# The Opportunities and Challenges of Blockchain Adoption In Supply Chain Management

by

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**Abstract**

Blockchain and its related technologies start to present the business values recently. The purpose of this study is to analyze blockchain adoption within the field of supply chain management by looking at companies that have already put blockchain technology into practice. Before looking at blockchain applications, a basic understanding of blockchain technology is provided. Blockchain was first introduced to the public in 2008 by Satoshi Nakamoto, whose identity is kept secret, released the whitepaper "Bitcoin: A Peer to Peer Electronic Cash System." Since then, fascination and doubt have grown exponentially will Blockchain technology, and with cryptocurrencies in general. Blockchain is the foundation technology of cryptocurrencies. It is a shared ledger that cannot be altered and facilitates the process of transactions and tracking assets in a business network. Since blockchain technology is relatively new, there is much to be looked at with thinking about its impacts, good or bad, on the field of supply chain management. This research investigates the challenges that companies will face and potential opportunities when adopting blockchain adoption. A case study approach was utilized in this study. Overall, the research question is ***What are the opportunities and challenges of blockchain adoption in Supply Chain Management***? This research conducts a case study of blockchain adoption within real companies. Different effects of blockchain on various aspects of supply chain management, such as quality, efficiency, traceability, are discussed and analyzed.

## I. Introduction

Blockchain was first introduced to the public in 2008 after Satoshi Nakamoto, whose true identity remains secret, released the whitepaper "Bitcoin: A Peer to Peer Electronic Cash System" (Marr, 2018). Nakamoto's whitepaper describes bitcoin as a "purely peer-to-peer version of electronic cash." The original purpose of bitcoin was to address the problem of double-spending, which is often a problem faced by digital artifacts. Digital tokens are known to be easily copied and spent multiple times, which is fraudulent. Copying digital tokens and spending them multiple times can cause inflation by creating large amounts of money that were not previously there.

Since blockchain is the technology that supports bitcoin, it caused major interest in blockchain technology to gain traction all around the world. Fascination since the whitepaper has grown exponentially for both blockchain technology and cryptocurrencies in general. Today, companies all around the globe are exploring ways to incorporate the technology into pre-existing business activities to meet new performance goals. Starting with the fundamentals, blockchain is a shared digital ledger that cannot be altered and facilitates the process of business transactions and tracking assets in a business network. These assets can be tangible or intangible. Examples of tangible items include cash, products a company sells, equipment, vehicles, and more. Intangible items are items such as intellectual property, patents, and branding. Blockchain can essentially track anything of interest to an organization, which makes it highly versatile in a broad range of industries.

To fully understand blockchain, it is crucial to first understand distributed systems. Blockchain, at its core, is a distributed system, which is defined as a "computing paradigm whereby two or more nodes work with each other in a coordinated fashion to achieve a

common outcome" (Bashir, 2017). It is modeled in a way that allows for end-users to see it as a single logical platform. To put into simpler terms, a distributed system is essentially a group of computers working together to appear as a single computer to the end-user (Kozlovski, 2018). The machines within a distributed system have a shared state but can fail independently without causing a huge problem, this makes them incredibly secure.

Blockchain, unlike a normal financial ledger, allows for parties to transact without the use of a central authority to validate the transactions (Jaikaran, 2018). Typically, the central authority is a third party such as a bank or another financial institution. Transactions within blockchain are not limited to financial ones. It may also include tracking items, identity logging, verifying complete actions, or any other activities not mentioned. In blockchain technologies there is no need of a third party because as the transactions are added, the identities of the parties conducting the transactions are verified, and the transactions are verified before putting them into the ledger as a block. Since each block of transactions is dependent upon the previous block, any change made will alert all users of change to the history of transactions, making it incredibly secure for all parties. Also, relationships between identities, transactions, and the ledger allow for parties to have a higher degree of confidence in the state of transactions (Jaikaran, 2018).

There are three main types of blockchain: public, private, and consortium blockchain. Each of the following technologies differ in terms of its accessibility, managing permissions, as well as operating characteristics (Asma Khatoon, 2019). This means that there are different scenarios in which one type would be more beneficial to use than another. For example, in a public blockchain each participant can access the database, store a copy of the transaction, and modify the transaction. One example of a public blockchain is bitcoin.

