AMERICAN UNIVERSITY OF BEIRUT

BLOCKCHAIN AND THE SUSTAINABLE SUPPLY CHAIN: FOCUS ON THE HEALTHCARE INDUSTRY

by
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When I started this project at the end of 2019, little did I know about what we would be facing in the coming year. Aside from the world pandemic, we experienced the third biggest explosion in the world here in Beirut. My acknowledgements would be incomplete without thanking the families of the victims of the Beirut explosion for inspiring us to believe in a better tomorrow.

ABSTRACT
OF THE PROJECT OF

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Major: Business Administration

Title: Blockchain And the Sustainable Supply Chain: Focus on the Healthcare Industry

Supply chain managers are being pushed today by changing customer demands and environmental factors, such as the pandemic, to improve their supply chain management capabilities so they can maintain a competitive advantage. The most necessary capabilities we identified are agility in responsiveness, flexibility in sourcing, resilience, visibility, assurance of quality and security, adherence to sustainability, as well as cost efficiency. Digitization is a promising panacea for the complications of the supply chain function, and our research shows that blockchain proves to be the prominent technology that can transform the supply chain. Blockchain technology has seven capability pillars: decentralization, automation, transparency, immutability, security, incentivizing, and inclusion. Each of these blockchain capabilities improves the sustainable supply chain across all three dimensions: people, planet, and profit. In our project, we synthesize our findings and analysis into a framework or a matrix that links every blockchain capability to a sustainability criterion. The healthcare industry is one that is known for a complex supply chain. Healthcare-specific supply chain management challenges revolve around protecting the identity and privacy of patients, enhancing data interoperability across organizations and systems, optimizing processes, and reducing inefficiencies. Blockchain technology has a powerful transformative role in supporting healthcare supply chain players to overcome those challenges. This role can be broken down to four main use-cases: pay-for-performance models, digital identity management, health data management, and workflow management. The role of blockchain technology has a substantial impact on all the healthcare supply chain players, but our research proves that blockchain has the potential to disruptively transform the retail of prescribed drugs. Therefore, the role and skillset of pharmacists might be transformed after blockchain hits the execution phase in the healthcare industry. Since pharmacists play a key role in fighting drug counterfeit, the impact of the transformation driven by blockchain technology extends to the sustainability dimension as blockchain can empower a more effective fight against fraud and counterfeit in the drug supply chain.

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CHAPTER 1

INTRODUCTION

The function of supply chain has been viewed since the late 90s of the previous century as one of the main competitive edges that companies should invest in. This is still true today. In fact, the year 2020 has given companies a stress test for their supply chain. They were able to identify areas for improvement, innovation, and transformation in their supply chain. Customers are constantly more demanding, and their expectations are more complex to cater for as they become more concerned about ethical and environmental aspects of production and procurement. People and organizations, public and private, are very sensitive today about the security and privacy of data and digital identities. In the following figure, we chose a handful of news pieces that are representative of the main customer trends of the infamous 2020. To the left of the diagram, we identified the key supply chain capabilities that are necessary to respond and meet those customer demands.

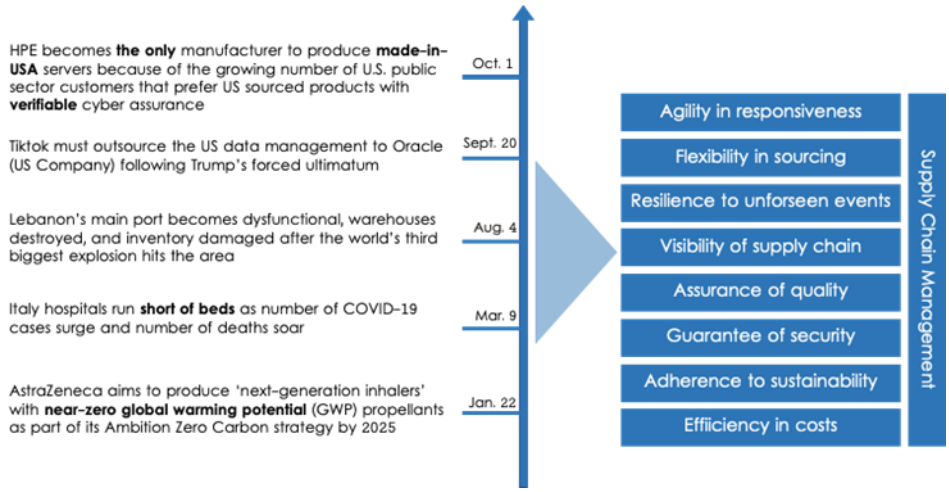


Figure 1 Supply Chain Management Trends and Capabilities

Therefore, a key question that every executive or strategist should be exploring today is: how to improve or re-engineer the supply chain to hone those essential capabilities? The answer to this question is not agnostic to industries. The easiest way to prove this is by looking at the capability "assurance of quality". While the quality of a diamond ring mainly revolves around aesthetics, the quality of a drug pill is measured in metrics related to effectiveness and efficiency. Therefore, we must focus on an industry vertical and attempt to find the ways to improve or re-engineer the supply chain in the specific context of the industry. In our research, we identified that the healthcare industry is one of those industries that have a complex supply chain. The healthcare industry ecosystem is composed of a complex network of multiple players. The payer is not necessarily the consumer, and the provider of the service is usually not the manufacturer. The global healthcare industry loses around $455 billion every year because of fraud, waste, and abuse. In more specific terms, the challenges in the healthcare industry today revolve around billing fraud, identity theft, drug counterfeiting, lack of system and data interoperability, unutilized expensive medical equipment, inflexibility in onboarding qualified suppliers, and more. When we speak of inefficiencies, we think of profit; when we speak of waste, we think about the planet; and when we speak of identities and abuse, we think about the people. Profit, planet, and people are three dimensions that fall under the umbrella of sustainability.

On the other hand, the healthcare industry is known to be of the laggard industries in the journey towards digitization. Today, digitization is a promising panacea for the complications of the healthcare supply chain system. In the world of information technology, blockchain is not only a prominent technology, but also it is believed to be the foundation of the fourth industrial revolution we might witness. In

our project, we explore the ways blockchain technology can potentially resolve the difficulties supply managers are facing in the healthcare industry.

- In Chapter 2, we provide an overview of the sustainable supply chain and its challenges.
- In Chapter 3, we discuss the main concepts and capabilities of the blockchain technology.
- In Chapter 4, we explore how blockchain technology improves the sustainability of supply chain.
- In Chapter 5, we qualify the transformative trends of blockchain technology in the context of the healthcare supply chain and evaluate their impact on pharmacies in specific.
- In Chapter 6, we focus on the dimension of sustainability in exploring the impact of blockchain technology on the pharmaceutical supply chain.
- In Chapter 7, we conclude, reflect on our findings, and suggest future research areas to be examined.

CHAPTER 2

OVERVIEW OF SUPPLY CHAIN

The world we know is modeled and has been evolving around many chains: the food chain, the supply chain, and most recently, the blockchain. Supply chain management has witnessed tremendous transformations over the years, and with it, and for it, the human being came up with concrete inventions such as the boat to sail and trade, or money as a method of exchange. The supply chain can be as complex as a hi-tech manufacturer producing a wireless speaker and managing supply, design, integration, and packaging for tens of items like the battery, the amplifier, the wireless adapter, and the processor, or as simple as a farmer selling his crops to a housewife standing on her balcony and dangling her basket to receive her vegetables (see Figure 2 (Poll)) – no intermediaries needed.

Figure 2 Selling in the Fifties in Beirut

2.1. Definition of Supply Chain

The forward supply chain is the set of processes involved in providing a product or a service to the consumer, starting from manufacturing, production, packaging, distributing, to selling to the end-user. The supply chain network includes players such as manufacturers, transporters, warehouses, distributors, and retailors. The skills required in the process vary from stage to stage as the functions vary, from product development, to manufacturing, to packaging and branding, down until delivery. According to Fisher's model, there are two types of supply chains, the functional and the innovative. (Fisher, 1997) The functional type is characterized by predictable demand, longer product lifecycles, low product variety, and longer lead times. As for the innovative type, it is usually deployed for products with unpredictable demand, shorter lifecycles, high product variety, and shorter lead times. As such, the strategic focus from a supply chain perspective is to minimize cost and maximize performance and utilization for the functional type. Whereas for the innovative type, the focus is to have a flexible supply chain system, such as modular supply chains, to cater for a market-responsive process. (Selldin & Olhager, 2007)

2.2. Challenges of Supply Chain

Like any other function, supply chain faces several challenges. In this section, we focus on the major timely issues that keep supply chain managers awake at night. We read several research papers and consulting company reports about the challenges of supply chain, and we shortlisted the seven most common challenges.

2.2.1. Lack of Visibility

The supply chain is demand driven; Afterall, it is all about creating value to the end-user. Lack of visibility on demand is driven by several factors such as uncertainty and variability. No matter how sophisticated the forecasting skills and tools of the analysts at 3M who produce N95 surgical masks and respirators, there's no way they could have predicted a doubling of production in the first two months in 2020. (Gruley & Clough, 2020) Similarly, there is lack of visibility of supply and how much suppliers can respond to surges in demand. Will a company invest in accommodating for an additional buffer capacity? Do they rely on outsourcing when needed? Matching supply to demand has always been a challenging game throughout.

2.2.2. Exponential Complexity

Producing one new product, whether for a low or a high volume, might require a set of new suppliers to deal with, which adds to the layers of complexity of a supply chain. Complexity, in turn, drives several new costs, and as a result, keeping the total cost under control becomes even more challenging. The number of suppliers is not the only factor that affects complexity. Another factor is the number of channels of a company uses to reach its customers. Every channel requires its dedicated set of technologies and equipment. One new addition to portfolio of products might require substantial changes for one or more channels. (APICS, 2016)

2.2.3. Risk

The supply chain risks vary from unforeseen operational delays, natural disasters, to political impact on trade. On August 4, 2020, a massive explosion occurred

in one of the warehouses at the Beirut waterfront significantly damaging Lebanon's main port. Shipping companies had to divert vessels to another port some of their offices were destroyed. (Paris, 2020) On another occasion, the tariffs war started by Donald Trump against China caused US companies to shift to other suppliers or to consider producing locally. The risks of supply chain must be integral part of any corporate strategy. (Conerly, 2018)

2.2.4. Cost

There are several factors contributing to the increase of costs in the supply chain industry such as the increase in fuel prices, higher labor costs, and more expensive raw materials. According to a survey run by McKinsey with more than 600 responses from diverse geographies, industries, and tenures, minimizing costs remains the number one priority for executives managing the supply chain. (McKinsey, 2010) Minimizing costs will always be a delicate issue as most supply chains cannot be cost-driven, for they cannot jeopardize the quality of customer service nor the resiliency of delivering this service.

2.2.5. Compliance

The compliance issue is two-fold, proliferation of regulations and continuously changing regulations. One of the executives of a company was quoted saying that almost everything they do has to go through a compliance check as the regulations increase. Many parties have their own mandate, and that includes US Environmental Protection Agency, the US Food and Drug Administration, the US Department of Agriculture, the US Occupational and Health Administration. The company created a

Chief Compliance Officer position and has a compliance officer in every division. (APICS, 2016) Regulations are not just increasing, they are continuously evolving and have become a moving target. To keep up with the changes, companies are spending lots of both their money and time.

2.2.6. Talent

As supply chains grow more complex, so do the competencies required for the supply chain talent base. Leaders will be looking for resources with technical competencies such as statistical modeling and risk management as well as professional competencies such as problem solving and change management. (Marchese & Dollar, 2015) Therefore, there is an increasing shortage of good supply chain talent which intensifies the talent competition in the market and makes it harder for firms to retain talent.

2.2.7. Sustainability

"Supply chain sustainability is the management of environmental, social and economic impacts and the encouragement of good governance practices, throughout the lifecycles of goods and services. The objective of supply chain sustainability is to create, protect and grow long-term environmental, social and economic value for all stakeholders involved in bringing products and services to market." (United Nations Global Compact; BSR, 2015) In 2015, the United Nations has defined ten principles of sustainability and provided a practical guide for companies to map those principles to the supply chain function. As such, companies that design operations taking into consideration the ten principles will be able to comply with standards and regulations

and help in making the business world more ethical. In the following diagram, we list and define the ten principles and we identify the relevant potential supply chain shortfalls.

