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Engineering and Management

Development of a framework to guide enterprises in the evaluation of Blockchain based solutions for their supply chain

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Academic Year 2019/2020

Acknowledgement

The most important chapter of my life comes to an end. It has been an incredible and unexpected journey that allowed me to meet extraordinary people, colleagues and friends along the way.

The biggest thank you goes to my parents who have allowed me to start and finish this important path. I would have not made it without their support and trust, together with my family.

Thanks to my roommate Giulia who has always been there for me. Thank you to all the friends from my home city, Elena, Valentina, Aurora, Giulia, Rebecca, true friendship is not undermined by distance. A final thank you goes to Priyanka for always supporting and motivating me.

Finally, I want to say thank you to Torino that made me feel home since the very beginning.

Abstract

The first successful application of Blockchain technology is widely known, the Bitcoin. A new digital currency that can be used for transactions between parties without need for centralized financial intermediaries, introduced to the world by Satoshi Nakamoto in 2008. At the beginning, the study of the technology has been focused in the same direction of its first application and both companies and experts have further investigated the possible use cases in the financial sector. However nowadays, the awareness of the potential of Blockchain is widespread and it is applied to a wider variety of sectors and business functions.

One of the most promising applications of Blockchain regards supply chain management. Supply chains have become more complex over the years due to different trends such as globalization, high volatility and fierce competition. Even if different businesses want to deploy the technology there is little guidance to understand which specific applications could be most promising for the use of Blockchain in supply chain. The scope of the thesis is to address this gap and to present a framework that can guide enterprises in their evaluation of adoption of Blockchain.

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Introduction

The born of blockchain is set in 2008 when Satoshi Nakamoto published a white paper explaining the bitcoin and its underlying technology. The big innovation Satoshi Nakamoto introduced in the society is a new digital currency that can be used for transactions between parties without the need of centralized financial intermediaries, the bitcoin. This is possible thanks to its underpinning technology, Blockchain, a decentralized digital database which is maintained and updated by a network of computers that verify a transaction before it is approved and added to the ledger (Morkunas, 2019).

At the beginning, the focus of companies and experts has been on further investigate the possible applications and business disruption of this new technology on the financial sector. However nowadays, blockchain holds huge promises for a wider variety of sectors and business functions. As a matter of fact, Gartner Hype Cycle for Emerging Technologies which studies new technologies and its possible impacts has classified Blockchain between top five technology trends in 2018.

Between them, one of the most promising application of Blockchain regards supply chain management. As a matter of fact, supply chains have become over the years more complex due different trends such as globalization, huge number of components used for each product and better customer experience. As a matter of fact, the dynamic, multi-functional and global nature that Supply Chains have now, (Mentzer *et al*. 2001; Choi *et al*. 2001; Choi and Hong; 2002) with their multiplicity of firms, processes and flows leads to big problem of complexity. This complication is determined by the number and variety of elements defining the supply chain and their interaction (e.g the number of participants, facilities, products, information flow, etc). Blockchain, thanks to its intrinsic characteristics of disintermediation and security, could help business executives to better manages and improve supply chains.

Different papers have been written on the promises of blockchain in supply chain and on the future use cases. However, there is little guidance to understand which

specific applications could be most promising for the use of Blockchain in supply chain for a business.

The scope of the thesis is to address this gap and to present a framework that can guide enterprises in evaluating the adoption of Blockchain. To come up with a final conclusion, the thesis has been divided in three parts. In the first part, a literature review concerning blockchain and the actual complexity of supply chain is presented. By defining blockchain and the actual limitations in supply chain management, this section will enhance the understanding of how the technology could really tackle and solve the actual challenges businesses face. In the second part, the methodology and the steps carried out to arrive to develop the final framework are explained. In the following chapter, data on pilot projects carried out by start-ups and incumbents, will enable us to understand the status of the applications of Blockchain around the world. The choice was driven by a will to deepen the understanding of the state of the application of the technology in supply chain management and to figure out what factors enable successful implementations. Studying and comparing different use cases, enabled the presentation of the final framework. In the third part, seven use cases, each of them belonging to a different sector, have been explained and analysed through the framework developed. Eventually, conclusions regarding possible evolutions and limitation of the research are given.

1 Blockchain

Blockchain is one of the most promising emerging technologies that has the potential to transform businesses and society. In this chapter, it is given a broad overview of the technology in order to have a better understanding of its possible applications in supply chain. The analysis is conducted not only from a technical point of view, but it is used a critical approach to study potential risks and outcomes.

First, the different actors that have led to the development and the use of the technology across sectors are presented. Then, the technology is analysed from a technical point of view and its possible use cases and architectures options are explained. The next step is an overview on the positive and negative aspects that surround blockchain. As a matter of fact, the technology can inhibit business frictions and create more value for stakeholder, but at the same time different obstacles are on the way. Also important is the understanding of the actual state of the regulations as it can really impact the speed at which the technology is adopted. Eventually, the concept of "Internet if Value" and its potential benefits for society are presented.

1.1 Participants in the ecosystem

Blockchain is a complex instrument that can be used for a wide range of scopes, from business to society. For its wide range of applications, a lot of actors are involved in the ecosystem. Some people, the innovators, who have been enthusiasts since the beginning and they have developed start-up based on blockchain solutions or invested in them. The venture capitalists, companies that have started doing big investments in start-ups relying on blockchain applications. PricewaterhouseCoopers, in its Global Fintech Report, has estimated that in 2016 the investments in this field are increased by 79% and in 2017 even more. Moreover, they have interviewed banks and financial services and 77% of them stated they expected to adopt blockchain as a part of a production system by 2020

(Pwc, 2017). Other actors involved are coders and developers who keep alive the system and work to improve it. An important role is also played by academic institutions that are funding labs to do research projects and by famous universities as Standford and New York where professors teach courses about this subject. In these years a lot of NGOs and civil society organizations are also born with the aim to use blockchain to protect in a better way human rights. As blockchain deals with financial assets, identities, votes and many other governments and regulators are studying this topic. Eventually, the last fundamental figure present is the user, all people in the world who decide to use platform based on blockchain application. (World Economic Forum, 2017)

Focusing the analysis on the start-ups developed during the lasts years it is possible to subdivide them in three categories: core infrastructure providers, applications developers and operators (Cambridge Center for Alternative Finance, 2017). *Core infrastructure providers* are the ones who develop all the core software necessary. They can be also further divided in firms providing protocols developments and companies focused on distributed ledger development. The major difference is that the second ones works on creating distributed ledger according to clients' needs using existing architecture. Nevertheless, it is challenging separating the two categories as the lines are blurred. As a matter of fact, an increasing number of protocol developers also assist customers and several network developers have built their own frameworks. *Applications developers* creates applications that run on existing distributed ledgers and *operators* are entities that provides different services and they operates using already developed applications. Recently, has been done a study by Cambridge Center for alternative finance, Ernest and Young and VISA on a sample of about 100 of start-ups and what stand outs is that the three segments are concentrated in the following way: 70 % are infrastructure providers, 10% are applications developers and 20% are operators.

Analysing from a broader point of view the start-ups ecosystem, it is interesting observing how many investments for blockchain solutions have been done over the years, how they are spread across countries and in which sectors they are concentrated. Statista (Statista, 2018) made a deep analysis about this and achieved

to discover different important findings. The biggest change in the amount of investments done worldwide, has been from 2016 to 2017 when the amount of money spent has passed from $ 500 M to $ 1000 M, a 100% of increase. Forecasts continue to be optimistic for the future and Statista predicts investments will reach $ 11.7 B in 2022. For what concerns where are located major investments, the biggest continent where entrepreneurs are finding funds is USA, followed by Western Europe and China. The distribution of the market value across industries has still its major concentration in the first sector where blockchain has been deployed for the first time, the financial one. Nevertheless it counts the 60% of the market value, other sectors are gaining traction, manufacturing and resources has 20% and distribution and services 15%.

As just see blockchain involves a high number of actors which lead the ecosystem in which it works to be quite complex and variegate.

1.2 Analysing blockchain technology

In this chapter, a broad overview of the blockchain technology is given. Firstly, the technology is explained from a technical viewpoint to foster reader awareness of its intrinsic characteristics. Then, other important aspect to know about the technology and its ecosystem are explained.

1.2.1 Technological running

A blockchain is a method for recording information that has the characteristics to be ordered, incremental, sound (cryptographically verifiable up to a given block) and digital. The name blockchain derives from its aspect to be composed by a sequence of blocks chained together through cryptography hashes.

Each block belonging to a chain has three important components: *block-data*, a set of information or transactions, a *chaining-hash*, a copy of the hash of the preceding

block and a *block-hash*, the hash value of the block plus the hash of the previous block. Each hash has a unique value that can be composed by numbers and letters with the function of a digital fingerprint. The hash functions are often based on-way functions, some mathematical problems which are easy to solve in a direction but not in the other. A simple example, given two number 9 and 12, it is computationally easy to calculate their product 9 * 12 = 108. By reverse, it is harder to state that 108 resulted from 9 * 12 as a composite number could have resulted from different combinations of numbers multiplied. In this way, the hashes characterizing the blocks permits to give to each of them their own identity, to create a secure chain and to connect all blocks together. New data can be added to the chain by creating new blocks while it is far more difficult to change the information inside an existing block. If something inside a block changes also its hash changes giving to it a new identity and causing the invalidity of all the subsequent blocks. Another factor that fosters the security of blockchain is that it does not resides in a single server, but it relies on a peer to peer network of computers. Each computer represents a *node* and has a copy of the ledger file.

Each time a user wants to add a block to the chain an actor has to validate it. To elect the leader who will decide the content of the block are used Proof of Work, Proof of Stake and Delegated Proof of Stake consensus algorithms. In *Proof of Work* algorithm an actor can become a leader by finding a solution to a mathematical problem. The only way to find a solution is by brute force (trying all possible combinations), therefore the actors better served are the ones with access to the most computing power. These actors are also called *miners* and when they validate a block they are rewarded with some currencies. This way to approve transactions is widely used but it leads to some limitations. First of all, it is true that everyone can mine, but at the same time to become a miner it is needed an important initial investment to have a server with enough computing power in order to reach a good possibility to mine a block. Moreover, miners are joining mining pools to increase their chance to gain rewards, in the following graph are shown the main ones:

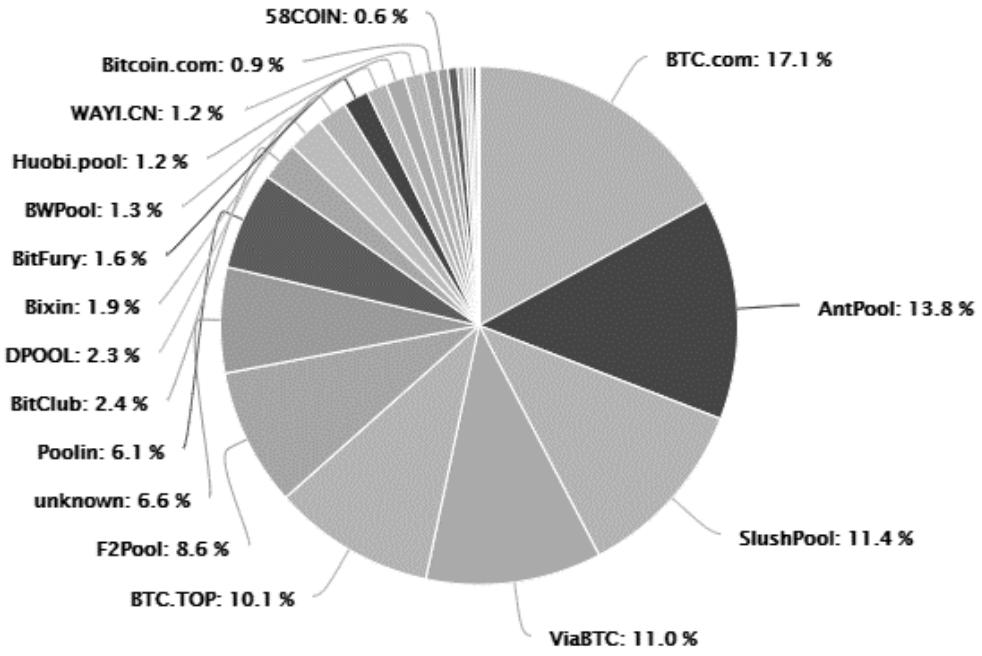


Figure 1 Pool distributions calculated by blocks validated in the last 3 months, BTC.com statistics

This can become a danger for the security of the system as if the three bigger pooling systems (Figure 1) decide to merge they would reach the 51% of the network and they could effectively control the system. This risk is called 51% attack. The other algorithm is called *Proof of Stake*, it takes away the energy consumptions and the computational requirements of Proof of work and replace them with stakes. Therefore, the actor, who will forge a block and receives the fees associated to it, is chosen by considering its wealth, the amount of data an actor is willing to lock up for a certain amount of time. This deposit is used as a guaranty in case the actor, once chosen as validator, approves a fraudulent transaction. Here it is not trivial to decide how to select the next validator, cannot be completely random because the size of the stake has to be considered, but at the same time taking in account only the initial deposit would be a strong bias in favour of rich people. Also in this case could occur the 51% attack but it is less probable as it would mean someone could afford to buy the majority of the network, that considering the case of Bitcoin and its value would be: 51% * market capitalization is equal to $ 79,826,299,343.7. The other algorithm derives from the last one described, Delegated Proof of Stake, tries to solve the problems of speed and

scalability. In this system, users vote to select *witnesses*, other users they trust to validate the transactions, and the ones who collect more votes have the right to proceed with the validation of the block. The weight of the vote of each user is not equal but it depends by its stake and users can also delegate their voting power to other users they trust. This is a continuous process so each witness in the top tier is always at risk of being replaced by a user who gets more votes and is therefore considered more trusted. As a blockchain grows, it becomes increasingly competitive to become or remain a witness in the top tier. Another figure present in this algorithm are the delegators, they oversee the governance and performance of the entire blockchain protocol, but do not play a role in transaction validation and block production. For example, the delegates can propose changing the size of a block, or the amount a witness should be paid in return for validating a block. Once the delegates propose such changes, the blockchain's users vote on whether to adopt them.

When a blockchain is created the algorithm provides for a set of rules to create and validate blocks. With the time going by, especially in case of open ledger, what can happen is a disagreement about the consensus rules. The change in protocol it is called "fork" and it can be of different type depending on the relationship of the rulesets. When the new rule emerged is incompatible with the previous one a *hard fork* occurs after some miners decide to mine on the new ruleset while others continue on the old ruleset. In this scenario, an example is the split in Ethereum and Ethereum Classic, no block produced under the new rules is valid under the old rules, and vice versa. Another case is when the two rulesets intersect and occur a *semi-compatible fork*. In this case miners can avoid the split by mining only the blocks who have the characteristics of the intersections. Otherwise there will be a chain of blocks coherent with the previous ruleset and with the intersection but when a block with the new rules appears will occur a split. A third case is the *compatible hard fork* when the ruleset expands by allowing further conditions. When a block has the new rules not belonging to the previous set the chain splits. The risk of this scenario is that if to mine the older and stricter conditions implies more work miners will tend to mine only the blocks with the new conditions. An example of this type of fork is Bitcoin XT, Bitcoin Classic, and Bitcoin Unlimited.