Within bitcoin incentives are provided to gain more users. Public blockchains are supported by cryptographic verification, which provides incentives to users. These users are called miners. Anyone in a public blockchain can be a miner. All users must follow an algorithm to verify the transactions. One of the main drawbacks of a public blockchain is the substantial amount of computational power that is required to maintain a distributed ledger of that scale. Another disadvantage of a public blockchain is that there is little to no privacy for transactions and the technology only supports a weak notion of security (Jayachandran, 2017).

In a private blockchain, authority is kept centralized to either one organization or one individual. Write permissions are given to one organization while read permissions may be public or restricted to some extent. This provides a greater notion of security. Applications of private blockchains can include database management, internal auditing, or provide financial solutions. This type of blockchain technology is the most beneficial for a company, given that it is private and provides greater security. Hyperledger Fabric is an example of private blockchain technology, as well as Gem Health Network. Hyperledger Fabric is an open-source community focused on developing a suite of frameworks for other companies. Gem Health Network is focused on providing a network to track patient information as well as other logistical components within the healthcare industry. The company is trying to create global standards for integrating blockchain technology into the industry.

The final type of blockchain technology is consortium blockchain, which is a mixture of both public and private blockchains. Consortium blockchain can be perceived as only partially decentralized. This means that data or transaction details can be open source or private and the node has the authority to choose which one will advance (Archana Prashanth

Joshi, 2018). One of the main advantages of consortium blockchains is that it gives authority to a predetermined set of people instead of being open to the entire public or to an entire company. Typically, a council is the group of people that would validate blocks in the blockchain instead of individuals. This creates the best security sense of a group of people will be held accountable.

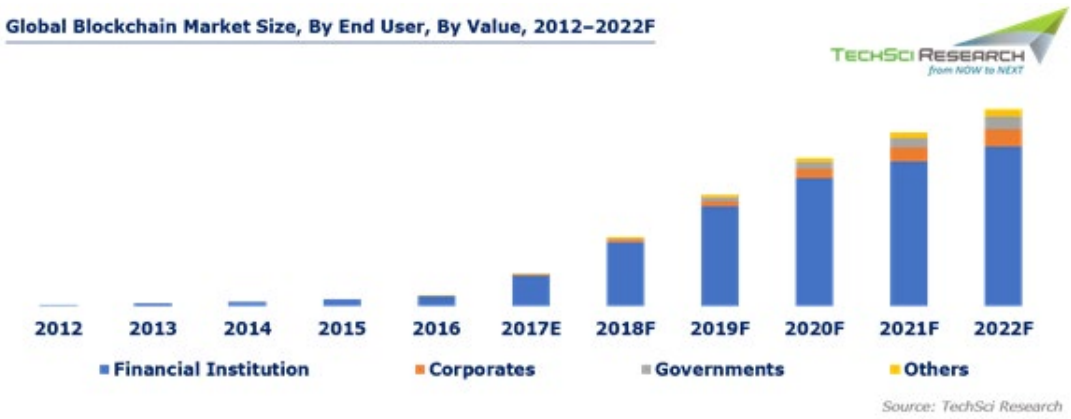
Since each type of blockchain is different, companies looking to pursue blockchain technology should be knowledgeable of the pros and cons of each type before creating its own. For example, private blockchains are more beneficial for supply chains. Private blockchains add additional security that both consortium and public blockchains do not provide. Within a private blockchain, sensitive information will be kept from the public, such as contracts, tracking information, trade secrets, or even information regarding the company's employees. Also, within a private blockchain, access can be limited to a small group of people, such as council members for the company or even important stakeholders. Public blockchains are more beneficial for companies looking to provide blockchain access to a wide range of customers, such as cryptocurrencies. Consortium blockchain, on the other hand, is associated with enterprise use since it is a group of predefined nodes on a network. Some examples of consortium blockchains include Quorum, Hyperledger, and Corda.

## II. Global Market of Blockchain Technology

Blockchain technology is one of the most promising upcoming and technological trends in the information technology domain (Grand View Research, 2019). The global blockchain technology market was valued at USD 1,590.9 million in 2018. It is expected to grow at a compounded annual growth rate of 69.4% from 2019 to 2025,

according to a new study conducted by Grand View Research, Inc. See figure 1 on the next page.

