POLITECNICO DI TORINO

Corso di Laurea Magistrale in

Engineering and Management

Tesi di Laurea Magistrale

How Blockchain Can Lead to Supply Chain Efficiency After COVID-19

Relatore

Prof. Carlo Rafele

Candidato

Francesco Fabozzi

Ottobre 2020

To my parents,
For giving me the freedom to make my own choices
And the support to face them.

TABLE OF CONTENTS

ABSTRACT

In early 2020, there was an outbreak of Coronavirus caused by a novel virus called SARS-CoV-2. The sudden explosion and uncontrolled global spread of COVID-19 demonstrate the limitations of existing health systems in dealing with public health emergencies in a timely manner. In such contexts, innovative technologies such as Blockchain and Artificial Intelligence have emerged as promising solutions to combat the Coronavirus epidemic. Certainly, Blockchain can combat pandemics by enabling early detection of outbreaks, protecting the privacy of users and ensuring a reliable medical Supply Chain while tracking the outbreak.

In this thesis, a study is presented on the opportunities that Blockchain technology offers in terms of possible applications for Supply Chain Management. Once the technological paradigm was outlined in broad outline, the focus was placed on the dimension of the Supply Chain and therefore on the relationships and transactions of which it is the scene every day. Starting from an analysis and review of the relevant literature or through consultation of articles and research, it was possible to reconstruct the architecture at the basis of the projects launched, outlining objectives, results achieved or, at least, theorized.

Subsequently, the projects developed in the Supply Chain sector at an international level have been described in greater detail. In support of the case studies, two interviews were personally carried out with professionals in the sector, which gave a more concrete basis to the research work.

The study also revealed that, in this phase of initial experimentation, in all the cases analyzed, interest and enthusiasm for the technology are partially held back by its robustness, which has not yet been fully tested. For these reasons, now the applications developed assign the Blockchain a role merely of support to process management, improving the way they are implemented but not their specific structure. Motivated by these, it has been decided to survey the use of Blockchain for combating Coronavirus (COVID-19) epidemics based on the rapidly emerging literature, considering the latest research efforts in a wide range of applications, focusing especially on Supply Chain.

INTRODUCTION

In recent years there have been various incidents in Supply Chains that have fundamentally jeopardised their operational performance and the existence of individual members. One example is the COVID-19 pandemic, which has recently threatened global and interconnected supply networks. [1]

In response, Supply Chains are investing in increasing Supply Chain resilience by developing capabilities such as redundancy, multi-sourcing, collaboration and inventory or capacity flexibility, which promise to better protect Supply Chains from unforeseen disruptions. [2] One promising new digital technology that is proving particularly useful in the area of transparent, secure and efficient collaboration is Blockchain Technology. [3]

According to a study by KPMG in 2019, 48% of the 740 global technology leaders surveyed believe that Blockchain Technology will probably or very probably change their business in three years. [4] In a Deloitte survey 53% of respondents already see Blockchain as a critical priority in their organisations. [5] This is why the Blockchain, rather than a technology, can be considered a new paradigm, that is, a new way of interpreting the great theme of decentralisation and collaboration.

And it is precisely within this context that companies and, in broader terms, Supply Chains have begun to show interest in this new model. The frictions in this field are numerous. The most debilitating are the lack of trust between the various actors, the lack of visibility and reliability of the data exchanged between the various levels of the Supply Chain and the considerable time needed for bureaucratic and financial/accounting operations.

The aim of this thesis is to present the main use cases of Blockchain technology in the Supply Chain fields where its possible applications have been studied or tested. As previously mentioned, the focus will be placed on the current critical circumstances due to the health emergency, but which can give rise to optimization and efficiency projects.

In the first chapter we will go over the raise of the technology and its main characteristics, the areas of use and some details on the most exemplary applications developed. It will provide a non-exhaustive description of Blockchain from a technical point of view, exploring those features that make it a disruptive technology. The technical/informatics foundations will be introduced that allow for the achievement of decentralisation, immutability and visibility of data.

