technology. Companies such as Wal-Mart, Unilever, Nestle, and Dole have already implemented such systems. For these companies, blockchains allow them to simply look at the ledger and immediately see every movement and transaction that their product has incurred. For food safety conscious consumers, the adoption of blockchains offers peace of mind. The data trail is detailed and highly visible. For every Dole pineapple perched on a shelf at the local supermarket there is an elaborate story recorded as a blockchain. The story begins the moment the fruit is harvested from the field. Then with each subsequent movement a transaction is recorded in the blockchain ledger. It is easy to see why a company in the food industry would be highly interested in a technology that would make conducting a forward or backward recall a seamless process, while also providing invaluable time stamped records on perishable goods. Blockchain technology also creates a platform that all but eliminates the space between the first link in the supply chain to the end customer. The very real possibility exists that within just a few years a diner sitting at their local steakhouse in New York City upon having just enjoyed their steak, can immediately look to see the origin of the steak, and before leaving the eatery can leave a tip not only their waiter, but the farmer that raised the steer on that very same blockchain platform (The Future of Blockchain, 2019). That immediate interaction with end customer is something highly coveted by suppliers at the early stages of the supply chain as they seek to understand the trends in the marketplace. The ability for seamless interaction across the span of the entire blockchain affords a level of intimacy that can be parlayed into tailored customer experiences and foster brand loyalty.

In the case of the luxury goods industry, companies such as Everledger are utilizing blockchains in their supply chains to ensure proof-of-origin for their diamonds and as definitive proof they are of genuine origin and are conflict free. The relative cost of testing the new technology is reduced, as their products tend to have higher margin sales.

While it is true that some companies have already jumped in and are utilizing blockchains in their supply chains, its use is generally being confined to the purpose of logistics and quality control. For these companies to unlock the full potential of what blockchain technology can offer them they would need to find ways to expand their use of blockchain technology in their supply chains and extend the utilization into other supply chain functions. Of all the various supply chain functions, procurement may stand as the largest barrier to the proliferation of blockchain technology throughout the entire supply chain. The area of procurement most often comprises information that is highly sensitive, making companies more hesitant to utilize the relatively untested technology with the highly sensitive information. In addition, purchasing often contains delivery stipulations and terms for payment that can be quite complex and not easily encoded into blockchains.

Despite the significant upside held in blockchains, the path to universal adoption is likely to be littered with both internal and external barriers to overcome. A significant area of the study will be in investigating the challenges blockchain technology faces as it seeks to become pervasive in the very near future (Rao, 2018). While far from comprehensive, Rao's list offers a high-level view of what adoption of the new information systems technology would entail:

- Adopting blockchain as an integral part of the supply chain is a big departure from traditional processes. Much of supply chain industry still dabbles in the 20th century in terms of traceability and verification. The adoption of blockchain technology must first cross the large hurdle of broad change management by engendering trust and buy-in.

- It is said that a chain is no stronger than its weakest link. If a vendor in the supply chain is not judicious about entering accurate information into the blockchain, the supply blockchain is only as strong as that vendor.

- Everyone in the chain must adopt and adapt, otherwise the process breaks down.

- There is an obvious tradeoff in terms of cost. With any burgeoning technology, until it is widespread and commonly used, costs could be prohibitive. In the short term, big corporations may be the only ones that can sustain this technology, with just portions of the supply chain being blockchained.

- As witnessed recently, no technology is 100% secure. There are bound to be security concerns with blockchain technology, and they must be alleviated appropriately.

These areas of concern must be assessed to determine their criticality and translated to how they pertain to the area of procurement.

Research Contributions

This research project will provide a specific contribution the field of procurement by providing a comprehensive resource for those working in areas of procurement to better understand where the leaders in the field of procurement technologies are investing their resources. By delving deep into the origins and inner workings of blockchains uses in cryptocurrencies, the research will correlate previous solutions utilized to overcome the issues faced in implementation in the financial sector to current barriers faced in broad blockchain implementation in supply chains.

Outcome Anticipated

It is expected this research project will serve as an educational resource to those in procurement seeking to understand the potential benefits blockchain technologies hold for their supply chains. This research will also serve to inform procurement professionals of the current barriers in broad implementation of blockchain technologies in procurement while providing risk assessment to each function in the P2P process flow.

Methodology

The primary research analysis utilized for this project will consist of secondary data analysis and previous scholarly works. The project will explore the early history of blockchain technologies and how the technology operates on a fundamental level using proof-of-work concepts to ensure security. It will further project these concepts into the area of procurement and identify potential areas of greatest opportunities and challenges.

The History of Blockchains and the Email Seen Round the World

The earliest notable mention of blockchains can be traced back to anonymous whitepaper written under the nom de plume of Satoshi Nakamoto titled, "Bitcoin: A Peer-To-Peer Electronic Cash System" (Nakamoto, 2008). It was written in the height of the economic downturn in 2008, when traditional currencies were highly volatile and held significantly more risk than at other economically stable times. Nakamoto's whitepaper was distributed as a simple email attachment to a self-described group of Cyberpunks and Cryptologists. The topic of cryptocurrencies was an idea that had been bandied about in that community for some time, but the group had always struggled with issues such as double-spending and security risks. The email attachment sent from the anonymous Nakamoto brought together many of the ideas such as proof-of work, mining, and blockchains all together neatly under the heading of a new alt-currency dubbed Bitcoin. On a fundamental level, Bitcoin uses blockchain technology to transfer the digital currency directly from peer to peer, completely bypassing the need for a financial institution as an intermediary. Since that time, there have been a multitude of other crypto currencies that have popped up, but

Bitcoin, the most famous, will always be inextricably connected with the earliest realization of the blockchain concept.