Table 1 Key Shortfalls of Supply Chain in Sustainability

Area	#	Principle Definition	Potential Supply Chain Shortfalls
Human Rights	1	support and respect the protection of human rights	• Child labor • Unpaid wages • Discrimination • Excessive work • Hazardous work • Degrading treatment • Extreme site conditions
	2	not be complicit in human rights abuses	
Labor	3	the freedom of association and the right to collective bargaining	
	4	the elimination of all forms of forced and compulsory labor	
	5	the effective abolition of child labor	
	6	the elimination of discrimination in respect of employment	
Environment	7	support a precautionary approach to environmental challenges	• Toxic waste • Deforestation • Water pollution • Greenhouse gas emissions • Loss of biodiversity
	8	take initiatives to promote greater environmental responsibility	
	9	support the development of environmentally friendly technology	
Anti-corruption	10	fight corruption in all its forms, including extortion and bribery	• Procurement fraud

CHAPTER 3

OVERVIEW OF BLOCKCHAIN TECHNOLOGY

In this chapter, we discuss the main concepts, components, and dynamics of the blockchain technology. We cannot move to evaluating the impact of blockchain on the supply chain without a solid understanding of the core concepts and dynamics of blockchain technology. The following figure summarizes the seven capability pillars we identified for blockchain technology.

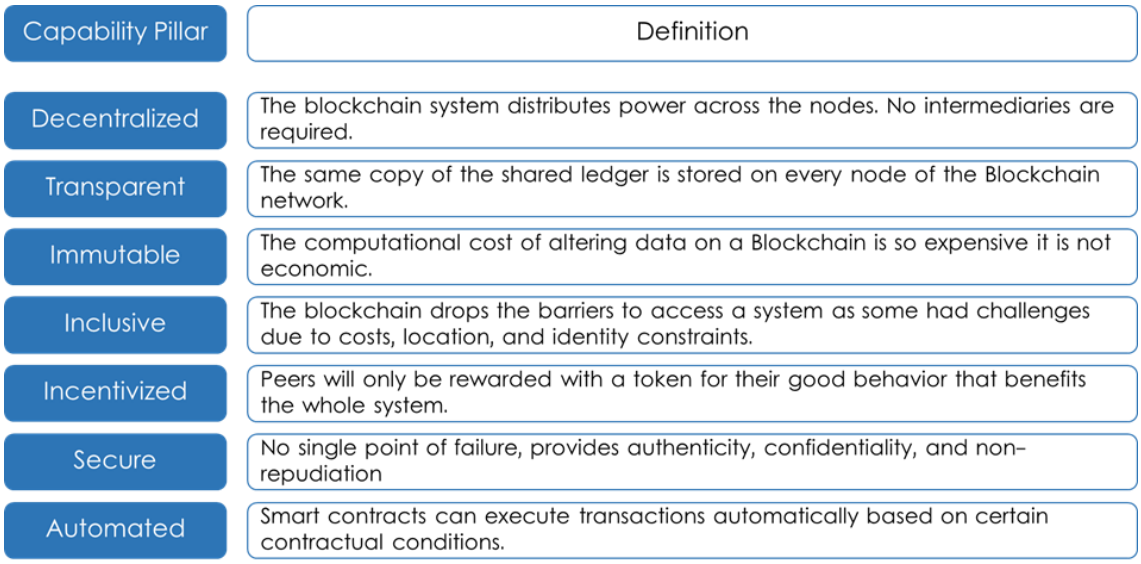


Figure 3 Blockchain Capability Pillars

3.1. Blockchain in a Few Words

A blockchain is a chain of blocks that contain information. A block represents one transaction and includes data about the sender, receiver, transaction information, and a unique identifier, also called a hash. In addition, every block also contains the hash of the previous block. We discuss the value of this feature shortly, but for now, it

is important to remember that every block is linked to the previous block, hence: blockchain.

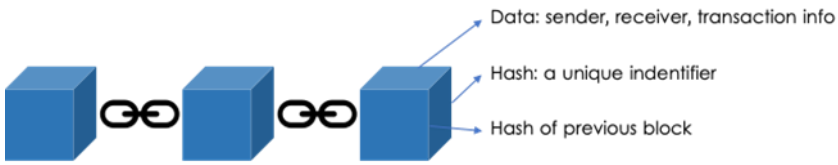


Figure 4 Information in a Block - Generic Example

The following figure illustrates an example of what a bitcoin block might include.

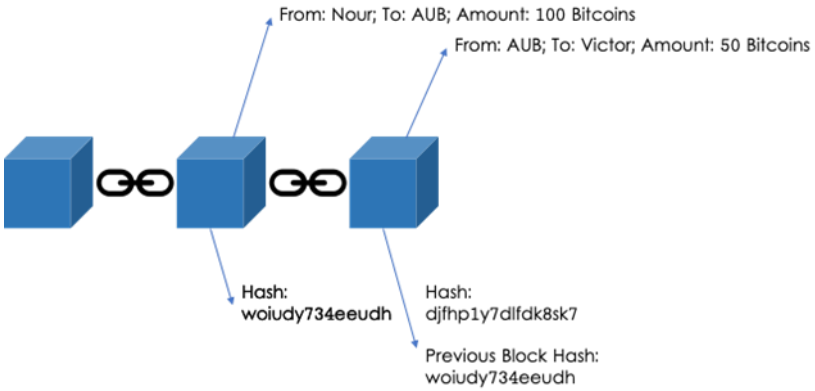


Figure 5 Information in a Block - Bitcoin Example

One of the most powerful and unique properties of the blockchain technology is that it is very difficult and expensive to alter data that is already stored on the blockchain. For instance, if someone tries to modify the number of bitcoins Nour paid to AUB from 100 to 110 in the example in the figure above, the hash will automatically change since the hash is a mapping of the content of the block. Therefore, all participants on the blockchain will notice that there is a mismatch between the new hash of block #2 and the previous block hash corresponding to block#2 in block#3. Technically, for anyone to be successful in modifying data on the blockchain, they

should be able to modify the contents of more than half the number of nodes on the network in a short time. By design, this requires intensive compute workload which is only possible if executed on expensive compute systems.

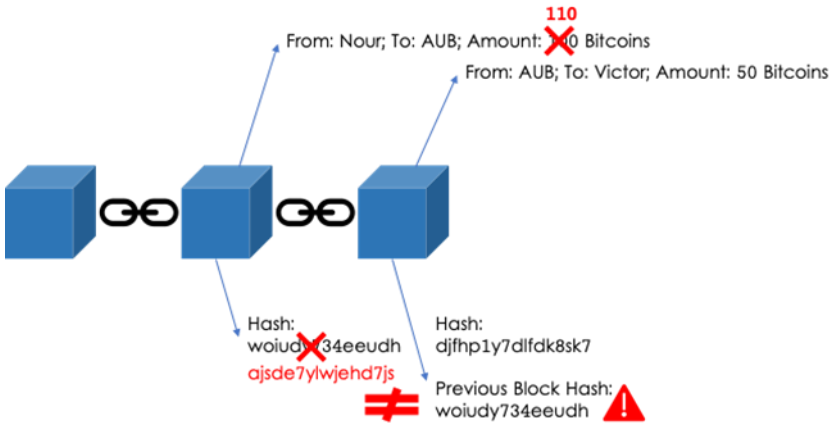


Figure 6 Blockchain Hash Mismatch Example

3.2. The Distributed Ledger

The chain of blocks is stored on a spreadsheet or a database, which is defined as the distributed ledger. This ledger is shared among the users of the blockchain network. Because everyone owns a copy of this ledger at all points in time, there is no need for an intermediary to verify the validity of information. Everyone knows everything. This is a fundamental concept of the blockchain technology which is behind the decentralized capability pillar of the blockchain. It is important to highlight, though, that the designers of the blockchain can choose a more selective set of participants to own this ledger instead of the wide public. Therefore, a distributed ledger is of two types:

- Public, whereby all users can read and write
- Private, whereby selective users can read, and selective users can write

In the figure below, we take tea farms as an example, and we see that we have everyone on the network, from the grower, to the processor, to transport companies, supermarkets, and consumers. The growers can input the quantity they sold and the conditions under which the tea leaves were grown; the farmer transport can input the quantity purchased and the temperature kept during transport. However, supermarkets can choose the set of data to share with the public and the other set of data to share with selective users to ban competition from knowing competition-sensitive information.

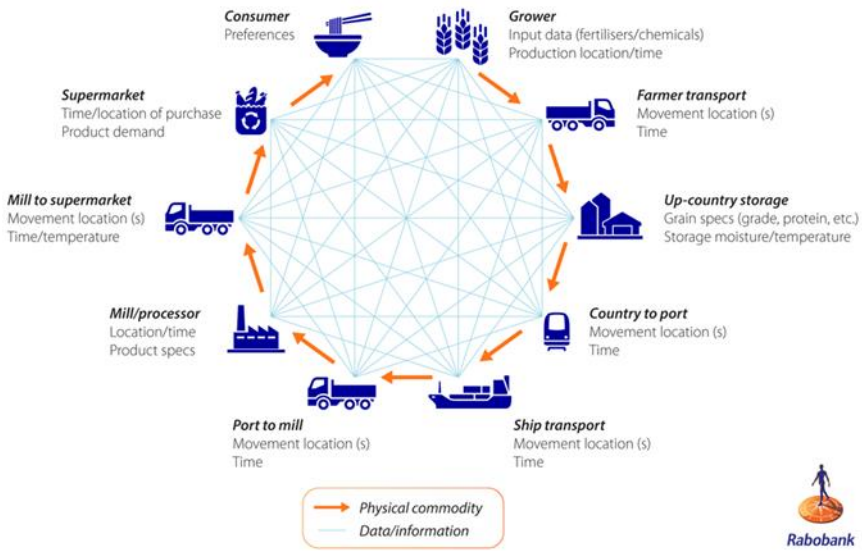


Figure 7 A Distributed Ledger of a Supply Chain (Lefroy, 2017)

3.3. The Smart Contract and the Blockchain Ecosystem

The blockchain, as we defined earlier, is a distributed ledger, but how do we populate its data? How do users make benefit of it? Can applications interact with it? If so, how? The answer to all those questions revolves around the smart contract. Let us explore what a smart contract means and how it interacts with other ecosystem components. The figure below showcases the main components of the blockchain ecosystem including dApps, Oracles, network of nodes, and others.

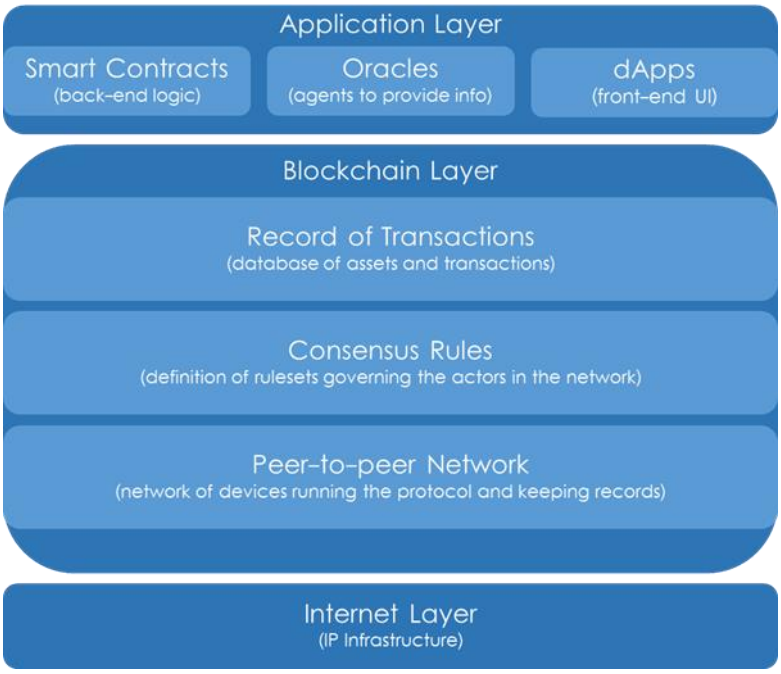


Figure 8 The Blockchain Ecosystem (Voshmgir & Kalinov, 2017)

3.3.1. The Interface

The smart contract is the interface that allows applications and users to interact with the distributed ledger. In more practical terms, the smart contract is a computer code running on nodes and is **automatically** executed based on certain conditions. For example, here's a simple pseudocode:

*if **product** is received*

*send email to **customer** that the **product** is delivered*

*execute payment from **customer** to **supplier***

The smart contract empowers the blockchain technology to be automated, which is the second capability pillar that we discussed so far, after the decentralized capability pillar.

3.3.2. The Users

Users can communicate with the blockchain system, via the smart contract, using applications that we are all familiar with right now. The applications that are designed for blockchain networks have a special feature: they are decentralized applications (dApps) that can run on a network of computers rather than a single centralized computer. (Voshmgir & Kalinov, 2017) After blockchain was being adopted for more and more use cases, companies had to design agents that feed data from their existing applications to the smart contracts upon certain conditions. Those agents are called Oracles. So, Oracles are the applications dedicated to providing data such as weather temperature, status of delivery, or inventory levels, to the smart contract to trigger events depending on certain conditions.