Currently, the annual value of fraud and cyber-attacks within the Banking, Financial Services, and Insurance (BFSI) sector is estimated to be thousands of millions of dollars. This has become a challenge for companies globally. As a way to overcome this problem, companies like Microsoft Azure and Deloitte are focusing on offering blockchain-as-a-service. Improved penetration in deploying "Proof of Concept" solutions by leading providers of blockchain technology and the rising need for faster and transparent transactions across various industries is expected to propel the expansion of the market during 2018-2025.




(Figure 1. TechSci Research) https://www.techsciresearch.com/report/global-blockchain-market/1462.html

As applications of technology in business processes are growing, the need for solutions such as blockchain technology is expected to disrupt current activities. One of the main drivers of blockchain adoption is the growing adoption of distributed ledgers among banking and financial institutions (MartketWatch, 2019). This is one of the major portions of blockchain technology. Another driver within the market today is the rising capitalization of

cryptocurrencies. As mentioned before, Bitcoin and Ethereum are prime examples of cryptocurrencies. The growing need for technological solutions is also a driver within the market for blockchain technology, especially in bigger companies that have a lot of resources to focus on. Another driver for the adoption of blockchain technology is the increasing venture capital investment in Blockchain and ICO's. ICO's is the funding of cryptocurrencies.

Researchers have found that more and more companies believe that blockchain technology will be very important within the next 24 months (Deloitte Insights, 2019). In a study done by Deloit, 53% of respondents believe that the technology will be critical, within the top 5 strategic priorities for them. Also, more respondents now than in 2018 believe that blockchain technology is broadly scalable and can be utilized in many different industries. Blockchains maturation is expected to continue as overall investment in the technology increases. This supports the notion that in the long term blockchain technology has much potential. Taking a closer look at companies putting into place blockchain technologies we can see the positive impact it has a on supply chains.

**Walmart Case Study:**

Walmart is one of many industry leaders that is putting into place blockchain technology initiatives. For example, Walmart Canada has launched the "world's largest full production blockchain solution for any industrial application" (Retail Info Systems, 2019). This initiative is a partnership between both Walmart and DLT Labs, which is a company solely focused on developing blockchain solutions for enterprises. The new system uses the distributed ledger technology to track deliveries, verify payments, and automate payments. It also tracks reconciliation between Walmart Canada and its carriers. The company's carriers deliver products to over 400 retail stores across Canada annually. Walmart Canada went live

with the operations in February of this year after completing two pilot programs with IBM: one for pork and one for mangoes.

Walmart worked with IBM to design and implement the food pilots using blockchain technology. According to McDermott, "Blockchain solves business problems where trust is part of the solution" by providing what traditional databases cannot, which is data immutability as well as speed and security and dissemination (Kamath, 2018). IBM's solution was based on Hyperledger Fabric, which supports modular architecture as well as plug-and-play components. Records within the system include audits, agricultural treatments, identification numbers, manufacturers, known security issues, granted permissions, and safety protocols. This data is logged in real-time and is permanently store for future use. The technology is thought to provide trust which enables higher efficiency as well as complete sharing of data, which is highly useful in supply chain environments, as well as business in general.

Walmart is using this technology in places such as China to ease consumers worries regarding food safety in the growing environment of food automation (Kamath, 2018). In October of 2016, Walmart launched the Food Safety Collaboration Center, where the center studies foodborne contaminants and develops risk assessment models for the use of other companies. Walmart has also invested in technologies to detect foodborne pathogens and to monitor package food contaminations. The cooperation with government agencies was crucial to the success of Walmart's pilot programs.

For the pork pilot, the process began at the pins of the pigs. In this location pigs were tagged with smart tags which had bar codes. These bar codes were used throughout the entire process, all the way to when the meat was packaged. Radiofrequency identification and

cameras were also used throughout the process to ensure the reliability of data. Temperature for the pigs was also recorded to ensure the safety of the animals.

In production, shipping trucks were equipped with temperature and humidity sensors. They were also equipped with global positioning and geographic information systems, to ensure that the products arrived on time and under safe conditions for consumption. Information such as farm organization, batch numbers, processing data, soil quality and fertilizers, and even storage temperatures were all tracked and could be linked to an e-certificate, which could be accessed by using the QR code found on the package of the items. Having this technology improved the company's ability to provide accurate information about each packaged item from farm-to-table.