Defining Blockchains

Before exploring current or future applications for blockchains, the starting point must be in defining what a blockchain is. "A blockchain is essentially a distributed database of records or public ledger of all transactions or digital events that have been executed and shared among participating parties. Each transaction in the public ledger is verified by consensus of a majority of the participants in the system. Once entered, information can never be erased. The blockchain contains a certain and verifiable record of every single transaction ever made" (Crosby, Pattanayak, Verma, & Kalyanaraman 2016). The key to blockchains is that they are completely decentralized. There is no single authority with access and responsibilities to record data points.

The term blockchain has been quibbled with, as some believe it is not an accurate description of the technology, but the over-whelming majority don't seem overly concerned that the moniker by which the technology exists may not suit it to a tee. For the purposes of this paper, the blockchain moniker is apt, as it describes a chain of transactions, each inextricably linked to the one before it. Each transactional link, referred to as a node, connotes a virtual or physical transaction that has taken place. As transactions accrue, the chain grows and becomes further entrenched (more on that later).

The keystone of the blockchain technology lies in the consensus by the participants which is most often referred to as proof-of-work. In order to understand how blockchains are both easily distributed and secure, it is best to walk through how each transaction (or node) is processed.

Because blockchain technology was originally created for, and is currently dominated by financial transactions, the following guidelines will utilize terminology most associated with financial transactions.

The rudimentary process of creating a node can be summarized in six (see figure 1) or seven steps:

1) The initial transaction is set into motion by a user authorizing the transmission of data or cryptocurrency to another user. In the case of cryptocurrency this transaction is initiated through a wallet application which stores the currency.
2) The second step is initiated by the wallet application, which broadcasts the transaction into a temporary holding location where it waits to be picked up by the recipient. These holding locations are most commonly referred to as *pools of unconfirmed transactions*.
3) Minors on the network select transactions from these unconfirmed pools and form them into a block. Every minor constructs their own chain, but multiple minors can include the same transaction as part of their block.
4) To add the transaction block onto an existing chain the minor needs to provide a signature which is generated by a *proof of work.* Proof of work is the solving of a complex algorithmic math equation that requires a significant amount of computation power.
5) When the minor solves the equation, they broadcast the signature and new block to the other minors.
6) The other minors check the work of the first minor by testing the signature as a proof in the equation and if validated, they will accept the addition on the new block to the

chain. At this point the updated chain gets sent out to the other nodes to save on their transaction logs, making the findings consensus widespread knowledge.

7) The final step is the reaffirmation that occurs to an added block every time an additional block is added after it in the chain. This step may seem unessential, but it is what makes blockchains incredibly secure. If at any point a hacker attempts to alter a block in the chain, the other minors will fail to confirm their proof of work and a consensus will not be reached. The more times the block is confirmed the further it becomes embedded and ubiquitous.

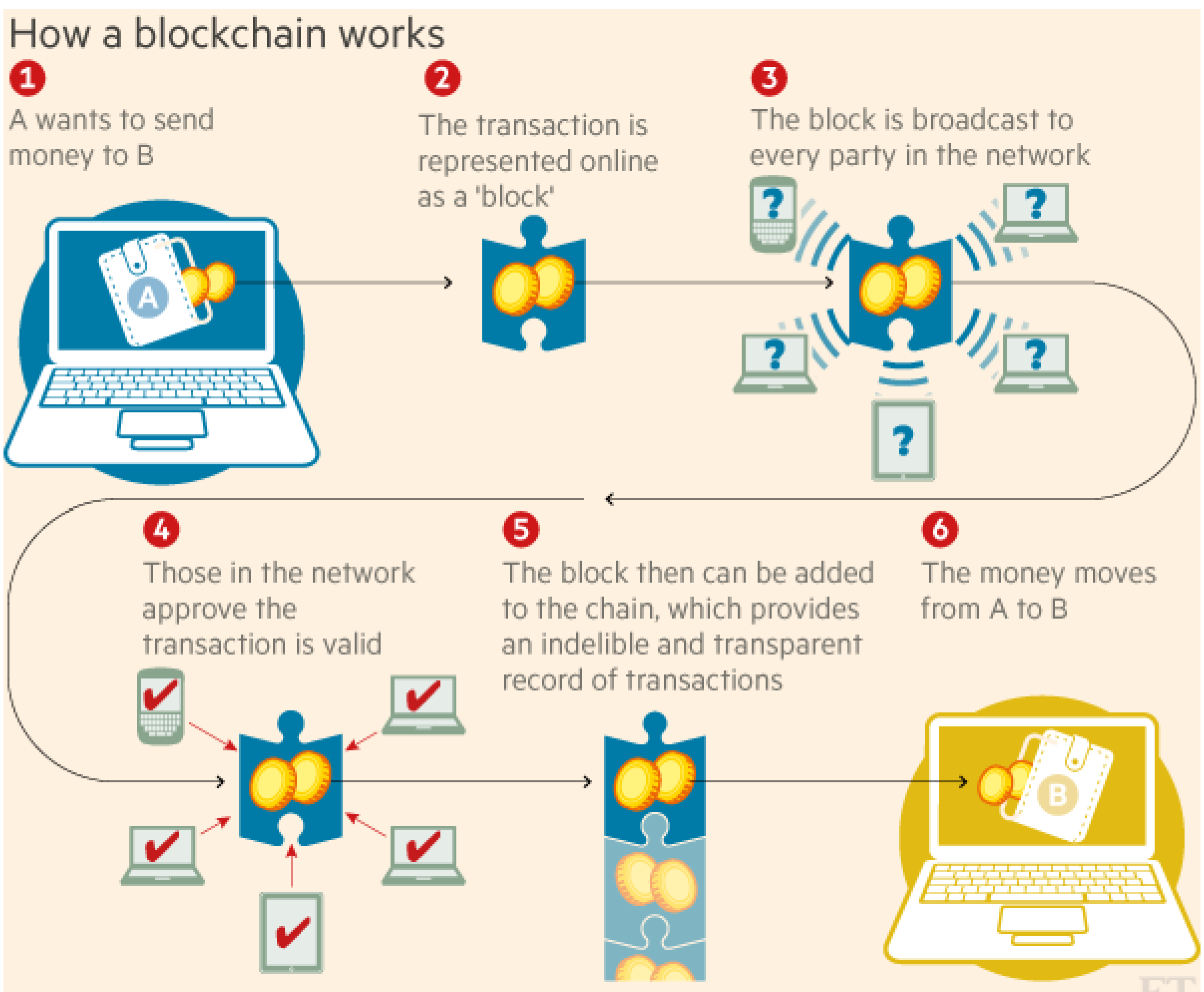

Figure 1. *How a blockchain works. Reprinted from World Economic Forum, by R. Hutt, 2016, Retrieved from https://www.weforum.org/agenda/2016/06/blockchain-explained-simply. Copyright 2019 by the Name of Copyright Holder.*