3.4. Operations and Dynamics

During the design phase of the blockchain system, representatives of participants meet and agree on the consensus rules that will govern this system. After the blockchain network is implemented, every participant who joins receives an identical copy of the database or ledger. Every new transaction is validated by all participants according to the agreed upon protocol. The identity of a participant is verified by asymmetric cryptography.

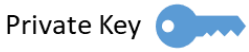
3.4.1. Asymmetric Cryptography

Blockchain is built on the science of crypto economics which raises the bar on the reliability of authorization and the validity of data. Therefore, the blockchain technology, by design, is **transparent**, **immutable**, and **secure**. Usually, systems that

require authentication are built on symmetric cryptography. If two participants want to exchange data while maintaining the secrecy of data against everyone else, the message will be encrypted by a key that is only known to both users. However, sharing the key means that both users know the key. There is no "secret" held between those two participants. However, asymmetric cryptography is what empowered blockchain to validate the identity of a user while preserving the anonymity of this identity. To explain, we discuss this simplified example inspired by a video published by Computerphile. (Computerphile, 2014)

Consider two participants, sender A and receiver B. Every participant has a key pair:

- A **public** key that everyone knows 

- A **private** key that no one knows 

Any message that is encrypted by one can only be decrypted by the other. For every transaction, the following steps occur, as described by the below figure.

1) A encrypts the message with A's private key.
2) A encrypts the message with B's public key.
3) B decrypts the message with B's private key.
4) B decrypts the message with A's public key.
5) A and B remain unknown to each other.

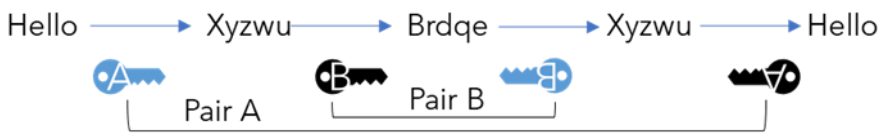


Figure 9 Asymmetric Cryptography

3.4.2. Inclusion

The blockchain is based on open-source technology. For example, if anyone would like to join the network of "miners" for bitcoins, the user is welcomed to download the code available online, run it on his or her machine, and hope for a good catch. There are no barriers for participation. Therefore, blockchain is known to be **inclusive**. In the example of bitcoin, blockchain is the technology that could finally provide banking for the unbanked, such as refugees, for example. Usually, people cannot open a bank account if they lack an official identity. The population of people who lack an official identity should not be underestimated. In fact, the World Bank estimates that 1.1 billion people lack an official identity. (Center for Digital Development, USAID) There are several ways the decentralized blockchain technology can solve this problem of identity. One simple example can be a cloud-based solution that uses the fingerprint of a person to create a unique identifier. The users can input their fingerprints by using their mobile applications to create their identity cards.

Figure 10 Users Create their Own Identities

3.4.3. Tokenization

There is one more important concept to discuss about the blockchain which is how users validate transactions. We mentioned earlier in the beginning of this chapter that every block is uniquely identified by a hash. How is the hash created? To simplify, you can think of the hash as a mathematical puzzle that every node on the blockchain

competes to find first. The user, or computer, who wins, by solving the puzzle first, is rewarded by a token. This token varies from blockchain system to another. In the bitcoin example, the user is rewarded by a bitcoin. In other examples, it could be loyalty points that the user can exchange for a certain product or service. Therefore, users on the blockchain network are only rewarded by "good" behavior, which makes the blockchain **incentivized** by design. After the hash is found by one of the nodes, it should be validated by more than half of the total nodes so that its associated block is added to the chain of transactions on the distributed ledger.

CHAPTER 4

HOW BLOCKCHAIN TECHNOLOGY IMPROVES THE SUSTAINABILITY OF SUPPLY CHAIN

In this chapter, we will construct a framework that defines how the seven blockchain design pillars, which were discussed in the previous chapter, can improve every dimension of sustainability of a supply chain. To do that, we first need to study how to evaluate sustainability. As you will see, the output will be a list of 15 sustainability criteria. Afterwards, we will build a 15x7 matrix so we can identify how every blockchain design pillar can enhance and support the sustainability of a supply chain. The following diagram summarizes the methodology we followed to map blockchain capabilities to sustainability metrics.

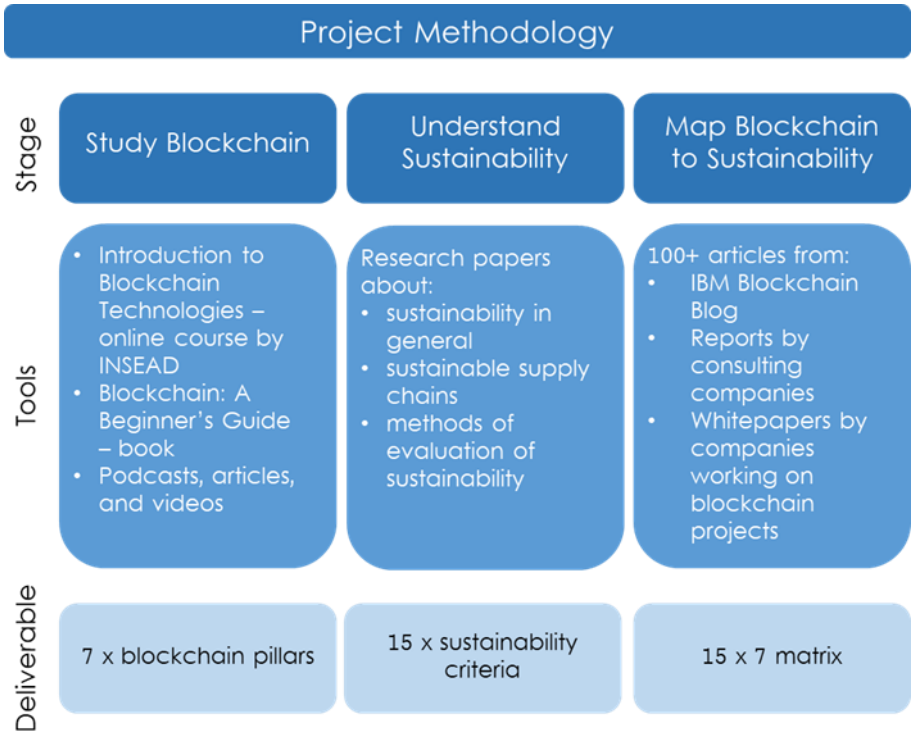


Figure 11 Framework Development Methodology

4.1. How the Sustainability of Supply Chain is Evaluated

When we talk about sustainability, we talk about the 3Ps, people, planet, and profit. To understand how blockchain can improve the sustainability of supply chains, we first explore how to evaluate sustainability in the subject of supply chain. We rely on a study whereby the authors studied several peer-reviewed articles published in the subject of supply chain sustainability, reviewed, synthesized, and created a list of criteria for evaluating the performance of sustainability of a supply chain. (Izadikhah & Saen, 2016) Afterwards, we will present how we grouped those criteria into a smaller set of broader criteria that more suits our case for blockchain technology analysis.

4.1.1. Reference Evaluation Criteria

The following table represents the original list of criteria as presented by the study of Izadikhah and Saen.

Table 2 Sustainable Supply Chain Criteria

People	Planet	Profit
Interests and Rights of Employees	Environmental Management System	Cost/Price
Work safety and labor health	Number of obtained ISO Standards	Quality
Employment Practices	Environmental Costs	Service Capability
Rights of Stakeholders	Green Design	Technology Capability
Information Disclosure	Green R&D	Production Facilities and Capacity
Respect for Policy	Green Product	Organization and Management
Local Communities Influence	Eco-design	Reliability
	Pollution Control	Flexibility
	Ozone Depleting Chemicals	Total Cost of Shipments
	Recycling	Number of Shipments
	Pollution Prevention	Delivery
	Resource Consumption	
	Water Consumption	
	Energy Consumption	
	Renewable Energy	

4.1.2. Blockchain-adjusted Evaluation Criteria

The downside of the presented criteria is that it is too detailed for our scope. For example, we will not dive into how blockchain reduces the "number of shipments" nor "ozone depleting chemicals". Therefore, we have re-grouped the 33 criteria into a broader list of 15 criteria. An elaboration of how each criterion was mapped into a new set of criteria is presented in the Appendix in the table named Adaptation of Sustainability Criteria. The revised list of sustainability criteria is presented in the following figure.

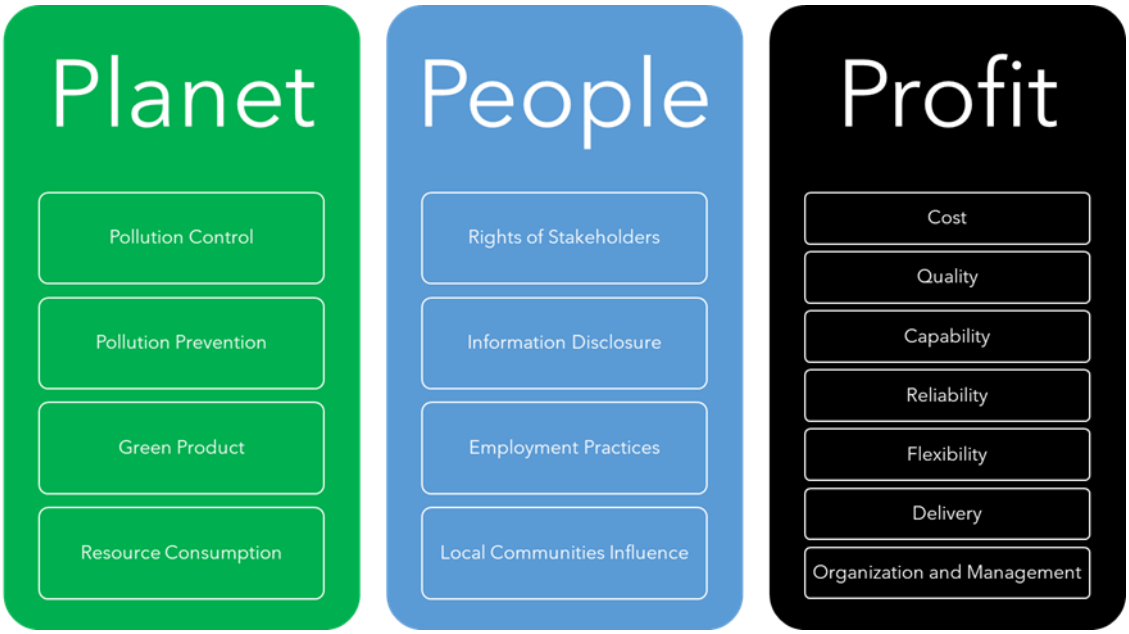


Figure 12 Summary of Adjusted Evaluation Criteria

4.2. A Framework of Blockchain and Supply Chain Sustainability

In this section, we dive deep into the details of how the design pillars of blockchain, such as including, automated, or decentralized, can enhance the sustainability of a supply chain in a dimension and criterion. We will start by

summarizing our findings into a Yes/No matrix (see below). A "Y" denotes a successfully identified sustainability use case of the blockchain technology, whereas the blank cells represent cases where we failed to identify successful use cases. Afterwards, we will divide the discussion across three sections in which we discuss the power of Blockchain technology for every sustainability "P" dimension. The introductory matrix is hereby represented as follows.

SUSTAINABILITY		BLOCKCHAIN PILLARS						
Dimension	Criterion	Decentralized	Transparent	Immutable	Secure	Automated	Incentivized	Including
Planet	Pollution Control	Y				Y	Y	Y
Planet	Pollution Prevention	Y	Y					
Planet	Green Product		Y	Y				
Planet	Resource Consumption					Y		Y
People	Rights of Stakeholders		Y	Y				
People	Information Disclosure	Y			Y			
People	Employment Practices				Y			
People	Local Communities Influence						Y	Y
Profit	Cost	Y	Y			Y		
Profit	Quality					Y		
Profit	Technology Capability	Y						
Profit	Organization and Management	Y						
Profit	Reliability				Y	Y		
Profit	Flexibility	Y						
Profit	Delivery	Y				Y		

Figure 13 THE SSC-BC Matrix

4.2.1. The Planet Dimension

4.2.1.1. Pollution Control

In this section, we discuss how blockchain technology helps in reducing the damage caused by produced pollutants.