Chapter II illustrates some of the challenges and criticalities that characterise Supply Chain Management in broader terms. From the analysis of the literature it emerges how technological innovation can be the key to overcome, even if partially, many of the problems that affect supply networks. The key element that these new tools have in common is their ability to provide solutions that encourage companies to re-engineer their processes to better meet the demands of the end consumer. Obviously, Blockchain is part of this panorama thanks to its ability to achieve cooperation and collaboration between the players in the Supply Chain.

The third chapter will focus on the ways in which these two realities can intersect, analysing the profitability of this interaction and the possible improvement made to the entire Supply Chain. There will be in-depth analysis and dynamics within two specific industries, the food and luxury industry, where the most concrete examples can be found today. To support the analysis, we will report those cases of use for which it has been possible to find as much information as possible on the net, because they are adequately documented or in a more advanced state of design.

Finally, chapter IV address the prioritisation and focus of this study on the subsequent Coronavirus disease 2019 (COVID-19)/the severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) and the major lockdown of 2020. In this context, Blockchain as one of the promising innovative technologies allows transparent, secure and timely data exchange and automation. It will undoubtedly make a positive contribution to making Supply Chains more resilient in these difficult times.

CHAPTER I - Blockchain Technology

1.1 Origins of the paradigm

The raise of the *Blockchain* is mainly due to the invention of the first cryptocurrency, known as *Bitcoin*. We can therefore refer to the year 2008 as the official year of its creation, since on that date, an individual or perhaps a group of people, under the pseudonym of Satoshi Nakamoto, published an article entitled "Bitcoin: a Peer-To-Peer Electronic Cash System" in which the author defined the Bitcoin system as "*a purely peer-to-peer version of digital currency that allows online payments to be made directly from one user to another without having to go through a financial institution*." [6]

In the years that followed, computer science and cryptography were the branches most captivated by the fascination of this new technology, and they tried to study it in greater depth, until the take-off of Bitcoin trade caught the attention of a wider audience. In fact, in line with Everett Rogers' theory of the innovation adoption curve (S-curve), the general process of interest and adoption towards a new technology, or rather innovation, is characterized by a few years of slow adoption and then it results in an exponential growth.

Concerning the Blockchain, there is no unambiguous definition shared by all but, generally, it is defined as a digital, decentralized and distributed register in which each transaction is recorded and added in chronological order, with the aim of creating permanent and non-alterable evidence and traces. In different words, the Blockchain can be defined as "a new type of data system that records and stores data allowing multiple stakeholders to share and allow access, in a confidential manner, to the same data and information." [7]

Having clear in mind the purpose for which this technology was created and its potential, it is now important to understand the mechanism for achieving these results. To this end we refer to the famous example of "*Alice buys a pizza from Bob*" which explains the mechanism behind Bitcoin and therefore also the Blockchain. [8]

First, we must take note that Blockchain uses, as mentioned before, cryptography, defined as the science of creating and using methods of masking messages, using codes, digits or other methods, so that only a few people can read the original message. Any operation that is performed in Blockchain, in fact, is encrypted through the SHA-256 system and transformed into a *hash*. [9]

Let's suppose at this point that Alice wants to buy a pizza from Bob using Bitcoins as currency. Assuming she has a virtual wallet containing all her available digital finances, Alice will create a message stating that she wants to transfer 1 Bitcoin to Bob to buy the pizza. This message is then encrypted to include the hash referring to the previous transaction from which that Bitcoin came, so that the entire "history" of digital currency can be retraced from its inception. In addition to the cryptography, the use of two keys is added to ensure that the privacy of users is maintained. The first one is a private key that: is created by the user himself, remains completely personal as the pin of a credit card and will then be used to create the public key. The public one, in fact, is obtained from the first, using elliptical encryption. In the next step the public key is further encrypted, this time using the SHA-256 system, to obtain the Bitcoin address to send the money to. Once Alice has defined her message and has Bob's digital address, she affixes her digital signature, again obtained from her personal key. The request is then circulated throughout the network.

1.2 Main technical and operational aspects

Diving more into the technicality of its functioning, every time a new information/data is received as a result of a transaction, a new block containing this information is added to the chain; the succession of information and data gradually forms a real chain of blocks from which the name of the technology derives. Due to the continuous addition of blocks, the size of this chain is bound to grow over time as each new set of information corresponds to one block.