After showcasing the Walmart and IBM's success in developing usable blockchain technology, the companies expanded their collaboration to include other companies such as Dole, Driscoll's, Golden State Foods, Kroger, McCormick and Company, McLane Company, Nestle, Tyson Foods, and Unilever. This expansion of collaboration will allow all companies involved to learn from each other and to develop industry standards to facilitate the applications of blockchain technologies. While Walmart originally focused on improving their own health standards, the adoption from other companies will ensure food safety for all.

Blockchain technology enables food traceability down to the item level, rather than batch level or even facility. Walmart's initiative helped to identify which information is important to track. This allows for categories of data to be documented as mandatory or option, as what data can be cut out of the tracking process. This documentation allows for the amount of data to be manageable and keeps the process efficient. The pilot program also

ensures the reliability of data collected and works out all potential problems that would otherwise be faced by the company.

**Coca-Cola Case Study:**

Another company who has deployed blockchain technologies is Coca-Cola. In November of 2019, Coke One North America (CONA) announced that they would be deploying blockchain technology (Williams, 2019). Coke One North America is the technology firm that manages IT operations for Coca-Cola's bottlers. Currently, the company is utilizing SAP's blockchain technology to shed light on the company's many transactions that occur each year. SAP is a German corporation that provides software as a service to other organizations. SAP's blockchain technology provides insights into the massive amount of transactions that occur between Coca-Cola's 70 different franchises.

An example of the type of transactions occurring is when one franchise purchases products from another organization to fulfill their own orders. Some of these transactions often go through intermediaries before being fulfilled, meaning they are often slow. Coca-Cola is using the blockchain technology to increase their efficiency in conducting transactions and increase their traceability. The company is also looking to save money by having these insights into transactions occurring. Often, corporations may have good visibility into their own company, but once it is out of their control, they lose this knowledge.

The blockchain technology allows bottlers to see into the inventory of other suppliers, giving them the opportunity to purchase the items needed to fulfill demand if not already on hand. The technology helps CONA by processing those transactions at a faster pace, making the company more efficient. Torsten Zube, who is head of the SAP Innovation Center Network, believes that the blockchain technology is creating a document flow across the

supply chain for CONA (Williams, 2019). The SAP Innovation Center Network is tasked with finding use cases for the new emerging technology. Using the tool, CONA hopes to spur greater productivity, increase cost savings, and speed up cash flow between the different franchises.

The pilot program originally started between just two bottlers, Coca-Cola United and C.C. Clarke. This program has been scaled across all bottlers after seeing improved results. With the technology put into place franchises can see if an order can be fulfilled and leads to necessary adjustments to happen faster. Blockchain technology also allows CONA to dispute disagreements on transactions faster and more effectively since the company can now see all the transactions on the online ledger. The technology makes the transactions clearer and more transparent.

Like Walmart, the company started with a large list of attributes that the company thought would be necessary to track. After utilizing the technology more, the company narrowed the list down making the data more manageable. The company is still refining the technology to this day, but that is to be expected with a new and coming technology such as blockchain. CONA worked with all the other franchises to develop the best system to work for Coca-Cola as a whole.

**UPS Case Study:**

Early 2019, UPS announced its partnership with Inxeption, creating the platform Inxeption Zippy. It is aimed to make setting up shipments and sending shipments easier going from business to business within the marketplace. The platform helps businesses market and distribute their products on multiple online channels, also making it more secure (Conwell, 2019). The platform allows for merchants to easily set up an account that enables

manufacturers, distributors, and wholesalers to be more connected and conduct e-commerce transactions. Since technology is blockchain-backed, sensitive information is ensured to be safe. The information collected is only available between the buyer and seller. The partnership between UPS and Inxeption allows for a more seamless end-to-end experience. Since the partnership involves UPS, merchants can view their entire supply chain every step of the way in the process.

UPS has also partnered up with HerdX, which provides end-to-end insights into food supply chains. The partnership between UPS and HerdX has already completed a test trial to use blockchain for beef traceability from a farm in the United States to Japan. HerdX's blockchain solution uses connected tags, readers, and verified data, much like Walmart (Ledger Insights, 2019). HerdX monitors both animal movement and health to ensure the best quality beef for consumers. UPS's partnership with HerdX allows for live updates of the product from farm-to-table essentially.

