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SUPPLY CHAIN MANAGEMENT INTEGRATION WITH BLOCKCHAIN

Venkat Veramallu

SUPPLY CHAIN MANAGEMENT INTEGRATION WITH BLOCKCHAIN

A Project

Presented to the

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In Partial Fulfillment

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in

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Approved by:

Dr. Nasrin Mohabbati, Committee Chair

Dr. Conrad Shayo,Committee Member

Dr. Javad Varzandeh, Department Chair, Department of Information & Decision Sciences

ABSTRACT

Maintaining the integrity of data within the supply chain is a challenge. Many current implementations lack a capability to provide a trustworthy system for the stakeholders in a supply chain, making communication amongst stakeholders easy but unreliable. Organizations are considering blockchain technology as it provides access control, immutability, transparency and trust amongst the stakeholders in a supply chain. This project is an investigative study on the benefits and challenges of implementing blockchain technology in supply chain management, a framework for integration of blockchain technology, and a project prototype which shows a blockchain use case implementation in supply chain management. The research was based on questions addressing the issues of supply chain disruptions, disruption consequences, and ways blockchain technology can help, while showing the challenges in the blockchain technology. The use cases show the implementation of blockchain technology, the benefits of the implementation framework, and a prototype application. Based on the conclusions from the results of the case studies, this study provides a recommendation for organizations willing to implement blockchain technology in their supply chains. The areas for further research identified in this project include: building a prototype to ensure data integrity amongst stakeholders in a blockchain; contrasting the advantages and disadvantages of blockchain technology; showcasing the implementation of blockchain technology in various

industries through case studies; establishing a framework for an organization to get them started on blockchain technology .

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CHAPTER ONE

INTRODUCTION

In the growing world, consumer needs continue to increase exponentially and organizations are actively optimizing their Supply Chains to ensure that each need is fulfilled. Supply Chain Management is the practice which maximizes the consumer experience while providing a competitive edge for an organization in a marketplace. Organizations are heavily invested in different ways to optimize the management of their supply chains, and one such way is using technologies such as automation and blockchain. As reported by McKinsey ,to optimize its supply chains an “organization can place sensors in everything, create networks everywhere, automate anything, and analyze everything to significantly improve performance and customer satisfaction” (McKinsey,2016).

Technology can improve supply chains by providing great insights to the participating organizations. Such technologies include: Artificial intelligence “(AI)”, Data analytics, and Internet of Things. AI gives organizations a competitive edge by eliminating manual processes like personalized promotion and marketing. AI can also predict trends from user data in realtime, optimize warehouse and logistics, and set prices on a product depending on trend or demand. Many e-commerce companies use AI to optimize their supply chain (Dash,2019).

AI heavily relies on data for the most accurate results. Data analytics as part of AI can provide organizations with spatial and graphical analytics to help them classify their business data, capture patterns and perform statistical

regressions to find insightful information. Data analytics enables organizations to apply descriptive, predictive and prescriptive analytics which results in making the best business decision, and consequently provides a competitive edge in their supply chain management (Oracle,2020).

Data generated by a supply chain can be captured by using internet of things (IoT) technology. IoT can help in condition monitoring of a shipment like food and vaccines and provide real time location tracking of a product. Such location data can also be used to create the most fuel efficient route to make a supply chain more efficient while providing real time monitoring data ensuring the shipment is not breached during the transportation. ”About 40% of supply chain executives want to invest in real-time supply chain visibility in 2021” (Relevant,2020).

All these listed technologies provide analysis ,automation and tracking but still have a few drawbacks which are reliability and tampering. This can be fixed when the listed technologies are combined with Blockchain Technology. blockchain technology is decentralized, immutable, reliable, and transparent as it optimizes business and industries supply chains (IBM,2019). When various industries interact with each other, there has to be a strong mode of communication which can be trusted by the stakeholders of a supply chain. Using blockchain technology, stakeholders of a supply chain can take the advantage of this collective knowledge. Then, collective knowledge will be trusted and tamperproof data is generated by the stakeholders. For example, the

Food and Drug Administration (FDA) announced the regulation for the manufacturers to notify consumers of “sugar added to foods" (FDA,2016). But a company producing protein bars would have no idea of how to provide proof to the consumer and authorities of the sugar content of its ingredients, and more importantly, how the organization can prove the marketing facts of the product such as which ingredients are included in its products along with its procurement history. However, blockchain technology can help to address such issues. As a supplier of the ingredients enters the information of the ingredients in the food the marketing team can show the sourcing information and content information of its products. This approach saves money and time. The above approach can also eliminate food recall issues as it can also provide information regarding origin and contents which can be traced in case of a foodborne illness (Blockchain for business, 2019).

Problem Statement

COVID 19 crisis highlighted the weakness in supply chains and showed that supply chains needed to embrace new technologies as organizations were not operational due to the COVID 19. Organizations were unable to fulfill orders, do an inventory check, or fulfill delivery. This crisis could have been averted only if new technologies were in place, which could automate these functions (World Economic Forum,2020).

COVID 19 pandemic also became the reason for the international trade to slow down as there were multiple stakeholders present in the supply chain who could not trust each other for reliable data or exchange documentation physically. This could have only been avoided if the organizations implemented blockchain into their supply chains as blockchain ensures data is reliable and tamperproof. blockchain technology also provides an automation functionality to exchange documentation or money through a smart contract without any central authority like a bank (abouzid,2020).

The integration of blockchain needs to be understood in order to implement blockchain into a traditional supply chain. While doing so, integration issues arise like which component on the supply chain the blockchain needs to be implemented, how one chooses a blockchain technology detail, how to make sure risk is mitigated during implementation, how to ensure blockchain is compatible with existing components or an upgrade is required and how to determine the project costs (Musienko, 2020).

This project addresses advantages and disadvantages of blockchain technology and integration issues. It also is an introduction guide for businesses to integrate blockchain technology into their existing ecosystem. Addressing the integration issues can ease the burden on organizations looking forward to adopting blockchain technology and transition their business using blockchain more easily.

Research Questions

This study addresses three questions:

1.What are the successes and challenges of applying blockchain technology by companies in various industries?

2. What are the emerging best practices for integrating blockchain technology into supply chains?

3. What are some recommendations for organizations to optimize supply chains using blockchain technology?

Methodology

This project first reviews existing literature on the existing problems in Supply Chain Management in order to investigate existing supply chain issues. Second, the project investigates the literature on how blockchain technology helps to address the existing problems in the supply chains and the blockchain adoption rates. Finally, the project identified realtime examples and test-pilots of blockchain implementation and preliminary outcomes of blockchain technology integration based on supply chain needs. This comprehensive research is used to draw conclusions about blockchain in Supply Chain Management and provide recommendations to small businesses to get started on blockchain integration.

Organization of the Study

This project is organized as follows: Chapter 1 covers an introduction to the research topic. Chapter 2 covers the literature review and issues in Supply Chain Management, solutions for issues and blockchain advantages and disadvantages. Chapter 3 provides an insight into the supply chain disruptions and how blockchain technology can solve such disruptions. It also includes the introduction to blockchain technology along with the advantages and disadvantages of it. Chapter 3 provides insight into the supply chain disruptions and how blockchain technology can solve such disruptions. Chapter 4 discusses the case studies where organizations have implemented blockchain technology. Chapter 4 also discusses how a business can get started with blockchain. Chapter 5 consists of the recommendations and summary.

CHAPTER TWO

LITERATURE REVIEW

Supply Chain Management is the combined activities of all business processes to deliver superior customer value for a less cost to the supply chain while satisfying requirements of other stakeholders like the governments or different organizations. The term ‘Supply Chain Management’ was coined by Keith Oliver in the year 1982. He worked for a consulting firm called ‘Booz Allen Hamilton’ (Jack van der vorst,2004).

Jack van der Vorst (2004) also defined supply chain as a web of services where providers and manufacturers work synchronously to fulfill the requirement provided by the end users, i. e., consumers. The web of manufactures and providers and different parties participating in the supply chain are known as stakeholders. The stakeholders are linked using physical flows such as tangible products, information flows like data and information exchanges, and monetary flows like money transfers and transactions. Here all the stakeholders should be following a collaborative process to optimize production, planning and manufacturing. Supply chain optimization can be done if there is transparency and collaborative information sharing amongst the supply chain stakeholders.

The above collaborative process could be done with absolute transparency using blockchain technology. According to the paper published by Queiroz et al (2020), blockchain technology is a decentralized database of records or a public ledger of all the transactions that have taken place among

participants to fulfill their task. A record when written cannot be erased as ledgers are immutable; each transaction is hashed with a hash generated from the previous transaction, creating a block and a set of blocks which when linked with multiple blocks create a chain. Such whole end ledger is a blockchain technology that has applications such as cryptocurrencies, smart contracts, gaming, and marketplace management. The paper also discusses the use cases with specific proof of concepts which were implemented in the Healthcare Industry (Rebecca Angeles,2019). Blockchain was implemented across various industries for different applications. Blockchain has been also used in industries which are required to maintain data integrity and trust. A few examples are the food industry and mining industry where blockchain was used for product traceability. In the finance industry, blockchain is used for asset management and insurance issuance and settlement.

A paper published by Lu and Xu (2017) provides a decentralized solution for product tracing, from manufacturing to delivery, through the supply chain to make the product tamper proof. The proposed system was implemented using blockchain technology. This paper also addresses the challenge by using Smart Contracts to track products across the supply chain. It concludes with the challenges a supply chain is faced such as the implementation scale and cost of the project implementation when the blockchain was in an early stage. The paper discusses a few advantages of blockchain in supply chain management.