Eventually, the last case is the soft fork when the ruleset is tightened. A soft fork is when the ruleset is tightened, and the Yellow rules are completely covered by the Red rules (thus only Orange and Red rulesets). The chain split can occur whenever a miner creates a block with the stricter ruleset. This type of fork occurred in Bitcoin's history numerous times with changes such as BIP66, CSV, CLTV, and is in the proposed SegWit Soft Fork.

1.2.2 Architecture options

Blockchains can be permission-less and permissioned, depending on the permissions granted to participants, public or in a private according to ownership of the data infrastructure. All the four emerging options have different characteristics and are generally applied in different business scenarios. The most famous permission-less and public application is the Bitcoin, the first digital currency created and the world first blockchain application. Ivren, is an example of public and permissioned application, a new way to control each ones' digital identity, where everyone can join but only authorized people can change the rules of the ledger. Eventually, the two types of blockchains, based on a private ownership of the data infrastructure, are the ones most deployed by companies. From Figure 2 it is possible to have a clearer overview of the four types of architecture options and same practical example of already tested applications (BCG, 2018).

	PERMISSIONLESS	PERMISSIONED
PUBLIC	• Anyone can join, read, write and commit • Hosted on public servers • Anonymous, highly resilient Example: Bitcoin Low scalability	• Anyone can join and read • Only authorized and known participants can write and commit Example: Sovrin Medium scalability
PRIVATE	• Only authorized participants can join, read and write • Hosted on private servers • Example: Multiple banks operating a shared ledger High scalability	• Only authorized participants can join and read • Only the network operator can write and commit Example: Internal bank ledger shared between parent company and subsidiaries

Figure 1 Different types of blockchain

1.2.3 Blockchain Myths

The scope of the following paragraph is to highlight the true characteristics of blockchain by distinguish from its myths (Mckinsey, 2018).

- Blockchains are not 100% secure but they are more secure that most of other systems. As a matter of fact, Blockchains employ cryptography for authentication, permission enforcement, integrity, verification, and other areas. Nevertheless, just the application of cryptography does not automatically make the system 100% secure. The system will be more resilient as data storage and permissions are distributed, but it is fundamental the management of private keys. The compromising of them in some network participants could give attackers access to the shared database and the possibility to modify transactions.

- Blockchains are not “truth machines”, they can verify all data and transactions contained but cannot assess if an external input is accurate. Even if blockchains are well suited for the record of assets or data, they cannot value whether a given input from the ‘outside world’ is true or not. If the input is inaccurate or wrong, the blockchain will just treat it as any other input and consider all transfers involving the input as valid as long as certain conditions are met. As a matter of fact, a trusted third party is required to verify and guarantee the accuracy of the input when inserting it into a blockchain.

- Blockchains are not trust less, they always require a certain level of trust. Although blockchains may help reduce the need for trust, they do not completely remove the need for trust. The sharing of trust is supported by the underlying cryptography. In the case of a permissioned network, trust must be placed in the operators and/or the validators. If well configured, permissioned blockchains are at best ‘trust-minimising’ in the sense that they enable participants to independently validate transactions and verify the state of the system.

- Blockchains are not immutable as transactions in some specific circumstances can be reversed. The belief that transactions are immutable derives from the illusion that data can only be added to, but not removed from the database. However, blocks comprising transactions can be reversed if enough nodes decide to collude. Reversing transactions may be even easier with permissioned blockchains than public blockchains, where colluding miners would at least need to spend computational power and/or cryptocurrency funds to do so. However, permissioned blockchain actors are bound by legal contracts and agreements that are designed to dis-incentivise collusion or other misbehaviour. If ‘mining’ in a permissioned blockchain is sufficiently decentralised across separate entities with different motivations, one can consider the blockchain to be tamper-resistant.

1.2.4 Possible Use Cases

Thanks to blockchain core advantages, there are several use cases companies and entrepreneurs are testing. In order to summarize all broad applications, it is possible to include them in six categories: static registry, identity, smart contracts, dynamic registry, payment infrastructure and other. [1]

Static Registry includes all the applications in which blockchain is used to create distributed database for storing reference data. For example, static registries have been developed to prove land titles, food safety and origins and patents.

Identity are distributed database with identity-related information, they are a particular case of static registry, they are treated as a separate group due to extensive set of specific use cases. Already a lot of start-ups have been created that belong to this category, such as applications to control identity fraud, civil registry and identity records.

Smart Contracts are a set of conditions recorded on a blockchain triggering automated, self-executing actions when these predefined conditions are met. It is one of the categories most important due to a wide range of benefits it can bring to several transactions in term of cost, time, and bureaucracy savings. Some of the applications already existing include managing insurance claim pay-out, cash equity trading and new music release.

Dynamic Registry includes dynamic distributed database that updates as assets are exchanged on the digital platform. The applications often involved the use of other technological tools as Internet of Things devices and they are nowadays used for fractional investing and drug supply chain monitoring.

Payment Infrastructure are dynamic distributed database that updates as cash or cryptocurrency payments are made among participants. Also in this case the applications done are several, including cross border peer to peer payment and insurance claim managing.

Other are use cases composed by several of the previous groups, examples can be Initial Coin Offer (ICO) and blockchain as a service.

1.2.5 ICO

ICOs can be defined as a mechanism used by new ventures to raise capital by selling tokens to a crowd of investors (Fisch, 2019). They are based on a mechanism similar to crowdfunding, but the unique aspect is the selling of tokens, a unit of value issued by the company. There are two types of tokens, *utility tokens* and *security tokens*. The first one is the one most commonly used and can be defined as a digital medium that allows the exchange of utility. A lot of start-ups have created their own cryptocurrency by issuing tokens that have the role to function as currency in the start-up's ecosystem. Security tokens are investment vehicles that can allows investors to participate to the control or ownership of the company. For each of the two types of tokens it has been created a secondary market where tokens against tokens or tokens against currency are exchanged. The first ICO was conducted in 2013 by MasterCoin, a digital currency. After that, the number of ICOs is increased sharply during the years. There is not a common platform where ICOs must take place, so it is not possible to have an exact estimate, but as various websites track the evolution it is possible to have some estimates. In 2017, 366 ICOs took place for an overall value of USD 6.2 Billions, while just in the first quarter of 2018 254 ICOs took place raising USD 7.8 Billions.

1.3 SWOT Analysis

The SWOT is an analysis carried out to understand the main strengths, weaknesses, opportunities and threats of a business. It is a powerful tool that permits to have a wide picture of the situation, by understanding what the opportunities are to exploit, the strengths to foster, the weakness to overcome and the threats from which defend. In the case of blockchain have been individuated the following characteristics.

Strengths:

- Possible huge market penetration, all people can access to it
- Less bureaucracy, documentations needed
- Eliminate powerful and monopolistic central authority
- Security and encryption

Weaknesses:

- System very rigid, low flexibility
- Time to record information too high for certain industries
- Complicate functioning for common people
- Potential conflicts with global regulations
- Low qualified workforce

Opportunities:

- Wealth for people excluded or penalized by the actual systems
- Give to people control of the data they leave on internet
- More transparent and efficient processes in the industries

Threats:

- More powerful computers that can decrypt data
- Possibility of mining attacks
- Undesired centralization in mining pools
- Scalability issues due to overloads for too many transactions

1.4 How Business Frictions Disappear

Over the years, the human progress has allowed to overcome different frictions. From the introduction of money to replace barter to the use of computers as typewriters, digital innovations have accelerated the process of frictions reduction. Internet has been an important tool against frictions, it has significantly improved transaction costs and imperfect information. Nevertheless, other frictions have grown as conflicting cross border regulations, cyber-attacks and powerful intermediaries. Today it is possible to identify three main types of frictions that cause high costs and are an obstacle for an efficient global business and trade: information, interaction and innovation frictions. (IBM, 2018)

Information frictions arise for different reasons. When participants interact in a transaction not all of them have access to the same information and this asymmetry causes several problems and delays in decision making processes. Moreover, the era of big data has originated significant challenges in term of data storing, processing, sharing and analysing and still there are some inaccessible information. Eventually there are technological risks to information, from hacking to cybercrime and privacy concerns.

Interactions frictions are due to transactions costs that increase sharply for businesses as they grow in size, resources and complexity. As a matter of fact, a lot of intermediaries are involved in each transaction and this degree of separation between them cause delays and potential risk of disruption by nimbler competitors.

Innovation frictions are caused by different legacy and bureaucratic systems that slow down companies' responsiveness and ability to change. Highly regulated industries and cross-border operations are daily stifled by delays. In this scenario new competitive business models made possible by new technologies introduction are tangible threats.

If all these frictions fall there are incredible advantages for companies in term of reducing cost, time and risk. With varying degrees to different industries, business model changes enabled by blockchain can really impact enterprises' profitability.

As a matter of fact, blockchain can help companies to be efficient, trusted and more competitive and this is due to six main characteristics of blockchain.

It is *distributed* and this means there is not a central database to hack but each blockchain runs on computers provided by volunteers around the world. This permits to send any form of digitalized asset directly and safely. Each computer represents a node of the chain and in some of them reside the miners who have the fundamental role to create new blocks.

It is *encrypted* as it uses heavy-duty encryption involving public and private keys to maintain virtual security. For example, in the case of the Bitcoin blockchain, to exchange bitcoins you need a digital wallet which is protected by a private and a public key. The private key allows you to unlock the wallet and make transaction, while the public key let the other users check the transactions.

In most of the cases it is *public,* so any people can download files and see transactions as the information are not stored in a central storage, but they reside on the network. This is especially true for financial application as Blockchain or sharing platform, but not for the use of industries that decide the actors involved in the system to protect their information.

It is *inclusive* therefore it gives to all people who have access to internet to join a platform or create a new one. There is no need of references or of minimum requirements as it is for example, to create a bank account. This creates a huge opportunity for people left out or penalized by the actual system. Not for nothing, an English artist, have a create the blockchain based platform Mycelia to give a sustainable future to music.

Each minute some transactions are verified, cleared and stored in a block that is linked to the previous one, creating in this way a chain which is *immutable*. As a matter of fact, if something inside a block chain is changed immediately its hash is modified by making invalid that block and all the subsequent ones.

The last characteristic is that it is *historical* so if you want to steal something you need to rewrite its entire history. Moreover, each transaction is time stamped so it

is easy to verify when the transaction happened. Generally, a timestamp is considered valid if is greater than the median timestamp of previous 11 blocks, and less than the network-adjusted time plus 2 hours.

The just cited features allow blockchain to provide promising solutions for a lot of fields, from the recording of anything of valuable for the humankind, to the exchange of assets, to the track of goods. These characteristics permit to industries to improve their service by meeting costumer needs, create more efficiency and speed up the processes.

1.5 Challenges to Address

The use of blockchain brings also some disadvantages and risks that need to be clarified to allow the system to perform in a proper and efficient way. Being aware of the limitations is an essential step in order to understand how to tackle them and avoid the failure in the execution. As a matter of fact, many times when new technologies and products are adopted before being demonstrated safe, secure and trustworthy, they have sadly resulted in immeasurable economic losses for companies.

First of all, blockchain is a *slow* process, each node needs to be validated by asking to all the network if the request is coherent with the norms of the transactions. Then, after the control, it is validated and re-written. Different businesses are working on more efficient consensus mechanism to accelerate transaction speed, for example, proof of stake is far quicker than the first method utilized, proof of work. The total process can require some minutes and for businesses with a lot of simultaneous transactions, for example IoT devices that interact continuously, is too much time to be an efficient system. Due to this big limitation many observers not consider blockchain as a viable for large-scale applications. (Deloitte, 2018)

Moreover, blockchain relies on intense computing power and hence consume lots of *energy.* This especially depends by the consensus algorithm used, with proof of work causing the highest energy consumption. It has been estimated by Morgan

Stanley that the original blockchain, the one of the bitcoin, uses almost the same energy of Argentina. The energy efficiency is key for the scalability of the technology and for this reason big tech companies as IBM, Amazon and Microsoft are working on blockchain networks by using cloud technology in order to reduce costs and complexity. Their work in the field is focused on creating what is known as blockchain-as-a-service, where effective "templates" are offered in order to make it easier for developers to set up and run blockchain networks (Zhao, 2017).

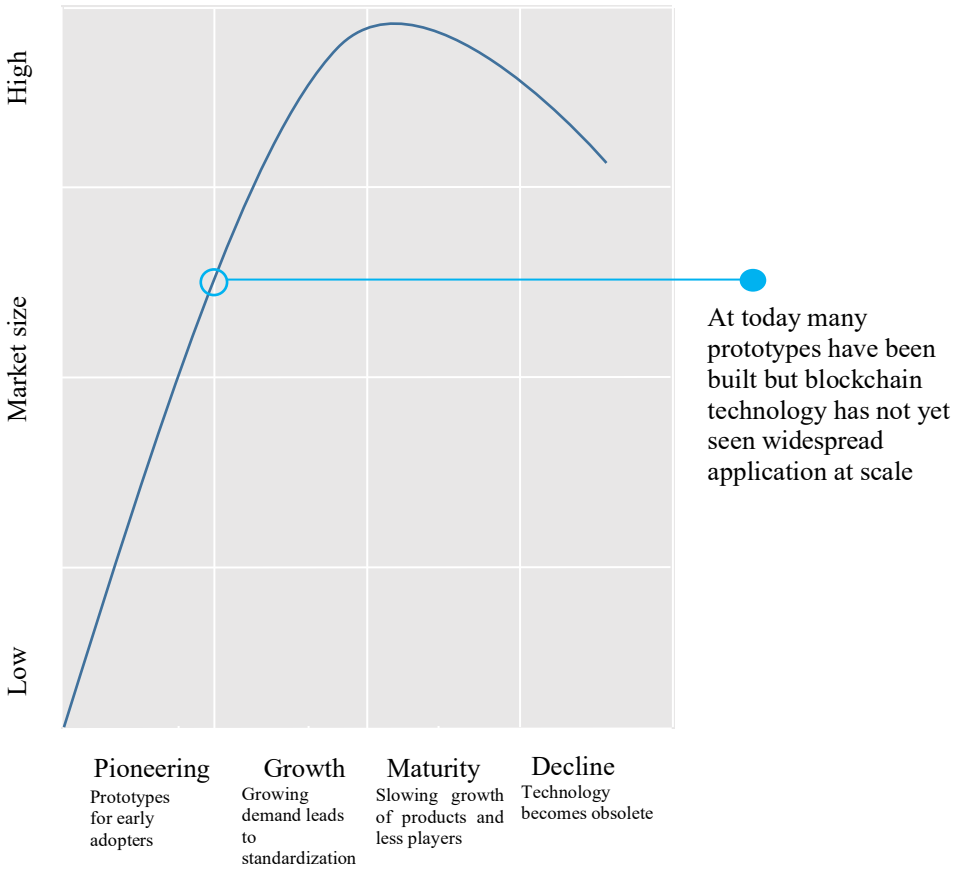
An increasing number of players is creating blockchain-based solutions using different coding languages, protocols, consensus mechanism and privacy measures. The *lack of standard* gives more freedom to developers and incentive the innovation phenomenon but makes the collaboration between actors involved in the ecosystem more complex. With so many networks the risk of non-interoperability between the applications developed is high. l. Organizations that include hundreds of members are working on creating a standard version of blockchain in order to overcome the interoperability problem. Nevertheless the efforts diffused, private and public sectors still need to cooperate and develop a proper legacy and regulatory framework at national and global level.