HerdX's blockchain collects data such as time of the animal's birth, where the herd was raised and enabled farmers to keep a watch on each animal. Since UPS is a transportation company, the partnership between HerdX and UPS allows for business to track shipments using blockchain throughout the entire supply chain process. UPS Logistics and Freight provides services for over 200 countries worldwide, which gives HerdX the massive scalability power to provide for cattle producers worldwide, changing the entire industry as more and more companies utilize the technology.

In the trial, a shipment of beef left from Kansas in one of UPS's temperature monitoring packaging (Ledger Insights, 2019). The packaging had sensors the monitored and recorded data throughout the shipments journey. Once the package arrived in its

destination, the data was recorded in HerdX's blockchain platform. Customers who want to look up where exactly a product came from can scan the QR code on it to view the verified health and data of the meat that they are buying. This creates trust between both the customer and the farm. This case can also be applied to other products, not just food.

## IV. Benefits of Blockchain Technology in Supply Chain

### Efficiency

Now, looking more closely at the cases presented, one can see that there are many potential applications and benefits of utilizing blockchain technology within supply chain networks. One of the main benefits of deploying blockchain technology is to improve efficiency for everyday business activities such as communicating with business partners, completing transactions, tracking documents, as well as much more. For example, the use of smart contracts is typically part of blockchain technologies. A smart contract is a self-executing contract where the terms of the agreement is directly written into lines of code (Frankenfield, 2019). After being written into the lines of code, it now exists in a blockchain network.

Within the field of the supply chain, smart contracts can be used to automate the transfer of title to goods and money, which removes the need for third-party facilities. An example of this is Letters of Credit. The use of smart contracts helps to streamline the whole process. Also, since there is no need for third parties the overall cost will be reduced, thus saving companies money in the long term. Smart contracts cause faster cycle times by reducing the amount of time it takes by creating a more efficient process.

Maersk's partnership with IBM is just one example of blockchain technology being implemented to improve efficiency. Through the use of blockchain technology, Maersk can

more efficiently and effectively work with the company's partners. For example, the average end to end container shipment involves more than 30 organization, more than a hundred people, and more than two hundred information exchanges. Through the use of the technology the process of sharing and collaborating with documents is streamlined. Blockchain allows for the transfer of data and information to be transferred at a much faster pace.

An example of this is with the bill of lading. The bill of lading is a document that proves that a container belongs to the company presenting the paper. A bill of lading has to be presented at each port that a container shipment goes through. The bill of lading also goes through many hands throughout the entire process of moving goods from one area to another. Through the use of blockchain a company has place to store the document and other documents allowing for access to be given to those individuals who need it beforehand, thus saving time. If using a private blockchain, securities can be put into place that allow all parties to communicate and share information within the document. Having the data in real-time makes the process of transporting goods faster and more efficient.

Another example is Kouvola Innovation, which implemented blockchain technology to enhance information flow and to remove inefficiencies within the company's supply chain (Peter Verhoeven, 2018). The company's main goal is to remove inefficiencies by reducing cargo transport times. The company, to combat this problem, wants to create industry standards of communication by utilizing blockchain technology. If the company is successful in creating an industry-standard, all companies within the industry will benefit from it. The technology and standards will decrease transportation costs for most companies, which is already one of the most expensive components of a company's supply chain. Kouvola also

wants to create industry standards for blockchain products in general. This would allow for an increased speed of data transfer and will lead to a more streamlined and efficient system. Looking to the future, if more companies adopt blockchain technologies it will prove beneficial for all involved.

**Transparency/Traceability**

As globalization and growing complexities in the marketplace grow, supply chain transparency becomes exponentially more important. Today, in the everchanging market companies are faced with a lot of problems due to lack of transparency in supply chain networks. An example of this is Coca-Cola's partnership with SAP to develop a blockchain solution to track and validate transactions that occur between the 70 different franchises (Battrick, 2019). Coke One North America (CONA), as mentioned previously, is the technology firm that manages IT operations for Coca-Cola bottlers. Currently, CONA oversees 12 suppliers with hundreds of thousands in orders.