While there is something beautiful about the security of blockchain coming from a distributed ledger model, it's also easy to see how the necessity for proof-of-work can create some hurdles in creating a responsive and inexpensive platform that can be scaled to accommodate the vast global supply chain networks that exists across the globe.

The Immutable Characteristics

Since the initial launching of Bitcoin, there have been countless other cryptocurrencies startups and other blockchain applications that have found their way to the marketplace, but not all are created equal. There have been many adaptations claiming to be platformed as blockchains but have modified key blockchain elements in their designs which led to the jeopardizing of the application's functionality or security. For that reason, it is important to isolate the immutable characteristics of a blockchain. If even one element is lacking or missing altogether, it would be wise to be skeptical of the authenticity.

There are eight essential characteristics of a true blockchain system (Antonopoulos, 2017):

I. ***Peer-to-Peer*** – Any intermediary between two parties could potentially act a single point of failure. A peer-to-peer information exchange ensures each party enters into the transaction with their intended business partner alone.

II. ***Distributed* –** The distributed nature safeguards against a central authority that can go rogue or be hacked. The fact that each minor holds a live copy of the ledger makes altering the ledger virtually impossible.

III. ***Consensus based* –** Without a central authority to validate transactions and safeguard against potential issues such as double spending, the blockchain creators relied on a consensus mechanism, whereby a majority of nodes validate the transaction before the block can be added to the chain. Without the consensus mechanism there is no sufficient validation process, since there is no bank or other central authority to be relied upon for validation.

IV. ***Crypto logically secure* –** Any legitimate blockchain system must utilize a form of key generation and validation via proof-of-work or other algorithm foundation, that can act as a security protocol to prevent hacking.

V. ***Immutable* –** The distributed nature is really what makes the ledger immutable because each node in the chain gets synchronized when a change occurs. Any system that has the ability to be manipulated and does not subsequently synchronize to show a change has occurred, is not a viable system.

VI. ***Global* –** The nature of blockchains is that they can be accessed from anywhere. Any constraint on location accessibility not only limits the functionality, but also compromises its security.

VII. ***Semi-anonymous* –** For currency transactions the concept of pseudo-anonymity was that each user could remain anonymous, so they are not announcing to world that they just stopped at the ATM. However, full anonymity could not be an option for regulatory purposes. For the purposes of supply chain semi-anonymity is crucial in protecting sensitive business information.

VIII. ***Decentralized -*** The concept of decentralization is really an overarching characteristic that encompasses many of the others. Decentralization acts as a barrier to single point failure, hacking, and allows it to be consensus based. Decentralization is at the very core of blockchain technology and should a platform attempt to utilize blockchains but centralize the data or access points, it ceases to be a viably secure platform.

All eight essentials are key to the accessibility and security of the system. If any blockchain is lacking in any of these elements, there is a need to be suspicious. As many of the largest software companies invest further in blockchain technology, it behooves customers to be mindful of the eight immutable characteristics to ensure security. It would be natural for these large developers to incorporate elements of centrality to their products to ensure continued reliance on their support, but any compromise in any of these areas compromises the delicate eco-systems that allows for undisputable transactional history and ultimate transparency.

Other Blockchain Applications

Deloitte recently reported that the number of blockchain related projects on Github, the largest online platform for the software development community, is now up to 26,000 (Short, 2018). While blockchains have already found a place in the financial world as a way to bypass third-party financial institutions, the utilization to date has seemingly just scratched the surface as companies such as Ripio and other bitcoin wallet applications begin to imagine the seemingly endless applications for peer-to-peer monetary transactions in the new world of crypto currencies. Blockchains have gained a significant level of trust among the largest financial institutions and are even being touted by some as the most tested and secure finance related platform tested to-date (Scott, 2019). However, even with the significant inroads and steep growth trajectory made in the financial sector, characterizing blockchain's market penetration as anything above minimal would be an overstatement (see Figure 2).