Another challenge lies in the design of a computationally infeasible *hash function*. The problem is that this characteristic cannot be static, but it must change with the advancement of mathematics and computing, a hash algorithm that is cryptographically secure today may not be cryptographically secure 20 years from now. This jeopardizes the possibility to design a distributed ledger system resilient over time. For this reason, it would be important to evaluate the creation of systems that allow changes in the hash functions.

Eventually it is diffused a phenomenon of *inertia* in the adoption: blockchain is based on the sharing of information and a lot of companies are reluctant to showing their data to external entities. By analysing the transactions, what comes out is that the data shared are not about companies know how or specific competences but about the happening of certain events (i.e timing of arrival, temperature of a product, etc.). For this reason, the companies that have decided to understand better the technology have overcome this initial obstacle. Therefore, it is important this

message is spread and understood by all companies so that they can cooperate in building networks.

For all these reasons blockchain is considered an infant technology that it is still expensive, unstable and complex. A further evidence is given Figure 3 (Mckinsey, 2019) where the technology is positioned on the product development life cycle. It is underline how blockchain is still at the beginning of its development as sales tend to be low and return on investment negative.



Even though some problems need to be fixed to make a good and efficient use of blockchain technology it holds big promises for society and businesses therefore both companies and individuals are working on it.

1.6 Regulatory Issues

Between the applications of blockchain there are also cases linked to unethical purposes, especially different bitcoin systems have been known for their scandals. Costa Rica based Liberty Reserve has been used to launder illegal activities in about 55million transactions and an estimated worth of US$ 6billion, Silk Road is known as a "darknet" where it was possible to buy illegal activities, from drugs to hit a man, and it counted US$1.2 Billion in sales and one million of costumers. These events have pushed people to associate blockchain with cybercrime (Yeoh, 2017).

For all these reasons is necessary a regulatory approach towards the possible misuse of the technology. Public sectors all over the world are concerned about the instabilities and the vulnerabilities associated with virtual currencies and their trading exchanges. However, there is still an absence of strategic governance to set up agreed rules and to ensure compliance. Governments prefer industries to lead in the advancement as they are afraid that regulating blockchain at the early stages may be counterproductive. Even if it is a fair concern, it might be a good option for governments participating as players in the bottom up governance ecosystem instead of as enforcement of top down regime of control. As a matter of fact, some entrepreneurs are afraid to invest too many time and money in a product that at the end will be declared not compliant.

The European decided to adopt a smart regulatory approach, combining two different initiatives: the creation of a virtual currency task force and the inclusion of virtual currency exchange within the ambit of the European anti laundering directive. They chose a precautionary monitoring instead of pre-emptive regulations as in this way they are confident they can have solutions in case

problems arrive. The message they want to transmit is that a permission less environment is necessary to really innovate, premature regulations would be an obstacle.

There are different critical points that European Commission wants to address. One of these regards tokens, as a matter of fact, it is not clear if classify a token as a security, a financial instrument or a mean of payment and this choice has then a huge impact on the regulation. One other point is about the tax and accounting treatment of crypto assets. An issue concerns also the smart contracts, self executing contracts can lead to big advantages for some businesses, but institutions are wondering if codes can really be law and how to handle possible litigations. Eventually one big question mark is how to conform blockchain to new General Data Protection Regulation (GDPR). GDPR is a comprehensive update to European data protection regulation with the objective to protect data rights of individuals and at the same time facilitate the free movement of personal data in Europe. The law has been conceived and written before the wide use of blockchain technology and many GDPR stipulations seem to clash with blockchain decentralized approach. For example, blockchains are always growing and they are databases where information can be added but not removed. This characteristic is in conflict with GDPR that explicitly gives to individuals the right to have their data amended to ensure it remains accurate. Moreover, in blockchain system is difficult to identify the "data controller", the person responsible for data collection, as all the nodes process the information (European Union Blockchain Observatory, 2018).

With these concerns in mind, the European Commission is committed to address a set of priorities. It wants to clarify the regulatory framework, with particular attention towards GDPR to be sure investments in innovation are not at risk on compliance ground. Moreover, it considers a central point to continue to invest in education and research in order to be competitive with US and to tackle blockchain talent shortage. Eventually, European Commission desires to promote collaborations between governments and companies, drive the adoption in public and private sectors and foster blockchain innovation by continuing to study the ecosystem and providing data on its growth and condition.

1.7 The Internet of Value

In the 1980s with the born of internet, it started the so called “era of information” where for the first time in human history it was possible to have access in a free and speed way to a huge variety of news and information. By 2003 tens of millions of people around the world were daily looking on Google for everything, from food to commerce, education, leisure, sport and music. This historic period has marked also the shift from traditional industry, born with the Industrial Revolution, to an economy based on technology. Innovation has not only changed people habits but has also disrupted the way businesses are conducted. World leading organizations as Coca-Cola or Procter & Gamble, have invested over years before establishing their products globally building customizing marketing campaigns, supply chains and assets. Nowadays, new companies are expanding with an outstanding speed and with less investments, as they can reach digitally connected customers through their platform. China’s Xiaomi, for instance, has achieved to become the second biggest player in the Chinese market in just two years, Uber has entered 77 countries in six years and Netflix has penetrated 190 countries in seven years. (BCG, 2017)

Through the diffusion of social medias and different peer to peer platforms, people started changing habits and behaviours in different situations. For example, nowadays people have completely overcome the fear to share something, as a ride or a house thanks to the development of accurate feedbacks and security systems. For this reason, in a lot of sectors, such as housing or transportation, the power of intermediaries has gradually lost importance, as people trust each other without the need of a third part approval. Nevertheless, the situation is different in other transactions as the transfer of assets, where there is still need of intermediaries like governments or banks. As a matter of fact, when people use internet to share something, they are not sending the original version, but a copy, and when it comes to assets, it is a problem. Therefore, society still relies on a lot of intermediaries to establish trust in the economy. This has created a lot of wealth but at the same time it has increased the social inequality; banks have allowed people to protect cash deposits and to invest money which has been a huge benefit for society, but at the

same time, not all people have enough money to create a bank account. The inequalities are particularly emphasized in countries as Africa and India where weak governance led to corruption and a weak enforcement of rights. For instance, about 90% of land is undocumented or unregistered in rural Africa and the lack of land ownership remains among the most important barriers to entrepreneurship and economic development also in other developing countries such as Honduras or India.

This problem could be exceeded with the use of the blockchain where every kind of assets from money to music can be stored, moved, transacted, exchanged and managed in a secure way. All people can have access to it and transact peer to peer. This would permit to switch from the internet of information to an internet of value. A lot of academics and people are enthusiast for blockchain also for this reason. The born of Internet allowed to create new jobs, give visibility to small realities, reduce bureaucracy, but at the same time has destroyed the business model of some industries. For instance, the sector of artists is one of the most penalized, the raise of internet has broken the system of intellectual properties and left artists in the misery. They are not the only segment disillusioned by the actual structure of the world, but a lot of people for different reasons have lost faith in the way institution work and manage your assets. Therefore, blockchain has the potential to be the tool to allow equal opportunity and rights to all members of society. (Kshetri, 2017)

A big supporter of blockchain diffusion is the American economist and business man Don Tapscott that, through his speeches and books, deeply points out the opportunities coming from it. In particular, he believes blockchain is not only a way to improve business processes and practices but the mean to reach prosperity in society. He believes the first era of internet brought wealth but not shared prosperity and an evidence of it is the increasing sense of anger, extremism and protectionism caused by the growing of inequalities. The American economist sees blockchain as the tool to change this situation by democratizing wealth creation engaging more people in the economy and then ensuring them a fair compensation. To allow people understand better what he means, he makes five practical examples of blockchain

applications with a huge impact in the world prosperity. According to him blockchain helps all the people in the world who have a land but not a tenuous title to it, creates a true sharing economy, ends the remittance rip-off, allows people to control the online identity and ensure a fair compensation for the creators of value. These are not the only societal implications of blockchain but by operating in only these five fields a lot of people can have a huge improve in their life. (Don Tapscott, 2016)

2 Blockchain in Supply Chain Management

Nowadays supply chain management is a strategic function for businesses. By efficiently organizing and improving supply chain companies increase profitability and deliver better experience to customers. For this reason, each time a new technology appears its possible application to the management of supply chain is studied.

For this reason, incumbents and start-ups have started to analyse and implement possible use cases deriving from the use of blockchain. The technology is still at an early stage of development, but thanks to the promising effects of its application, different companies are already engaged in pilot projects.

In this chapter, the complexity and the challenges global supply chain faces today are presented. The analysis goes also through an understanding of the main worries and objectives for executives that daily deal with this topic. Then, the development of the blockchain applications in supply chain management is explained to understand what use cases are more promising. Eventually, an overview on how to assess the possible creation of value in a business with the application of blockchain.

2.1 Supply Chain Complexity and Challenges

Handfield and Nichlos (1999) defines supply chains as all the activities associated to the flow and transformation of goods from raw material to the end customers. Supply chains have evolved over the years and Andrew Cox (1999) gives a more modern vision of what supply chains mean nowadays. He underlines how the technological revolution allows to fundamentally transform existing supply chains through the erosion of dis-intermediation and the speeding up of information between final customers and all the stages of supply chains. As a matter of fact, the dynamic, multi functional and global nature that Supply Chains have now, (Mentzer

et al. 2001; Choi *et al*. 2001; Choi and Hong; 2002) with their multiplicity of firms, processes and flows leads to big problem of complexity. This complexity is determined by the number and variety of elements defining the supply chain and their interaction (e.g the number of participants, facilities, products, information flow, etc). The key to successfully manage such complex supply chains is to effectively integrate functions and channels such as all business processes are aligned to achieve the overall system objectives (Sahin and Robinson, 2002, 2005). At this purpose, Andre Cox (1999) underlines how effectively managing supply chains have two dimensions, one operational and one entrepreneurial. The main focus of companies has always been to develop unique supply chains, constructed to receive inputs and outputs and to then deliver products and services to customers. All companies have operational supply chains which are specific to the kind of business and product they serve. However, it is also important to focus on entrepreneurial aspects in order to have a supply chain competitive also from a strategical point of view. Companies need to understand the best way to structure the supply chain in order to capture value.

Given all these considerations, it comes easy to recognize all the challenges that derives from supply chain management. Both manufacturing and services have started to source from different countries in order to gain a competitive advantage through effective supply chain management strategies. In particular, the reasons behind this strategic choice are the will to achieve technological innovation, shorten the product lifecycle, reduce product price and decrease total cost of ownership (Angappa, 2015). Moreover, the same structure of products, with suppliers specialized in producing just small components, has added complications to supply chains. As a matter of fact, most of the companies nowadays have multi-tier supply chains with hundred or thousands of suppliers which contribute to the final product.

McKinsey has carried out an extensive analysis (Mckinsey, 2016) in order to deepen this topic and what stands out are the major concerns for executives dealing with supply chain management. They can be classified in the following categories:

- Increasing volatility of customers demand
- Increase competition

- Increasing customers' expectations
- Increasing cost pression on logistic and transportation
- Increasing complexity in suppliers' landscape
- Increasing volatility of commodities price
- Increasing complex pattern of customers demand
- Growing exposure to different regulations
- Increasing environmental concerns
- Geopolitical instability

In order to successfully face all these risks and still be competitive in the industry, executives have established different goals within their companies:

- Reduce operating costs
- Reduce inventory level
- Improve quality
- Improve customer service
- Decrease production time
- Decrease time to market
- Improve information sharing
- Create greener supply chains

Another important insight, about how to switch from operational to strategical supply chains, is given from the force field theory (Stanley 2008). Stanley underlines as within a company driving forces (e.g external threats) must exceed existing forces (e.g culture) in order to survive in changing environment. As consequence, the key for each company is to identify potential barriers (e.g inter-firm rivalry, lack of partners' trust) and then implement effective bridges (e.g technology, people empowerment).

As it is evident from these considerations, supply chain management is recognized not only as an operational role, but also a strategic one. As a matter of fact, by implementing the right strategies companies can effectively gain a competitive position and advantage towards competitors. For this reason, companies are investing and implementing new technologies to improve their supply chains,

between them, one which gives different opportunities in the sector, is the blockchain.

Products innovation adds complexity to supply chain

Over the past 50 years, information technology has brought to industries big changes in term of competition and strategy. Firstly, during the 1960s and 1970s, it automated individual activities in the value chain, from order processing and bill paying to computer-aided design and manufacturing resource planning. Then, during the 1960s and 1970s, the raise of internet enabled coordination and integration across individual activities between multiple figures: outside suppliers, channels, and customers spread all over the world. Now we are getting to the third wave of revolution where information technology is an integral part of the product itself and permits to create smart and connected products. (Harvard Business Review, 2014)

Customers are demanding this kind of products which are characterized by three main parts: physical, smart and connectivity components. Physical components comprise the product's mechanical and electrical parts, the smart ones include the sensors, microprocessors, data storage, controls, software, and, eventually connectivity components are the ports, antennae, and protocols enabling wired or wireless connections with the product.

Companies are working to offer them and their production means reshaping the value chain, by changing product design, marketing, manufacturing, and after-sale service. An important aspect to underline is that now companies not try anymore to sell a product, but to satisfy a costumer's need and with the entrance of smart and connected products this means widening the industries. The basis of competition thus shifts from the functionality of a discrete product to the performance of the broader product system, in which the firm is just one actor. The manufacturer can now offer a package of connected equipment and related services that optimize overall results.

This scenario of big changes in term of competition and industry structure is where the blockchain is situated. What now companies have to offer is a broader range of interrelated products connected between them and this means having huge and complex supply chains. Buyers deals with an increasing number of specialized suppliers spread all over the world which raise the difficulty to manage processes and information. Therefore, blockchain aims to be a solution to the growing problem of how to manage increasingly complicated network of manufacturers and suppliers at a time where transparency, speed and agility are critical.

2.2 Blockchain Applications Beyond the Myth

At the beginning of its discovery technologists thought it was the technology capable in few years to disrupt all the business sectors. However, with a better study of the phenomenon the limitations have emerged and now technologists are focusing on the most likely applications, the ones that permit to have a positive return on the investment already at the early stages of development.