4.2.1.1.1. Decentralized

- **Extending accountability:** traditionally, producers are the only ones held accountable for managing the waste and recycling; there are no digital transaction systems available to hold every member of the chain including consumers, as individuals or companies, accountable for how they manage waste. With the decentralized indisputable record that blockchain technology provides, everyone will be on the network, so blockchain helps in extending the visibility, and hence, accountability, to all the players on the network. (Staub, 2019)
- **Simplifying return logistics:** no matter how far the products travel, if blockchain is implemented, it is easy to trace any product back to its original equipment manufacturer (OEM) who is responsible for their goods.

4.2.1.1.2. Automated

- **Paying for performance:** waste reduction metrics, such as metrics related to tracking hazardous wastes, can be integrated in smart contract execution agreements. Suppliers can be paid more

when they better control and reduce the number of hazardous wastes during production. (Kouhizadeh & Sarkis, 2018)

- **Paying for value:** in addition to designing contracts to pay based on performance metrics, payment can also depend on the quality of the material, which can be traced by data such as the history of the cost of the product or material. (Kouhizadeh & Sarkis, 2018)

4.2.1.1.3. Inclusive

- **Connecting recycling companies:** by creating a more efficient means of communication, recyclers can collaborate to balance the burden of materials. When one company has an excess of recyclable materials in stockpile, they could reach out to the blockchain's network to identify another member who could process the remaining materials instead of diverting to a landfill. (Staub, 2019)
- **Connecting consumers to producers:** consumers of e-waste, such as smart phones, earphones, USBs, and other electronics, mostly do not recycle the waste even if they aware of the positive value it brings to the environment. This is due to the difficulty in finding producers who are interested in their e-waste. Studies show that only 20% of e-waste is recycled. (Staub, 2019) When connected to the network, consumers can easily find producers who have demand for their electronics or e-waste.
- **Including unbanked consumers:** collectors of plastic are usually part of the poor population who lack access to traditional

banking systems. Therefore, it is not only important to help them connect to remote producers who are in demand of their plastic, but also to find a way to reward them directly without jeopardizing them to the corrupted intermediaries that are commonly available to abuse them in such countries. Any basic smart phone today can provide the means to a digital wallet, so the plastic collectors can more easily monetize the waste. (Frankson, 2019)

4.2.1.1.4. Incentivized

- **Offering digital rewards to everyone on everything:** while everyone is on the blockchain network, companies can choose to reward employees for sticking to environmentally friendly operations. For examples, drivers who maintain safe and efficient driving behaviors can be tracked and rewarded. Municipalities can also reward residents as they recycle.

4.2.1.2. Pollution Prevention

In this section we discuss how blockchain technology helps in minimizing the generation of wastes that in turn produce pollutants.

4.2.1.2.1. Decentralized

- **Going paperless:** ninety percent of the products we use every day are transported by ocean freight. The shipping industry is one that heavily relies on paperwork. According to Maersk, a simple shipment can go through nearly 30 parties and more than 200 interactions. By providing a secure digital platform, whereby data

is partially shared with clients but invisible to competitors, the big players like Maersk and CMA CGM were ready to join the Blockchain system TradeLens so they can electronically transact with clients in a secure way that does not expose sensitive information to competitors. (Wieck, 2019)

4.2.1.2.2. Transparent

- **Minimizing the carbon footprint**: measuring carbon footprints is increasingly being recognized as vital today. Organizations try to minimize their carbon footprint by the addition of carbon credit and carbon credit offsets. The calculation tools have made the numbers unreliable due to difficulties in tracing the location and validity of the offsets. However, as the blockchain technology empowers the network peers to believe in the transparency of the records on the shared ledger, companies become more motivated to increase the offsets since the offsets are now certainly acknowledged by everyone on the chain. (Kouhizadeh & Sarkis, 2018)

4.2.1.3. Green Product

In this section, we will explore how Blockchain supports companies in designing, manufacturing, and certifying greener products.

4.2.1.3.1. Transparent

- **Raising the quality of sourcing:** companies must go through sourcing and onboarding processes every time they need a product that their current trusted suppliers do not offer. Finding and qualifying trusted suppliers are exhausting tasks for

procurement departments. Blockchain technology simplifies the sourcing and onboarding processes by providing an existing trusted blockchain-based supplier network to validate that the supplier meets technical standards. (Chainyard, 2019)

- **Providing reliable information for eco-design systems:** for eco-design systems to provide an accurate output, they should be fed with accurate input. Blockchain is a reliable and transparent information delivery vehicle that can reduce information uncertainty, providing better modeling inputs and outputs for eco-design tools. (Kouhizadeh & Sarkis, 2018)

4.2.1.3.2. Immutable

- **Certifying green credentials:** MineHub is a Blockchain platform that empowers mines to attach mine origin and sustainability certifications to minerals as they move through the supply chain. This motivates mining firms to invest in sustainability practices as they can validate the green credentials of their material to their clients and better differentiate themselves from the competition. (MineHub, 2019)

4.2.1.4. Resource Consumption

Blockchain also supports companies in consolidation, collaboration, and more efficient processes to reduce overall resource consumption.

4.2.1.4.1. Inclusive

- **Broadens the crowd-shipping set of participants:** blockchain technology reduces transaction costs which allows for lower-

income companies to jump onboard. Any company who has additional warehouse capacity can sell this capacity for those who require it. When crowd-shipping is empowered by a democratic system such as the blockchain, efficiencies are increased by consolidating materials and reducing the need for building warehouses. (Kouhizadeh & Sarkis, 2018)

4.2.1.4.2. Automated

- **"Uberizing" the corporate transportation:** blockchain empowers companies to authenticate drivers and pay them via tokens leading to the "uberization" of corporate transportation. Companies can more simply and flexibly exchange excess of vehicle capacity, which results in a higher utilization of overall vehicle freight, improving efficiencies, and reducing waste. (Kouhizadeh & Sarkis, 2018)
- **Bringing unutilized residential solar energy to the corporate world:** by integrating the Blockchain ecosystem via smart contracts to the digital wallets of individuals, payment for residential houses with solar rooftops can be easily automated. Residential houses can therefore "sell" unutilized solar energy to the supply chain network and get paid automatically via the execution of the smart contract.

4.2.2. The People Dimension

4.2.2.1. Rights of Stakeholders

The supply chain is a network of multi-players who execute plenty of interactions. Protecting the rights of all stakeholders is essential, and blockchain technology plays a great role in preserving those rights.

4.2.2.1.1. Transparent

- **Facilitating recall management:** by owning the trusted data on the Blockchain general ledger, manufacturers can use this data to better negotiate with suppliers on issues related to recall management. (Chainyard, 2019)

4.2.2.1.2. Immutable

- **Eliminating nuances of contractual disputes:** after parties agree on the terms of the smart contract, the enforcement of contract terms becomes irreversible which ensures that the contract will never be interfered to appeal the action. (Verma, 2019)

4.2.2.2. Information Disclosure

Most international organizations today declare the right to information as one of the human rights. In the following part, we will discuss how Blockchain works in favor of more information disclosure.

4.2.2.2.1. Decentralized

- **Removing asymmetry from markets:** manufacturers often utilize the advantages of the efficient systems or services that they own by accessing full visibility and traceability of data about materials used in production. However, consumers are left blinded, which puts

manufacturers at an unfair stronger advantage. Shared ledger solutions help in democratizing the data that everyone needs thereby empowering all players to be at the same level. In other words, the shared ledger reduces asymmetry. (Ayres, 2019)

4.2.2.2.2. Secure

- **Enticing to disclose more**: we have discussed that there are different types of shared ledgers, the private, and the public. Even in the most public ledgers, companies can still control who access their information, so they can be enticed to disclose more to their client while they do not worry about exposing data to the competitors.

4.2.2.3. Local Communities Influence

Social objectives are becoming more popular. Giving the welfare of individuals a primary concern is not enough. It is also important for corporations to care about the society at large. In this section, we discuss how blockchain helps companies in strengthening their positive impact on their local communities.

4.2.2.3.1. Inclusive

- **Empowering the end-user:** a mobile application was built as part of a pilot project done by IBM and the FDA to empower end-users, who are patients in this case, to access the data and trace products from the point of origin till dispense. As such, users can quickly and effectively identify, investigate, and communicate about a relevant suspect or illegitimate product. (IBM Blockchain Pulse, 2019)

4.2.2.3.2. Incentivized

- **Awarding small companies for compliance:** small companies often find difficulty expanding their network. To deal with bigger scale companies, they should invest in governing more sustainable practices. For small-scale miners, this means they should put expensive effort to reduce the severity of working conditions. With the Blockchain technology, small companies join the bigger network and gain more exposure which renders their investment in sustainable practices more economic. (Garrett, 2019)

4.2.2.4. Employment Practices

Today, more attention is given to ethical sourcing, and employment practices are one of its most challenging aspects to measure. We will discuss how blockchain technology helps in improving the standards of employment practices.

4.2.2.4.1. Secure

- **Giving workers a say:** large corporations, such as Coca Cola, work with suppliers that are remote. A trusted decentralized ledger that can onboard laborers to share their working experience without risking their job by remaining anonymous helps producers, such as Coca Cola, ensure that their suppliers are adhering to their standards of employment practices. (Williams, 2018)

4.2.3. The Profit Dimension

4.2.3.1. Cost

4.2.3.1.1. Decentralized

- **Smoothing out cash flows:** blockchain eliminates the need for data reconciliation between the supplier and the receiver. As an example, invoice reconciliation will be no longer required. As such, days sales outstanding, or the number of days it takes the company to collect a payment, will be reduced. (Chainyard, 2019) Another way blockchain can smooth out cash flows is by providing real-time data for asset movement. Miners and their respective banking partners who are on the MineHub platform will be able to issue and track letters of credit which improves the liquidity management. (Halford-Thompson, 2019)
- **Reduces late delivery fees:** blockchain shared ledger provides timely and accurate data which helps companies resolve disputes about delivery, which leads to a reduction in late delivery penalty fees and interest fees. (Chainyard, 2019)

4.2.3.1.2. Automated

- **Eliminates the need for audit companies:** for companies where audit and compliance are important and usually costly, smart contracts can used as a more cost-efficient substitute to audit all transactions. Furthermore, smart contracts can deliver more exhaustive testing since smart contracts can run through all transactions while audit companies can only choose samples.

(Chainyard, 2019) Therefore, companies do not only save the costs they put for audit, but also improve the quality of their testing processes.

4.2.3.1.3. Transparent

- **Eliminates redundant testing**: consider a company that produces smart speakers. This company probably buys microphones from an external supplier to install them in their smart speakers. Traditionally, if the company does not trust the testing results provided by the microphone supplier, they must redo the testing to guarantee they meet their standards of quality. However, on the blockchain, companies trust that data on the network is transparent. They can, therefore, rely on the testing results provided by suppliers and save the time and cost required to do another test in their own labs. (Chainyard, 2019)
- **Removing intermediaries**: just like how transparent information eliminates the need for testing, trusted transparent information eliminates the need for central intermediaries that are hired to certify the validity of results when the two counterparties do not trust each other.

4.2.3.2. Quality

4.2.3.2.1. Automated

- **Empowering proactive maintenance**: blockchain is increasing the adoption of the digital twin technology, which is the digital enablement of a physical product, or in other words, giving a

physical product a digital replica. Companies will be able to analyze and monitor the performance of products and more importantly, the performance of integrated products. By leveraging machine learning, companies can use this data to proactively discover potential issues in similar product configurations across the world and notify the users.

4.2.3.3. Capability

4.2.3.3.1. Decentralized

- **Enabling more efficient decision-making:** as data is decentralized, whenever one party updates the shared ledger, the same data will be written across all nodes, so all parties can see the same timely data in real-time mode. As such, faster decision making can be executed. As an example, a recycling company in France was able to optimize sorting of waste streams as they had timely updates of the amount of waste collected in each waste bin. (Staub, 2019)

4.2.3.4. Reliability

4.2.3.4.1. Automated

- **Quantifying trust:** the smart contract is an interface that can communicate with the blockchain ecosystem parties to capture data about system behavior, content, and IoT devices. By consolidating this data, companies will be able to analyze and measure trust based on quantifiable metrics. Automating those

business processes ensures consistency and timeliness of trust metrics.

- **Governing contracts in real-time**: smart contracts can be configured to automatically trigger an alert for potential breach of contract to all parties. This could be related to temperature levels required for storing a certain item.

4.2.3.4.2. Secure

- **Strengthening interoperability between parties:** traditionally, every company has its own systems, which creates data silos that can lead to inaccurate information. With blockchain, interoperability between all parties is improved, so the data silos are transformed to shared immutable records.

4.2.3.5. Flexibility

4.2.3.5.1. Decentralized

- **Providing visibility on supply:** the trusted shared ledger provides real time data about the stock levels of the suppliers that a manufacturer deals with. This provides the manufacturers the visibility that they need to make timely decisions about resorting to other suppliers when a contractual supplier cannot meet a certain demand at the needed time.