Since Coca-Cola is so large, the ultimate goal of the technology is to increase efficiency, reduce cost, and accelerate cash flow in the company's supply chain. Coca-Cola's supply chain is currently worth 21 billion in yearly revenue, which is a massive amount. With SAP's blockchain solution, CONA is able to reduce the duration of order reconciliation from 50 days to just a few days (Huillet, 2019). This drastically improves their efficiency as well as provides the company with more insights. The technology also provides real-time insights into shipment information and the transactions made by all the different bottlers on the network. As an example, let's say a bottle maker is short of stock for an order. The network will quickly provide options for filling the shortfall. This allows for fewer shipping errors, less missed deadlines, and lowers operational costs as a result.

If more companies were to implement technology such as this, transportation costs across many industries would be significantly reduced. This is because they would get shipments faster and would have less cost associated with the holding of items being shipped. Also, this would allow for increased transparency, giving companies better insights into how its efficiency is and would provide companies the opportunity to invest more into components of it business practices rather than efficiencies.

As mentioned previously, Walmart is also utilizing blockchain technology to improve transparency within its supply chain. Currently, there is no widely adopted industry standard for how the food industry tracks and records data for traceability purposes. Often, companies within the industry will record data on paper while other companies use digital methods to track. While there are some companies using these digital methods, there is no way for the companies to communicate effectively and efficiently. The current system for food tracking is highly limiting transparency for all organizations within the industry. Since the system is lacking, Walmart is leading the industry in creating a solution for this problem (Yiannas, 2018).

In 2006, an outbreak of E. coli erupted due to contaminated spinach. This outbreak is thought to be both a warning and an example of the need for better traceability capabilities. Since then, there have been many outbreaks that further show the need for better traceability capabilities. During a more recent outbreak, the Food and Drug Administration (FDA) announced that "FDA scientist and investigators are working with federal and state partners and companies as quickly as possible to collect, review and analyze hundreds of records in an attempt to trace back the source of the contaminated romaine lettuce". According to Walmart's Frank Yiannas, a digital, transparent food traceability system could have identified

where the problem came from way before officials figured out the source by providing more traceability in the supply chain. This outbreak is an example for Walmart employees as to why the company needed to put into place blockchain technology.

Not only can the technology be used for food safety, but it also can improve sustainability for the company by reducing waste and lowering the companies cost by eliminating food system inefficiencies that previously existed. The company also believes that the technology will provide greater insights into questions such as "How was food produced" and "Was it sustainably grown?". These types of questions are increasingly becoming more important as shoppers are becoming self-conscious on these issues.

In October of 2016, Walmart and IBM announced two proof of concepts (POCs) to demonstrate that blockchain technology is a viable way to track and authenticate food from farm to store with both speed and precision. The POCs focused on two main elements which were traceability and authenticity. The examples that the company used was the mango supply chain and pork supply chain that was previously talked about. With the original system in place, it took six days, 18 hours, and 26 minutes to identify the farm that harvested a specific mango that was bought from one of the company's stores (Yiannas, 2018). To provide proof, IBM and Walmart used the new technology to trace mangoes that were farmed in Mexico to two stores that were located in North America. For this test, each stakeholder put data on the blockchain. The stakeholders included where the farms were, packing houses, transportation companies, importers/exporters, processing facilities, distribution centers, and stores.

Once all data was entered, the blockchain then linked the datasets together to tell the story of the journey. This resulted in a massive reduction in time taken to track the mangoes

from farm to store. The time went from around 7 days to 2.2 seconds (Yiannas, 2018). This is about the same amount of time that it takes for a person to complete a thought. Walmart chose two reasons to track mangoes instead of other food products. One because it has a highly complex supply chain and the other because produce is one of the most frequent causes of foodborne illnesses.

While observing the mango POC, Walmart noticed increased visibility in regard to the speed of the company's supply chain. Typically, it is easy to blame certain parts of a supply chain, such as the farmer harvesting the mangoes taking too long. Utilizing blockchain technology can pinpoint exactly how long a company's product is sitting in each portion of the supply chain. This allows for increased efficiency and better shelf life of products. As Frank Yiannas put it, the company can do more "fact-finding" than "fault-finding" when issues do arise for the company (Yiannas, 2018).