Gartner, the consulting company which each year draws the hype cycle of the emerging technologies, come to the same conclusion and through the graph (Figure 4) underlines as blockchain has just overcome the hype of expectations and both companies and scientists are now concerned with its possible applications.

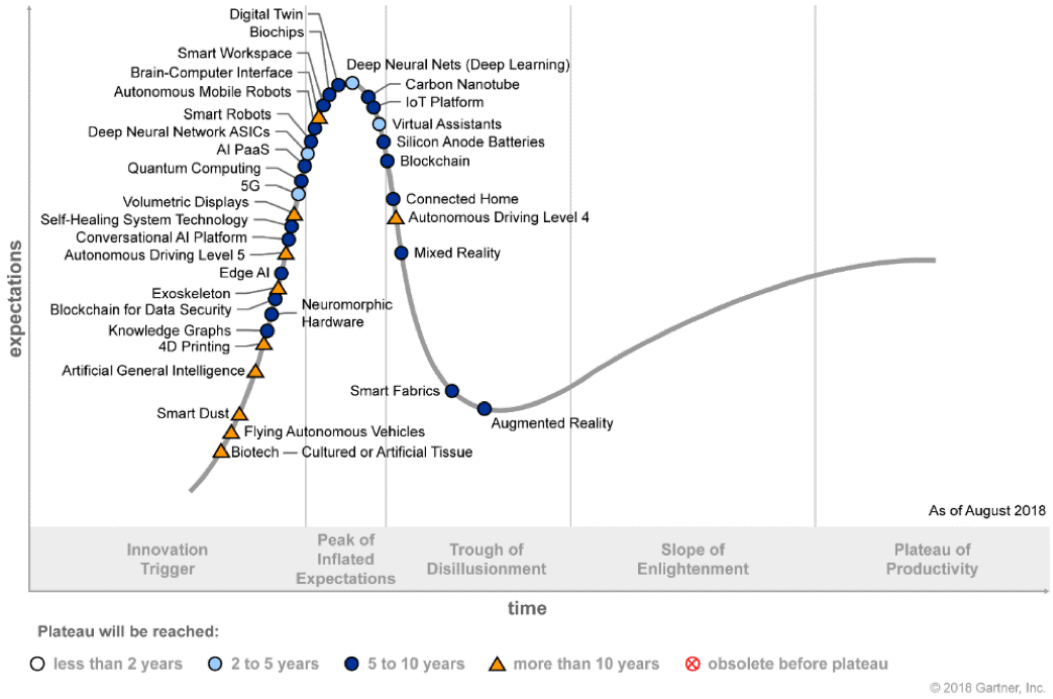


Figure 4 Gartner's Hype Cycle

A business entity in which blockchain holds huge promises is the supply chain. In this chapter the attention will be focused on the reason behind this consideration and on the sectors in which transparency and tracking of right information is essential to the business. This permits to justify the adoption of blockchain nevertheless it is still an immature technology which requires substantial investments. From a narrow operational standpoint, blockchains are not, in and of themselves, more efficient than centralized data systems and they require additional computation power. What they have more is the unique ability to solve important issues of trust and visibility in increasingly complex manufacturing and supply networks. When supply chain partners share data, financial information, and even intellectual property is thanks to the trust they have developed in one another's integrity and performance over the years. In today's complex manufacturing ecosystems, participants often don't know each other and they lack visibility into each other's data and activities. Trust must be built and blockchain can be the mean to do it (BCG, 2018).

There are different pains points that both incumbents and new entrants can tackle. In particular, they can be classified in nine categories: inefficient data and document management, complex regulatory compliance, trade-base money laundering and fraud, suboptimal equipment utilization, costly letter of credit process, non-transparent pricing and booking, complex claim and change of ownership, limited traceability, complex process in reverse logistics.

Nevertheless, all the possible use cases that derives from it there are some practical limitations that are delaying its application on large scale. The power of this solution increases with the network and not all the parties involved, have the degree of computerization necessary or the desire to share their data. Moreover, global supply chains work in a complex environment that requires parties to comply with different regulations and norms and translate them in transactions norms of the blockchain is not always easy.

These challenges are not stopping companies which are working to address and solve the challenges as the benefits deriving from blockchain are much bigger than the obstacles to overcome.

2.2.1 Incumbents and Innovation

The approach of big and established companies, when a new and potentially disruptive technology arrives, is a very critical factor. With the years, a lot of companies have understood, from the failure of some big companies as Nokia, that is better to embrace new discoveries and avoid being disrupted from innovative new entrants. As a matter of fact, different companies in the various sectors nowadays have learnt the importance of testing and investing in new technology. Nowadays a lot of them are committed to better understand the implication of blockchain in their business. Even if all the companies know this technology and its potential benefits, not all of them are in the same stage of application. Just the ones which have a strong culture towards innovation and the resources to invest are already in the phase of producing products. Globally companies have invested € 1,5 Billion (Statista, 2018) to study more the applicability of this technology, with the major

investments carried out in USA. In particular, from the following graph it is possible to have a look on the different stages of development of the technology in the various sectors.

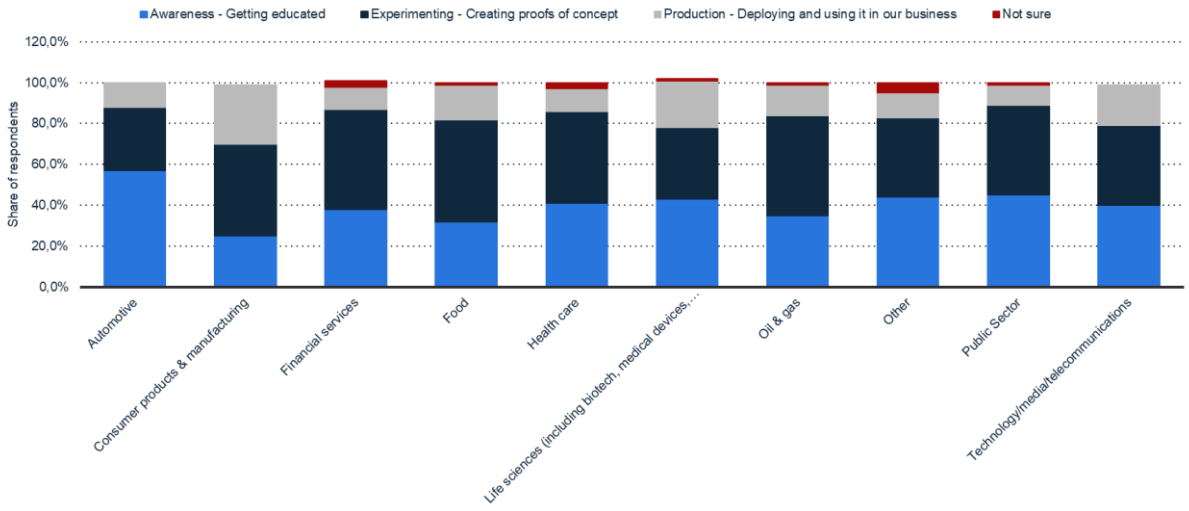


Figure 5 Blockchain applications per sector, Statista

What stands out from the graph is that financial services, healthcare, food and oil and gas are the sectors in more an advanced adoption phase. As a matter of fact, about the 20% of respondents in that sectors affirm they are already developing products using blockchain technology. Another positive factor is how all sectors are aware of the importance of the technology and, even if they have not already tested or developed solutions, they are getting educated about the possible applications of blockchain. Fortunately, nowadays most of the businesses have learnt the importance to have a proactive behaviour once a new technology steps in.

2.3 Value Creation

All world's leading companies run Enterprise Resource Planning ERP and other supply chain management systems in order to plan their production and inventory,

but they do not have access to a clear overall overview of products status locations. As a matter of fact, supply chains are no longer small networks, but they are vast ecosystems with different products variants moving from multiples companies and countries (Milgate, 2001). Although the inherent complexity for a lot of applications traditional databases are still an efficient solution. For some specific cases, especially when it is needed trust in the transaction, blockchain based solutions are more effective thanks to the support of smart contracts. In particular, it is possible to evaluate the suitability of blockchain applications by analysing the importance of automation and trust in the specific contest. If the value of trust and automation are critical for the application is where the blockchain is more suited (Figure 6).

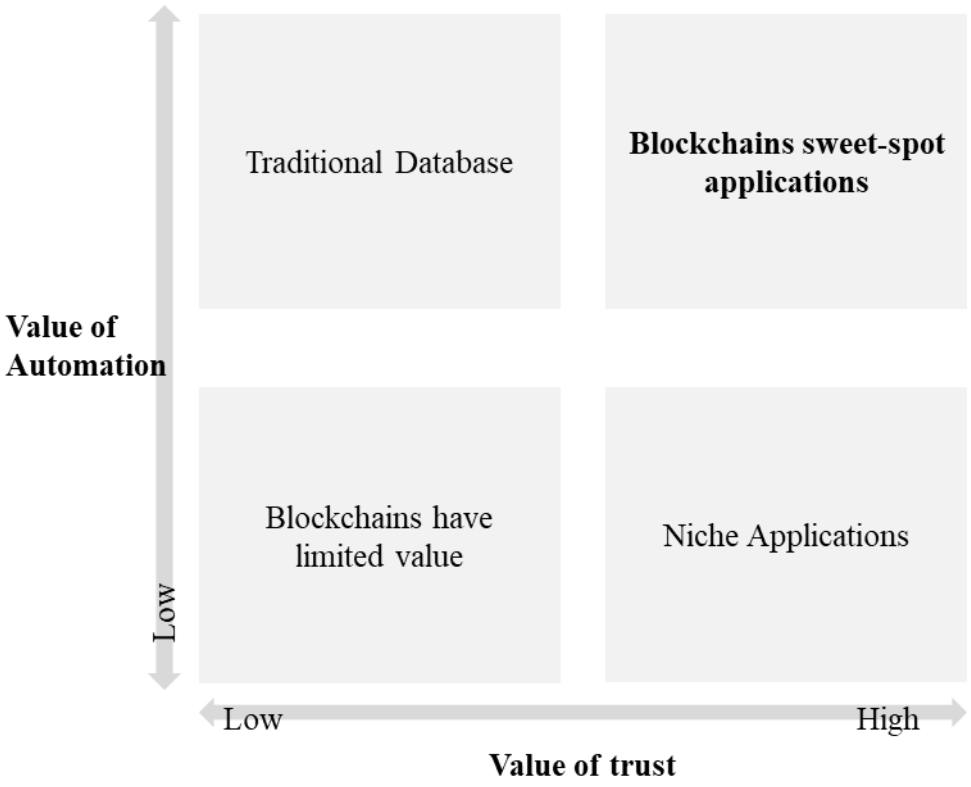


Figure 6 Blockchain Key Factors

Studies show as the link of supply chain and blockchain help to improve the business processes by optimizing key typical objects: cost, quality, speed, risk reduction, flexibility and sustainability. There are different use cases of the

application of blockchain in supply chain and some of them regard traceability and visibility of information. Here below are reported some typical advantages it is possible to reach.

Having a trustable and efficient supply chain is fundamental for companies as customers are demanding to receive the right products in a fast and reliable way. Disappointing some clients is the cause of big problems to the brand image as with the raise of internet and the diffusion of social media the phenomenon of the word of mouth can be faster and wider. Therefore, companies relying on supply chain as a key competitive advantage to serve value to the costumer are working to adapt blockchain based solutions. There are also other reasons for this choice.

With blockchain systems is possible for a company to understand what bottlenecks are in the process that have caused a determined delay or problem as the data put on the ledger by the parties involved are immutable and accessible in any moment. As a consequence, deciding what actions to take to overcome the issues become easier and efficient. In this way companies become more flexible in respect to the changing environment and with a higher adaptability to different requests.

At the same time a better control of the stages permits to decrease costs. For companies become possible to monitor suppliers' performance daily eliminating middleman that perform audits. In case of defective goods, they can pinpoint the faulty products without redrawing all the batches.

The amount of paperwork to manage by companies to move goods around the world is critical due to the approvals, interactions and communication flows needed, with blockchain all can be on made on the ledger, increasing the speed and lowering the costs. Moreover, the other side of paperwork to consider is that it can be tampered while the software can eliminate both this risk and the cybersecurity related risks.

What is most important to fully exploit blockchain as a source of transparency in the supply chain is the collaboration with other players. It is possible to observe how a lot of companies are aware of it in the sector and they have started to form consortium (BCG, 2019). For example, nine companies between carries, terminal

operators and software solutions providers created Global Shipping Business Network in order to improve speed, transparency, collaboration and digitalization. Maersk and IBM have set up TradeLens, a shipping solution to support information sharing and transparency along the supply chain. Eventually, Blockchain in Transport Alliance, composed by more than 400 companies in different sectors, strives to drive industry wide blockchain adoption.

3 Methodology

Different companies have engaged in blockchain pilot projects and a lot of start-ups have been created to tackle supply chains problems. However, as blockchain is still an immature technology, it is missing a clear framework to guide enterprises in evaluating the adoption of blockchain in their supply chain management.

This thesis has the scope to outline the key points companies, especially the ones which do not have the means to directly test new technologies, must consider in order to understand if blockchain is the right technology for them.

In order to answer to the research topic a qualitative approach it has been used. The rational behind this choice is that the stage of application of blockchain, as a matter of fact, is at an early stage of development and its knowledge is not still widely diffused across sectors and individuals. The qualitative research will be carried out with two methods, document and use cases analysis. As a matter of fact, document analysis is often used in combination with other qualitative research methods as means of triangulation (Yin, 1994), in order to create a confluence of evidence that breeds credibility. Moreover, this method provides different advantages in term of efficiency, availability of data, cost-effectiveness, lack of obtrusiveness, exactness and coverage (Bowen, 2009).

In particular, to arrive to the final framework with a solid and structured approach, the thesis has been organised in four phases (Figure 7).

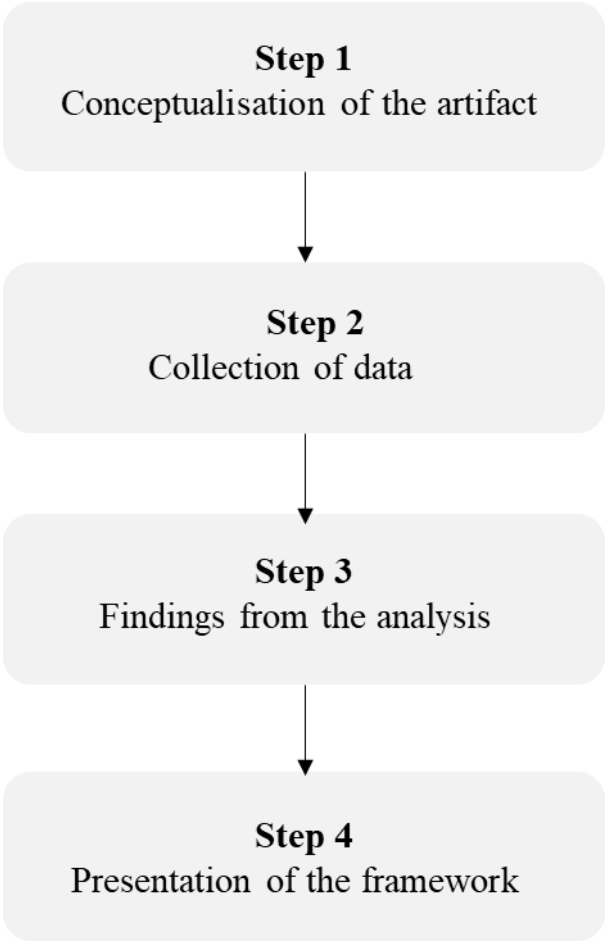


Figure 7 Steps towards the Final Framework

3.1 Conceptualisation of the Artefact

As in the literature review the current situation has been already analysed from a theorical point of view, in this part the study is focused on documents explaining the practical aspects and a particular attention is given to the use cases already existing.