A paper published by Mackey and Clauson(2017) studies the causes of counterfeit medicines in a pharmaceutical supply chain and how blockchain technology can be used as leverage to combat counterfeit pharmaceutical devices and medicines. This paper addresses the counterfeit problem by combining the implementation of Internet of Things (IoT) technology with blockchain technology to provide real time tracking and monitoring the conditions of medicines. It concluded with the positive impact it had on a supply chain and how the consumer trust can be elevated due the implementation of blockchain.

Now that the flexibility of blockchain technology in different supply chains is established, the immutability characteristic of blockchain technology was discussed. Dorri and Raja (2017) published a paper which introduces blockchain technology to the automotive industry as a way to leverage smart cars and smart devices like traffic lights to create a record that could benefit the user in an event of insurance claim. It also stores car data securely using ledger technology. This implementation helped many stakeholders ranging from the owner of the cars, the insurance companies, car manufacturers and finally authorities to monitor driving conditions and accident-prone areas. This whole system will work only if the record or logs stored were authenticated, tamper proofed and signed each time the record was accessed. This was all possible due to the distributed ledger technology that the blockchain is based on.

Now that we have investigated the implementation of blockchain in an enterprise setting it is helpful to study a use case to enforce a policy or a verdict in an organization ranging from enterprise to governments.

Shermin (2017) talks about the implementation of blockchain for efficient and effective organizational governance. The paper looks at it in various scenarios which could either be a company or a government. Blockchain is a self-executed and trust-based technology it could be relied upon to complete a governance task without the involvement of bureaucracy which usually causes delayed results. The paper by Shermin also explores the possibility of money without banks, companies without managers, countries without politicians by the implementation of technology which is trusted and decentralized. In such technology all the operational nodes (computers) were not stored at the same location and it provides governance by code. In conclusion, it should be noted how blockchain can potentially replace traditional governance models by saving transactional costs and eliminating moral hazard to an extent. This paper also discusses the potential challenges of such implementation which are the adoption rate and implantation scale of blockchain, ending the paper with a note that future research can develop and scale such technology empowering the people through decentralization and transparency as better decision making capabilities through the consensus algorithms. Now that blockchain technology's applications have been introduced, let's move to the importance of why

blockchain technology in the supply chain. Table 1 shows a summary of some studies about blockchain applications.

Literature review is a documentation analysis of open-source surveys, books, technical reports, and case studies. The primary sources of literature for this project are the journals published on science direct, journals found on the CSU library's OneSearch tool, Google Scholar, a book by the name Blockchain for Business by Arun and Gaur (2019). To ensure high quality review articles are selected from reputed industry publications the OneSearch tool accesses content from all CSU schools' libraries, including over 150 databases (John M. Pfau Library,2021). Google Scholar searches articles, theses, books, abstracts, and court opinions, from academic publishers, professional societies, online repositories, universities, and other websites, from free and subscription sources. Since not all sources are open access, the results require more scrutiny. Secondary sources of data are blogs and news articles.

The literature review for the project is found using a set of keywords as the search criteria: Blockchain and Supply Chains Management, Smart contracts, blockchain technology in small businesses.

Table 1 : Databases Searched, Keywords Used and Relevant Articles

Database Searched	Library Search Words	Number of Hits	Relevant Articles you used in the study	Authors
IEE	Blockchain Consensus Algorithms,	673	1	Mohammad Jabed Morshed Chowdhury(2019).
IEE	blockchain systems for product traceability	99	1	Qinghua Lu;Xiwei Xu(2017).
IEE	blockchain based Automotive security	25	1	Ali Dorri(2017).
Arxiv	blockchain technology	899	1	Dylan Yaga and Karen Scarfone(2019).
Arxiv	Blockchain Consensus Algorithms	152	1	Md Sadek Ferdous and Alan Colman(2019)
CSUSB Scholar	Blockchain	14	1	Rebecca Angeles(2019)

works				
Science Direct	Blockchain , supply chain management, Applications	2,814	1	Pankaj Dutta and Richa Butala (2020).
ACM Digital Library	Quantum resistant	44,186	1	Ray A. Perlner, David A. Cooper(2009).
Google Scholar	Blockchain integration with supply chain management	44,000	1	Maciel M. Queiroz, Silvia H. Bonilla (2019)
Google search	supply chain management integration with blockchain research consulting firms, organizations	2,120,000	6	IBM,HCL,Capgemini,DHL,Forrester, United Nations center for trade facilitation
Google search	blockchain supply chain case studies live on Ethereum mainnet	86,200	1	ethereum.org

Table 2: Journals Selected, Implementation and Authors

Blockchain Application Journals selected	**Implementation**	**Authors**
Product traceability	A case study of Blockchain based on product tracking.	Lu and Xu (2017)
Pharmaceutical supply	using Blockchain to combat fake medicines	chain by Mackey and Clauson (2017)
Automotive security	vehicular security enhancement using Blockchain	Dorri and Raja (2017)
Blockchain-based Healthcare	Blockchain use cases in healthcare industry for data exchange, Drug research and auditing, Clinical trial monitoring	Rebbeca Angeles (2019)
Disrupting governance	Utilization of smart contracts to enforce governance without any bureaucracy.	Shermin (2017)

Multiple incidents reported by the FDA and CDC were regarding the virus outbreaks caused by frozen food products which were directly linked to suppliers. This means supplier traceability is very important but is not provided with the existing Supply Chain Management models (Capgemini, 2018).

The Integration of blockchain technology with traditional supply chains provides the ability to track consumer products across the supply chain which helps in crisis handling. Blockchain can also create an audit trail which includes origin and ingredients of the products once the source of a problem is identified. Then, similar products with the same ingredients, origin, and supplier's products can be traced for a recall (Capgemini,2018).

Organizations are willing to integrate new technologies into their supply chains to optimize supply chains, and blockchain is one of the technologies being tried and tested. The organizations have experienced cost saving, enhanced traceability, and enhanced transparency as the outcome for blockchain integration (Capgemini,2018). Capgemini surveyed four hundred and forty-seven organizations from which thirty three percent were manufacturing organizations; thirty four percent were retail organizations, and thirty three percent were consumer product organizations. According to this report, implementation of blockchain in the manufacturing industry is three times the share of implementations by consumer products and retail industry.

The importance of using automation and technology could only be realized if there were a supply chain disruption and it was not possible for a stakeholder to conduct an onsite investigation.

To summarize the literature review one can understand the different applications of blockchain technology in various industries and how each application was proposed as proof of concept and not actual working proof. This study plans to build upon these applications and explore projects which are live on Main-net, proving that blockchain technology is more than a proof of concept.

CHAPTER THREE

SUPPLY CHAIN DISRUPTION AND CAUSES

This chapter will provide an insight into the supply chain disruptions and how blockchain technology can solve such disruptions. This will be followed by the introduction of blockchain technology along with its advantages and disadvantages.

The COVID-19 pandemic has highlighted problems in Supply Chain Management. Most organizations were not prepared for such disruptions and were not able to adapt very quickly. However, some organizations understood the importance for automation and digitization and were more prepared to address their problems by adapting technologies like blockchain. Such technologies have improved data quality, data integrity, and transparency (Forrester Research,2020).

IBM commissioned Forrester, “the research company”, for an investigation on how supply chain leaders are using data to handle disruptions today and how adoption of blockchain can help in the future. This investigation was done using the data provided by a total of one hundred and fifty organizations which were based in different regions like North America, Europe, the Middle East and Africa. The investigation discussed the reason for supply chain disruptions, followed by the solution which could solve the disruptions using blockchain integration into their organizations (Forrester Research,2020).

Blockchain Technology and the Pandemic

The COVID-19 pandemic spiked the disruption of supply chain networks resulting in new problems. Sixty three percent of surveyed organizations encountered short-term challenges and forty five percent saw long term challenges. As shown in Figure 1, between September 2019 and September 2020, the top reasons listed for supply chain disruptions were: COVID-19 pandemic, Suppliers going out of business, Price/currency fluctuations, Transportation failures, Unplanned technical and Communication outages, Product problems, Cyberattacks, and new laws/regulations. A few of these problems had already existed for a long time. These disruptions show that supply chains must adapt as quickly as possible.

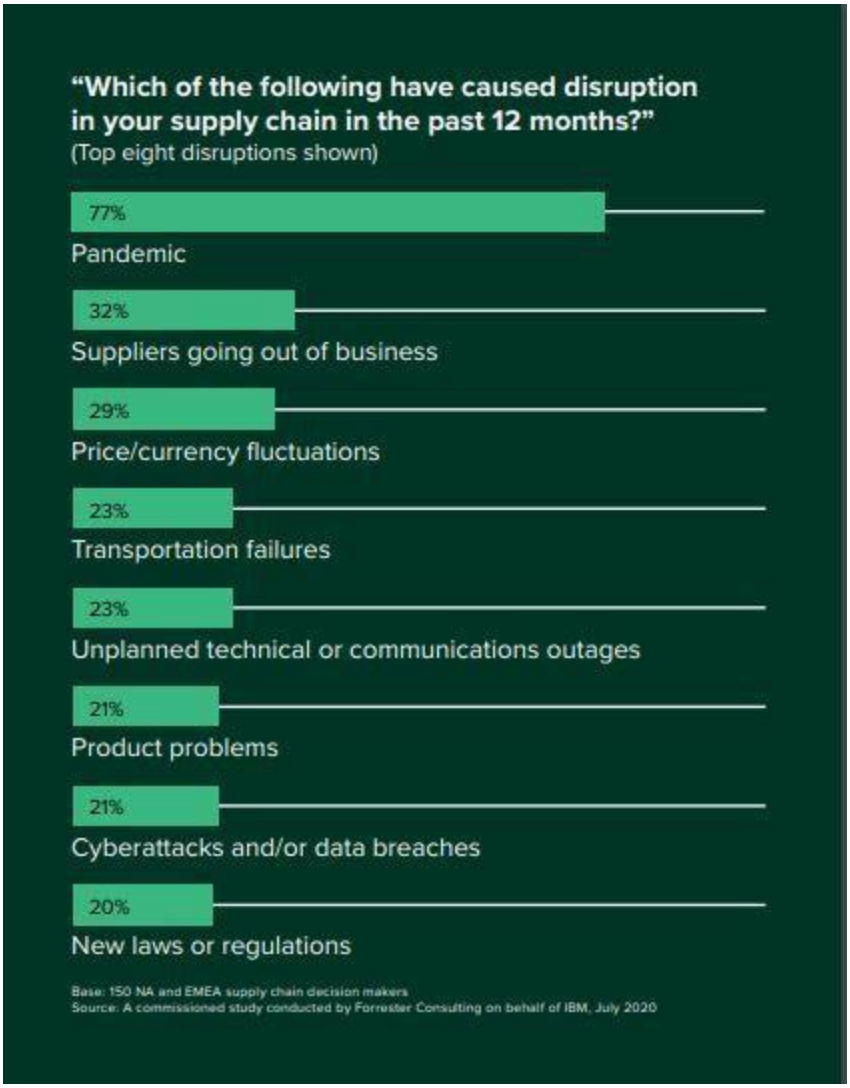

Figure 1: Supply Chain Disruptions September 2019 - 2020 (Forrester Research, 2020)