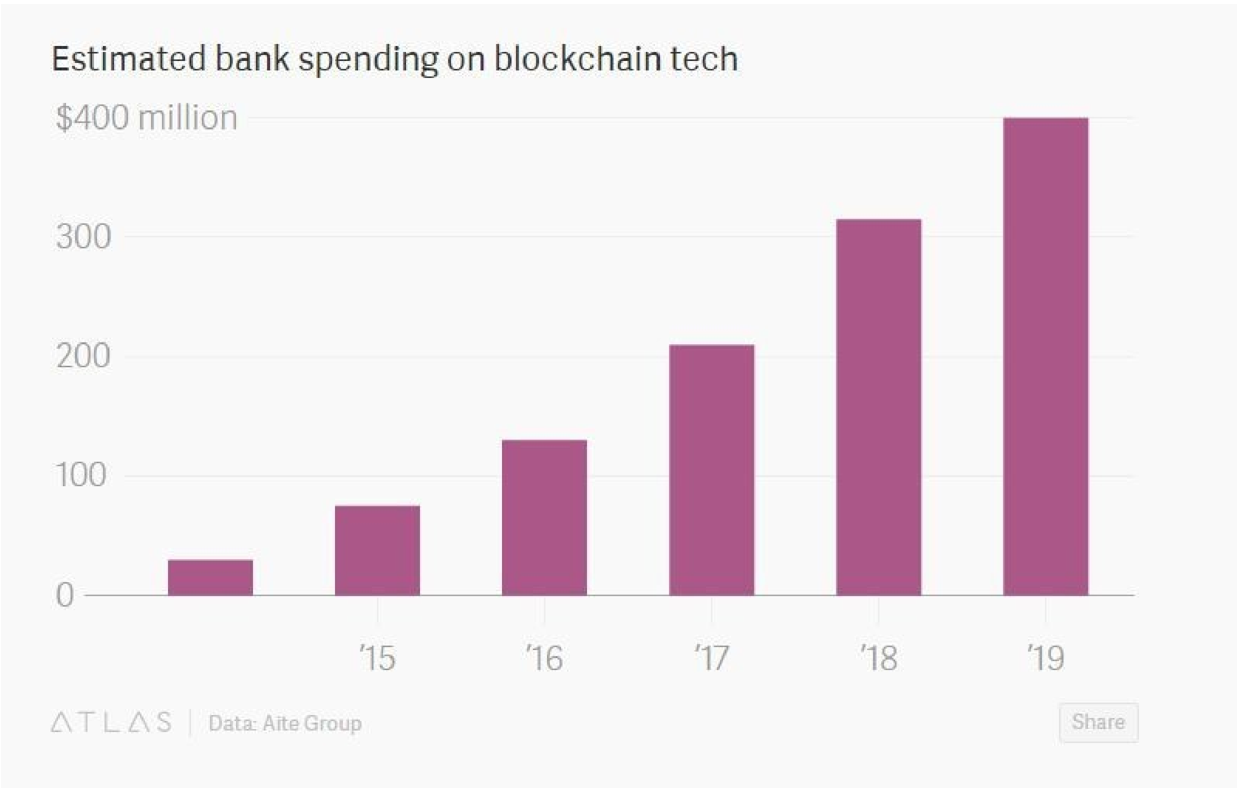

Figure 2. *How a blockchain works. Reprinted from World Economic Forum, by R. Hutt, 2016, Retrieved from https://www.weforum.org/agenda/2016/06/blockchain-explained-simply. Copyright 2019 by the Name of Copyright Holder.*

Meanwhile, the number of potential non-financial applications appears to be endless. The legal community is playing with the idea of applying the proof-of-existence concept to all their legal documents. Healthcare systems are investigating the usage of blockchain for storing and transmitting health records instead of a local data-base system. Even the music industry is working to apply blockchain technology to its complex royalty payment structures. In the ever-increasing digital world, where peer-to-peer interactions and transactions occur at a greater rate than ever before, blockchains have the potential capabilities to serve as the primary conveyance of both information and currency.

Challenges in Universal Adaptation

While it is true that supply chain appears to be fertile land for blockchain growth, with some even prognosticating its reshaping of the entire field, it is also true that blockchain faces some significant challenges to overcome before it can be considered for universal widespread growth (Chang, Lakovou, and Shi 2019).

One of the most significant challenges in universal adoption of blockchain technology in supply chain platforms is the lack of knowledge and trust that exists in the broad public. The inherent complex and abstract nature of the technology makes it difficult to explain, which often results in the audience clinging to a certain level of mistrust. Therefore, supply chain platforms seeking to incorporate blockchain technology are faced with an uphill climb in selling their products to general consumers. While it’s true that the mistrust is expected to fade over time as the prevalence of blockchain technology makes headway into various industries, the task of the promoters will be to expedite that process.

In addition to overcoming natural public skepticism, proponents of blockchain are faced with several further challenges cited by Chang, Lakovou, and Shi in their article, *Blockchain in Global Supply Chains and Cross Border Trade: A Critical Synthesis of the State-of-the-Art, Challenges and Opportunities*:

1) ***Scalability***

Currently, the two largest peer-to-peer blockchains are Bitcoin and Ethereum. Both platforms are estimated to process between just three to thirty transactions per second. As detailed above, each transaction requires a tremendous amount of computation power and interactions between several nodes to confirm and add the block to the chain. As a frame of reference, Visa's platform is tasked with processing a whopping average of 60,000 transactions per second (Guigato, 2017). Since blockchain has a decentralized architecture, platform creators will need to find a way to increase the speed of the transactions exponentially before the technology can become the global force which many are predicting.

2) Interoperability

Interoperability is the ability to transact across multiple blockchain platforms. It would be the equivalent of someone sending

Bitcoin currency and the receiver receiving Ethereum without the necessity of a third-party exchange. This requirement becomes far more imperative in supply chain applications when each supply chain participant has a multitude of business partners both upstream and downstream which must be able to be transacted with seamlessly. It would be ludicrous to think that there will be but a single global platform in which all users would agree to use, and just as absurd to construct a system in which business partners can only interact with others that utilize the same network.

One of the significant challenges in creating interoperability stems from the problem most often referred to as the fork in the road problem. In the desire to transact with another system, the originating system disassociates the most recent chain and “directs it” to the recipient’s system. At that point the chain becomes orphaned from its origin and loses its validity in the eyes of the recipient’s system.

To this point there hasn’t been a recognized solution created to the interoperability problem, but there are many proposed solutions which are expected to be available in the near horizon. Most of these solutions are bridge concepts which act as both facilitators that allow for communication between both systems and validators that seek to solve the fork in the road problem by validating the orphaned message to make it trusted by the recipient’s system.

3) Standardization

In order to achieve a solution for interoperability that would be both universal and sustainable as the technology evolves, a level of standardization must occur. There must be a common basis on which each blockchain platform must be built. Current blockchain users in the global logistics industry have emphasized this very point. They have stated emphatically that the future success of the shipping industry hinges upon the standardization of blockchain (Tirschwell, 2018). To achieve this goal, there are several ongoing international efforts by leaders in the global standardization industry such as the International Organization for Standardization (ISO) and the global business communications standards organization (GS1) to establish a baseline standard.