However, this chain has an immutable nature because, as a rule, its content once written is no longer modifiable or eliminable, unless the entire structure, whose integrity is guaranteed using cryptographic primitives, can be invalidated. In summary, the Blockchain can be defined as “an ordered, incremental, solid, digital chain of cryptographically linked blocks.” [10]

The Blockchain also needs additional components in order to work:

- Blocks
- Transactions
- Nodes
- Hash
- Ledger

Each block contains a certain number of transactions. Transactions are transfers of digital resources between the nodes of a network, which determine a change of ownership of the exchanged resource. These use a peer-to-peer network to be stored in a distributed manner across the network. [11] The ledger is the public register in which they are listed with the maximum transparency and in such a way as to all transactions carried out in an orderly and sequential manner. It consists of the set of blocks that are chained together through an encryption function and thanks to the use of hash.

The hashing function allows to transform input data into a string of defined length composed of alphanumeric characters apparently randomly arranged. With a well-designed function, it is extremely unlikely that two sets of input data will have the same hash as the output, even though the possible combinations of input data are infinitely larger than the possible hashes. The purpose for which hashing is used is to prove that the information transmitted is not tampered with or modified. If a subject has the correct hash of the input data, he can compare it with the hash he has: if there is a mismatch between the two there is absolute certainty of tampering with the data, in the case of a match there is a high probability that the data has not been modified. [12]

For a new block of transactions to be added to the Blockchain, it must be checked, validated and encrypted. Only with this step can it then become active and be added to the Blockchain. The person within the Blockchain system voluntarily validates transactions and adds the block to the chain is called a *miner*. The miner validates the Blockchain through a consensus mechanism on which the entire security and validity of the chain depends. Anyone can become a “miner" and can compete to be the first to solve the complex mathematical problem related to the creation of each new transaction block in a valid and encrypted way that can be added to the Blockchain. In this regard, each node, i.e. computer connected to the bitcoin network, which has the task of storing and distributing an updated copy of each block, has a decentralized copy of the Blockchain, thus ensuring the quality of data through a massive replication of the database. In fact, there is no official centralized copy and no user is more credible than others: all are at the same level of credentials. [13]

The main feature of the hashing functions is the asymmetry: the transition from input data to the output string is simple from a computational point of view, but at the same time it is extremely expensive to make the reverse path. This allows hashing to be used as a consensus algorithm in the Blockchain. Whenever a miner wants to enter a given block, it must be able to excel at solving a computational reverse hashing puzzle called *Proof-of-Work*. It is required to find a pseudo-random number, called *nonce*, combining it with the data present in the block in question to obtain a hash with certain characteristics, generally used as a constraint "a number of zero bits". [6]

Once the nonce is found, the individual miner node transmits its solution to the entire network via broadcasting. As already mentioned, passing from the required hash to the data necessary to obtain it is complicated from the computational point of view, but the passage from input to output is instead immediate: it is therefore easy to verify the goodness of the solution proposed by the node. The purpose of PoW is to encourage competition between the various miners in order to eliminate the risk of monopoly of the entire network by a single node.

The direct consequence of this stated objective is the increase in the difficulty of the cryptographic puzzle, called difficulty, in proportion to the number of miners present in the network. Approximately every two weeks (exactly every 2016 blocks inserted), in fact, the difficulty-value is updated to guarantee a constant inter-time validation of new blocks of about 10 minutes. [14]

As for the Bitcoin Blockchain, the validation mechanism used is the proof of work, but there are also others such as the *proof of stake* which is one used by the Blockchain *Ethereum*. This simplifies the mining activity as it distributes the computational effort required to perform the verification process among the individual members in proportion to their percentage of participation. For example, if a user owns 20% of total Blockchain activity, they will have to perform 20% of the required mining activity. This reduces the complexity of the verification process, generating significant energy and operational cost savings. [15]

1.3 Domains and fields of applications

Like all technological novelties, disruptive technologies began in a niche market and then expanded into larger markets, leaving all those companies and technologies one step behind in the field. In this specific case, the niche field of Blockchain was Bitcoin: the first use of Blockchain was in the cryptocurrency market, used to allow decentralized payments. This, however, was only one of many possible applications of this new disruptive technology. [16]

Since its launch in 2008, the Blockchain has gained great visibility, especially because of the important financial implications. But virtual currency is only one of the possible applications of the distributed database. In fact, thanks to its founding features and its technological peculiarities, Blockchain presents many different solutions that transcend cryptocurrency. Despite numerous experiments, to date the technology is still in an embryonic phase and will take years before it can enter organically into our lives.