4.2.3.6. Delivery

4.2.3.6.1. Decentralized

- **Increasing on-shelf availability:** end-to-end visibility across the inventories of the supply chain proves to enable higher on-shelf availability, generally with lower inventories. (Sashital & Kallianpur, 2019)

4.2.3.6.2. Automated

- **Streamlining deliveries:** take a product that is transported by sea shipping as an example. “Automating processes reduces port and terminal congestion, minimizes customs and inspections delays.” Access to real-time data empowers companies to react responsively to disruptions as soon as they occur. (Wieck, 2019)

4.2.3.7. Organization and Management

4.2.3.7.1. Decentralized

- **Boosting forecast accuracy:** blockchain provides visibility on reliable actual sales data and details about end-user information so manufacturers can better forecast future sales and plan more optimally for production and distribution. (Chainyard, 2019)
- **Simplifying vendor onboarding:** using the existing blockchain-based supplier network, a company can quickly find suppliers that are trusted by others, facilitating the vendor selection process. (Chainyard, 2019)

4.3. Framework Insights

Looking at our findings from a bird's eye view, we can infer that the **decentralized** and **automated** pillars are the most generous contributors to sustainability dimensions. To realize the benefits of blockchain technology, decision makers should first make sure their business problem requires disintermediation and automation.

SUSTAINABILITY		BLOCKCHAIN PILLARS								
Dimension	Criterion	Decentralized	Automated	Transparent	Inclusive	Secure	Incentivized	Immutable		
Planet	Pollution Control	2	2		2		1		7	15
	Pollution Prevention	1		1					2	
	Green Product			2				1	3	
	Resource Consumption		2		1				3	
People	Rights of Stakeholders			1				1	2	7
	Information Disclosure	1				1			2	
	Employment Practices					1			1	
	Local Communities Influence				1		1		2	
Profit	Cost	2	1	2					5	15
	Quality		1						1	
	Technology Capability	1							1	
	Organization and Management	2							2	
	Reliability		2			1			3	
	Flexibility	1							1	
	Delivery	1	1						2	
		11	9	6	4	3	2	2		

Figure 14 Framework Findings

In other words, the answers to the following three questions must all be "yes":

- Are you trying to remove intermediaries?
- Are you working with assets that can be represented in a digital format?
- Can a permanent record be created for the digital asset in question?

When it is proven that decentralization and automation are required, blockchain technology is likely to bring about benefits across all the P dimensions: planet, people, and profit.

CHAPTER 5

KEY BLOCKCHAIN TRANSFORMATIVE TRENDS IN THE HEALTHCARE INDUSTRY

The healthcare space is one of man's greatest achievements in the journey of evolution. In the 20th century, we have doubled the average life expectancy from the high thirties to the mid-seventies. (Harari, 2011) Yuval Noah Harari expects that the revolution of the 21st century will be a revolution in biology, whereby the natural selection that used to govern life will cease to be the main player after man proves evolved capabilities to create organs and, probably, bodies. However, until today, the healthcare and pharmaceutical industry still belong to the group of laggards in digitization. (McKinsey Global Institute, 2019) The healthcare industry is a broad complex industry of several players that are presented in the following figure.

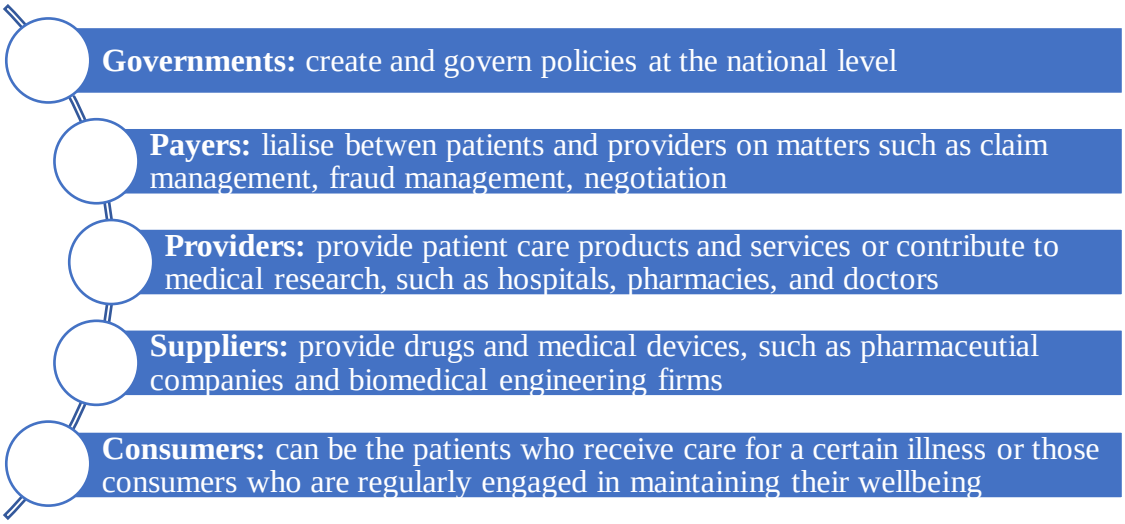


Figure 15 Stakeholders of the Healthcare Industry

In this chapter, our purpose is to understand and analyze how the key transformative trends are driving the healthcare industry towards digital transformation and to describe the role that blockchain technology is playing.

5.1. The Transformative Trends

After reading about pilot projects and collaborations among leading companies from technology providers to healthcare companies, we can infer that there are four key trends driving the transformation in the healthcare industry. The diagram below shows a set of random news throughout the last three years that are representative of the four transformative trends we identified to the right of the diagram.

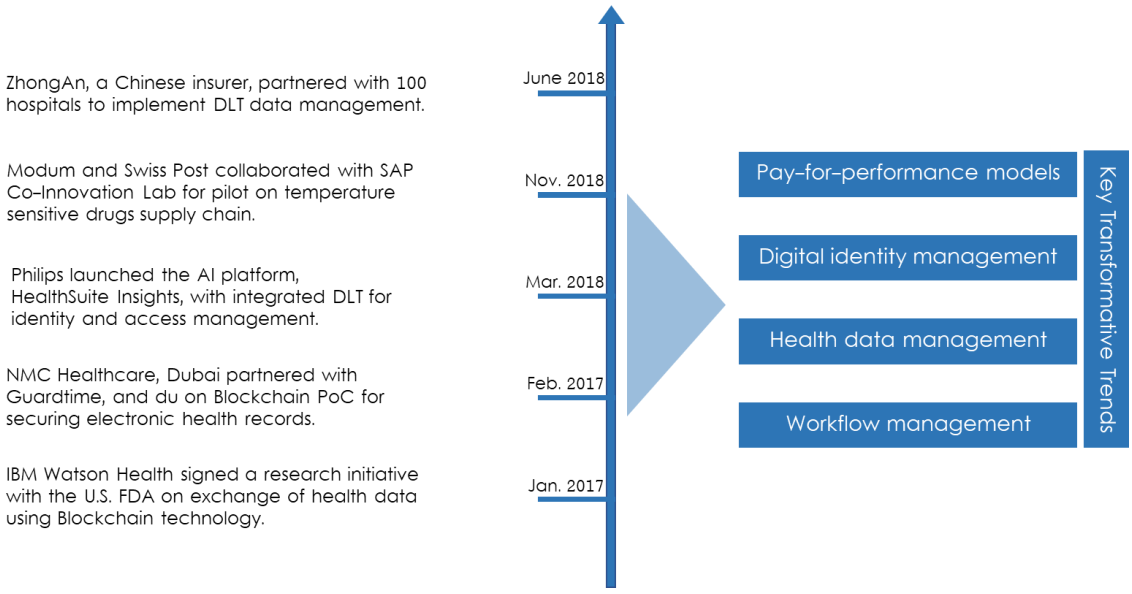


Figure 16 Key Transformative Trends

Indeed, blockchain looks promising in the healthcare industry. However, how real is it? What is the timeline of this transformation? What about market readiness? Is the technology mature? Are there viable business cases? To answer this question, we

rely on Gartner's Hype Cycle to evaluate where blockchain technology stands today between the hype and business viability in the context of the healthcare supply chain.

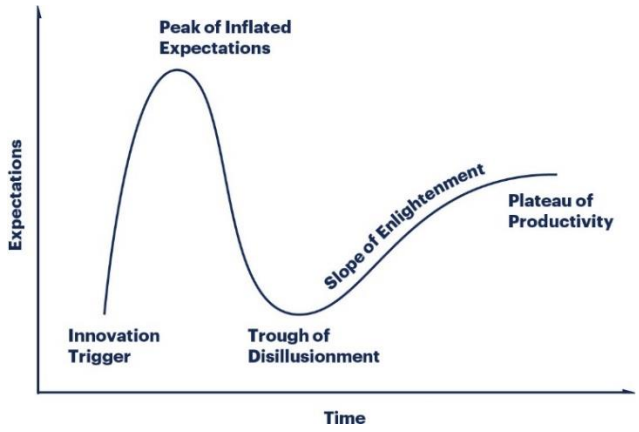


Figure 17 Gartner's Hype Cycle

We can map what we understand about the evolution of blockchain technology since its genesis hitherto. The innovation trigger happened in 2008 when Satoshi Nakamoto came up with Bitcoin as a peer-to-peer cash system that proved to disrupt the banking industry. Then blockchain technology became one of the buzzwords in the field of digital transformation. It took scientists and technologists around a decade to discern the hype from business viability. Today, researchers, technologists, scientists, and business strategists are working together on identified use cases in select industries that are likely to be disrupted by blockchain.

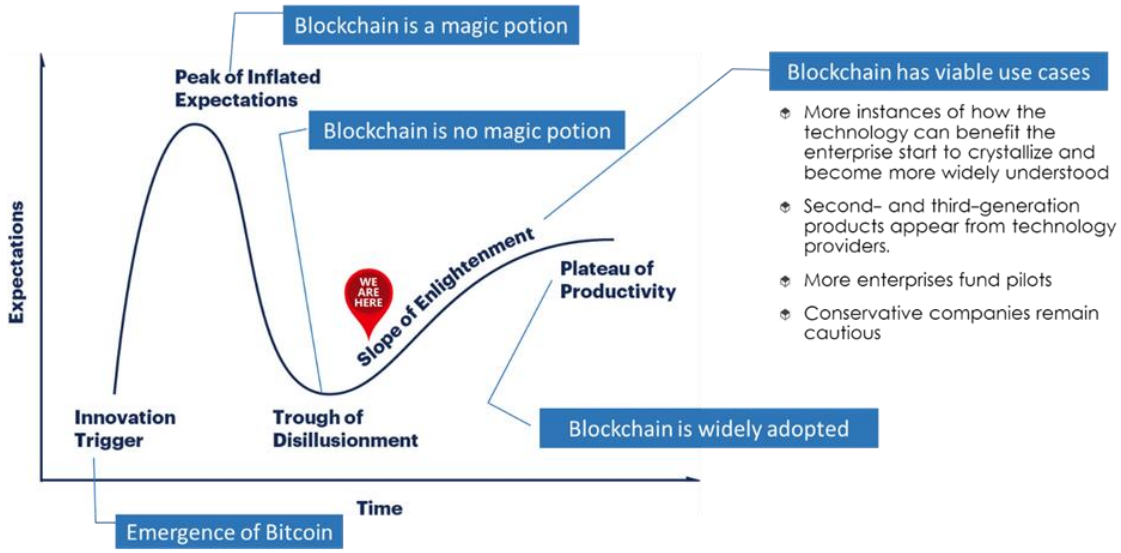


Figure 18 Gartner's Hype Cycle Applied to Blockchain

5.2. Blockchain Use-cases in the Healthcare Industry

As introduced in the previous section, we identified that blockchain technology is currently at the stage of enlightenment in Gartner's Hype Cycle because the healthcare industry market indicates there are viable business use cases. In the following table we present the use cases of blockchain per key transformative trends and the impacted industry players for each use case.

Key Transformative Trends	Blockchain Use Cases	Industry Players
Pay for performance (PFP) models	• PFP through blockchain	• Payers • Providers • Suppliers • Consumers
Digital identity management	• Healthcare professional credentialing • Universal medical profile	• Governments • Providers • Consumers • Payers
Health data management	• Managing and incentivizing data sharing	• Providers • Suppliers • Consumers • Governments
Workflow management	• Blockchain-enabled drug supply chain • Audit and insurance process automation	• Payers • Providers • Suppliers • Consumers • Governments

Figure 19 Blockchain Use-cases

We have seen that the players in the healthcare supply chain are all likely to be affected by the blockchain technology. Therefore, it is important to analyze and evaluate how those players are responding to this wave of transformation.