4) Binding the Physical and Digital for Complete Trust

Binding the physical and digital may sound esoteric but is quite simple; each digitally recorded transaction must reflect what occurs physically. In many ways that concept is just as true regarding the current standard enterprise resource planning platforms (ERP’s), but even more so in blockchain applications. The current enterprise resource planning systems store data in a central database that can be corrected if needed. Therefore, if a manufacturing location was to send 1,000 widgets to the company’s distribution center, but only shipped 997 and neglected to update the shipment information, it is likely that issue can be corrected simply by an adjustment made in the system by the receiving distribution center, since both operate on the same system. Blockchains are decentralized and therefore the distribution center would have no ability to correct for the error. Therefore, while always the goal, the imperative for binding the physical to the digital is far greater in a blockchain application.

To aid in this endeavor, there have been several advances in key technologies that would automate digital triggers as physical events occur. Some of the noteworthy technologies include near field communication (NFC) chips, radio-frequency identification (RFID) proliferation, and possibly the most noteworthy, sensors. The same sensors used in our smart phones that sense when we switch from walking to driving are becoming increasingly cost effective to insert in shipments. Many believe sensors will soon be cost effective enough to be embedded on componentry so that inventory can simply be tracked via sensor data. To take that idea a step further, tying sensor data directly into a blockchain platform would enable a financial transaction to be initiated based on sensor data from a shop floor. An example to illustrate this idea would be if a component would fall on the floor during assembly. The embedded sensor could immediately send a message to the platform to adjust the inventory by one and also trigger an order for the replacement part. This is just a single example of how ancillary technologies are expected to work in parallel with blockchain platforms to bind the digital world to the physical world in real time.

5) Legal and Regulatory Challenges

Since a blockchain is decentralized by nature with nodes created by various business entities spread across the globe, there is difficulty in tethering the blockchain to a specific county's legal structure. The amorphous nature leads to ambiguities in jurisdictions, ownership, and accountability. The potential lack of accountability is a very large concern for potential early adopters of the technology. In addition to the concerns over accountability, there are concerns over data privacy. While blockchains are widely believed to be secure, they are also public networks which have the potential of holding sensitive data which can be transferred or accessed anywhere.

There is no coincidence that the early adoption in supply chain has primarily taken place in quality control and logistics applications. Those two functions are areas in which there is a high importance on speed and visibility, but the data tends to be non-proprietary and not associated with the highly sensitive topic of pricing.

Despite these challenges being significant to the widespread adoption in the near-term, Chang, Lakovou, and Shi remain optimistic these hurdles will be overcome in a fairly short period of time. In their optimism, they quote an article (CNBC, 2018) projecting the growth in adoption occurring between 5-10 years from when the article was written:

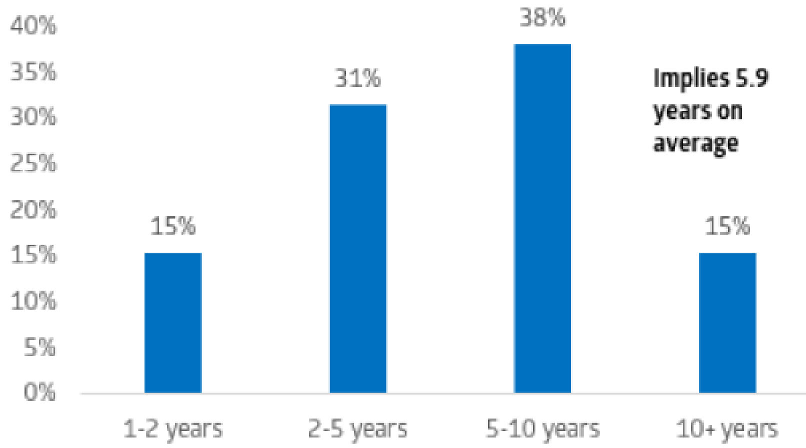

Figure 3: *Expected years for widespread adoption of blockchain (CNBC 2018)*

The purpose of the article was to state the case that for all the hype, widespread adoption of blockchain in supply chains is still a long way away. But in light of the challenges stated, to have an outlook that each of the barriers will be removed or overcome to the point of no longer hampering widespread adoption seems to be making the opposite case. If in fact the potential impact to supply chains cannot be overstated, then we are already on the precipice of blockchains forever changing the capabilities of global supply chains.

Smart Contracts

From the previous explanation of the creation and building of blockchains, it easy to see how they can easily be incorporated into the more linear transactional process flows within a supply chain. The examples used earlier, such as logistics and quality assurance through traceability are such process flows. Each of the flows are essentially a series of processes that are documented in a ledger, which takes a passive role by simply recording events and transactions as they occur. If that was the extent of the functionality of blockchain in supply chain, there would certainly be advantages in cost effective security and widespread access to information, but it would be quite limited for functions in the supply chain such as procurement. For blockchains to take the next step in their development from a simple distributed ledger to having the ability to execute transactions based on events recorded in the chain they require the addition of smart contracts.

The concept of smart contracts pre-date the earliest concepts of blockchain, with the seminal paper written by Nick Szabo in 1997. Szabo's characterization of smart contracts is that they "combine protocols with user interfaces to formalize and secure relationships over computer networks. Objectives and principles for the design of these systems are derived from legal principles, economic theory, and theories of reliable and secure protocols (Szabo, 1997)". While there are many other definitions of what a smart contract is, a simple one is, "smart contracts are systems which automatically move digital assets according to arbitrary pre-specified rules" (Buterin, 2015). Simply put, these smart contracts are nodes placed within or on top of the blockchain that are programed to execute a transaction in the event certain stipulations have been met. The literature on smart contracts takes on an interesting contrast between the technical writers' concern with smart contract functionally, and the legal writers' concern for the contracts legal standing, and in extrapolating their technical capabilities to the deep and murky waters of contract law. While many technical writers seek to disassociate smart contracts from traditional contract law in attempt to shy away from the controversial topic, Szabo's initial definition clearly stating the derivation from legal principles has only added fuel to the fire by implying that smart contracts are self-governing and operate above governmental jurisdiction. Adding to the complexity is the aforementioned issue with jurisdiction on blockchains more broadly, when there is no single entity in control or possession of the blockchain.