As the well-known American company Gartner says, the possibilities offered by the Blockchain are extraordinary and the future can only carve out surprises and opportunities for us. According to Gartner, we must expect applications that we cannot even imagine today. [17]

Finance and the economy have pioneered the use of Blockchain technology, in fact, allowing speed and reliability in transactions and eliminating the need for *a superpartes* entity that guarantees the authenticity of the transaction, it is becoming almost essential for banks and financial institutions to take a leading position in this new market full of opportunities to invest in. The American banking giant, Goldman Sachs, has officially declared that Blockchain is destined to revolutionize the financial sector. [18]

1.3.1 Smart Contracts

The concept of *smart contract* was first introduced in the late 1990s by Nick Szabo but remained rather abstract until the launch of Ethereum in 2015. It is a contract that automatically verifies the fulfilment of certain conditions and self-executes actions automatically (or by arrangement for such actions to be carried out), when the conditions determined between the parties are reached. [19] The smart contract represents the contract but, in digital format, and for this reason it requires legal support for its drafting but not for its verification and activation. This allows the elimination of the intermediary and consequently the need to establish a relationship of trust between the parties. "This is because an intelligent contract is both defined by the code and executed (or applied) by the code, automatically, without discretion." [20]

As far as the technical aspects are concerned, the absence of a human intermediary means that the smart contract must be structured on extremely precise descriptions involving all possible circumstances and situations that may occur. At the same time, for the contract to be drawn up correctly, the data sources since which the contract must be adhered to must be precisely defined. In fact, smart contracts are called to receive data and information from subjects or third parties that must then be read and interpreted by the software program based on precise rules.

These rules represent one of the most important and strategic parts of the contract and obviously determine the final output. The automatism, however, in addition to defining new rules at the technical level, determines a substantial and structural change in the bargaining field. Because of what has been said above, the absence of human intervention also determines the absence of an interpretative contribution. [21] It is possible to define and summarize the fundamental characteristics of a smart contract tracing the essential elements that are: *autonomy*, *self-sufficiency* and *decentralization*.

With autonomy we refer to the ability of the contract to self-execute itself by completing the transaction after having been "signed" (or become code), without the contractors remaining in contact or agreeing to what has been established; with self-sufficiency we refer to the ability of a smart contract to manage resources autonomously without the need for any human intervention. [20]

Finally, smart contracts are decentralized and distributed or, once signed, they are visible from all nodes of the network and there is no central authority responsible for their execution. This not only makes them unchangeable and transparent, but also allows anyone interested to verify the truthfulness of the information exchanged.

Through smart contracts there is therefore the possibility of creating a new ecosystem of technical automation capable of producing a new shared fabric that allows the birth of new and powerful forms of social efficiency, personal mobility and institutional transformation stimulating the adoption of automated visions of the future. [22]

1.3.2 Healthcare

The Supply Chains for medical and pharmaceutical devices are extremely complex, with all purchasing, manufacturing, testing and distribution activities taking place simultaneously. Lack of efficiency, transparency and authenticity, the root cause of many challenges faced for years in the healthcare sector, ended up bringing it to its knees in the pandemic caused by Covid-19.

In addition, in order to support the work of governments and national health systems, therefore, it is necessary to adopt a multisectoral approach that, by leveraging the potential offered by digital innovation, can ensure homogeneity of treatment and the necessary traceability of infections. Every emergency, however negative it may be, brings with it the need to rethink the logic with which activities are managed and, therefore, the opportunity to develop new transformative solutions capable of creating new value for citizens, businesses and public administrations.

For this purpose, applications based on Blockchain technology can make a significant contribution to improving health care systems by helping health care facilities to manage more effectively and efficiently data relating to the spread of disease and more generally those relating to patient records.