5.3. Blockchain and the Players of the Healthcare Supply Chain

According to a study by Frost & Sullivan, investments related to blockchain technology in the healthcare industry are expected to reach $1,200 Million by 2022. By looking closely at the types of players actively investing in blockchain technology, one can notice that all players except the pharmacies are onboard. Governments, drug companies, hospitals, and dental clinics are all exploring blockchain applications, as you can see in the figure below.

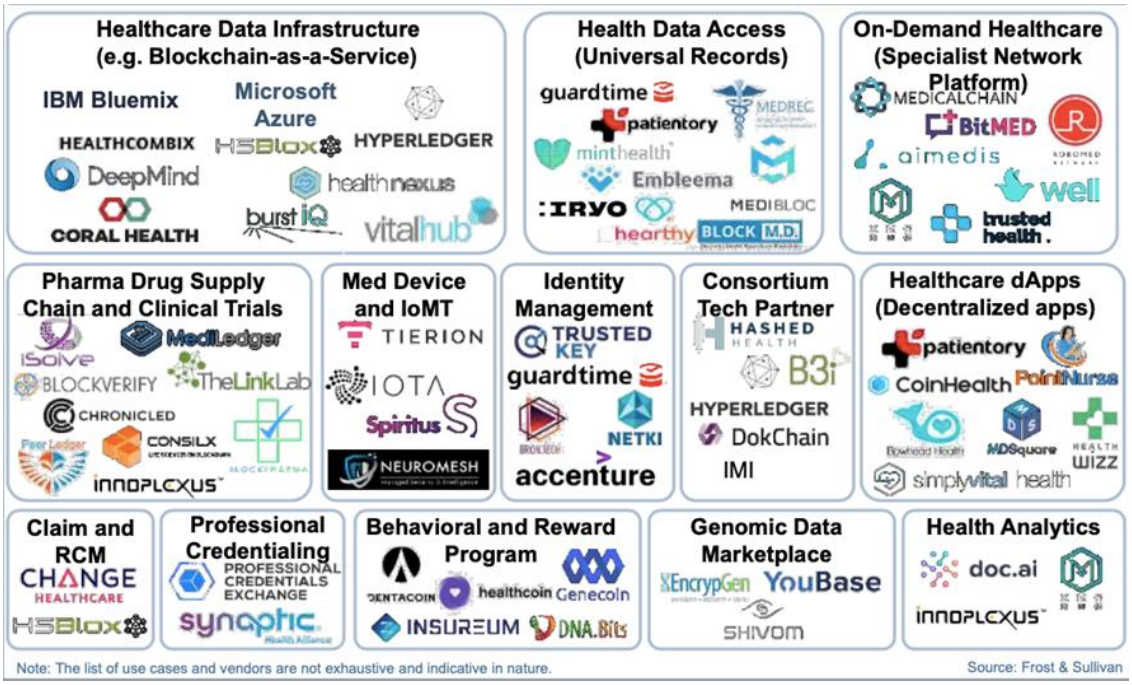


Figure 20 Major Applications of Blockchain in Healthcare (Frost & Sullivan, 2019)

In fact, pharmacies have also received little interest from researchers on the topic of blockchain. Pharmacies seem to be the “weakest link” in the supply chain. Therefore, we planned to analyze the situation of pharmacies and how they could be impacted by the transformation driven by blockchain technology. The following flowchart showcases the itinerary of our analysis.

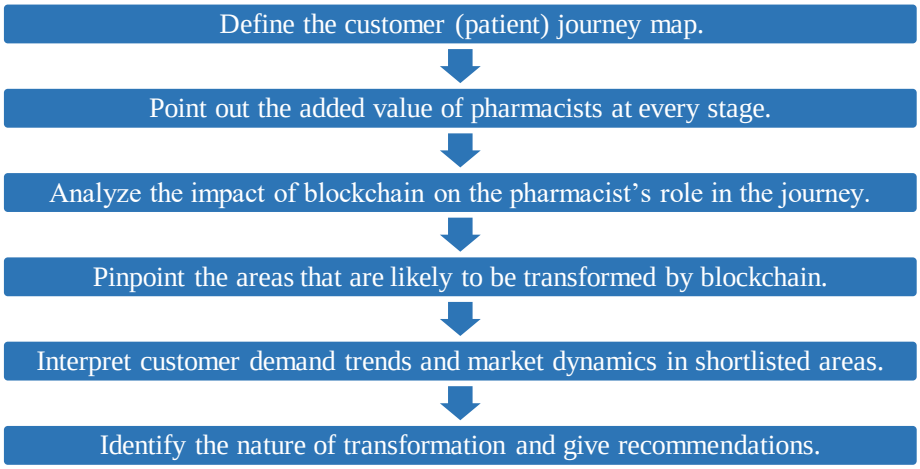


Figure 21 The Itinerary for Analyzing the Transformation of Pharmacies

5.3.1. Evaluation of Impact on Community Pharmacies

The first step is to understand the customer journey phases and the value chain of the community pharmacy. How does a pharmacist create value? Where is blockchain expected to alter how pharmacists create value for their customers? The following diagram is a high-level representation of the five phases a customer ideally goes through.

Figure 22 The Healthcare Customer Journey

Then we evaluate the effectiveness of the blockchain use cases based on criteria like time, complexity, and relevance. Our evaluation opts for a three-point scale: high, medium, and low. While the evaluation may not be fully scientific, it serves as a scientific baseline for a more focused and exhaustive analysis of this problem statement. The following diagram highlights our evaluation analysis.

Use Case		Impact of blockchain on customer journey phases				
Name	Overall Impact	Awareness and Symptoms	Consideration of Doctor/Therapy	Purchase of Medication	Application of Treatment	Recovery and Survivorship
Blockchain-enabled drug supply chain	H	L	L	H	H	H
Pay for Performance pricing models	M	L	L	H	M	L
Universal medical profile	M	L	M	H	L	L
Patient data sharing and management	L	L	L	L	M	M
Automation of audit and insurance processes	L	L	L	M	L	L
Healthcare provider credentialing	L	L	M	L	L	L

Selected use cases with the highest overall impact of blockchain on customer journey phases in a community pharmacy

H: High M: Medium L: Low

Figure 23 Impact of Blockchain on the Healthcare Customer Journey Phases

5.3.2. Community Pharmacies: Under Innovation or Disruption?

All disruptors are innovators, but not all innovators are disruptors. Blockchain is already playing an innovative role in the healthcare supply chain industry and has the potential to upgrade its role to disruptive. In the following sections, we carry out the required analysis to identify the nature of transformation that will likely hit pharmacies. The following figure outlines the flow of our analysis.

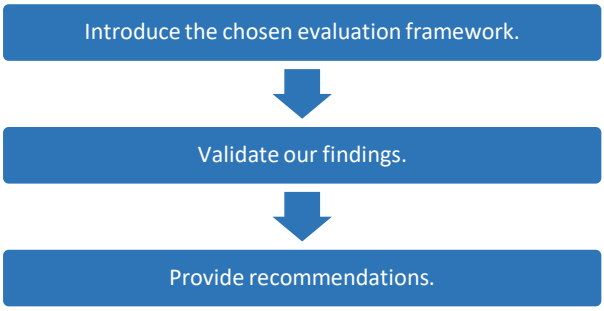


Figure 24 Outline of the Evaluation Analysis of Transformation

5.3.2.1. Evaluation Framework

There are several approaches to categorize innovation. The most fitting framework that we found is that of VIIMA, which is a company who offers innovation management solutions for corporate companies. Examples of their customer references include L'Oréal and CMA CGM.

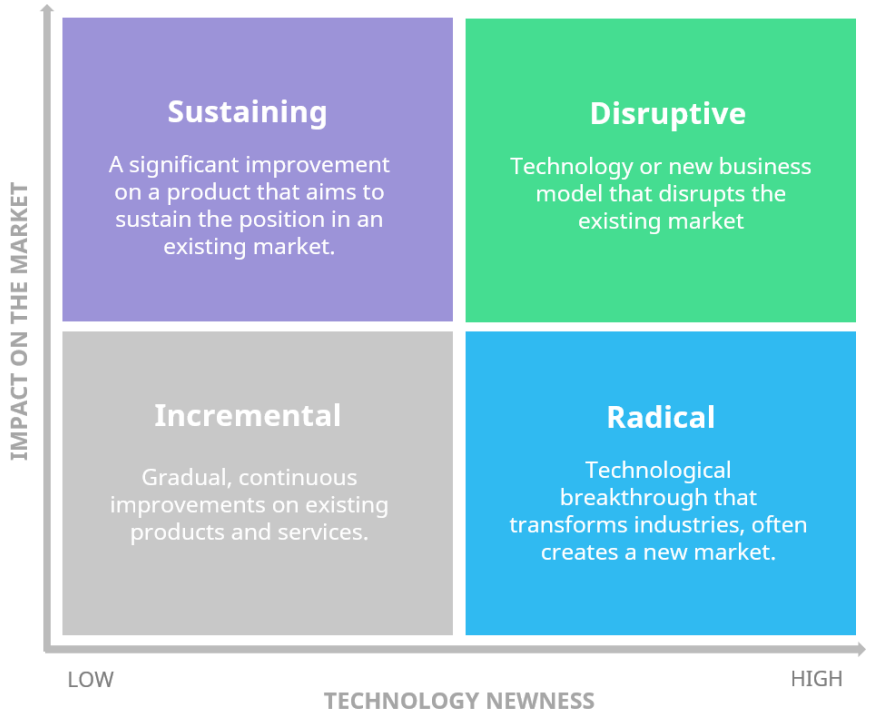


Figure 25 The Innovation Matrix (Nieminen, 2019)

As we can see in the above matrix, there are two criteria to look at: technology newness, and impact on the market. Since blockchain scores high on the technology newness, the types of innovation can be either one of the two: disruptive or radical. The difference between the two innovation types is mainly about the creation of a new business model. Now, the question is narrowed down to: is there a potential for blockchain to create a new business model?

5.3.2.2. Evaluation Findings: A New Business Model is Likely

Let us examine the current market of pharmacies. How does it look like today?

5.3.2.2.1. Market Overview

According to our research, we found out that the market looks similar across the countries. Revenue from prescription drugs make up around 70% of the total sales revenue in pharmacies. The first infographic illustrated below shows the revenue

breakdown of CVS Health in the United States whereas the second infographic shows equivalent numbers for the pharmaceutical industry in China.

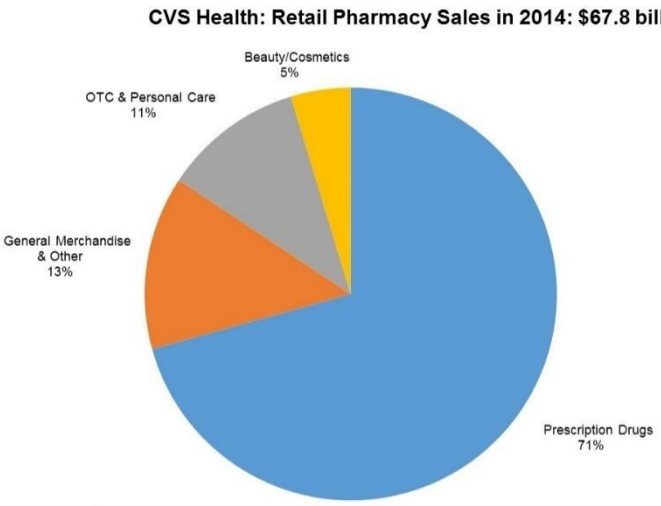


Figure 26 CVS Health Retail Pharmacy Sales (Soni, 2015)

Figure 27 Figure 20 China's Pharmaceutical Industry Products

Therefore, as the revenue breakdown of retail pharmacies around the world proves that prescription drugs contribute to around 70% of all revenues, any

fundamental change in the value chain of prescription drugs is likely to bring disruption to the community pharmacies. This brings us to explore how blockchain can transform the market of prescription drugs from the aspect of the community pharmacy.

5.3.2.2.2. Blockchain and the Prescribed Medication Segment

The purpose of this section is to evaluate the impact of blockchain technology on the prescribed medication segment. First, we will look at a more specific variation of the healthcare customer journey map by focusing on the prescribed medication segment. The customer goes through six phases while purchasing a prescribed medication from the community pharmacy, as shown below.