The first point is to investigate different use cases across multiple sectors in order to understand the main factors and drivers for the implementation. Blockchain has been applied in all the sectors, from entertainment to hospitality (Appendix 1), but

its application for supply chain improvements characterizes especially the logistic, food, luxury, healthcare, energy and aviation sectors. This is due to inherent characteristics of such businesses. As a matter of fact, in the just citied sectors supply chain is very complex and fragmented. Each transaction involves an enormous amount of operations and actors leading to a huge need of trust and transparency. Nowadays companies operate on a global scale and even if they belong to different sectors, it is possible to outline a schema which shows what a global supply chain implies (Figure 8).

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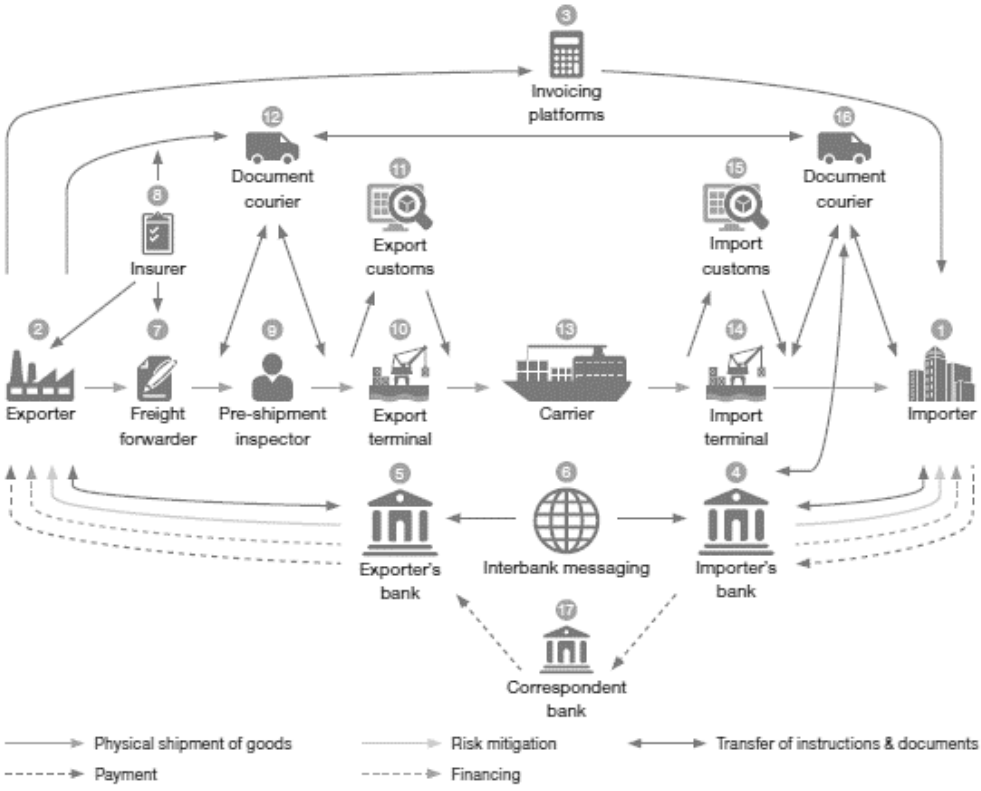

Figure 8 Typical Supply Chain, PWC (2017)

Managing goods in supply chain generally involves more than fifteen actors and different flows in terms of payments, financing, transfer of documents and physical shipment of goods.

In this workflow the actors involved face daily different frictions that cause multiples problems in term of quality, cost and profitability. Given the complexity of supply chain, different startups and incumbents, are working to tackle and solve this inefficiency. In particular, they want to provide a smoother process thanks to blockchain technology.

Even if most companies know blockchain could impact and improve their supply chain management, just a small portion is actually working on testing it. This is due to different reasons as the lack of an innovative culture or economic funds. Within most manufacturers today, even if seems to be a conviction that innovation is a vital source for competitive advantage, there is a vast gap between intention and actual capability (Strategic Direction, 2004). However, overcoming this "innovation paradox" is crucial to survive and succeed in the market.

Given this big concern that characterizes all companies, having a practical and simple framework to evaluate if the implementation of blockchain technology is favourable can be a first step towards the engagement in more innovation initiatives.

From this derives the formulation of the research question of the thesis: What are the factors to consider in evaluating the application of blockchain technology to improve supply chain management?

3.2 Collection of Data

In order to understand the actual development of the technology across different companies and sectors, an extensive analysis of the actual applications implemented so far has been carried out. The study includes about 100 use cases of start-ups and companies which have developed a blockchain based solution for their supply chain (Appendix 2 and 3). In particular, the data have been collected through the analysis of different academic papers, companies' and journals' website. Each of the selected initiatives has been then classified considering what kind of problem solves and in which sector. Moreover, for what concern start-ups it has been also outlined the funding received and if they have issued any ICOs.

The classification of the different use cases in specific sectors was not obvious. Especially when it comes to start-ups, due to the early stage of development, some of them were not already focused in a specific application, but they were more concentrated to solve a specific problem (e.g traceability). At the same time, other start-ups in a more advanced phase have already carried out projects for different sectors. Given this, the applications have been classified in: food, healthcare, transportation and logistics, energy and minerals, defence and automotive, other sectors.

Another point regards the clarification of the applications considered in this thesis which have been grouped in "traceability", "supply chain finance" and "operations improvement". With traceability are included all the initiatives that want to enhance the transparency of the process by digitalizing assets and by allowing companies to track their products and check if there are any counterfeit ones. Here blockchain is not used alone but with the integration of other technologies as sensors, internet of things, cloud computing and databases. In supply chain finance are part the applications which have the scope to improve the profitability of the parties involved in the process (e.g optimizing credit risk). Eventually, in operations improvement are included all the use cases that want to enhance some aspect of the operations within supply chains (e.g sourcing activities or inventory management). It is possible to summarize the critical points of each of the three applications.

Traceability features:

- Data Storage
- Dashboard of information
- Tracking of goods
- Checking products compliance
- Forecasts
- Regulatory Requirements

Supply Chain Finance features:

- Improve utilization of assets
- Enhance investments in the supply chain

- Allow smoother payments to suppliers
- Applications that impact revenue or costs

Operations Improvement features:

- Monitor processes
- Source suppliers and partners through the platform
- Integrate supply chain collaboration to better manage orders and inventory

This analysis is helpful not only to gain a deep insight on how the technologies have been used across different sectors and countries, but also to create a data set companies could use to find start-ups with whom collaborate. As a matter of fact, collaboration between companies and start-ups is becoming always more diffused, thanks to the advantages it brings to both parts. For this reason, big companies as Volkswagen or Danone, have developed internal venture capital divisions in order to buy, invest or collaborate with start-ups. However, other companies, especially smaller ones, do not have this type of organizations and do not know what kind of start-ups are developing solutions that could bring benefits to their operations.

In Appendix 2 are reported blockchain applications carried out by start-ups in supply chain management while in Appendix 3 the initiatives incumbents are developing. More information has been collected in the file excel. (T=Traceability, OI=Operation Improvements, SCF: Supply Chain Finance).

3.3 Findings from the Analysis

Different results can be deducted from the study of the collected use cases. In particular, it is possible to understand where blockchain solutions are concentred and what characteristics they have. Before going to the analysis of the findings, a simple verification of the consistency of the data gathered has been performed. In particular, it has been checked that the percentages of use cases found per sector is coherent with the main assumptions done in the previous chapters and with other studies carried out. In the data set collected for this thesis, only two projects

regard the automotive industry, while the most of use cases are about the food industry, the healthcare and the transportation industry, In Table 1 the subdivision of use cases across sectors is reported.

Table 1 Results from use cases analysis

Food and Agriculture	35%
Healthcare and Life science	17%
Transportation and Logistics	15%
Defence and Automotive	4%
Energy and Minerals	5%
Retail	4%
Other Sectors	21%

These data are consistent with studies performed by Statista and IBM. For example, IBM states that only 2% of Original Equipment Manufacturers (OEMs) are actually testing blockchain solutions (figure 9) and Statista (figure 5) underlines as the same sectors are the ones in which are more diffused pilot projects.

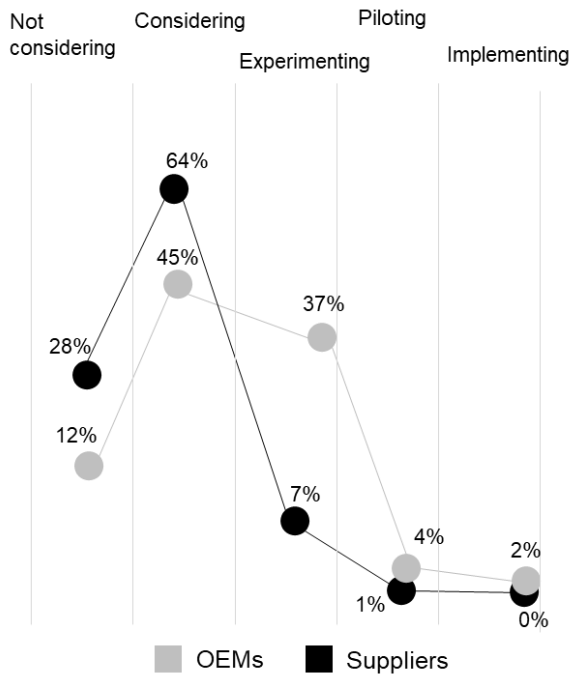

Figure 9 Approach towards blockchain in the automotive sector, IBM

Figure 10 gives an easy to understand representation of the subdivision of use cases of the data set across sectors.

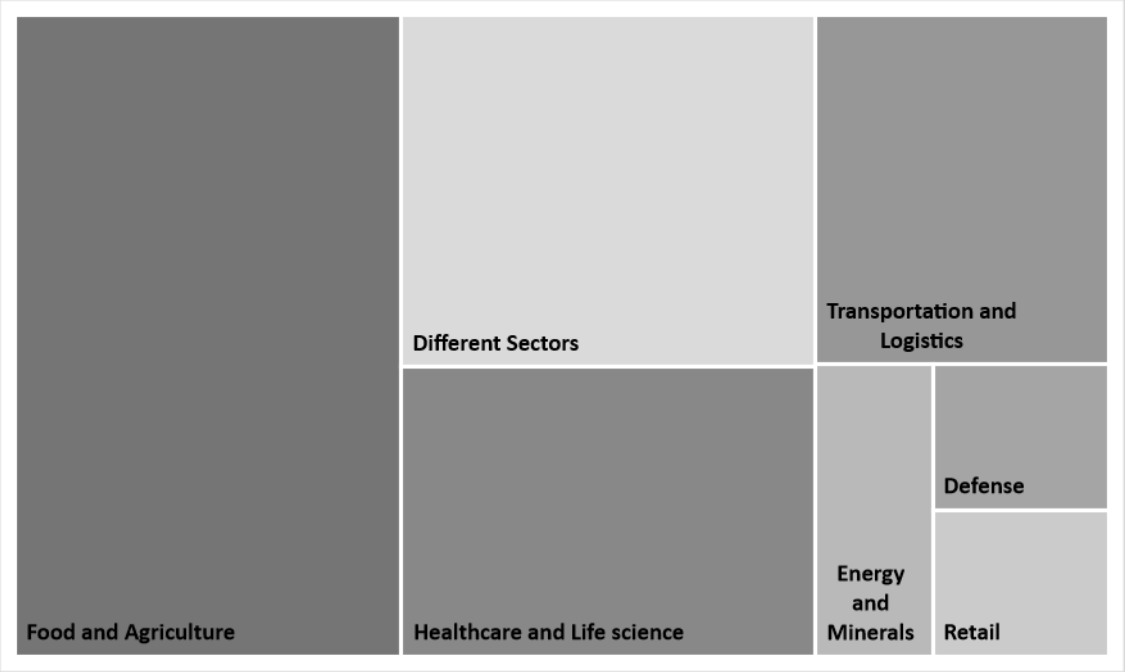

Figure 10 Use Cases per Sector

Then, it is possible to study what are the main applications in the different sectors. What stands out is that pilot projects carried out by famous companies such as Nestle, Carrefour and Walmart are mainly about traceability. As a matter of fact, Blockchain used in integration with other technologies is allowing to better track products along the supply chain. This is useful for companies for different reasons such as finding counterfeit products or assuring a sustainable sourcing to customers. As big companies are investing in this direction, also start-ups are concentrating on tackling this pain point incumbents have. This explains the results of Figure 11 where is presented the subdivision of start-ups developing solutions in supply chain finance, traceability and operations improvement.

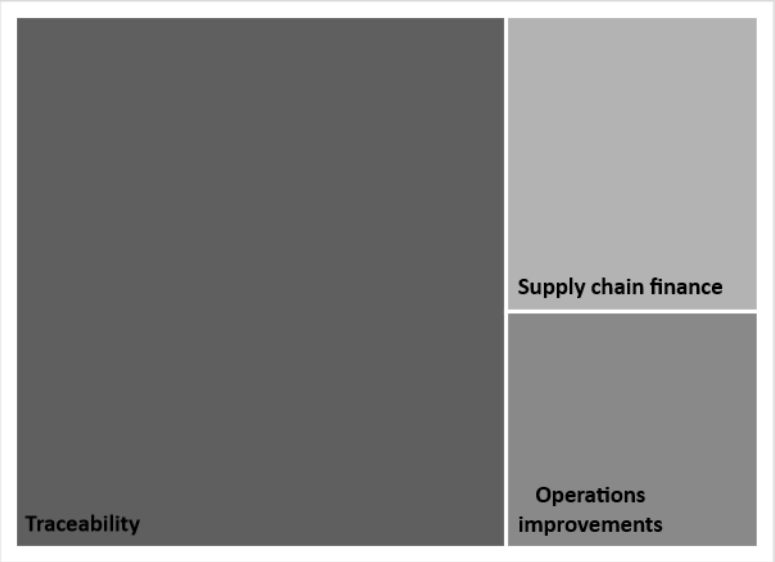

Figure 11 Start-ups applications

Another important point is companies' awareness of the importance of the collaborations across the different entities involved across the supply chain. As a matter of fact, to solve traceability issues all the actors should share their data. This is why companies have created blockchain consortium as the IBM Food Safety Alliance where now more than 350 000 data transaction are present and the Clean Shipping Alliance that counts more than 35 members in the transportation industry.