The research indicated by Forrester's investigation shows that Supply chain disruptions have caused increased costs and a loss of revenue which had a negative huge impact on the organization. Disruptions also resulted in delaying

product releases and created a bad consumer experience (Forrester Research, 2020). This directly influenced the organization's planning capability as it was impossible to make any commitments to customers as the business could not track their own goods at a given point of time. Figure 2 shows the consequences that organizations have experienced (Forrester Research, 2020).

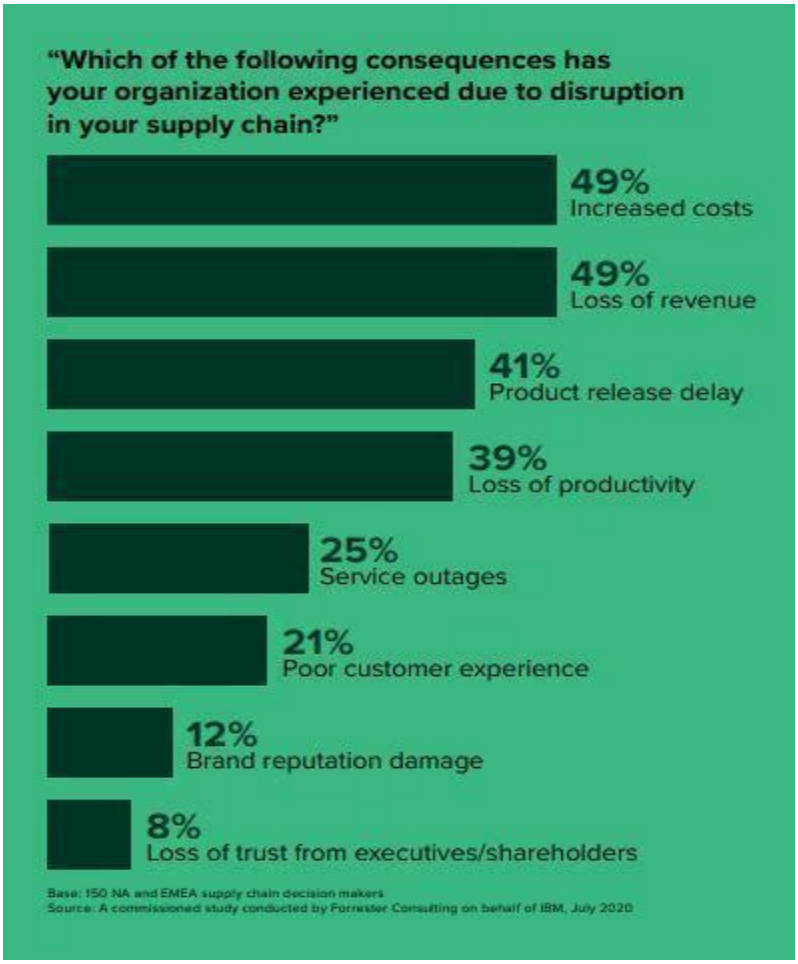

Figure 2: Consequences of negative impact on the supply chain (Forrester Research, 2020).

Supply chain data integrity, visibility, and sharing are essential issues which have to be resolved the supply chain issues, as shown in figure 3, and many organizations were not prepared for the disruption. A root cause analysis for the problems above shows that not having any trustworthy data from suppliers and their buyers regarding a business decision was caused by data integrity, data sharing and lack of visibility problems. These problems can challenge the automated decision and predictive analysis process of the business.

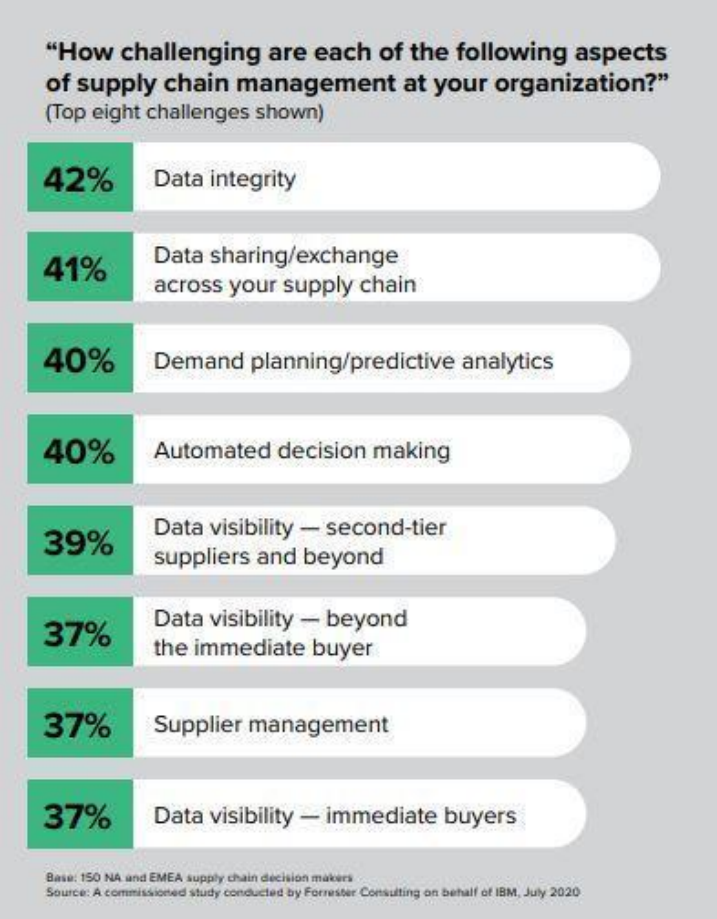

Figure 3: Challenging aspects of the supply chain (Forrester Research, 2020).

A Digital Overhaul of Blockchain Technology

Most of the supply chains still rely on paper processes and have integrated a digital process by using email, spreadsheets, etc. The pandemic has reminded organizations that they should either improve or adapt to a digital supply chain.

Blockchain implementation is still in its early stages. In the study by Forrester (2020), sixty three percent of the respondents were using blockchain. Blockchain also poses great business challenges like developing a governance model which is a plan where blockchain needs to be implemented, selection of actors in the blockchain needs to be done, and the legal requirements need to be established.

Blockchain, when implemented by most businesses, helps with digitized paperwork, and has yielded results such as improved data integrity and data sharing across organizations (Forrester Research, 2020). More examples will be stated in the use cases in the next chapter.

Blockchain Technology Advantages

Blockchain has helped various industries in numerous ways ranging from supplier contract management to product tracking capabilities. For example, Foxconn, which is Apple's largest electronics contract supplier, launched a blockchain called “chained”. It issued loans to its manufactures for a working capital, where the company was able to track each transaction which took place, then transactions were to be signed for release of funds ensuring accountability and transactions took place directly from peer to peer without the involvement of a central authority like a bank (Capgemini, 2018).

Consumer product manufactures are heavily invested in tracking provenance which allows organizations and consumers to track their products

geographical history from the place of origin, shipping route, delivery time and the number of times the product has changed hands. This process can be augmented when blockchain is paired with IoT and can also determine condition parameters which have an impact on the product, i. e. , temperature, humidity, moisture and any containment breach.

Blockchain also ensures that products are transported according to the regulations set by the government. Blockchain also helps in providing warranty as it shows a precise change of ownership which can help authorities or consumers issue a warrant for counterfeiting a product. Figure 4 shows how blockchain can be used for product tracking.

Figure 4: Ability of blockchain in product tracking (Capgemini Research Institute,2018).

According to a technical report by Crosby (2015), blockchain is immutable which means changes cannot be made to the record once stored in the blockchain. This means every record made in the blockchain is true, these records are tamper proof, and if changes were to be made to a record, the blockchain appends an update to the transaction. Each transaction or record made into a blockchain is time stamped and signed with a unique signature which is present with every participant involved in the blockchain.

According to different journals by individuals and industry reports stated above, blockchain has provided three key benefits to Supply Chain Management: it provides transparency of data amongst supply chain stakeholders, it provides trust using the data immutability feature and finally, it reduces cost using automation (Crosby, 2015; Capgemini Research Institute, 2018; Forrester Research, 2020).

According to a paper published by Dutta and Butala (2019), data transparency can be shown by adding provenance to a product or goods in a supply chain. Provenance is data showing the origin of an item, the number of times it has changed ownerships, making the product certifiable and verifiable. An organization’s trust in the provenance is established from using blockchain technology as the provenance data is recorded to the blockchain, then, each transaction must be signed ensuring accountability and recorded data is immutable meaning that it could not be edited by anyone.