The article, Smart contracts: terminology, technical limitations and real-world complexity (Mik, 2017) attempts to deal with these very issues by eliminating as much ambiguity as possible. In order to accomplish the goal, Mik's first task is to clarify definitions, and secondly is to apply constraints to what is legally and technically possible. The first task is fairly straightforward, but the second task requires knowledge of not only existing contract law and smart contract technology, but also requires a great understanding of how each can be stretched to their limits.

In determining the technical requirements of smart contracts in blockchains, Mik has some interesting critiques. Most noteworthy is her skepticism that smart contracts are the correct strategic fit for blockchain technology. After all, the bedrock of blockchain is its ability to be secure by being trustless, and only allowing modifications based on distributed consensus. According to Mik, the very beauty of blockchain is its simplicity and lack of intermediating logic. The addition of a node with complex logic which is programmed by an outside source and interjected directly into the blockchain undermines a significant positive trait of the technology and undermines the strength of its transparency. The equivalent would be an excel spreadsheet with only values, in which each party cannot modify, but can only add values in a newly inserted row. The addition of smart contracts would be equivalent to interspersing calculated fields agreed to by just two parties and recorded by just one, with extremely complex functions into the spreadsheet. The calculated fields are without a doubt an added feature that simple value fields cannot match, but the feature undermines the integrity of the spreadsheet as an easily transparent data source.

Mik goes on to draw a clear distinction between smart contracts and contracts in a legal sense. Smart contracts operate as any other node in a blockchain in that they are validated via the mining process through distributed consensus. In a blockchain context, the contract becomes validated, but the mining and proof of work concepts do not transfer to common law which has a far wider scope to prove contract validation. An example of such a disparity in scopes would be the inclusion of the mental state of the parties of interest in common law, while there is no way for the smart contract to make such a distinction. Common law also takes into consideration if a party was under duress in agreeing to terms and mental competencies of the parties involved. Smart contracts are narrower in scope as they seek only to determine if the agreed upon parameters have in fact been met. Another fundamental distinction between contract validation in common law and smart contracts refers back to Chang, Lakovou, and Shi's fourth stated challenge; the binding of the digital and physical worlds. Smart contracts exist in a digital space and their scope extends only to the transactional history recorded in that sphere, while common law is tailored around the physical sphere. These distinctions are not barriers to the utilization of smart contracts, but instead state the case for why smart contracts must be governed within the constraints of common laws and cannot be seen as having equal footing in a legal context.

Mik proceeds to delve further into another significant feature of the smart contract, their self-enforcement. Traditional contracts are generally executed by the involved parties and are therefore subject to the cooperation of the parties involved. In the event a party becomes disgruntled and becomes non-compliant, an intermediary or court must be brought in to mediate. Smart contracts on the other hand are programs not susceptible to human emotion. The program will follow the terms of the agreement to a tee. The self-enforcement feature necessitates the crucial requirement that smart contracts must be completely tamper-proof. In order for a smart contract to be tamper proof, no party can have access to the contract. The smart contracts must essentially be locked from the inside with no one home and no key to get in the house. This creates three concerns for Mik

1. If there can be no access, then the code must be immaculate at the time of agreement. If there are any errors in the writing of the code they cannot be corrected. Therefore, while self-enforcement offers perfect performance in theory, it must be accompanied by flawless coding.
2. Once again, if the code cannot be modified, the terms of the deal must be recorded in an exacting manner which convey both parties' intent perfectly. This becomes more challenging in smart contracts because the process of programming a fairly complex program would in all likelihood fall on a third party coding the inputs given to them by the legal teams of both interested parties. Any miscommunication recorded in the smart contract is irreversible for the life of the contract.
3. Finally, if the tamper-proof requirement mandates a total lack of editing access by any party, each and all eventualities must be accounted for at the time of the agreement. Therefore, smart contracts are likely to be better suited for simplified agreements with terms to be satisfied in the near-term, versus complex terms to be satisfied over a longer period in which several unforeseen variables are likely to arise.

Mik raises a number of interesting concerns regarding the use of smart contracts, but each challenge is more likely to limit the speed and scope of widespread adoption instead of preventing their use at all. For procurement to be integrated into the future supply chain model built on blockchain technology, smart contracts must play a pivotal role in extending the capabilities of blockchain beyond a simple distributed ledger to an active platform able to follow complex process flows with alternate paths.

Blockchain's Future in Procurement

Each function within a supply chain presents different arrays of opportunities and challenges for blockchains, but possibly none more-so than procurement. The entirety of the procurement function encompasses not only the end-to-end purchasing cycle that can be easily tracked on process map, but also incorporates many of the softer, less-tangible sciences such as negotiation and even some elements included in supplier selection. For the purposes of this paper, the area of focus will be confined to the processes which make up the procure-to-pay (P2P) flow where the potential impact of blockchains can be more easily extrapolated to project opportunities for advancements.