Eventually, some other information of start-ups use cases are about the financing stage. Half of them have already received important funds through ICOs or venture capitals, for a total amount of € 325 M. Interesting is that even if most of the start-ups are about traceability, the ones that regards supply chain finance are more attractive for investors receiving € 160 M against of the € 130 M collected by start-ups dealing with the tracking of goods.

3.4 Presentation of the Framework

After having studied the literature review about the application of blockchain in supply chain and the actual stage of development of the technology in the sector by analysing what companies and innovators are doing, it is possible to draw up a framework. This framework has the scope to guide companies in evaluating the adoption of the blockchain technology in their supply chain. In particular, it goes through the assessment of four different areas: problem, partners, profits and progress.

The **problem** has to be analysed in a quite different way compared to the classical individuation of a pain point. As a matter of fact, for blockchain application it is important that the problem has also a connection with a lack of trust. As underlined in figure 6, blockchain gains a competitive advantage when the value of both trust and of technology for a specific application are high. Digitalization is always key for companies, while trust is important in specific cases, such as where there is the need of collaboration with other parties.

Once individuated the lack of trust, the next step is understanding the **partners** with whom is necessary to collaborate to set up the initiative. As a matter of fact, blockchain success depends by the involvement of the right partners and it is important to understand who they are in order to then organize the right strategy to involve them in the process. In particular, companies can think to apply three different approaches:

- Business Differentiation Network: creating private network with partners of the same or complementary business
- Industry Utility Network: setting up collaboration with also competitors and giving also the possibility to industry participants to join
- New Market Network: considering non traditional partners that could bring value by joining the network

Companies in this phase have to well design the Minimum Viable Ecosystem (MVE) in which they want to operate.

The third step is understanding how it is possible to positively impact the **profits** through the new initiative. Profitability can be achieved in different ways such as saving time of some processes, creating new business models or decreasing risk. This aspect is key as the application of blockchain has to bring value and to be sustainable in the medium long term for a business. Therefore, companies need to set up strategies to recover initial investment. It is valuable also considering other kind of benefits such as brand improvement, higher reliability of the service or less environmental impact.

Eventually it is key finding a way to engage partners in the application. Therefore, the owner of the initiative has to understand partners' needs and pain points in order to set up a clear strategy that has the objective to bring partners in the collaboration. To progress in the application, it is important to share or bring benefits in the short term or in the long term with all members that are part of the ecosystem.

Here below it is presented the framework that company can fill in order to evaluate any initiative.

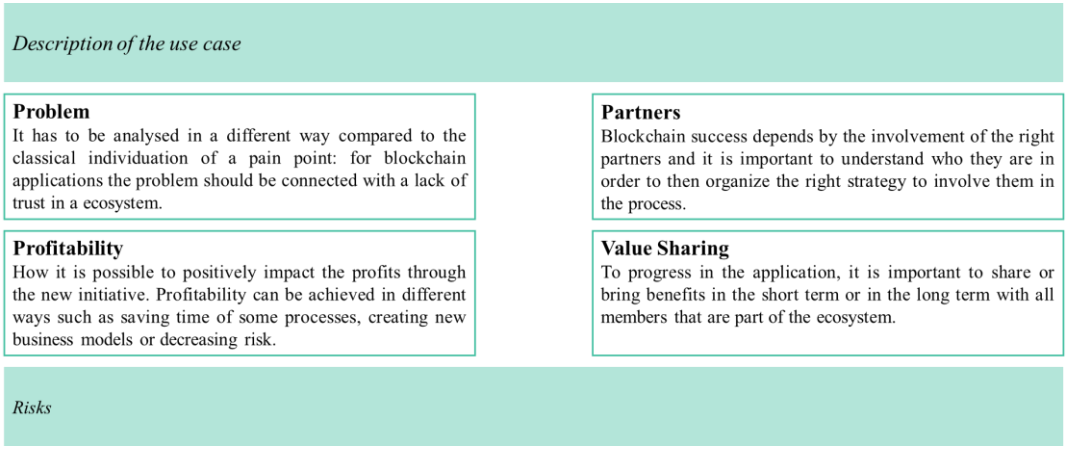

Figure 12 Evaluation Framework

An important point is that the application of the framework is not one shot, but it is an iterative process. As a matter of fact, companies have to fill in the framework and then when implementing it, evaluate if proceeding in this way is feasible. In case of obstacles, companies should start considering new factors such as collaborating with other partners or finding new ways to involve them or to make

profits out of the initiative. Therefore, it is important companies are ready to pivot the initiative and find new ways to make it successful.

Moreover, companies need to address blockchain strategies with rigor and commitment as for any new innovative and transformative technology.

3.5 Further Aspects to Consider

Companies should apply the framework for more than just one problem in order to see which scenario is the most feasible and urgent to address. A good approach could be to use design thinking techniques such as empathy mapping or extreme scenarios to come up with some interesting problems that could be solved with blockchain technology. To add value in this process, participation of workers belonging to different departments should be incentivized.

One way to choose the most promising initiative is to evaluate each of the possible projects considering feasibility and impact. Then, by plotting them as in Figure 13 it is possible to easily find the project that holds more advantages.

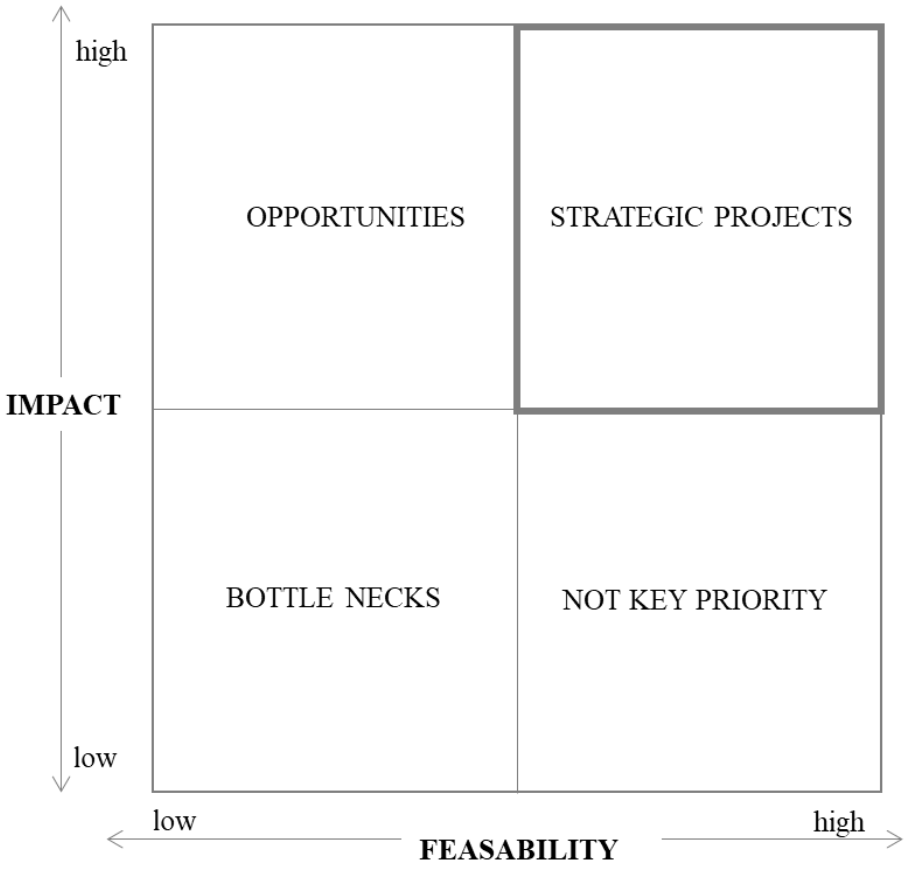

Figure 13 Project Prioritizing

Once chosen the most promising scenario for the application of Blockchain, the next step is about collaboration. Keeping in mind the objective to start in an easy to manage and simple way, companies should start to collaborate with a small number of partners (e.g three or four) in order to agree on the first critical decisions. One of them regards the governance system, in order to well define the roles that each of them will have and the legal implications. Then, the other areas of the framework, progress and profit, have to be carefully analysed.

Application of the Framework in the Use Cases

In this chapter; the framework will be applied to seven different use cases that belong to the sectors individuated through the research. Each of the use cases can be classified as part of the three most used application for supply chain: traceability, supply chain finance and operations improvements.

The use cases selected are promising start-ups and incumbents' projects that work on solving business problems regarding different sectors:

- Cargo X, Logistics and Transportation
- Modum, Pharmaceutical
- EximChain, Multiple Sectors
- Food Trust Alliance, Food and Agritech
- OPA Platform, Retail Sector
- Everledger, Minerals
- Parts Pedegree, Aerospace and Automotive

After a presentation of the industry in which the initiative takes place, each of the three use cases will be firstly extensively explained and then the framework will be applied.

3.6 Transportation Sector

Operations include all the applications that have an impact on the transactions between the actors in the supply chain. These use cases regard all the aspects of supply chain management, from sourcing to manufacturing and distribution. Nowadays there are different inefficiencies due to lack of transparency and a complex supply chain. For this reason, various solutions have been developed. In

particular, the use cases collected want to improve sourcing activity, allow better inventory management and increase the efficiency of transactions exchanged between parties.

In this thesis, the use case of CargoX, a company that wants to improve the managing of the Bill of Lading is analysed in detail.

3.6.1 CargoX

Each second around 20 million of containers are travelling in the ocean to transport goods from local suppliers to consumers and over the year more than 100 billion tons of volume are traded globally (CargoX). Supply chain in this context is complex to manage as goods not only cross oceans, but they go through different actors and steps. The main actors involved are:

- Exporter: entity who produce goods in a country and sell them in another
- Importer: party bringing in the goods deriving from another country
- Shippers: party that coordinates the transport of goods
- Freight Forwarders: person or company that organizes shipments for individuals or companies
- Carriers: person or company who transport goods and which is responsible for any loss or damage
- Consignees: person who receive the shipment

Even if it is one of the biggest industries, it still relies on paper to issue and exchange proof of ownership from one actor to another, the so called Bill of Lading (B/L). The B/L is issued by the carrier and then sent to the exporter. The exporter after receiving the payment from the importer, it sends the B/L to him. With this document the import can then receive the goods from the carrier. Here below is reported a schema of all the steps.

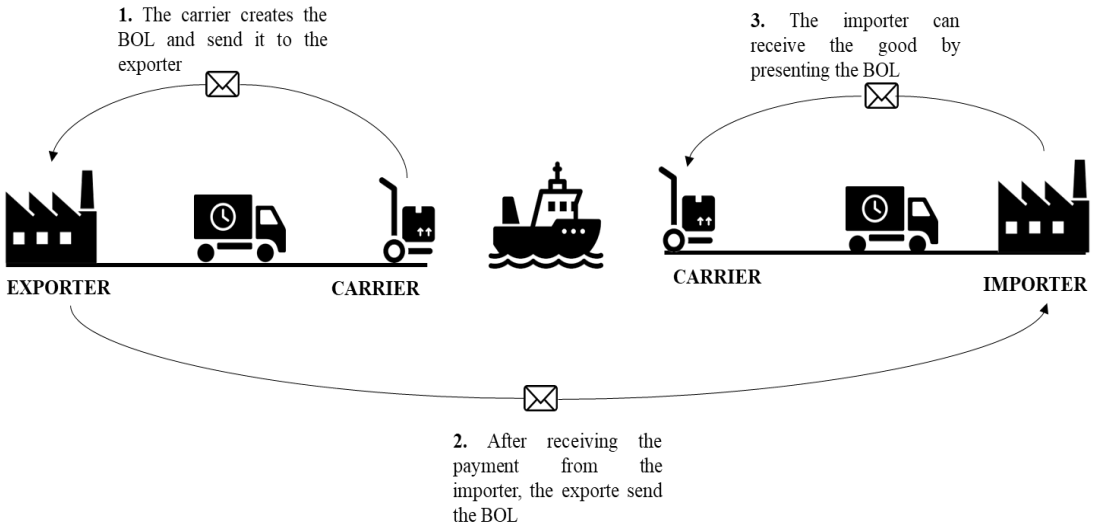

Figure 14 Bill Of Lading Schema

Anyone who has the B/L can claim the ownership of the goods, for this reason it is considered the most important document in the shipping industry whose value is generally equal to the value of the cargo inside the container.

As it is possible to imagine, different risks and problems are involved in the process that they can be grouped in:

- Speed: it generally takes 10 days for the B/L to go through all the three steps
- Costs: average cost to send the B/L three times through delivery companies such as UPS or FedEx is $ 100
- Volatility: the document can be lost and this leads to further time to wait and penalties to pay
- Fraud: the document can be stolen or falsified and be used for fraud or criminal activities

These actual problems in the industry create an opportunity for CargoX. As a matter of fact, CargoX believes is now possible to connect all the parties in a decentralized ecosystem with transparent and predefined rules. CargoX wants to digitalize the bill of lading and modernize shipping industry by helping actors to exchange goods in a faster and safer way. The solution proposed by CargoX is a digital equivalent

called CargoX Small B/L based on public blockchain and smart contracts. The decentralized B/L will bring different advantages for the actors in the shipping industries as costs decreased up to 90%, transparency and security. Moreover, even if the B/L is securely encrypted and stored in a decentralized system, all sensitive information are hidden and they are only shown to the importer, the exporter and the issuer of the B/L.

The company is getting a lot of support from the various entities involved. Over 10 000 companies and individuals have completed CargoX procedure and have registered their interest in contributing to the project. Moreover, the company has already received $ 20 M of funds which is using to improve the product and increase the partnerships.

This use case has all the characteristics to be a successful implementation of blockchain in supply chain. As further evidence, it is possible to apply our framework (Figure 15). From the framework it is possible to see how CargoX has developed an initiative that shows coherence with the advantages deriving from blockchain (need of trust) and gives benefits for all the parts involved (Cargo X and other actors of the shipping industry).