According to a paper published by Yaga and Scarfone (2018), data immutability means data cannot be changed once recorded. In the case of blockchain that is not completely true. Blockchain is tamper evident which means that each change made is possible by a stakeholder who has access and is a trusted authority in the blockchain. Each change made in a blockchain is just added to the original change and every change made is signed using their digital signature.

Now that records are trustable and immutable, it is helpful to take a look at the financial gains blockchain can bring through automation according to a publication by the United Nations center for trade facilitation and electronic business(2020). In the maritime transport process, automation stops as the asset's ownership transfer is required and is held for a due time as this is usually regarding a payment. For example, goods are to be shipped from point *a* to point *b,* and usually the seller sending the goods through a logistics company needs to verify all the documentation. In order to verify whether the shipment has reached the correct destination and the condition of the shipment on arrival a trusted channel should be used. Once the details are verified then, the seller proceeds to make a payment to the logistics company. This process can take a few business days leaving mounting costs on the seller and time wasted for the logistics company.

The solution for such a problem is using blockchain technology which is paired with the Internet of Things (IoT). blockchain technology provides users with

smart contracts which is an automated contract that is executed when a specific condition is met. The seller and logistics company can draft a smart contract where the condition of shipment is monitored using IoT, and data is updated to the blockchain. This data is trusted and signed by the stakeholders on the arrival of the shipment at the destination. This is tracked using GPS, and finally, the lading bill is approved by the port contract. It will self-execute, and the logistics company will get paid. This process saves time and money UNECE (2020).

Blockchain Technology Challenges

Blockchain challenges can be divided into two parts. The first part will address the technological challenges and the second part will address the organizational concerns towards blockchain technology. There is often a hype around new and emerging technologies which are still in a development stage. Technologies as such are not vulnerable until widely adopted and implemented. But on paper, blockchain technology has a few vulnerabilities like consensus algorithm issues and encryption issues to overcome.

Consensus Algorithm Issues

According to Ferdous and Colman (2020) consensus algorithms are the driving force of blockchain. This algorithm has certain functions to follow:

1. It ensures that all the transactions recorded in the blockchain are correct by all the stakeholders arriving at the same conclusion.

2. Every block is linked with the hash of the previous block and the next block is hashed with the hash result generated by the previous block. This process creates a chain.

3. When a new user joins the blockchain ensure that the user gets to build on the block which is accepted by all the stakeholders.

Yaga and Scarfone (2018) discussed the four types of consensus algorithms and their problems:

1. Proof of Work Consensus Model (POW):

A block is published by the node which solves the complex puzzle first. This model is computationally heavy and its complexity increases overtime. This is made up by its benefit for validation as nodes can validate blocks easily. This model can be controlled by a person with a 51% attack where the person owns more than half of the nodes and can make their own changes to the blockchain.

2. Proof of Stake Consensus Model (POS):

As the name suggests, every node must give an initial stake into the blockchain to get a chance to compute a block. If a node has 10% stake in a blockchain the node is selected ten times more than the other nodes. This model is computationally less complex and open to any entity which wishes to stake their cryptocurrency. The disadvantage of the model is an attack where 51% of the stake is held by a single entity which is almost impossible, but entities can merge creating a centralized authority.

3. Round Robin Model:

This consensus model is implemented in permissioned blockchains where blockchain is not open to the public. With this every node gets an equal chance to create a block, and this model requires trust amongst the nodes as this model is used by enterprises.

4. Proof of Elapsed Time Consensus (POET) model:

This consensus model requires a node to request a time slot and the node is assigned time by secure hardware in the system more like a token system. This is less complex than proof of work but requires hardware equipment which are compatible with clocks.

To conclude, consensus models are different, each model has different advantages and disadvantages as shown in table 3.

Table 3: Consensus algorithm with advantages and disadvantages.

Consensus Model	**Aim**	**Advantages**	**Disadvantages**	**Vulnerabilities**
Proof of work (POW)	To publish blocks amongst untrusted stakeholders	Easy to check and validate blocks	Most complex algorithm, requires high computational power over time	51% control, hold 51% of nodes in a network to control it.

Proof of Stake(POS)	To publish blocks with less complexity among untrusted stakeholders	Less complexity than pow	stakeholders can control the system	51% control, nodes can stake 51% of the whole worth of the Blockchain and control the chain.
Round Robin	To publish blocks amongst trusted stakeholders	least computational power is required	Stakeholders should be trusted completely	Only trusted stakeholders can access the Blockchain
Proof of Elapsed Time (POET)	To publish blocks with a great sense of security, improved upon POW	Less computational complexity than POW and more secure	Expensive hardware equipment is required	Hardware clock can be compromised.

While the consensus algorithm has advantages and disadvantages, blockchain is completely based on private-public key cryptography so cryptographic challenges must be investigated. Next, the cryptographic challenges are investigated.

Public-Private Cryptography

Public-Private cryptography is an encryption method where a set of encryption keys are generated. The first one is a public key which is available to everyone, and the second is a private key used to send a message but first it is encrypted with the receiver's public key. This encrypted message is sent and can only be decrypted by the receiver's private key. There are different encryption standards to generate a set of keys: RSA, DSA, etc (Bybit, 2021). It is virtually impossible to find private keys from the public keys. This is not possible as there is not enough computational power present to solve the problem.

When quantum computing was proposed, it rendered this encryption method useless. According to a paper published by Perlner and Cooper (2009), there are a few encryption algorithms which can resist quantum computing to an extent, as they were able to sustain under Shor’s algorithm. This does prove that until an ideal quantum state is achieved, cryptography is secured and can be trusted.

Organizational Challenges

Now that the technological concerns have been investigated, this subsection is focused on the organizational concerns such as industry adoption, governance and culture.

Blockchain has the potential to deliver vast savings by improving operational efficiency and generating value through new business models (DHL, 2018). However, as with many emerging technologies, considerable challenges

must be overcome before blockchain can achieve mainstream adoption in all industries. Industry adoption is one of the determining factors of whether blockchain is successful or not, specifically in the logistics industry, as organizations are able to securely exchange data with accuracy and accountability. These features are very important within the community. For example, A social media website like twitter only became popular when more people adopted it, the stronger the community became (DHL, 2018).

A powerful network in the supply chain is formed when stakeholders reach a critical mass which means reaching an adoption number to encourage organizations to integrate blockchain into their ecosystem. As more organizations participate, the more valuable the blockchain becomes making it a standard Industry norm. However, it will be difficult at first to obtain stakeholder commitment because of differing levels of digital readiness and the initial requirement to recognize the mutual benefits of blockchain-based collaboration. This will be particularly tricky when there are legacy processes, regulations and laws governing various aspects of the business, as stakeholders will incur costs to migrate from legacy systems and integrate with new systems and practices (DHL, 2018). Governance and standards are also a challenge for blockchain. This means that there are multiple blockchain implementations across various industries and each blockchain is designed according to its own set of standards. organizations should set a unique set of standards which can allow them to share

data among blockchains if that happens in the future. Some organizations have started taking initiatives like BITA (Blockchain in Transport alliance) (BITA, 2019).

Governance is followed by the organization and cultural challenges which are the key for any industry to adopt a new technology. Adoption of new technology requires a collaborative mindset from the stakeholders who should actively push blockchain technology to be used, alongside managers working in IT departments who should gain knowledge and expertise in blockchain technology and pro-actively suggest adoption for blockchain-based solutions. To conclude, organizations should have a collective mindset to benefit from the advantages of blockchain technology.

The consequences of supply chain disruptions can be addressed to some extent by the solution which is blockchain technology. After blockchain technology is introduced, one can understand the benefits and challenges of blockchain technology. The next chapter will provide use cases to show detailed implementation of blockchain technology.

CHAPTER FOUR

BLOCKCHAIN USE CASES IN VARIOUS INDUSTRIES, SUCCESS AND THE CHALLENGES

Use cases that have been chosen for this project are operational and functional on the Ethereum ecosystem at full scale. The case studies that have been selected in this project are available from the Ethereum website which shows live projects on the Ethereum Blockchain. These use cases are regarding Supply Chain Management in various industries ranging from mining to financial. The following examples show real world use cases and a few pilot programs, challenges they faced, the solutions used, and the corresponding outcomes. Ethereum website [1].

From these case studies, I draw the implementation methods, the impact of the solutions used to solve a problem, and how effective the solutions are. A second source for use cases is the Hyperledger Fabric website. These are a set of permissioned Enterprise projects on this website. After looking at these use cases, blockchain use cases and the features of blockchain technology that are used to solve the existing challenges can be understood. Hyperledger Fabric website[2].

[1] https://ethereum.org/en/enterprise/
[2] https://www.hyperledger.org/use/fabric

Case Study 1: CargoX

CargoX is a digital courier services company which aims to make physical paper obsolete. Its solution for digital courier is based on blockchain technology which ensures proof of authenticity and proof of ownership. CargoX specializes in a smart bill of landing in the logistics industry which supports ocean freight, air freight, road freight and rail freight documentations (CargoX, 2020).

Challenge: Ensure paperwork cannot be tampered and paperwork is signed each time when ownership is changed. Also, expedite the paperwork process amongst various stakeholders in a supply chain by providing a digital bill of lading by port authorities to a seller, receiver, and logistics company instantaneously.

Solution: Proof of authenticity ensures the document is not tampered after it is uploaded to the blockchain and the document is signed by the original uploader and each time the document is transferred using a hash algorithm ensuring authenticity. Proof of ownership ensures accountability when a document is uploaded and it is treated as a legal document which verifies the ownership of an item. An audit log is attached and transferred with the document which contains the history of ownership. Once this is attached to the document, the sender can view this document. Once the document is accomplished, destroyed, or released, the workflow stops and the document cannot be transferred anymore (CargoX, 2020).