Despite the high degree of reliability of those who hold the information and the appropriate regulatory protection regarding data protection (e.g. EU Regulation 2016/679), in the management of these traditional systems, there are more and more cases of unauthorized sharing, intrusions into the life of the patient published on social networks or theft of sensitive data that constantly erode the trust of citizens in health institutions. With a Blockchain system it is possible to overcome these problems, eliminate the function of the central institution that holds and manages the data and at the same time maintain the trust and security between the parties involved in the transmission and circulation of clinical/health information of patients. Trust in this case is placed in the Blockchain network instead of in the health care institution on duty.

Applications based on this technology also offer better transparency than current registers and systems. Any changes within a Blockchain system are visible to all users and once transactions are made, they cannot generally be altered or deleted. With traditional systems, however, it is possible to modify the database and hide any changes to other users. This lack of transparency within traditional systems has made it possible for years to alter or manipulate data without the people involved knowing it.

Thanks to Blockchain, most of the actors involved must approve transactions and any changes before they are added to the Blockchain and, therefore, there is a significant increase in the transparency of the entire system.

Therefore, Blockchain technology would create a shared, fast and inviolable system in which healthcare professionals could record, modify and verify patient information. If we consider that health services are provided by a multiplicity of facilities with very different management systems, infrastructures and in general digital 'stories', we can understand how it could happen that information of a patient receiving a service in one of these facilities could be lost, or not recorded in such a way that any other facility could in the future access and display it, leading to a loss of efficiency and effectiveness for the care of the subject.

This problem of multiple sources in healthcare is reflected, for example, in the absence of a single national register for pharmacological treatment prescriptions, but multiple sources often fragmented among themselves must be coordinated. In this respect, a secure and decentralised management system in which each health care institution can access and view information about a patient can be an interesting response in terms of speed of access, making the service more effective and timelier. According to the *Protenus Breach Barometer* report, in 2016 there were 450 data breaches with an impact on 27 million patients. This will bring a total paradigm shift, where Blockchain will applied in the management of the electronic health record, in payments for healthcare services or in insurance practices for reimbursement in case of illness or injury. In the case of clinical trials, for instance, the promoters will have the possibility, thanks to Blockchain, to obtain scientific work finally certified step by step.

1.3.3 Energy & Smart Grid

Blockchain has opened up new prospects for the creation and diffusion of a new market for energy where citizens and companies with *individual production* can directly bring their excess production capacity to the market or buy it in case of need, creating a new market that can also bring important benefits in terms of balancing the networks.

The transition from a centralised logic to a decentralised logic in energy production and consumption management has been made possible. In concrete terms, it is possible to take a step forward from a situation in which small producers or individual micro-producers use the energy produced for "individual" consumption and give the grid, through the reference operator, the "excess" energy to a situation in which these subjects can exchange and/or sell their energy with and to other subjects also in a direct way. This means - simplifying matters - selling to the neighbour the energy that has been produced in excess of one's own needs and that is not used. And you can do this with tools that also allow you to manage the transaction related to this exchange or marketing.

However, it is significant that the research company *Markets&Markets* has predicted a 78% growth in the use of the Blockchain for applications dedicated to the Energy market to generate a business volume of over $7 billion by 2023 compared to a starting figure (2017) of just under $400 million.

In particular, the most interesting prospect of investment seems to be linked to the scope of P2P Energy, i.e. the introduction of exchanges between two individuals in the energy market. In this sense, final consumers are understood to be those who have chosen to produce and use energy for personal or household use and are therefore defined as *Prosumers* (producer-consumers). Hence the concept of *Smart Grid*, an intelligent grid that uses analytics and exchange platforms to manage electricity consumption and production as efficiently as possible in order to reduce waste as much as possible.

A Smart Electricity Grid connects producers and consumers, integrating the functionalities of an information network into the distribution network; the latter takes information, in real time, from meters, vehicles and all products and tools connected to users, and then rationalizes and distributes energy efficiently, avoiding overloads and voltage variations.

At this stage, however, it must be recognised that it is not easy to manage a complex of distribution networks where ideally every consumer could also be a producer and where, looking to the future, a significant number of 'users' (electric vehicles, in particular) do not have a position and number known in advance. In support of this decentralisation, Blockchain technology makes it possible to reduce this complexity by using distributed registers in which transactions linked to individual energy exchanges can be entered. This Blockchain management is independent of the type and volume of transactions, so it can be applied both in exchanges between large operators and between private or small local entities.