Figure 28 Prescribed Medication Customer Journey Map (Partridge & Bassi, 2011)

How does the pharmacist add value in each stage in a traditional supply chain? How does the blockchain "engine" add value? The following diagram compares how community pharmacies operate without blockchain (current business model) and with blockchain (new potential business model) in the scope of e-prescribed drugs. The role of a pharmacist in the traditional supply chain defined below is based on the Electronic Prescribing Workflow Analysis Handbook published by the eHealth Observatory. The analysis on the role and impact of blockchain is based on our understanding of the blockchain technology and the customer journey. Indeed, Blockchain has a solid opportunity to create new a business model, which is what we prove in the following figure.

Table 3 Comparison of the Roles of the Blockchain Engine and the Pharmacist

Workflow processes for e-prescribed drugs	How a pharmacist adds value in the traditional supply chain	How the smart engine adds value in the blockchain-enabled supply chain	Does the smart engine add more value?
Identify patient	Validate the identity of the patient or the authorized caregiver	By asymmetric cryptography, blockchain validates the identities of users while keeping them anonymous at a time	**Yes,** the engine must execute the step while pharmacists can skip intentionally or not
Access patient record	Ask the patient to provide his/her record which can be a digital or printed document, formal or informal	dApps feed data into the smart contract automatically once transactions occur, the format is standardized and immutable	**Yes,** the engine is hard corded to accept records of a certain quality or standards
Evaluate e-prescription validity	Access the prescription from the online site the physician used, review for any authenticity issues regarding patient or prescriber information	dApps for e-prescription feed data into the single source-of-truth shared ledger that is available for all nodes for profile-customized read/write access	**Yes,** only authorized physicians can input data to the ledger and the data is validated upon input/output
Evaluate medication-specific factors	Evaluate the prescribed medication to check for complications related to current and past illnesses, medications, allergies, or other issues	The engine can evaluate based on rules coded into the contract as long as the patients' data is added to the ledger by the physician or patients themselves	**Yes,** all patient medical history is secure and private on the shared ledger ready for the engine to analyze
Evaluate availability or substitution	Check for stock availability, expiry date validity, and potential substitutes in case of unavailability of unaffordability	All medication details (expiry, quantity) are fed into the ledger and are transparent and immutable. The engine has a wider secure stock to choose from	**Yes,** the engine can check from a wider variety of suppliers and warehouses who are on the network
Dispense the medication	Reconcile dispensing and prescription on the online system, and update the patient record	The dApps interact automatically with the smart contract that is designed to execute transactions and update records	**Yes,** reconciliations and updates are enforced and automated by the smart contract

5.3.2.3. Recommendations for Community Pharmacists

Because there is a chance the business model of community pharmacies will transform, it is important to discuss how pharmacists could respond to this transformation to maintain or grow their businesses. When thinking of the business model, one should focus on the customer: what does the customer want? In fact, patients are increasingly seeking ways to receive medical services outside of hospitals or traditional medical offices. According to a whitepaper published by Urgent Care Association, the number of urgent care centers is growing, while there is a decline in the emergency room growth in hospitals. The number of clinics has ballooned from 6,946 in 2015 to 8,285 as of June 2018 in the United States. It is estimated that urgent care represents 12.6 percent of all outpatient physician visits. (Urgent Care Association, 2019)

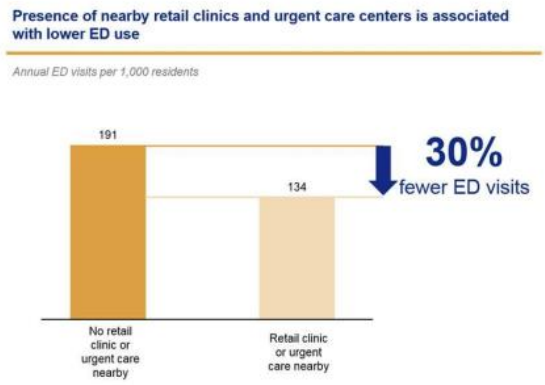


Figure 29 Decline in Emergency Visits (Urgent Care Association, 2019)

Therefore, can pharmacies leverage this new customer trend as an opportunity to grow? Let us take a step back and think of the growth opportunities any business owner has in general. As explained in the following diagram, to grow, a strategist can think of four approaches.

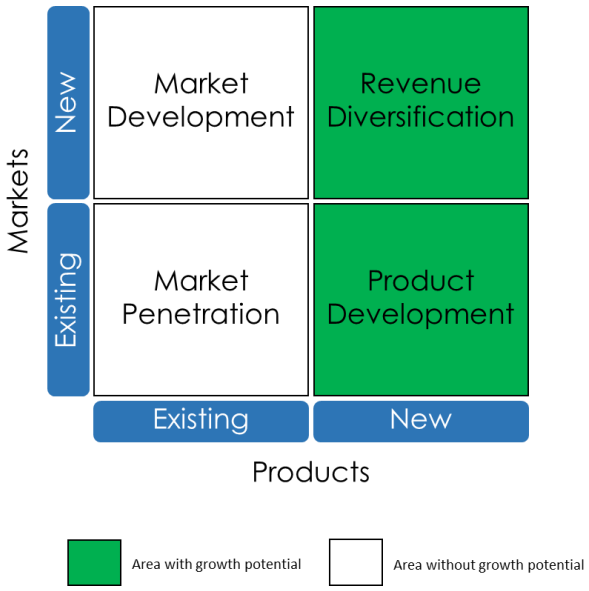


Figure 30 Matrix of Growth Opportunities

With the existing products such as prescribed medication, off-the-counter drugs, and other beauty and self-care products, pharmacies will struggle to grow. As discussed in the previous section, the blockchain engine can add more value than the average pharmacist in the customer value chain. Therefore, pharmacists must think of strategies revolving around new products.

5.3.2.3.1. Value-added Clinics

Because research shows that customers are inclining for care services outside of hospitals, pharmacists should think of ways to lure those customers in by offering healthcare-related value-added services. One of the articles published by MarketScale discusses services that can be offered in pharmacies for customers who do not want to consider the hospital as a first choice. (Mcllrath, 2019) Inspired by this article, we list several value-added services that can be considered by pharmacists who want to diversify their revenue stream.

Offering value-added services related to general healthcare checks, medical tests, and consultations	Blood tests
	Diagnostic testing (x-rays)
	Basic healthcare services (blood pressure check)
	Nutritional consultations
Offering value-added urgent care services that can be done by pharmacists and/or nurses independently from physicians	Splinting fractures
	Intravenous treatments
	Urgent care for asthma/diabetes patients

Figure 31 Value-added Offerings for Pharmacists

5.3.2.3.2. Drug Delivery Services

In fact, value-added clinics are not a pharmacy's only way to grow business. Pharmacies and pharmacists can utilize their experience and knowledge in drugs to offer drug delivery services. The drug supply chain is complex. There are regulations as well as environmental requirements to abide by. Certain drugs are temperature-sensitive, so their transport requires tailored transportation vehicles and services. Online drug delivery is already picking up. Amazon recently acquired PillPack, which is an online full-service pharmacy that offloads the patient by taking care of communicating with doctors for new prescriptions, insurance companies for payments, and of monitoring and management of drug refills whenever it's time to deliver a new batch to the patient's door. Pharmacists must think of services that are beyond the pill when the prescribed pill might stop being their exclusive product.

CHAPTER 6

HOW BLOCKCHAIN TRANSFORMS THE SUSTAINABLE HEALTHCARE SUPPLY CHAIN

In Chapter 4, we established that if the business problems of the healthcare supply chain require decentralization and automation, blockchain will very likely bring about sustainability benefits. This means we should answer the following three questions to validate the viability of blockchain use cases in this industry.

1. Are you trying to remove intermediaries?

Yes, the healthcare supply chain has one of the most complex networks and disintermediation would reduce costs and delays.

2. Are you working with assets that can be represented in a digital format?

Yes, body temperature, DNA, drug package, and human identity can all be represented digitally.

3. Can a permanent record be created for the digital asset in question?

Yes, medication results, human identities, and drug product updates come from a single source at a time and are definite records that do not need to be changed.

In fact, this is a second way to prove that blockchain use cases have a positive impact on the sustainability in the healthcare supply chain. In the following table, we present this evaluation in more details.

Table 4 Impact of Blockchain on Supply Chain Sustainability

Impact of Focused Supply Chain Use-cases in Healthcare on Sustainability	Planet	People	Profit
Supporting drug counterfeit fighting	Y	Y	Y
Simplifying serialization and saleable return	Y	Y	Y
Enhancing drug temperature control	Y	Y	Y
Simplifying device lifecycle management	Y	N	Y
Improving demand and supply visibility of drugs	Y	Y	Y
Simplifying vendor onboarding for hospitals and drug manufacturers	Y	Y	Y
Uberizing the transport function of drug/device distribution companies	Y	N	Y

6.1. A Sustainable Pharmacy Business Model

In specific, the new pharmacy business model such as value-added clinics caters, mainly, to two sustainability pillars. The following infographic discusses and analyzes the impact of the value-added business model in the context of the 15 sustainability criteria.

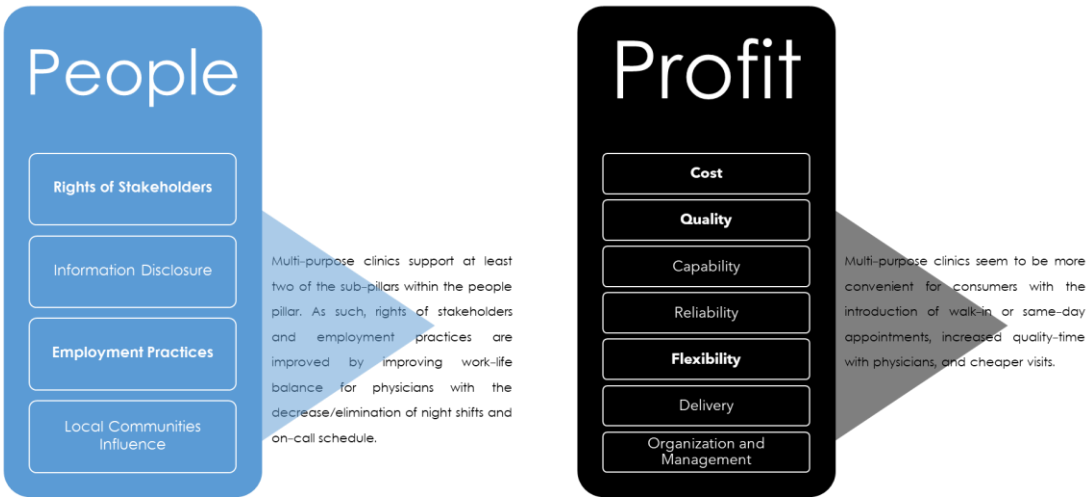


Figure 32 Value-added Clinics and Sustainability

6.2. Special Focus: Blockchain and Drug Counterfeit

Drug counterfeit is a big challenge for the drug supply chain. In this section we explore how blockchain transforms the fight of community pharmacies against drug counterfeit. Drug counterfeit is defined by "products deliberately and fraudulently produced and/or mislabeled with respect to identity and/or source to make it appear to be a genuine product." (Williams & McKnight, 2014) For example, they are medications that contain:

- no active ingredient
- an incorrect amount of active ingredient
- an inferior-quality active ingredient
- a wrong active ingredient
- contaminants
- repackaged expired products

The impact of counterfeit medications on the global pharmaceutical market has been estimated at $75 billion.

- US and Europe: 1% of prescription medications sold are fraudulent
- Developing nations: 30% of prescription medications sold are fraudulent

6.2.1. Current Limitations

Limitations exist in the traditional supply chain's fight against fraud. The following table showcases how community pharmacies operate without blockchain (current business model) which is based on an article published in the journal of American Pharmacists Association in 2012 (Chambliss, et al., 2012) and the respective impact effectiveness.

Table 5 Drug Counterfeit in a Traditional Supply Chain

Actions to fight drug counterfeit	How players fight in a traditional drug supply chain	Effectiveness of Impact
Validate procuring from reliable resources	• Purchase medications from known, reliable sources	• The effectiveness of the impact remains dependent on the intention of procurers to stick to reliable sources and products
Certify product integrity	• Examine products for suspicious appearance • Refrain from selling suspicious products until further investigation results are out	• There is no governance mechanism to validate the reliability of test results • It is the call of the sellers to refrain or not from selling suspicious medications
Report and monitor suspicious medications	• Monitor counterfeit product alerts • Report suspect counterfeit medication	• Traditional supply chain systems are configured for real-time monitoring, so the impact is effective • Reporting suspect counterfeit products is not enforced by any mechanism
Educate and raise awareness	• Warn patients of the dangers of purchasing over the internet (non-blockchain systems) • Educate themselves, coworkers, and patients about the risks of counterfeit medications	• The effectiveness of the impact remains dependent on the intention of procurers and on the seriousness of the patients to stick to trusted channels
Track and trace	• Ask for the drug pedigree and validate transaction history • Maintain pedigree by adding purchase details once the deal is done	• There is no mechanism to enforce the validation of the pedigree by procurers • There is no mechanism to validate the transparency of data fed into the system

6.2.2. A More Powerful Fight

Blockchain empowers the healthcare supply chain players to fight fraud more effectively. The following diagram showcases how we think community pharmacies would operate with blockchain and the respective impact effectiveness. Accordingly, we believe blockchain technology can help improve sustainability by fighting fraud more effectively.