CargoX platform adapters have seen various benefits, listed in table 4.

Table 4: Benefits of CargoX Solutions.

Conditions	**Traditional bill of lading**	**Smart bill of Lading**
Cargo Information like conditional monitoring (temperature, location) etc.	no	yes
Can be stolen or lost	yes	no
Archive	Expensive paper storage	Digital Document storage
Change of Ownership	Only done physically	Instant
Time of Transit	five to ten days	Instant

Indian ocean ports are using a bill of lading solution provided by CargoX (LeaderInsights, 2020). The Indian Ports Association (IPA) and the trade bodies in the Federation of Indian Logistics Association (FILA) have seen the importance of going digital as the global pandemic struck hard. The Government of India accordingly started evaluating ways to implement electronic bills of lading, electronic delivery orders, certificates of origin, letters of credit, and other trade documentation. Apart from Implementation, the integration process was also very swiftly completed, India’s ports were previously using Portall

Infosystems. This whole integration and implementation of the project was completed in a span of six months.

Conclusion: The solution provided by CargoX saved time and better documentation management as users could easily browse through paperwork at the hit of a button. It ensured authenticity of the document, the document was signed each time it changed ownership and finally logistics companies have seen expedited processing of shipments at ports.

This shows that paperwork can be trusted even if it was digital as it was tamper proof and authenticity was guaranteed. This digital paperwork also provided features like shipment conditional tracking where stakeholders had to trust the paperwork. This paperwork process is not limited to ocean freights but also includes road and air transport.

Case Study 2: Minespider

Minespider is a company which specializes in product traceability leveraging the blockchain technology, one of such applications is their project with Luna smelter, which is located in Rwanda, Kigali. Luna is the only tin manufacturer in East Africa which is in compliance with the responsible minerals initiative (Minespider, 2020).

Challenge: The company Luna smelter had to ensure their customers that tin was responsibly sourced while making profit. Their competitors went to extreme methods to ensure profit by exporting cassiterite (tin oxide mineral, an important source of tin) to different counties where they have established smelting facilities, and this practice added less value to the native country.

Luna smelter adopted blockchain technology to have tamper proof and time stamped tin shipments. This also led Luna smelter customers to receive documentation instantaneously and provided the customers the ability to conduct supply chain audits (Minespider, 2020).

Solution: Luna Smelter teamed up with Minespider to implement blockchain technology. This project was developed using a grant from the raw chapters of the European institution of innovation and technology. The project was built on three different data layers: a public layer, transparent layer, and a private layer. The public layer allowed for an audit while the private layer ensured that no confidential data was leaked regarding the Luna smelter or its customers. Finally,

a transparent layer was added to bridge these two, where a stakeholder with authority could trigger an audit.

These layers on blockchain had certificates issued by Luna smelter which were accessed using a QR code printed on each shipment with detailed information like location history, material type, date of delivery, owner details, customer details and finally weight of the shipments. This certificate could not be tampered with, ensuring safe sourcing of the metals.

Conclusion: There are three outcomes for Luna smelter due to the project implementation: The first was digitalization. All the company's paperwork was digitized making shipment transfer more efficient. Compliance assurance is the second outcome and each shipment is equipped with a QRcode which ensures traceability history and the correct data needed for regulation compliance, like the EU conflict Mineral Regulations, followed by strengthened brand image, increased brand value and finally increased client satisfaction as their clients are assured that the tin they are using is responsibly sourced as they have access to Luna's shipment data (Minespider, 2020).

Case Study 3: Walmart

Walmart is a leading grocery and ecommerce chain-based in the United States of America and has 10526 locations spread across the world (Walmart, 2021).

Challenge: Walmart wanted to bring food safety and transparency to the mainstream through the implementation of blockchain technology. Walmart ran a pilot program with IBM to track their food produce. The aim of the pilot program was to track two food products, one of which is pork sold in Walmart's China store and the second was mangoes sold in Walmart stores in the United States of America (Walmart 2018).

Solution: Walmart considered moving forward with Hyperledger fabric for its blockchain implementation as it was permissioned and one of the few enterprise grade blockchain. Walmart leveraged the smart contract system called the chain code. A terminal was set up at the farmers end and one at the store end. At the farmers end, produce was tagged with a QR code which leads to a digital document showing the composition of the produce like fertilizers used, whether it is organic or non-organic, the origin location details and packaging date alongside storage and shipment conditions. This ensured the when was packed, manufacturing history and shipment details. Through this QR code, in case of an outbreak, tracking the products and recall procedure was completed within a matter of hours.

Conclusion: The pilot was a great success as Walmart can now track products within 2.2 seconds which was an improvement to the previous seven days. This program is intended to ensure food safety in case of a food disease outbreak. Now, Walmart can quickly recall the affected product without any delays (Walmart, 2018).

Walmart has teamed up with IBM to continue this project and track over twenty-five products from different suppliers and the list of produces which Walmart tracks today are produce like fruit and green leafy vegetables, meat like chicken, and pork, Dairy products like almond milk, yogurt and finally multi ingredient products such as salsa and baby foods (Walmart 2018).

Case Study 4: HSBC

HSBC (Hongkong shanghai Banking Corporation) is one of the world's biggest banking and monetary administration associations. HSBC serves more than 40 million clients through their worldwide organizations by providing services like Wealth and Personal Banking, Commercial Banking, and Global Banking and Markets. Their organization covers 64 nations and domains in Europe, Asia, the Middle East and Africa, North America and Latin America (HSBC, 2021). HSBC implemented the first Blockchain based letter of credit.

Letter of credit is a document provided by a bank ensuring the seller is paid on time and in full amount. This is a required document for international trade, for when buyers and sellers belong to a different region: country. This document ensures that the seller receives the buyer’s payment in full and on time (International Trade Administration, 2021).

Challenge: Traditional paperwork amongst stakeholders takes extensive processing time as banks involved in international trade are present in two different countries. This process had to be streamlined and had to involve trust into the system as banks acted as intermediaries. Before the implementation there was always a lack of trust. The traditional processing of a letter of credit took a period of 5-10 days resulting in slow trade. Banks require a system where trust is established amongst the stakeholders (i. e, the banks, suppliers and buyers) and maintained while the whole process takes place under 5 days to

process the paperwork and complete the payment after the paperwork is processed (r3, 2018).

Solution: HSBC and ING banks joined hands with r3, a Blockchain solution-based company, to implement a test pilot program as a proof of concept. This program was designed with privacy in mind: when a letter of credit was issued only the issuing bank and its client had knowledge about it and not the beneficiary bank. This provided the banks with access control. Now this letter of credit is paired with a digital bill of lading which ensures shipment is delivered and only then the beneficiary bank receives the copy of the document and finally receives the payment.

Conclusion: The implementation of blockchain technology in letter of credit ensured trust amongst different parties as no document was tampered with and it also showed the parties that have accessed the document and when the letter of credit was paired with lading document. It also automated confirmation time and reduced the payment processing time and this whole process was completed within 24hrs. Previously, this process took 10 days of completion due to the traditional systems.

This implementation demonstrated that blockchain technology could transform international trade to a new era where all the paperwork is digitized, all the stakeholders of the supply chain had trust in the document, i. e., banks need not to physically verify information and payment could also be automated as there was no need for verification.

A similar working solution is provided by Amazon and its implementation of blockchain technology for Contura Energy.

Case Study 5: Contura Energy

Contura Energy is a Tennessee-based coal supplier with affiliate mining operations across major coal basins in Virginia, West Virginia, and Pennsylvania. It is stated in their report that “We export metallurgical coal, a key raw material in steelmaking, to customers on five continents and approximately 25 countries” (Contura Energy, 2021).

Contura delivered around 12 million tons of metallurgical coal in 2020, and approximately 7–8 million tons are bound for the fare market. Contura utilized letters of credit (LC) surpassing $250 million out of 2019 to work with their worldwide exchange. LCs assist with moderating nation and client hazard. The current cycle requires numerous layers of correspondence among Contura and third parties, for example, cargo transporters and outsider coordination, that set up a few key archives, like the bill of filling and declaration of weight for adherence to the LC. Each progression requires manual action and the utilization of a dispatch, which is wasteful, expensive, and subject to human blunder. The outcome of the LC cycle is affirmation by Contura's bank, which guarantees installment if the archives are considered clean.

Challenge: Any inconsistencies in the documentation could prompt a postponement in installment or a most dire outcome imaginable where Contura loses the chance to convey a vessel because of discrepant desk work. Something as straightforward as inconsistent documentation led to a possible reason for a bank to dismiss the documentation. The documentation doesn't

permit a lot of time to address mistakes with actual mailing archives to people as they are in radically different time zones, regions, and areas.

Solution: Contura teamed up with Amazon web services to implement blockchain technology-based solutions. A smart contract was drawn in between the banks and third parties to automate the whole process. This was implemented with an access control which enabled users to give authority to view documentations on a need-to-know basis. This was implemented using Hyperledger Fabric's native control, authentication and authorization of users was done through Amazon Cognito. This software provided users with certificate authority, permission of usage and access levels.

Business logic is embedded into the smart contract to enforce certain business rules. For example, after Contura's advising bank has completed publishing the terms of the LC data, those terms are locked in the smart contract and are no longer editable. When this happens, the contract state is updated to reflect that the LC is now awaiting Contura to receive and publish required documents as they receive them from various third parties.

An automated audit and log system was created using DynamoDB which is used to capture all the events in a Blockchain.

Conclusion: This whole implementation was done as a pilot where Amazon web services were easily integrated and elevated with blockchain technology and the whole process integration was completed without making major changes to the existing platforms. As of now, this pilot program is successful, and Amazon is

ready to scale as soon as it has more customers willing to use this platform. This platform can now support customers, banks, sellers, buyers, and logistics companies.