As previously mentioned, UPS has also started to use blockchain technology for its own operations. Last year, the company applied for a United States patent to use blockchain technology to track packages through multiple carriers globally. This technology allows the company to track international air freight shipments and verify shipments. Also, in 2017, the company joined the Blockchain in Transportation Alliance. This is a group of corporations that came together to set a standard of utilizing blockchain technology in transporting products. Having a set standard is beneficial because the more companies that utilize blockchain, the better off they all are using the technology. Having other businesses within the same industry utilize similar technology allows for the technology to grow as well as each company can learn from each other.

**Quality**

Blockchain technology also has the potential to provide many insights for companies looking to improve the visibility of its entire supply chain as well as increase efficiency and improve product quality. One of the ways that it enables higher quality products is by providing essential information such as environmental aspects when transporting goods throughout the entire process. By providing essential information, manufacturers can pinpoint exactly where problems may occur.

By looking at the food industry, this can be seen very easily. For example, if there is a truck transporting milk, there are strict temperature guidelines that must be followed to keep the product healthy for customer consumption. Blockchain technology can track what temperature the truck is transporting the goods as well as information regarding if the product is spoiled or not. If a truck thermostat topped working, the company would be able to see that the temperature is wrong, as well as pinpoint exactly when it malfunctioned. This would allow the company to pinpoint exactly which group of products is affected by the malfunction, enabling the company to save time and money by knowing exactly which products need to be thrown away.

This type of example can be transferable to all other products. Another example of this is cars being manufactured. Recalls are widespread within the car industry and cost manufacturers a lot of time and resources each year to fix. Often when a part is recalled, the company does not know which exact cars have the defective part. If car manufactures were to put into place blockchain technology, it would save the company a lot of time and resources by enabling the company to see where exactly the defect happened, as well as which cars were affected instead of the company guessing a large batch of vehicles. This would allow for fewer resources to be wasted, saving the company a lot of money each year.

## V. Vulnerabilities of Blockchain Technology

Since the technology is so new, there are many potential problems that companies should be aware of before deciding to implement blockchain technology. One problem with blockchain technology is double-spending. Although blockchain technology was created to combat the problem of double-spending, it can still happen. Double spending is a fundamental problem that businesses could face after implementing blockchain technology. Double spending happens when a user makes multiple payments using one funding form. This can occur because transactions are validated by solving a mathematical problem. When unprocessed payments are broadcasted across the network, broadcasting disruptions can happen, causing double-spending (Hasanova et al., 2018). For example, an attacker could trick a retailer into accepting a transaction that the retailer cannot reverse by doing the following.

The attacker in this scenario could start a transaction just like the original except change the recipient's address. If both transactions are initiated at the same time to peers on the chain, the chain will not accept multiple transactions that share common inputs. Instead, they will only accept the version of the transaction that reaches them first. Although, the transaction could go out to other peers, making it successful in causing double-spending. There is no way for companies to get around double-spending; it will always be a potential threat.

Another potential challenge faced by companies implementing blockchain technology is a 51% attack. Both a 51% attack and double spending can happen at any time, meaning companies must be aware of this possibility. A 51% attack refers to a group of miners controlling more than fifty percent of the network hash rate, which is the computing power.

During this attack, an attacker could be able to obstruct the confirmation of new transactions. Also, an attacker can reverse transactions, but only if they hold the majority power over the network. This could cause double-spending. Although a 51% attack could happen, it would be tough for an attacker to take over the blockchain. This is because transactions are locked prior to the start of an attack if the attempt has to do with historical blocks.

In August of 2016, both Ethereum Krypton and Shift experienced 51% attacks. While they experienced the attacks at low levels, a 67% attack would cause severe problems to a company (Hasanova et al., 2018). At the level of 67%, the attacker can essentially block and reject any transaction they want to. They can also form any transaction themselves. To combat this, there must be precautions set into place to make sure that something like this does not happen. Also, companies should take necessary measures to protect themselves and to protect customers within the system.

Another challenge of blockchain technology is that it takes up a large amount of energy and can be costly because of it. Currently, developers are looking into ways to make blockchain technology more energy-efficient, as well as develop the technology to be faster than it already is. One of the ways that developers are looking to make the technology more efficient is by enabling parallel processing. This allows for simultaneous transactions to be processed. Some recently developed technologies can process thousands of transactions per second, making the technology highly scalable.