Table 6 Drug Counterfeit in a Blockchain-enabled Drug Supply Chain

Actions to fight drug counterfeit	How a blockchain—enabled drug supply chain fights	Effectiveness of Impact
Validate procuring from reliable resources	• Invalid transactions will be detected and banned by the cryptographic voting on every transaction	• It is very expensive computationally to get more than 50% of the nodes of the system to vote for an invalid transaction
Certify product integrity	• Examination is automated and governed by smart contracts and dApps • Suspicious products are flagged so the system prevents their sale	• The blockchain technology is capable of full enforcement of rules, it only depends on the framework used to evaluate product integrity using dApps and smart contracts
Report and monitor suspicious medications	• Stakeholders on the blockchain network receive real-time updates/alerts • Suspicious products are flagged automatically	• Monitoring and reporting are hard-wired into the system and are done on real-time basis
Educate and raise awareness	• Once on the blockchain, all data is transparent, immutable, and safe for online purchasing	• The effectiveness of impact is limited to those who choose to purchase via blockchain-enabled systems but cannot contribute to purchases done via untrusted channels
Track and trace	• The essence of blockchain technology is founded on the validation of all past transactions • Blockchain technology forces users to feed transaction data electronically and validates them	• Traceability can be done on the package level from source to end-user and is as effective as designed to be

CHAPTER 7

CONCLUSION

Supply chain managers, in healthcare and other industries, are challenged to hone the capabilities of their supply chain to overcome the challenges of the current times, improve the supply chain sustainability, and maintain competitive advantage. We defined what sustainability means in the context of supply chain across the three P's: planet, people, and profit. Our thorough research about how blockchain can improve supply chain sustainability was synthesized into a matrix that maps every blockchain pillar to a sustainability criterion. However, blockchain technology is not a magic potion. Business owners and strategists must validate the business case for blockchain technology in the context of their industry and product. The number one step should be answering the question: are we looking to remove intermediaries? We proved that when blockchain technology has a viable business case, the sustainability benefits across planet and people dimensions must follow. The healthcare industry is one that is sure to benefit from disintermediation. Indeed, blockchain technology has the capabilities to empower the use-cases that the healthcare supply chain industry is looking for. Tokenization and automation can accelerate the move to pay-for-performance pricing models that are already gaining traction. Decentralization is key for universalizing the medical profile of patients, and immutability and transparency work together to guarantee the security and privacy standards that consumers, corporations, and governments require. As the various industries look for process re-engineering and automation as the way to enhance customer service and improve efficiencies, smart contracts enhance the interoperability levels among the set of players, applications, users, and infrastructures involved in any healthcare supply chain activity.

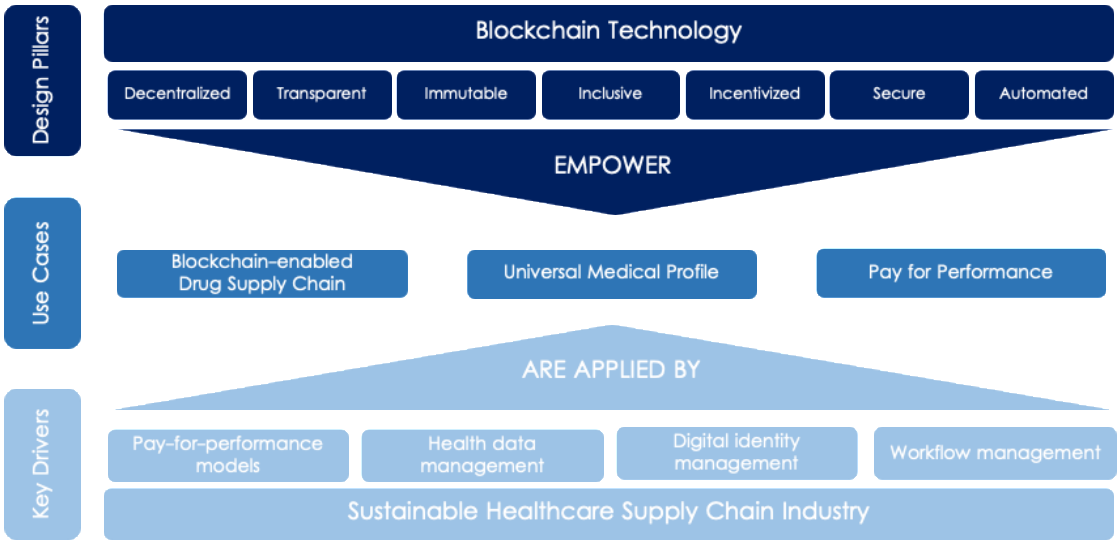


Figure 33 Blockchain Serves the Needs of the Sustainable Healthcare Supply Chain

We identified that blockchain has the potential to disrupt the business model driving the pharmacy's largest revenue stream: prescribed medication. Accordingly, we recommended that pharmacists consider diversifying their portfolio by introducing value-added services to their customers. In fact, our analysis shows that multi-purpose clinics, which is one of the options of value-added services that pharmacists can think of, have a positive impact on the dimension of sustainability.

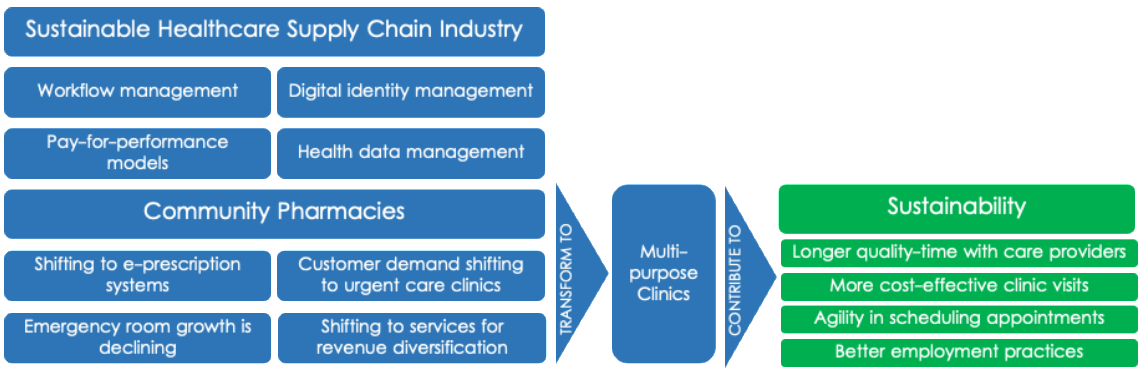


Figure 34 The New Pharmacy Business Model and Sustainability

Pharmacies seem to be the weakest link in the healthcare supply chain, and they have received the least attention in the subject of blockchain technology. We encourage researchers, technology evangelists, blockchain enthusiasts, who are interested in the function of supply chain or the healthcare industry, to further explore the impact of blockchain on the pharmaceutical traditional value chain and business model. During our project, we came across a few questions that are worthy of further investigation. We will end our report with our list of questions and hope that they would inspire readers to find the answers that might guide pharmacists on how their business and careers would change during the digital transformation journey.

- How does the pharmacist add value to every step of the patient journey? Accordingly, how can pharmacists maintain the sustainability of their competitive advantage against the threats of artificial intelligence, blockchain technology, and process automation?
- Why hasn't e-prescription replaced traditional prescription yet? Will blockchain be the catalyst that digitizes the overall prescription process?
- How will the creation of new pharmacy business models impact the role of current drug manufacturers and suppliers?
- As the role of pharmacists transforms under the light of the digital transformation, what will the pharmacist's career path and skillset look like soon?
- How should graduate and undergraduate education transform to bridge the gap between the labor market and current pharmacy education programs to equip students to an industry that is being disrupted?

APPENDENCIES

APPENDIX A

Table 7 Adaptation of Sustainability Criteria

Original Dimension	Original Criterion	Criterion #	Criterion Name	Dimension	Reasoning
Planet	Environmental Management System	0	NA	NA	too detailed
Planet	Number of obtained ISO Standards	0	NA	NA	too detailed
Planet	Environmental Costs	1	Cost	Profit	redundant
Profit	Cost/Price	1	Cost	Profit	
Planet	Green Design	2	Green Product	Planet	
Planet	Green R&D	2	Green Product	Planet	redundant
Planet	Green Product	2	Green Product	Planet	redundant
Planet	Eco-design	2	Green Product	Planet	redundant
Planet	Pollution Control	3	Pollution Control	Planet	
Planet	Ozone Depleting Chemicals	3	Pollution Control	Planet	too detailed
Planet	Recycling	3	Pollution Control	Planet	redundant
Planet	Pollution Prevention	4	Pollution Prevention	Planet	
Planet	Resource Consumption	5	Resource Consumption	Planet	
Planet	Water Consumption	5	Resource Consumption	Planet	too detailed
Planet	Energy Consumption	5	Resource Consumption	Planet	too detailed
Planet	Renewable Energy	5	Resource Consumption	Planet	redundant
People	Interests and Rights of Employees	6	Employment Practices	People	
People	Work safety and labor health	6	Employment Practices	People	redundant
People	Employment Practices	6	Employment Practices	People	redundant
People	Rights of Stakeholders	7	Rights of Stakeholders	People	
People	Information Disclosure	8	Information Disclosure	People	
People	Respect for Policy	9, 12	Respect for Policy	People	too detailed
People	Local Communities Influence	9	Local Communities Influence	People	
Profit	Quality	10	Quality	Profit	
Profit	Service Capability	10	Quality	Profit	redundant
Profit	Technology Capability	11	Technology Capability	Profit	
Profit	Production Facilities and Capacity	11	Technology Capability	Profit	redundant
Profit	Organization and Management	12	Organization and Management	Profit	
Profit	Reliability	13	Reliability	Profit	
Profit	Flexibility	14	Flexibility	Profit	
Profit	Total Cost of Shipments	1	Cost	Profit	
Profit	Number of Shipments	12	Organization and Management	Profit	redundant
Profit	Delivery	15	Delivery (Time)	Profit	

APPENDIX B

Table 8 Breakdown of Blockchain Effects by P Dimension

Blockchain Design Pillar	People	Planet	Profit
Incentivized	1	1	0
Decentralized	1	2	5
Secure	2	0	1
Including	1	2	0
Automated	0	2	4
Immutable	1	1	0
Transparent	1	2	1

APPENDIX C

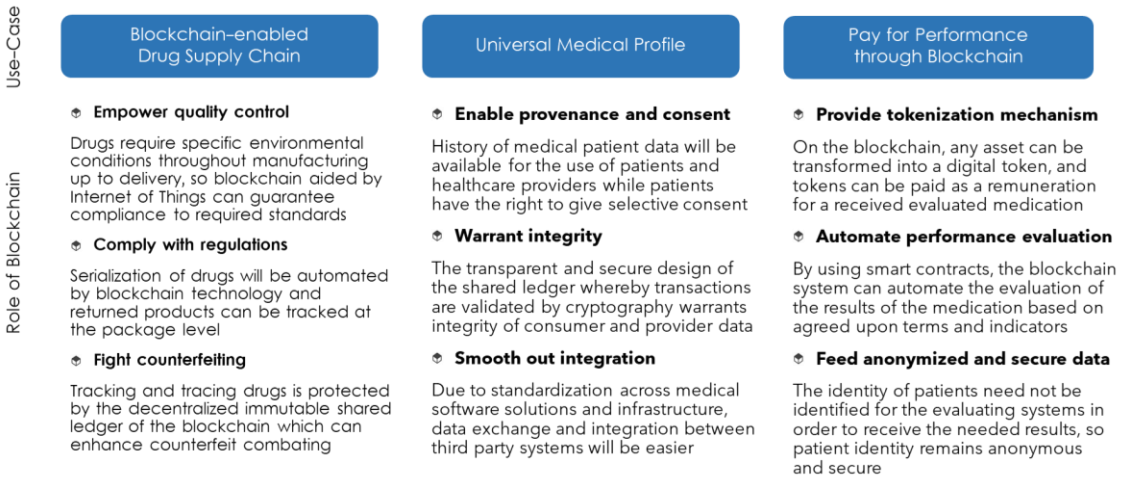


Figure 35 Blockchain Use-cases in More Details

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