Real time implementations and pilot programs of blockchain technology in a supply chain and the challenges it had addressed for supply chains, the integration process and finally the outcomes of the implementation were all successful. A framework is required for a successful project. An organization should develop a framework on how it can implement blockchain technology. Such a framework is the foundation on which software developers can build a program for a specific application. In the next subsection, a framework is presented for blockchain implementation.

Blockchain Framework for Businesses

A business can get started on blockchain by developing and implementing a framework which ensures smooth integration of blockchain into their business. Enterprise implementations of blockchain require a business plan on how an organization prepares for the adoption, how it selects its blockchain and finally how it will mitigate its risks in the process of adoption.

A methodology shown in figure 5 is the prescribed methodology by IBM Blockchain specialist Nitin Gaur, which is a four-step process: 1) identify the appropriate use case, 2) draw a business blueprint from refining or tuning the existing business process, 3) develop the technology blueprint, and 4) ensure

integration with the legacy systems (Blockchain for Business, 2019). Each process is explained in detail.

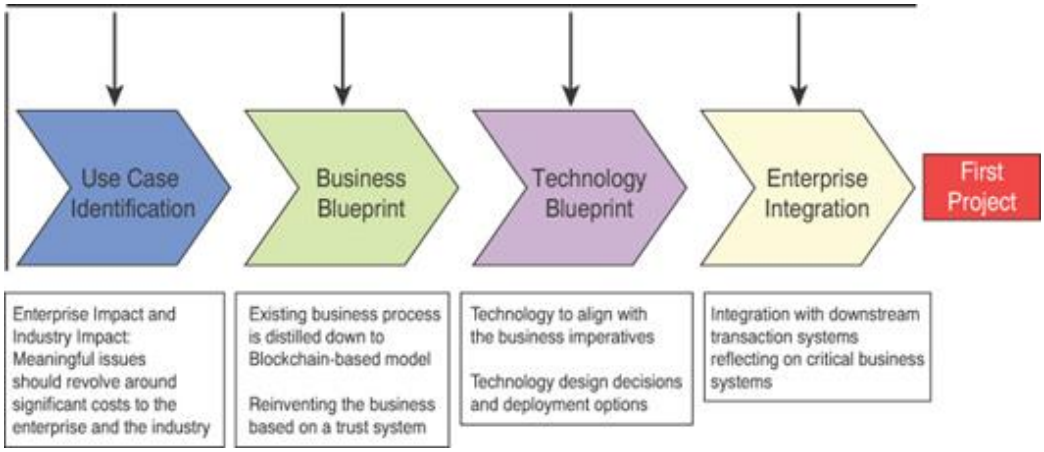

Figure 5: Integration Framework of Blockchain into Business Process (Blockchain for Business, 2019).

1. Identify a Use Case:

An organization must spend more time and effort to find use cases which would be similar to their project. When the blockchain use cases are selected, the implementations should have passed the testnets test (i.e., a simulation of the actual blockchain that provides a sandbox capability without disruption to the mainnet). The testnets are evaluated on three factors that are trade, trust and ownership.

Trade factor determines the number of stakeholders taking part of the blockchain. Trust factor showcases the reliability of the transactions taking place in the blockchain. Ownership factor ensures accountability and authority whether a stakeholder is able to make transactions in the blockchain or not. This step will determine the capital required for the blockchain project and the overall return on investment.

2. Business Blueprint with Refined Process:

Considering the existing business model of the supply chain, a plan is drawn to see how the supply chain can be transformed into a blockchain based transactional model. This will determine the technical elements of the business. For example, consider a business plan conversion framework like asset and transaction model. Here assets are the things which need to be tracked like vehicles, shipping containers or files, text information. In addition, transactions will be the business process which has an impact on the assets like timestamps, locations, or sizes and so on. This is how a business should transform its business process according to the transactional model of blockchain as the whole business will be reinvented on a trust-based system.

3. Developing a Technology Blueprint:

This step will determine the technological decisions to be made like choice of blockchain, logging requirements, audit capability and choice of consensus

algorithm, security requirements like authentication and authorization, visibility of data, and transaction requirements.

This technological blueprint, when completed, will have the following details like block data format which determines whether the data generated is enough or does the business process need transformation. Data visibility shows how data will interact with other systems internally or externally. The consensus algorithm determines how a ledger will function or which usernode is selected to mine data. This step will also determine the deployment mode of the project, i.e cloud, on-premises or hybrid. Deployment mode will have a huge impact on the project's budget. Hence the most efficient deployment method should be chosen. At this stage, choices are made to address the business requirements which are the transaction speed and transaction number. The final step is determining the project's cost.

4. Integration with Legacy Systems:

Once the blockchain is developed or ready to be deployed, organizations should also check organization's adjacent systems for compatibility as it should be working in cohesion with blockchain. Hence, transformation costs and compatibility should be considered early on when the project is designed.

This four step process ensures that a proper framework is built. Such a framework ensures the integration of blockchain into business processes without any mishaps. The implementation of the blockchain lies within the business on how it would like to implement blockchain. There are two ways to implement

blockchain into a business's ecosystem: the first option is to get help from a big name consulting company, or a blockchain solution-based company for the implementation. Consulting firms which specialize in blockchain include IBM, Capgemini, DHL, MAERSK Accenture and Deloitte. Apart from the consultancy firm one can also look into blockchain solutions companies like Simbachain, Binance, CargoX, Minespider, and Consensys.

The second option is to hire all the required technical personnel or train the existing personnel to acquire a new skill set which can enable the integration of blockchain into their supply chain. Table 5 summarizes the companies providing Blockchain- based solutions.

Table 5: Companies providing Blockchain-based solutions

Blockchain Application Journals	**Blockchain solutions**	**Source**
IBM Blockchain	Supply chain management solution to a wide range of industries ranging from food to media and entertainment.	https://www. ibm. com/Blockchain
Vechain	Combines IoT and Blockchain to Monitor Food and Drug products.	https://www. vechain. com/
Simba Chain	Blockchain solutions for multiple industries using smart contracts.	https://simbachain. com/resources/use-

		cases/
Capgemini	Banking, supplier contract management, structured finance and Manufacturing organizations.	https://www. Capgemini. com/beyond-the-buzz/Blockchain /#smart-contracts-from-hype-to-reality
Consensys	Asset management and global trade	https://consensys. net/blockchain-use-cases/global-trade-and-commerce/
Minespider	Blockchain based Supply chain Management solutions for upstream and downstream Industries. Upstream is where minerals are extracted from the ground. Downstream is when minerals are processed and the final product reaches the store.	https://www. minespider. com/

Binance	Financial solutions and blockchain-based cloud	https://cloud. binance. com/
CargoX	Blockchain based document transfer.	https://CargoX. io/

So far blockchain technology has been implemented in various industries.

According to the forrester report, data integrity was the highest cause in supply chain disruption , in order to avert data integrity blockchain technology should be used.

I have built a project prototype which can ensure data integrity in a supply chain. The project is built using the SIMBACHAIN platform.

Project Prototype

A Blockchain prototype application was developed using the SIMBACHAIN platform.

The goal of this project application is to maintain data integrity and automate a few transactions between stakeholders in a supply chain for a logistics company, buyer, seller and their respective banks. Data integrity was maintained by providing stakeholders with the assurance of tamperproof documentation and providing container provenance as the shipment changed hands throughout the supply chain. This is made possible using smart contracts that is constantly tracking the status of a container using data provided from a sensor which has the capability to monitor status like temperature, weight and also report active locations of the container, this data will be combined with shipment documentation and will be recorded on blockchain as a transaction.

Designing the Smart Contract:

The smart contract was built on the SIMBACHAIN platform was designed as follows:

1. Input “Port_Authority”, “Bank_Buyer”, ”Bank_Seller”, ”Buyer”, ”seller” and “Logistics” as assets in the SIMBACHAIN contract graph. Input “Bill of Lading” and “Letter of Credit” as a transaction on the SIMBA graph. Then, it is proceeded to illustrate their asset to transaction relationship by connecting them together.

2. After the graph is completed, the attributes to the asset and transaction were added by clicking on them. Figure 6.1 shows all the stakeholders present in the blockchain i.e port_authority, banks, Buyer, Logistics and Seller. The stakeholders are connected via transactions i.e Bill_Of_Lading and Letter_Of_Credit.

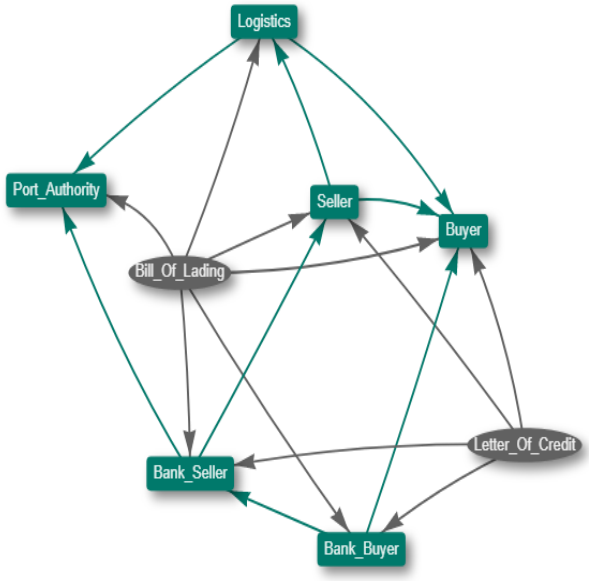

Figure 6. 1: Graph Illustrating Supply Chain Smart Contract.