P2P simply put, is the step-by-step process flow of how a company purchases the materials needed for their business. The process flow begins as early as a request for proposal to potential suppliers and ends with the financial department releasing payment for the goods or services provided. P2P software platforms are designed to streamline the process by automating as much of the process as possible by maximizing accuracy and buying power. Currently, P2P system developers are facing challenges in further generating significant sustainable cost reductions through disintermediation, efficiency improvement, fraud control, and transparency enhancement (Accenture, 2016). Blockchain technology has the ability to provide enhancements in each of those areas as well as provide additional operational benefits in increased speed, reduced security costs, and decreased workload, by facilitating the transfer of information ("How blockchain can bring Greater Value", 2016). Blockchains hold the potential to affect virtually every area of the P2P process flow, but in differing degrees:

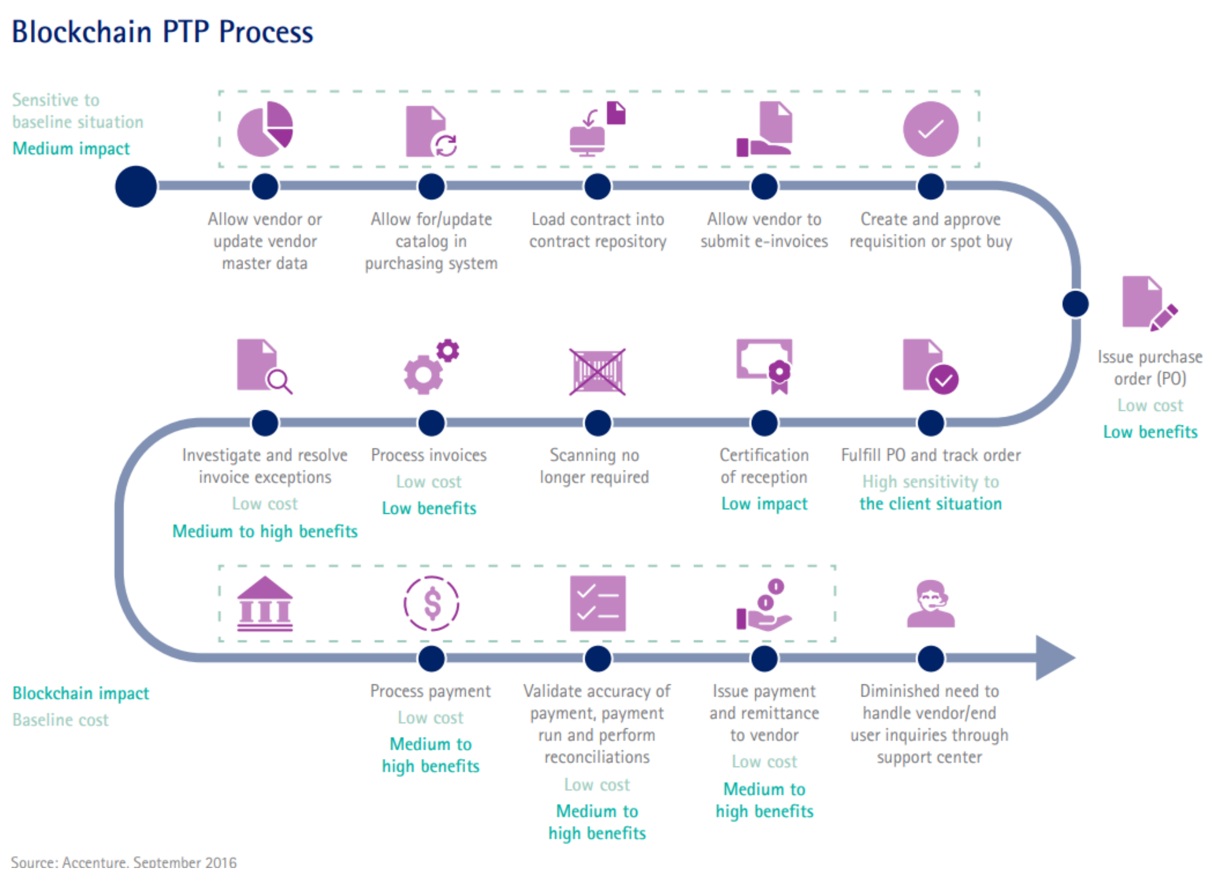

Figure 4: *How Blockchain can bring Greater Value to Procure-to-Pay Processes (Accenture, 2018)*

Blockchain's distributed nature allows for disintermediation to be achieved at most phases within the P2P process, but sees its largest impact in areas requiring both greater transparency and security concurrently. As organizations progress further in their willingness to incorporate blockchain technology in their P2P processes, they will need to understand which areas hold the greatest opportunities for capitalization of the benefits and which may be most affected by the challenges yet to be overcome.

Areas of Greatest Benefit	
Front-end System	A new front-end system can be easily configured to authorize new vendors, place new purchase orders or even sign new contracts.
Validation and Authentication	A blockchain would support swift distribution of authentication rights along the P2P chain, thereby helping to prevent fraud and improve security across the PP process.
Purchase Order Management	Purchase order and good receipt data would be exchanged on the blockchain at an accelerated pace when compared to current performance levels. As well, the blockchain could help identify the nearest and most cost-effective vendor within the network.
Invoice Processing	Invoice scanning would no longer be required thanks to shared access to the database, with the exchange of invoices supported by the blockchain.
Settlements	This would also help render the reconciliation process far less cumbersome as all authorized parties could review the same transaction, eliminating the need for reconciliations.
Enquiry Management	Blockchains greater transparency would diminish the need for enquiries and process status follow-ups, thus streamlining current enquiry management.
Additional Benefits	• Reduced fraudulent risks
	• Greater trust between shareholders due to increased transparency
	• Strong audit trail

	• Greater transactional security

In each area likely to benefit most from blockchain adoption, there are challenges to overcome. Chang, Lakovou, and Shi's concerns raised would likely impact adoption at each stage. The promise of vendors having the ability to enter master-data inputs directly into a shared front-end system seems like a great opportunity for eliminating double entry and excess communication between a supplier and customer. Yet, until there is a solution to the issue of standardization, there is a strong likelihood of suppliers being asked to utilize a plethora of platforms to input the data, which can create more work and cost than it would save. The same logic would certainly hold true for the issue of interoperability. If the ultimate goal is to optimize the supply chain's efficiency by furthering the trend of eliminating boundaries between supply chain partners, there must be a way for companies to utilize separate platforms to communicate. After all, what good is access to a shared database of invoices if they can only be opened by business partners utilizing the same blockchain platform?