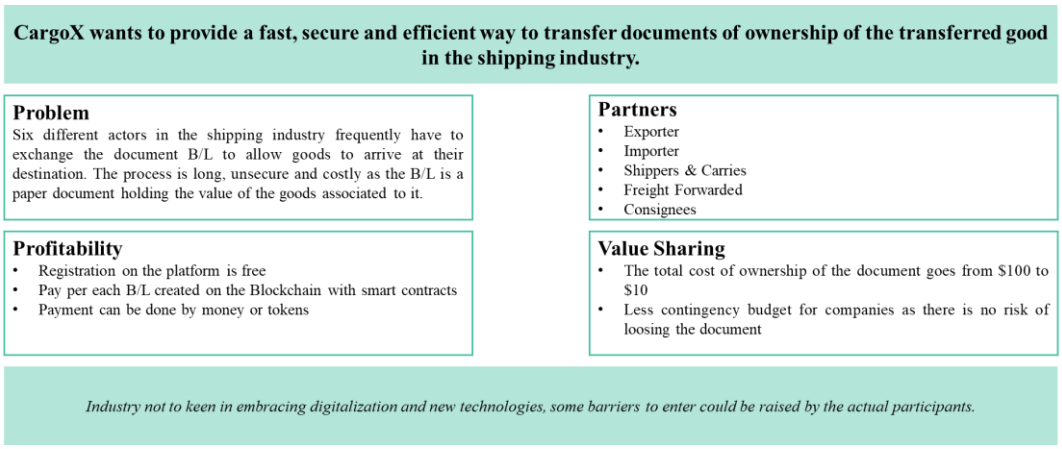

Figure 15 Application of the framework to the use case CargoX

3.7 Pharmaceutical Sector

Nowadays a central focus of companies in the different sectors is the traceability of products. As a matter of fact, customers are more and more sensible over products' history and they are demanding transparent supply chain. However, a better traceability is implemented not only to improve costumers experience, but also to grant products safeness. Even though safety standards are globally respected, different non encouraging data arrive from the food and the pharmaceutical sectors.

The centre for disease control and prevention estimates that annually still 48 million of people become sick from foodborne illness (CDC, 2017). The annual market value of counterfeit drugs is estimated to be around 200 billion. Pfizer carried out one of the largest investigations over fourteen European countries and estimated that western Europeans unconsciously spend more than US$ 14 billion a year on illicitly sourced drugs. Moreover, this regards not only drugs manufacturers, but also the producers of medical devices as The World Health Organization (WHO, 2017) estimates that 8 percent of the medical devices in circulation today are counterfeit copies.

In this thesis the attention will be on Modum, a start-up addressing the limitations characterizing the pharmaceutical sector.

3.7.1 Modum

Among the industries where blockchain holds huge promises the health care has a leading position. A complex supply chain, a high number of players and critical data are some of the reasons for its prominence. Different studies have analysed the possible applications of blockchain, its characteristics enable different use cases that can be grouped in:

-Secure supply chains by tracking goods through every step

-Better use of patients' data in order to improve diagnosis and cures

-Accelerate RD through smart contracts in order to approve protocols and gather different data

-Develop new services to clients by creating business models that improve customers' experience, decrease costs and accelerate processes

However, as confirmed by the analysis performed by BCG the scenario in which blockchain will most likely have an impact in the short term is the one regarding supply chains. Thanks to the integration of blockchain, IOT technologies and smart contracts it is possible to have different improvements along the supply chain as the validation of products' state (e.g temperatures compliant with requisites) and the verification of counterfeit materials.

Different start-ups (e.g Chronicled, Provenance, Modum) and incumbents (e.g IBM) have started pilot projects around the application of blockchain in supply chain in the pharma sector. In this thesis, the use case analysis is focused on the start-up Modum.

Modum addresses the need of controlling drugs' temperatures along the supply chain and of granting their well-functioning and their conforming with regulations. Users can predefine requirements for each shipment and evaluate its performance and conformity.

Before each shipment occurs, the temperature specifications are fixed through a dashboard in order to allow smart contracts to check conditions have been met. Moreover, during the packing process, the operator after scanning the shipment information, receives the serial number of the temperature logger and places it in the corresponding package. During the journey, the temperature is monitored through sensors, and the data is stored in the temperature logger and in the blockchain. At each change of ownership, data authenticity is certified by the smart contract smart contracts automatically send notifications about shipment conformity.

The company has already gone through three different pilot projects. The first one was conducted in Switzerland in 2016 where shipments from a SME pharma

producer to a wholesaler have been monitored over a period of six weeks. The company has found the solution useful for compliance with regulations and scouting of efficient partners. However, they underlined as the speed of data transfer should be improved and a dashboard for data analysis should be created. The second pilot has been carried out for the shipments between a wholesaler and several pharmacies and volumes managed have been increased of one order of magnitude. Moreover in this project, the temperature logger's connectivity and data transfer speed were improved and a dashboard for quality assurance and customer service departments of the wholesalers was introduced and tested. The last pilot project was conducted with a third party logistics and mail-order pharmacy. From this project the company has realized how the integration in the processes of a third-party logistics provider already serving high shipping volumes would greatly help modum.io scale as pick-up and hand-over would be handled by the same company.

Thanks to experienced founders and the successful pilot projects, the company has been able to gain trust and it raised 10 million that plans to invest in further product development and in acquiring customers.

Eventually, the framework developed in this thesis is applied to the Modum use case.

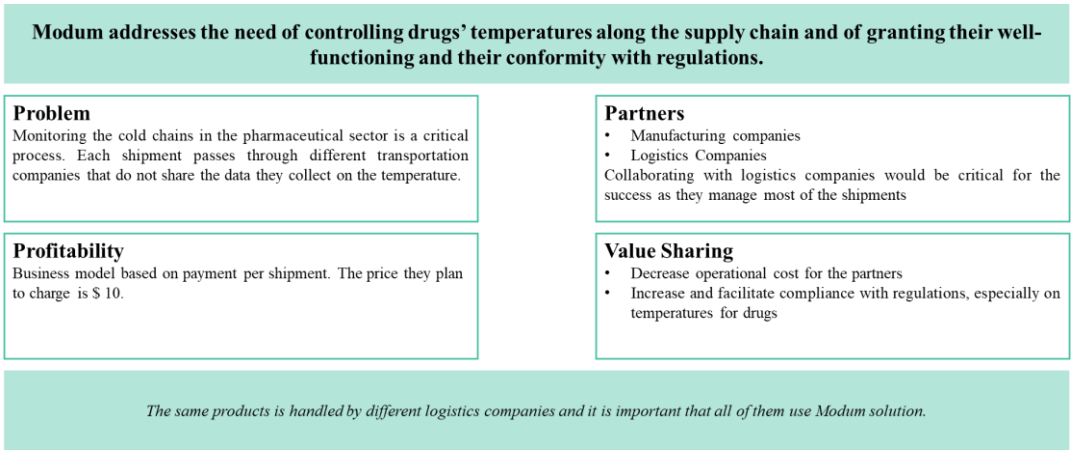

Figure 16 Application of the framework to the use case Modum

It is possible to derive different conclusions from the analysis of the framework. Even if the solution developed by Modum has a clear focus on the problems to address and on the partners to involve, needs to better define a strong method to

engage different actors. As a matter of fact, as each shipment goes through different actors all of them should be involved with Modum. This is an ambitious goal, but thanks to a good funding and team, the company could reach to achieve its purpose. Moreover, a strengthening of the regulation about the cold chain monitoring could give a further boost to the start-up.

3.8 Multiple Sectors

Supply chain Finance is a set of technology-based business and financing processes that allow financiers to fund an organization's operations through its supply chain relationships. Supply chain Finance allow buyers to optimize working capital and suppliers to generate additional operating cash flow while simultaneously minimizing risk across the entire supply chain. Moreover, SCF enables buyers and sellers to decrease their inventories, collect money from customers faster and delay payments to their suppliers. (Huertas, 2018)

Also here blockchain holds huge promises and different solutions that addresses this opportunity have been developed. In particular, here below is presented and explained the start-up Eximchain that wants lower financial barriers for Small and Medium Enterprises.

3.8.1 Eximchain

Eximchain has developed a public permissioned blockchain that wants to optimize supply chain by allowing SMEs to gain access to capital in an easier and cheaper way. Small and Medium Enterprises have a huge contribution to global GDP, however they lack the funding possibilities big companies have. One of the biggest problems is that they do not have a tool that provide transparency over their operation. As a matter of fact, investors often do not have the possibility to have a clear overview of the current state of small and medium companies and this made

them reluctant in investing. However, with better information available investors would be more willing to lend them money.

From this problem that nowadays characterizes companies, Eximchain has been able to create a product that has the scope to enable Small and Medium Enterprises to have access to affordable capital sources thanks to a better transparency of their supply chain operations and cash flow. The platform developed uses smart contracts to enforce Supply Chain Finance solutions and it assures data privacy thanks to the permissioned fork of Ethereum. The ecosystem in which the company operates is composed by suppliers, manufacturers and lenders and each of them can reach different sources of value by joining the network. The principal advantages for stakeholders are explained here below.

Risk mitigation

Buyers often contributes to suppliers' investments, especially if they develop innovative products or solutions specific for their business. However, buyers cannot have a clear overview of the fairness of the amount of money demanded. By having access to more information on the platform, lenders can be aware of the reasons behind choices carried out by purchasers and suppliers, allowing them to better asses the risk. The digitalization and standardization of the contracting process will also enhance transparency and lower the risk, creating a better performance of the loan. Eventually, this saves the time usually deployed in managing the paperwork and understanding the different covenants.

Investment opportunity

Over the years it has been created a system where funds and banks asses borrower's position by studying its financial statements, performance, historical credit and guarantees. The new concept introduced by Eximchain is that any person, available to assess the risk and financial capable, can lend money. This can at the same time, lower the barriers to entry for lenders and allow the use of a new type of credit product.

Credit Rate Arbitration

Buyers, through the platform, can use their better credit ratings, compared to their supplies to fund their supplier in exchange for better prices or terms. For example, if a supplier's access to capital is 5 percentage points higher than the buyer's 2.25% financing rate, a simple calculation will show the buyer that a 30-day invoice for $500k can be extended to 96 days without adding costs to the supplier. Same smarts contracts that allow a better management of supply chain will be developed by EximChain, as the ones just cited, while there will be also the possibility for companies to have personalized solutions.

The use case Eximchain has been chosen to show how some applications can really create new business models and transform the market, also in supply chain. For the huge impact the company can have, it has gained the interest of different investors and over three rounds of ICO it has raised $ 20 million that intends to use to go on with the development of the platform and building the ecosystem.

As last step in the analysis the framework is applied to EximChain use case.

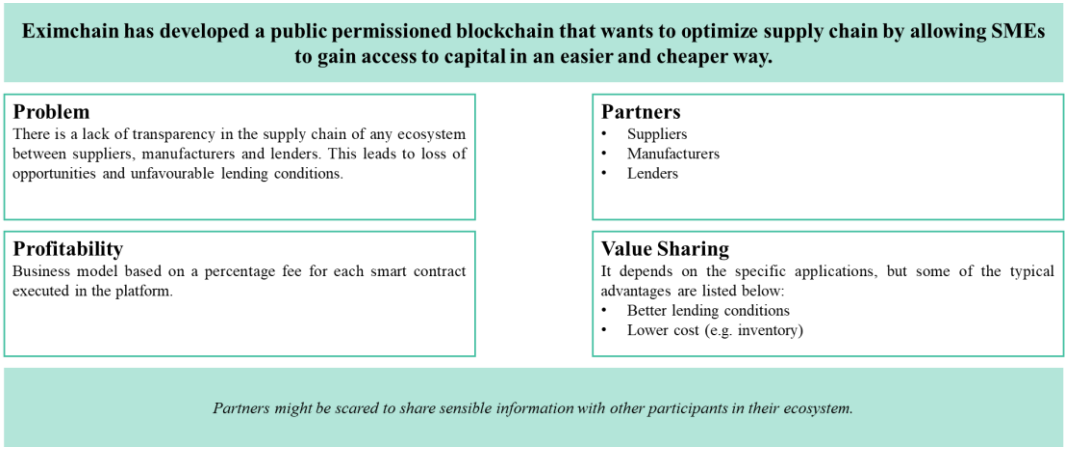

Figure 17 Application of the framework to the use case Eximchain

Eximchain has found an interesting market opportunity that could be addressed by using blockchain. However, it is important to keep in mind different risks the company faces. As a matter of fact, it will not be easy for Eximchain to convince all the actors to join the network as they could be reluctant in sharing their

information. They could gain access to a cheaper capital and more investors, but at the same time, sensitive information could be taken by competitors.

3.9 Food Sector

The food sector is where most of the Blockchain applications take place. This is due to a variety of reasons, on top of them the increasing need of transparency required by customers. As a matter fact, customers' sensibility regarding different aspects of the supply chain, such as sustainable sourcing, is becoming a key decisional factor in buying products. Customers, especially new generations, want to be sure products they buy are healthy and they have been harvested in respect of workers and environment. The benefits of better transparency are not only related to insights customers can have but also to the fast recall in case of damaged products. The hurdle for companies is the collection and unification of data, as a matter of fact, before having the final product customers find on supermarket shelves, it passes through different production processes and actors along the supply chain.

Here is where Blockchain comes to support companies, in order to allow them to improve the traceability of their products along the supply chain. The applications include different start-ups (e.g Origintrail, Provenance, GenuineWay and others) and big companies' pilot projects. In particular, in USA ten different food companies have decided to collaborate in order to speed the Blockchain application and together with IBM they have formed the Food Safety Alliance.

3.9.1 Food Safety Alliance

Dole, Driscoll's, Golden State Foods, Kroger, McCormick and Company, McLane Company, Tyson Foods, Nestlé, Walmart and Unilever, have started collaborating with IBM a year ago, in order to monitor the supply chain through Blockchain

technology. In particular, IBM created the IBM Food Trust, a permissioned blockchain platform that has the scope to set up a collaborative network of the different actors involved in the food supply chain.

Nestlé, after having started the use of the platform with a single ingredient food product, canned pumpkin, now is experimenting the solution on Garber baby food products as it wants to test the strengths of the application for products with multiple ingredients and cross border transactions.

Walmart is part of the collaboration with IBM since 2016 and has tested the tracing of mangoes packages. This first pilot project conducted it has been successful as the time to trace the product history has been just few seconds instead of weeks. Moreover, recently, some packages have been recalled by a supplier in northern Australia, saving damages to the company and problems to customers. Now the company is expanding the testing of other products on the platform.

Albertsons Companies, which operates nearly 2 300 stores across the USA, has recently started a pilot project with IBM Food Trust to trace romaine and after the results, they will consider expanding to other food categories.

Unilever has launched a one-year pilot project that leverages blockchain technology to manage transactions on its tea supply chain.

As just pointed out different pilot projects are characterizing the Food Trust Alliance. Positive results are coming out as companies tend to go further with the experimentation of blockchain with IBM protocol. However, even if IBM is a pioneer in blockchain based solutions, the platform developed still needs continuous improvements in order to be ready to scale. The interfaces have to better tackle and present the multiple datasets often with different formats coming from the various stakeholders that form the food supply chain (e.g farmers, processors, etc.). As a matter of fact, companies belonging to the Food Trust Alliance should start creating standard based method of data collection in order to facilitate the process. Second, all big companies collaborating on the platforms have to involve and expand the ecosystems of farmers and suppliers that are willing to step in in the alliance.

Also this use case, it is possible to be analysed with the framework developed.