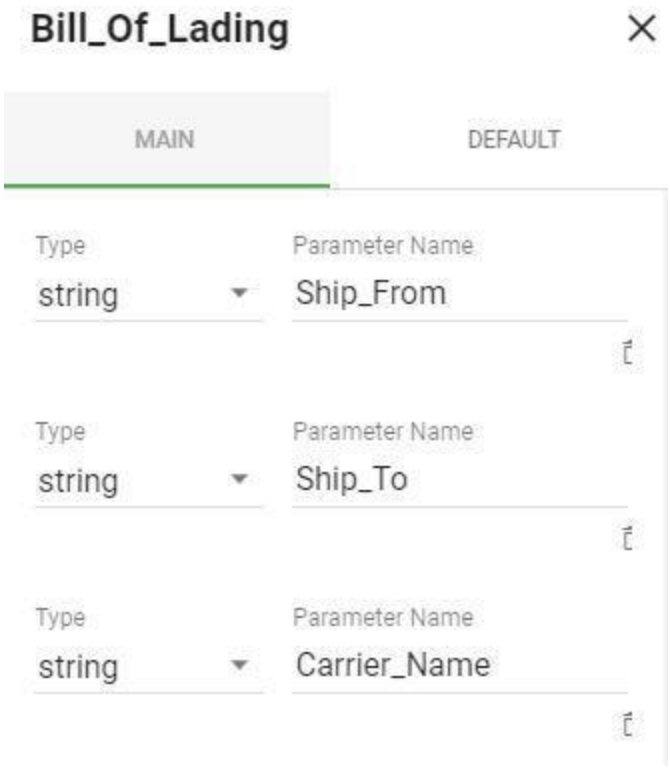

Figure 6. 2: Adding Attributes to the Assets in SIMBACHAIN.

Figure 6. 2 shows the Attributes to the assets in SIMBACHAIN i.e each asset should have a name , in this case buyer , seller ,logistics company and the banks. Parameters of the package being sent by the seller , the delivery details of the buyer, their respective bank details and logistics company details.

3. After saving the attributes, I clicked on “<>” at the bottom right of the screen to view the code of the smart contract. Figure 6.3 shows the smart contract code which was programmed in solidity programming language.

```
pragma solidity ^0.5.12;

contract Application {

    constructor() public {}


    function Buyer (
        string memory __Buyer
    )
    public {
    }

    function Seller (
        string memory __Seller,
        string memory __Buyer,
        string memory __Logistics
    )
    public {
    }

    function Logistics (
        string memory __Logistics,
        string memory __Buyer,
        string memory __Port_Authority
    )
    public {
    }

    function Bank_Buyer (
        string memory __Bank_Buyer,
        string memory __Bank_Seller,
        string memory __Buyer
    )
    public {
    }
    public {
    }

    function Bank_Seller (
        string memory __Bank_Seller,
        string memory __Seller,
        string memory __Port_Authority
    )
    public {
    }

    function Port_Authority (
        string memory __Port_Authority
    )
    public {
    }

    function Bill_Of_Lading (
        string memory Ship_From,
        string memory Ship_To,
        string memory Carrier_Name,
        string memory Shipment_id,
        string memory _bundleHash,
        uint64 datetime,
        string memory __Port_Authority,
        string memory __Bank_Seller,
        string memory __Logistics,
        string memory __Bank_Buyer,
        string memory __Seller,
        string memory __Buyer
    )
    public {
    }

    function Letter_Of_Credit (
        string memory Beneficiary,
        int8 Amount,
```

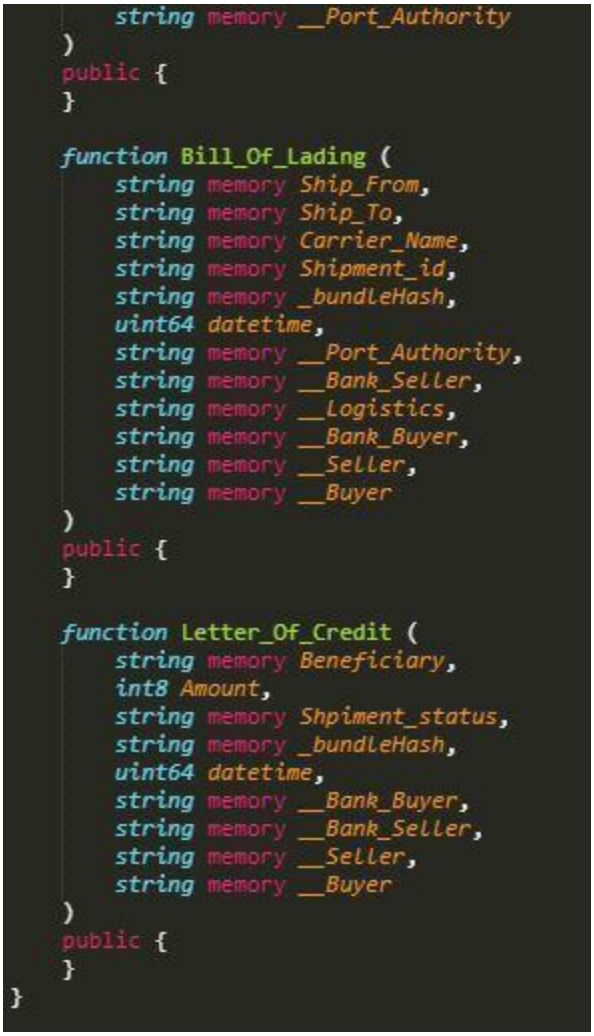

Figure 6. 3: Toggle from Graph to Code View in SIMBA

4. Then, I clicked on the cloud icon on the bottom left of the screen to save the newly created smart contract. Figure 6.4 shows the smart contract project is saved to the cloud.

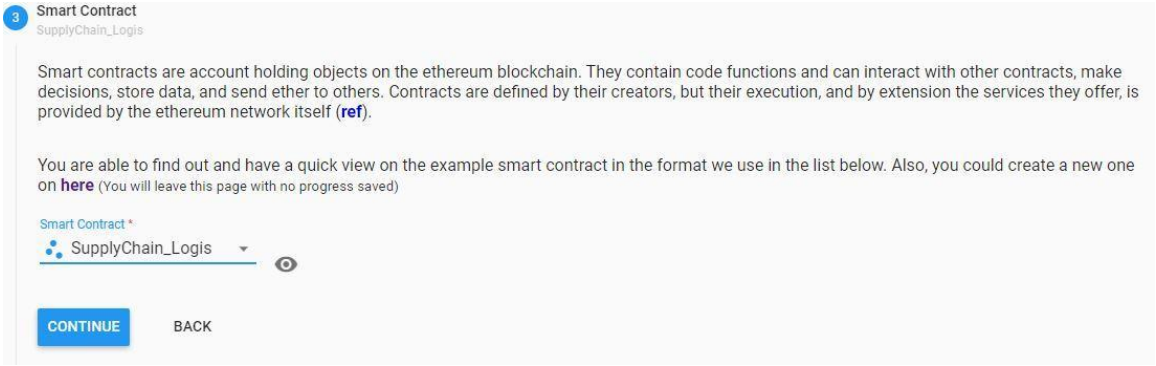

Figure 6. 4: Saving and Naming the Smart Contract.

Deploying the Smart Contract:

The smart contract “SupplyCHain Logis” was deployed on the Quorum Testnet by using following steps:

1. Click on the “application” tab on the SIMBA dashboard and choose your newly created smart contract. Choose the intended Blockchain Type and Network Type. Figure 6.5 shows the deployment method and blockchain selected is quorum and the smart contract is deployed into the testnet.

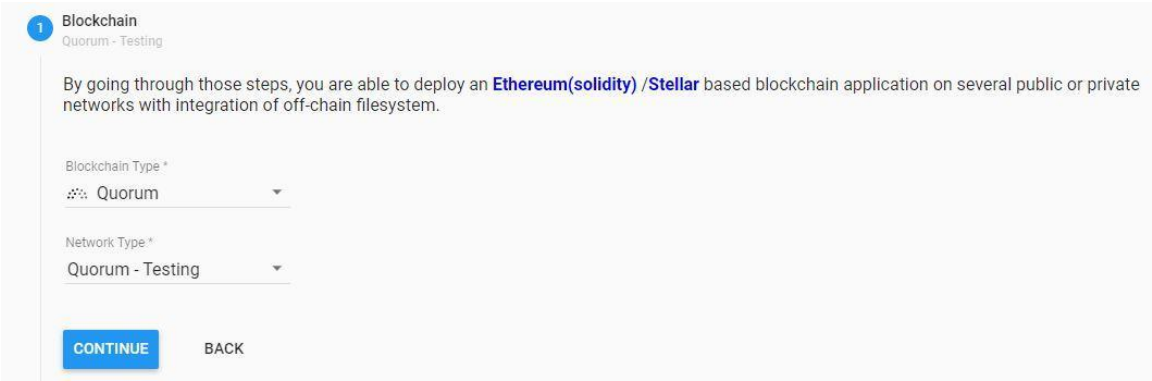

Figure 6. 5: Deployment Type and Blockchain Network Choice.

2. Choose the off-chain filesystem to utilize. Figure 6.6 shows how cryptographically hashed data can be offloaded into a peer to peer network using the IPFS network protocol.

Figure 6. 6: Choosing an Off-Chain File System

3. Next, name the application along with the API appropriately, as shown in Figure 6.7. This API can be used to integrate the smart contract into the stakeholders application.