Another important challenge is that blockchain systems have high development costs associated with them. Blockchain technology can circumvent the need for third-party intermediaries but can prove to be not worth it if there is already a good system set into place. Blockchain technologies prove to be worth the cost if there is a very high inefficiency

already, making it beneficial to use blockchain technologies as a solution. An example of this is energy usage. There may already be a database put into place that is easier to use and more cost-effective than blockchain. The best example of this is legacy systems that users have already learned, and learning blockchain may prove to be too hard and not cost-effective. Blockchain technology may also cause special equipment at work, making it more costly and will require more training for employees.

Also, while there is a lot of growth within the industry in developing blockchain technologies and implementing it, there is still not a standard for the technology. Since there is no standard, companies must figure out on their own how to either develop their own technology or how to implement an already developed version of the technology. This can cause massive amounts of money to be invested and to be improperly used. This would essentially be creating a technology that will not be used and would be a burden to the company. Although this is an issue, as more companies utilize the technology, standards will be developed thus benefiting all companies utilizing similar technology.

## Conclusion

Blockchain technology can prove to be highly valuable for companies willing to learn new technology and willing to take some risks. While blockchain technology is fairly new and evolving, there are many potential benefits that make investing in technology worthwhile. Some of the benefits seen are improved efficiency, transparency, traceability, as well as the ability to enable higher quality products to be sold to consumers. Blockchain does this by providing distributed ledgers that are immutable and provide real-time data regarding shipments as well as provide access to documents needed throughout the supply chain process.

While improving efficiency, transparency, and traceability, the technology allows for a company to save money by producing products more effectively. Blockchain technology enables companies to spend less time completing tasks that are tedious to do without the use of blockchain. Activities such as shipping details, tracking details, ad much more can all be stored in one place and can be accessed by various company groups. This data can also be shared with people outside of the company, making collaboration easier to accomplish, enabling greater productivity and higher cash flow as a result.

While there are many benefits to deploying blockchain technology, there are also potential issues that need to be thought about before scaling the technology company-wide. This is why companies such as Walmart, Coca-Cola, and UPS do pilots before fully committing the technology to their entire organization business practices. Some of the risks include double-spending, cyber-attacks, high energy costs, and high set-up costs. While the technology was created to combat the problem of double-spending, it can still happen. Keeping this in mind, companies can take protective measures to help ensure their information is secure.

Since technology is online, there is always a potential of cyber-attacks. This can take form in many different ways, one of those being a 51% attack. Companies such as Ethereum Krypton and Shift have both reported this kind of attack happening to them.  As the problem of double-spending companies should take countermeasures to ensure that their information is as secure as they can make it and be careful about which data is stored. This can prevent anything bad from happening to the company's data.

High energy cost and high set-up cost can also be avoided. Often companies will provide the software as a service, enabling organizations to focus more of the practical usage

of it rather than deal with the high costs associated with maintaining it and developing it. In many cases there is at least a framework developed which will save costs. Also, the adoption of blockchain technology will save companies more money in the long run, making the investment worth the high set-up costs. Overall, companies should weigh both the potential benefits and challenges that are associated with blockchain technology.

## Limitations

The main limitation of this study is that there is little to no quantitative data to measure the direct impact of blockchain technology on supply chain networks. The research within this study is mostly based on theory and not necessarily has data to back it up. As more companies introduce the technology, the association between the technology and its impacts will be more measurable. Currently, since the technology is so new much of the data regarding its direct impacts are kept secret within the company itself. It is not out there for public access. Also, as more companies use the technology, the data will become more accessible, and a conclusion regarding its impacts on a supply chain will be directly seen.

## Future Research Direction

This thesis looks at qualitative data drawn from real company case studies and draws conclusions based off that. In future research of the topic, quantitative research should be addressed to add to assumptions already made. As the data becomes available, it will allow for a more holistic view of the direct impacts of blockchain technology on supply chain networks. The direct costs associated with the implementation of blockchain will be addressed as well as the amount of cost savings for each company. This will allow for both researchers and companies looking to implement the technology to plan ahead better, as well as provide them with the knowledge to make business decisions regarding the technology. As

more companies implement the technology, it impacts on other areas besides efficiency, transparency, traceability, and quality can be addressed. Research in these areas can also be added to, providing more research overall.

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