In addition, many of the benefits gained by increased transparency would be mitigated if there is anything but complete trust that the digital chain of events parallels the physical chain of events without the opportunity for deviation. The distinct advantage blockchain offers to enquiry management is that the events are both completely transparent and undisputable. Once there is even a modicum of doubt whether there is a mismatch in the digital and physical records, there ceases to be an advantage being offered by blockchains.

Each of these concerns raised by Chang, Lakovou, and Shi weaken the foundational support upon which smart contracts must be built. The introduction of smart contracts to the P2P flow (figure 4), would exponentially increase the potential of disintermediation by automating many processes entirely. But smart contracts are built entirely on the basis of complete transparency and undisputable records verifying if the terms in the contract have in fact been met. If there is a lack of interoperability, there can certainly be no smart contracts, as a transactional record is sure to be incomplete. Without a fix for the interoperability issue, a smart contract wouldn't have the visibility to connect the dots between a shipper shipping the product on one system, and the customer entering the receipt in another. The result would be the inability of a smart contract to verify if in fact the contract terms have in fact been met. The same concern would certainly hold true if a discrepancy could exist between the digital and physical records, but the problem would be exacerbated if there is a discrepancy that would result in the triggering of invoicing and payment by the smart contract. Blockchain's largely touted asset to enquiry management would be turned into a liability as both parties would seek to understand which chain of events paralleled reality. Additionally, any discrepancy between the physical and digital would be impacted by the necessary limitation of smart contracts to be modified simply. Even if a discrepancy is found before a payment is released, editing the chain in advance of a known mistaken release of payment could prove impossible.

Of the five concerns cited by Chang, Lakovou, and Shi, one is examined thoroughly by Mik before concluding that the perceived problem may be perception alone. Mik's conclusion is that the legal and regulatory challenges facing blockchain are nothing more than a mirage. Mik's contention is that while much of the literature published by the initial blockchain developing community theorized that blockchains would operate above or outside current legal framework, that is simply not the case. Mik's belief is that the current structure governing global e-commerce would apply to blockchains with little modification, and that each transaction or node is not taking place in a virtual space but is nothing more than a way of coding a transaction between two parties very much existing in the physical realm.

Additionally, the scalability concern is slowly becoming diminished as the technology has matured. As expected, computer chip manufacturers continue to improve on their product offerings, and in just the span of a couple years have already made drastic gains on maximizing computing power to reduce the time it takes for the proof of work equations to be solved and verified. Another factor diminishing the scalability concern has come from the innovative marketplace. Server farms have recognized the increased demand for computing power and have seized the opportunity by monetizing excess computing power by renting out the bandwidth to miners during non-peak times of day (Dickson, 2018). These quid-pro-quo agreements have pooled together global resources to maximize the potential computing power available to blockchain networks. To what degree these factors have diminished the scalability issue has yet to be fully determined, but the trajectory is clearly headed in the right direction, and the progression will no doubt be furthered as the technology continues to mature. However, even with the gains made in solving the scalability issue, many prominent members in the blockchain community believe the problem is one that will always exist and cannot be solved in its entirety (Deka, 2019).

If the large software developers and the blockchain community can come together to solve two of the remaining issues of interoperability and standardization it would open up the opportunity for P2P software developers to encourage widespread adoption by promising greater efficiency by vastly reducing the required communication between supply chain partners.

The increases in transparency and informational speed may alone be a sufficient selling point for supply chains, but in order to optimize the value of what blockchain has to offer, the issue of binding the digital and physical chain of events must be solved to a degree that would allow for no potential discrepancies to exist. While solving each concern to an absolute degree seems like a daunting task, the development of many supporting technologies and developing marketplaces have made the solutions seem more like a pending inevitability than long-term question. An example cited earlier is the reduced cost and proliferation of sensor utilization. The increased reliance on sensors will both aid in the efforts of disintermediation and help bind the physical and digital chain of events. Similarly, the advancements in RFID will no doubt bolster the same efforts and will greatly impact the company's ability to track the location of goods without manual entry.

Conclusion

As blockchain and complimentary technologies continue to develop, the foundational infrastructure upon which the technology is built will become increasingly sturdier and more well-developed. At some point the cost and risk threshold for companies to test the technology will be low enough that they will no longer be able to refuse the possibility of a secure cost-effective information system that will offer superior transparency. The strongest likelihood is that companies will continue to adopt blockchain technology in their supply chains but will be slow to entrust the technology for their P2P information system. Even with the extensive background of blockchain in the financial sector, the reluctance to adopt the technology in the high leverage P2P process flow is understandable until it can be proven trustworthy on a large scale. Only once the technology has proven its security and reliability in seamlessly sharing information with business partners is it expected to be adopted in widespread fashion for P2P information systems.

Similarly, if or when widespread blockchain adoption occurs in P2P information systems, it would be expected that smart contracts would be utilized in extremely limited fashion at the onset. Early uses of smart contracts would likely be structured around simplistic contract terms with a high likelihood of fulfilment. For smart contracts to be extended to uses with more complex conditions it would likely require the development of third-party infrastructure, whereby the smart contracts would be programmed and monitored. The third-party structure would also provide the potential for intermediation should an edit be required, or a dispute should arise.

In just a few years, fully integrated blockchain networks with smart contracts executing complex conditions may be the norm, or supply chain managers may still be searching for an elusive technology with the capability of offering cost-effective security and transparency. While it may still be too early to say for certain, like most things in life, the truth of what will be is more than likely somewhere in the middle. Progress in the field of P2P information systems is likely to lag after other lower leverage process flows within the supply chain. However, when a solution is found that revolutionizes the function in the way many envision of blockchains, the notion of business partners being mere extensions of each other's organizations with seamless information sharing will finally become a reality.

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