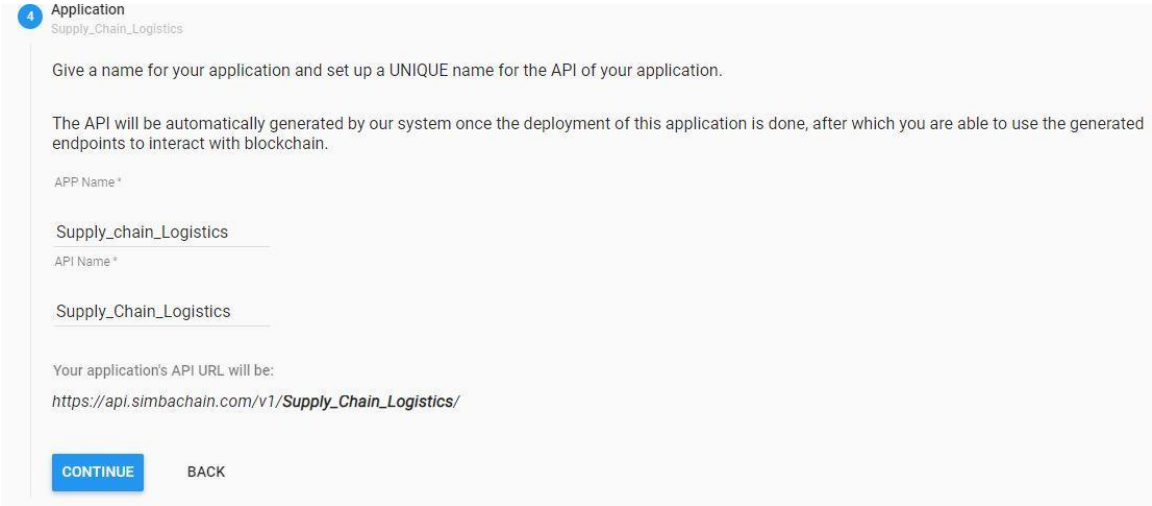

Figure 6. 7: Naming the Application and API

4. Lastly, choose a wallet or create one if you do not already have one. Input your password and click “Unlock”. Proceed to click “Deploy” and your application will begin deployment on the Quorum Testnet. Figure shows the smart contract has been deployed and transactions between the stakeholders have to signed using their private keys.

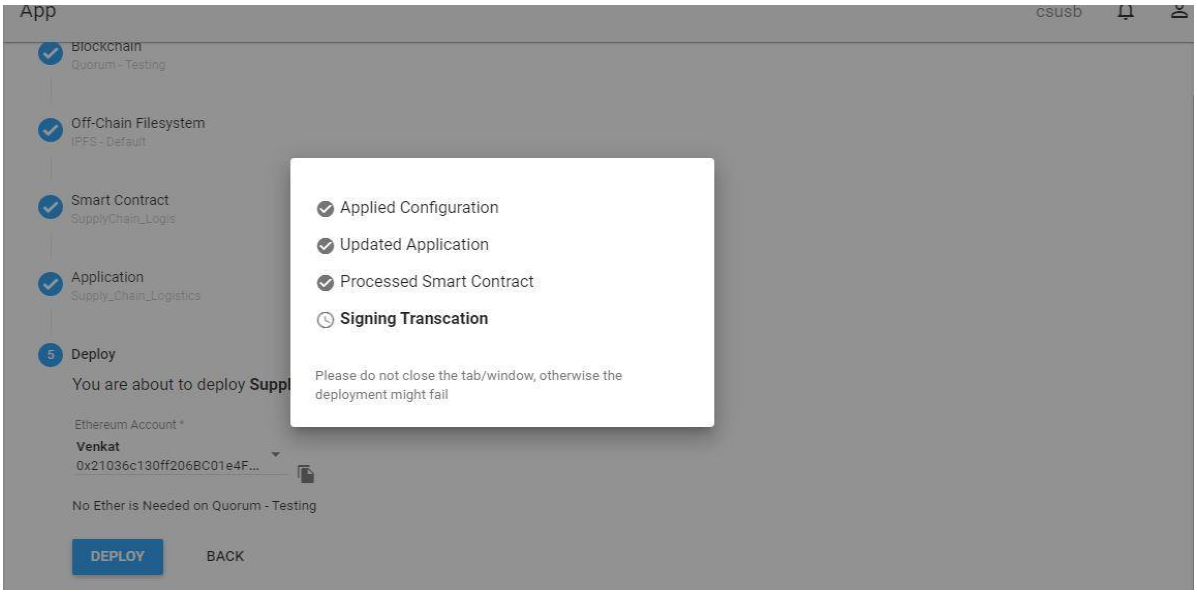

Figure 6. 8: Setting the Ethereum Wallet and Deploying the Application

The smart contract ensures that data entered by every stakeholder is signed using the stakeholders private key ensuring authenticity and data entered by these stakeholders is tamper proof which is ensured by the blockchain's encryption standard. The seller enters shipping details, buyer bank details, seller bank details and package details to be shipped. The seller can enter elevated monitoring conditions for the package which is monitored by IoT devices present with the logistics company and the data is written into the blockchain.

When the delivery status is updated by the port authority while ensuring the package conditions are fulfilled by the logistics company the smart contract will execute on the bank's end which automatically triggers the payment to the

buyer and the buyer's bank is notified. This results in successful transfer of the package.

The smart contract will be destroyed automatically, if the delivery conditions set by the buyer or the seller were not fulfilled or if the delivery was not fulfilled within a certain time period.

The outcome of this prototype case ensures that the data shared between the stakeholders is authentic, authenticated and tamper proof. This also saves time by automating the process of sharing the required documents to the respective stakeholders.

The buyer and the seller are happy as they can track their package in real time without worrying about the integrity of the data and the banks are happy as they get verified documentation which has been signed by the seller, buyer, port authority and the logistics company .The banks do not need to initiate a payment as it is already automated if the package delivery was a success.

To conclude, in this chapter, the integration framework of blockchain technology into the business ecosystem and a project prototype is presented.

The framework provides a four step process which can be followed by an organization which is interested in implementing blockchain technology. If the framework was followed step by step, the integration would be completed swiftly without a hitch. This framework provides the organization all the required elements to move forward with the integration plan. An organization integrating blockchain can determine the implementation through a use case, take into

account the required business transformations, the implementation costs, the risk mitigation costs and finally the integration of a compatible fit of blockchain technology into their existing ecosystem.

Also, in this chapter, a prototype case has been presented which ensured data transparency, integrity, authenticity and validation amongst the stakeholders of the blockchain.

CHAPTER FIVE

DISCUSSION, SUMMARY AND RECOMMENDATION

Discussion

Looking at the recent supply chain disruptions caused by the Covid-19 pandemic, majority of the companies who were surveyed agreed that it has caused a major supply chain disruption and are looking towards technology for a solution to the disruption problem. Organizations are actively transforming their traditional supply chains into digital supply chains which will help them operate their supply chain while satisfying stakeholders requirements. This digital transformation is being implemented with technologies like Blockchain, Internet of Things, Data Analytics, Automation and Artificial Intelligence.

Blockchain adoption rate is not high. However, it is widely accepted by organizations that blockchain can address their existing supply chain issues especially when blockchain is paired with different technologies like Internet of Things. This way organizations can have automation while having trust in their supply chain. Organizations are still waiting for blockchain technology to become mature as there are limited options of blockchain for an organization to choose from (Blockchain for Business, 2019).

Blockchain technology showcases a number of challenges and opportunities for an organization. Not all the existing blockchain technologies available are scalable. For example, they cannot necessarily support an

organization which currently does not have a data center to operate. However, over the past few years a few organizations have successfully implemented projects which are at scale and completely operational.

In this project, the blockchain challenges have been investigated in different use cases. Blockchain challenges are more about taking an initiative but once completely implemented the benefits overcast the challenges. Challenges faced by the organizations are related to transformation, integration and capital, meaning how an organization has to transform its business to fit blockchain into its ecosystem. This is followed by integration where once the business process is transformed into a transaction-based business model how will it incorporate this technology with other systems which are legacy systems. Finally, calculating the capital investment required for the project is challenging which also accounts for the return on investment.

In this project, the blockchain benefits have been investigated. Blockchain can benefit supply chains in different ways as presented in the case studies. Organizations have seen faster processing times due to digitization, increased reliability for consumers as organizations were able to prove traceability of a product, and finally, organizations were sharing reliable information amongst the stakeholders of their supply chain.

Recommendation

Based on the use cases that are presented in this project, some conclusion remarks and recommendations are presented as follow:

Early adoption:

The adoption rates of blockchain technology are still at the early stages. More organizations are taking interest in blockchain technology which only means that blockchain adoption in the future will become expensive. According to the report published by Capgemini (2018) we have entered the final transformation and adoption phase of blockchain. Also, the report by the Forrester investigation in the year 2020 shows that more organizations are willing to digitize and adopt blockchain (Capgemini,2018).

Using a Framework for Transformation:

Now that the businesses are willing to transform, it is best to prepare a framework which suits the existing business process while making sure the transformation takes place easily. This will eliminate any risks which will arise during the transformation. This framework will also determine the capital required for the project as well as the return on investment (Blockchain for Business, 2019).

Considering Financial Grants for Projects:

Consulting firms like IBM, Capgemini, and Tata Consultancy services are providing free consulting services for an organization to get started on blockchain. Apart from these free services, governments are providing grants to organizations for the complete development of blockchain-based solutions. This was, for example, the case for Luna smelter. The whole project for Luna smelter was completed using financial grants from the European Union.

Limitation of the Project

The scope of research was limited to a few databases using a set of keywords to browse through the database. There is the possibility that all relevant studies and literature may have not been covered. Furthermore, the recommendations are derived using theoretical knowledge and they have not been used or tested. Due to a shortage in live case studies this led to a limitation on the scope of the project.

Future Work

Future research is needed for adopting the recommendations of blockchain technology in practice. This project only determines an initial process to be followed which were shown using a few existing use cases. Actual implementation of blockchain requires extensive research.

Conclusion

Blockchain technology in Supply Chain Management involves much more than installing a software program. It requires careful planning and implementation of business processes. A suitable solution for an organization depends on the project use case, available capital and the required mindset of the organization. Taking into account the blockchain opportunities when contrasted with the challenges, will benefit Supply Chain Management greatly.

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