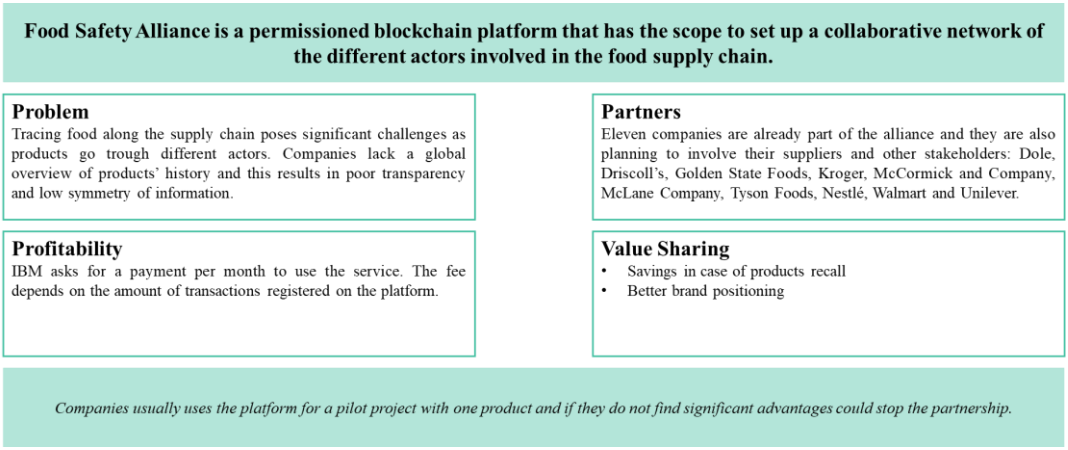

Figure 18 Application of framework to the use case Food Trust Alliance

3.10 Retail Sector

In the retail sector most of the applications regards traceability and avoidance of counterfeit goods. What come out from the use cases research is that most of the start-ups working in this sector have not developed a specific solution for the retail industry, but a flexible one for different sectors. For example, Everledger, a UK start-up which has already raised more than € 10 Million, created a solution applicable to the retail industry, but also for minerals, arts and diamonds. Similar focus it has been chosen also by other start-ups such as Bonafi and EmTruth. For what concerns big companies in the fashion industry, it is possible to see how there a lower than the average commitment for experimenting blockchain based solutions at the moment. As a matter of fact, most of them are waiting the technology makes more progress before heavily investing in them. However, a biggest contribution to Blockchain in the retail sector comes from food industry.

The few applications in the fashion sector are associated to the luxury industry. As a matter of fact, different use cases regard the protection against counterfeit products and the possibility to have certified goods.

Between the various applications in the retail sector, the start-up OSA Platform it has been selected. It is a start-up focused on operation improvement, a really important opportunity for companies, even if not always tackled.

3.10.1 OSA Platform

The company started with the individuation of what it thought was one of the biggest problems for retailers, the Optimal Shelves Availability (OPA). OPA is the availability of products where and when the customer expects them. According to Lee, the retail industry loses $ 400 billion in sales annually from product shortages and understocked inventory. As a matter of fact, each time a customer does not find the product he was looking for, it is a big damage for a company, as he will probably buy one other brand. This constitutes a big risk for companies as the customers can be lost after he tries a new product.

They collect fragmented data from the entire supply chain and use machine learning to process, analyze, and clean it. After that, the use software based on machine learning techniques in order to make forecasts that improve the OPA for customers. Moreover, smart contracts are deployed on the platform to protect data providers and consumers. There are also a set of KPIs, product ratings, and rewards which are stored on the blockchain to secure them from manipulation. The first pivot has been launched in 2016 with forty-one large retail stores and the results have been extremely positive, they resulted in 5,4% sales increase across the product categories on which the test has been performed. Between the companies involved there are five big multinational manufacturers of consumer goods: Mars, L'Oreal, DANONE, EFES and JTI.

Thanks to the good results, within only two months after launching the OSA Platform, the team signed $ 2.5 Million worth of service agreements.

Also OSA Platform can be analysed with the framework.

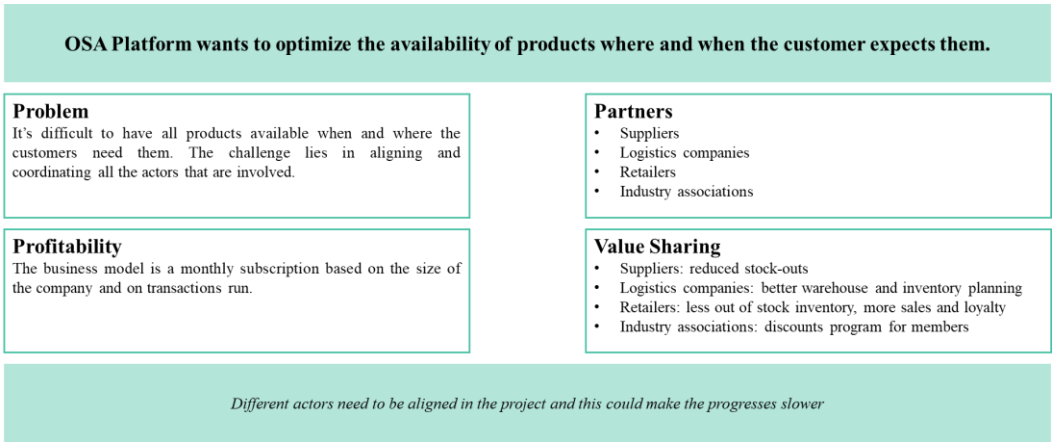

Figure 19 Application of the framework to the use case OSA Platform

3. 11 Minerals

Between minerals, a big attention is given to diamonds. As a matter of fact, two big problems characterize the industry, the black market and conflict minerals. Unfortunately, still child labour is utilized in lots of poor countries to extract minerals. At the same time, due to the high value of diamonds, they are always object to thefts. Society is demanding more transparency about workers' conditions, but it is not easy to have it. Moreover, if a person goes to a shop to sell a diamond, it is almost impossible to know its provenance.

To tackle both problems, Blockchain can be a reliable solution. This is why different start-ups are working on it and one of the pioneers is Everledger.

3.11.1 Everledger

Everledger is one of the oldest blockchain based start-ups that tackles supply chain problems, it operates since 2014. In particular its vision is the protection and the tracking of any items of value. Even if nowadays it tackles provenance problems of different industries, the first application it developed was about diamonds.

Everledger has involved in the project the major certification houses in the world and it has been able to create a digital thumbprint for diamonds which has been then

integrated in the Blockchain. Nowadays, more than 2 Million of diamonds have been recorded on Everledger.

Everledger is the example of a successful application, the company has been able in just few years to collaborate with important stakeholders, as diamonds certification houses, and to gain traction in the sector, involving more than one million of people in registering diamonds on it.

Also this use case, it is possible to be analysed with the framework developed.

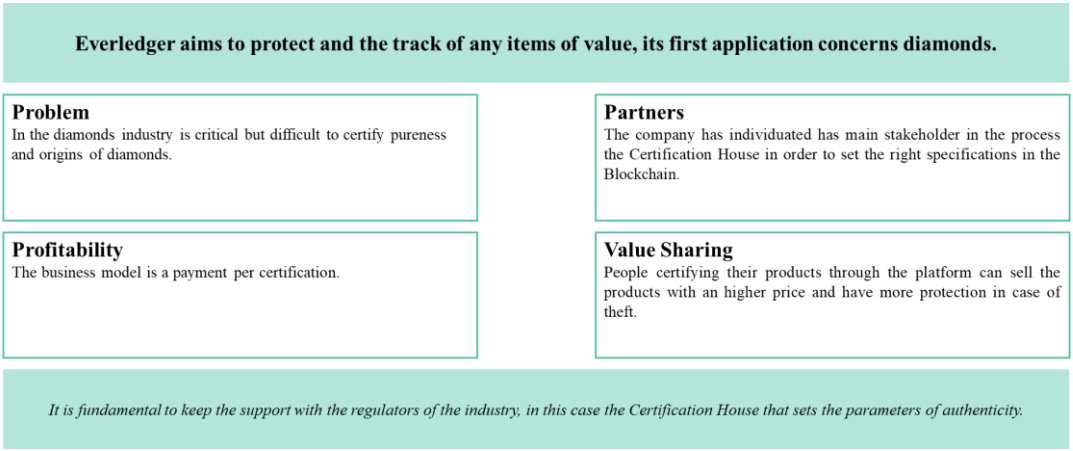

Figure 20 Application of the framework to the use case Everledger

3.11 Aerospace and Automotive Sectors

The aerospace industry together with the automotive one is where Blockchain is actually less deployed. The aerospace industry is not known for leading the development of this kind of new technology, but it usually waits they become solid and proven applications. On the other hand, the automotive sector is under big changes and it is mostly concentring its investments and efforts on the electrification of vehicles.

In the aerospace and in the automotive industry the Blockchain based solutions developed regarding supply chain are mostly focused on the traceability. In

particular, through the use cases research carried out, two start-ups have been individuated, Parts pedigree and Blockaero technology.

The use case presented is Parts Pedegree which is developing a solution suitable both for the aerospace and the automotive industry.

3.11.1 Parts Pedegree

Nevertheless the aerospace industry is very big, still the digitalization is not diffused. This increases data fragmentations and lost, with resulting problems for assuring parts compliance with regulations. Companies in the sector miss a huge opportunity, as thanks to better data management and analytics it would be possible to improve operational processes and financial position.

For example, each time a repair occurs, it is required a quality and provenance certification of the part. This certification called pedigree, is a crucial step for both safety and legal reasons. As a matter of fact, the pedigree is a legal proof of the part security and authenticity and often there are problems in issuing this certification due to fragmented data.

This is at the base of Parts Pedegree project that wants to give visibility to each part history. As a matter of fact, it is working on creating an ecosystem that includes Original Equipment Manufacturers, Distributors, Airlines, Maintenance Repair and Operation companies. The platformed, powered by different technologies as blockchain, cloud and image recognition, provides as analytics warranty management, customer support, trade compliance and paperless shipping.

It is possible to have a better overview of the project by applying the framework.

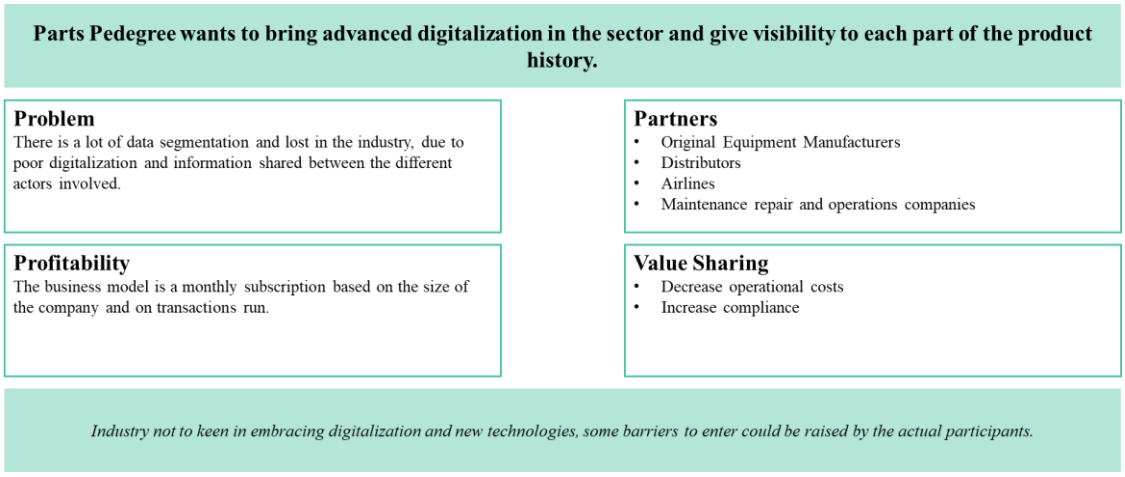

Figure 21 Application of the framework to the use case Parts Pedegree

Conclusions

Each time a new technology enters the market, the pace at which it is adopted varies a lot across sectors and countries. Especially, when potentially disruptive technologies emerge, different obstacles are on the way, as the resistance from actual businesses and the immaturity of the discovery. However, when Innovation conquers the market, it radically changes it. Before Internet, companies invested over years on market campaigns, supply chain and assets to become globally recognized brands. Nowadays, new companies are expanding with an outstanding speed and with less investments, as they can reach digitally connected customers through their platform. China's Xiaomi, for instance, has achieved to become the second biggest player in the Chinese market in just two years, Uber has entered 77 countries in six years and Netflix has penetrated 190 countries in seven years. (BCG, 2017). As the Internet it has been, also Blockchain has the potential to be a game changer in the ways different businesses are conducted and mediated.

Nowadays, different constrains limit the potential of the technology. Collaboration between actors is difficult to achieve, the profitability of the investment is not granted and resistance toward change is diffused in some enterprises. However, different actors believe in the potential of the technology and multiple pilot projects have started to emerge. In particular, where it holds huge promises is in tackling and solving supply chain related problems. However, as it is a new technology and its knowledge is not spread, a concern for companies regards the assessment of the possible applications in their enterprises. As stated in the report "Does your Supply Chain Need a Blockchain" written by The Bolton Consulting Group "*The key is knowing whether and how to capitalize on a blockchain, when to combine it with other digital technologies for even greater synergies, and how to weigh its cost/value tradeoffs*".

The study has come up to the conclusion that it is possible to evaluate the suitability of Blockchain based solutions by analysing four main factors. Each company, before engaging in a blockchain project, should consider how the blockchain can overcome an issue of trust, how to make a profitable investment, what partners need

to be involved and how to engage them in the application. Additionally, after applying the framework to three different use cases, the findings suggest that already some applications have incorporated these factors.

Although the analysis contributes to help enterprises to evaluate the application of blockchain in their supply chain, there are several limits. First, the size of the sample of use cases collected could have been more representative. Moreover, as the technology advances, further factors should be included in the framework. Eventually, it could have been interesting interviewing some experts in order to integrate their opinions and feedbacks. However, the study has been able, through a solid method and research, to come up to an easy to use framework, that can be useful to guide enterprises in the evaluation of blockchain base supply chain solutions.

Appendix 1

Summary of the use cases across the different sectors. The sectors in which there is at least one application in supply chain management have been outlined in bold.

Sector	**Use Case**
Energy, Utility and Mining	• Peer to Peer trading platform • Smart utility metering system
Entertainment and Media	• Disintermermediation of records label • Control of ownership right of data media
Financial Services	• International peer to peer transactions • Anti-money laundering
Government and Public Services	• Land ownership records • Tamper-proof voting records • Digital identity of citizens
Healthcare	• Tracking of drugs • Anti counterfeit • Storage of clinical reports
Hospitality and Leisure	• Loyalty programs
Logistics and Transport	• Supply chain transparency • Trade Finance • Trade documentation • Manage bookings
Food	• Tracking • Sustainable sourcing • Transparency
Luxury	• Anticounterfiet • Tracking • Reward programs

Aviation and Defence	• Distribution of tickets and ancillary services • Passenger identity management • Loyalty program
Insurance	• Peer to peer insurance policies • Micro insurances

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