The market, for its part, is responding with great intensity. Estimates of the development of an Energy market linked to the Blockchain show very important growth rates. They are different points of observation, depending on the type of services considered and the perimeter of services, but in any case, the research companies see in the Blockchain an important potential for the start and growth of a new market. The outlook is particularly positive due to the need and possibility of enhancing the data heritage that comes from the ever-increasing diffusion of smart metering in many areas. These tools make it possible to "interact" and develop forms of "integration" with projects aimed at the development of decentralised energy systems. Decentralisation is certainly favoured by the parallel development of renewable energy sources that lend themselves well to being managed in a decentralised manner. The themes of sustainability and the search for ever greater optimisation in the use of energy resources are in turn intended to encourage the use and spread of decentralised energy platforms, capable, among other things, of making an effective contribution to balancing the networks.

According to *Global Market Insight*, the weight of Blockchain's services and projects in the Energy market was $220 million in 2018, and the research company forecasts an annual growth trend of 50% over the 2025-time horizon.

Figure 1 https://www.Blockchain4innovation.it/mercati/energy/

According to *Wise Guy Report* estimates the Global Blockchain in Energy market promises to grow from $285.21 million in 2017 to over $34 billion by 2025 with an annual growth rate of 82.24% over the period 2018-2025. MarketsAndMarkets in turn estimates the Blockchain market for Energy at $279 million in 2017 and expects growth to over $7 billion by 2023 with a growth rate of 78.32%.

1.3.4 Internet of Things

Blockchain applications can be used within the manufacturing sector and in broader terms within the panorama of the Fourth Industrial Revolution which we will discuss in detail in the following chapters.

The IoT through precise sensors offers the unique ability to monitor key parameters (humidity, temperature, brightness, CO, CO2, vibrations, smoke, etc. ...) or to track assets (machinery, equipment, vehicles, containers), not forgetting the increasing use of IoT in smart city (parking sensors, smart building, pollution monitoring, waste management) and Industry 4.0 for any type of business with countless use cases.

The data collected is sent and stored on Cloud platforms, allowing any company or PA to view and take prompt action to boost their business or use it to support business strategies. An IoT network can therefore find in the Blockchain the possibility to quickly and securely identify interconnected objects, eliminating the need to have people behind the items, allowing them to be recognized and then activate the exchange. Secondly, it allows companies in the B2B world and users in B2C to know the complete history of all components, with the changes of ownership. In addition, thanks to the possibility to preserve the data, it is possible to increase the security, reliability and transparency of production and supply processes.

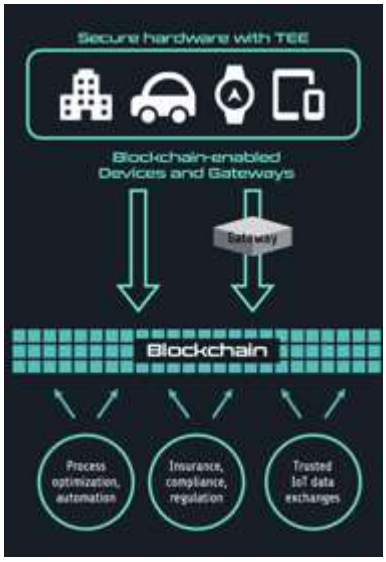

Figure 2 https://www.Blockchain4innovation.it/mercati/internet-of-trusted-things

In projects involving predictive maintenance, for example, it is essential to have tools that can guarantee the identity of each component involved in a complex product, such as an automatic machine intended for production.
Knowledge of the history of each component is of enormous importance in order to analyse the risk factors and define the methods of intervention.

IBM's idea is to merge IoT with the Blockchain and it came to life in 2015 through the ADEPT (Autonomous Decentralized Peer-to-Peer Telemetry Proof-of-Concept) project in collaboration with Samsung, with which Smart Contract on Ethereum structure was realized. [23]

ADEPT has established a decentralised network of IoT devices based on a public register through which they communicate with each other and manage the issue of recognition independently. Thanks to the implementation of these solutions, the connected *W9000* washing machine has developed the ability to buy detergent itself when stocks run out, request maintenance, order spare parts and optimise washing cycles to reduce energy consumption.

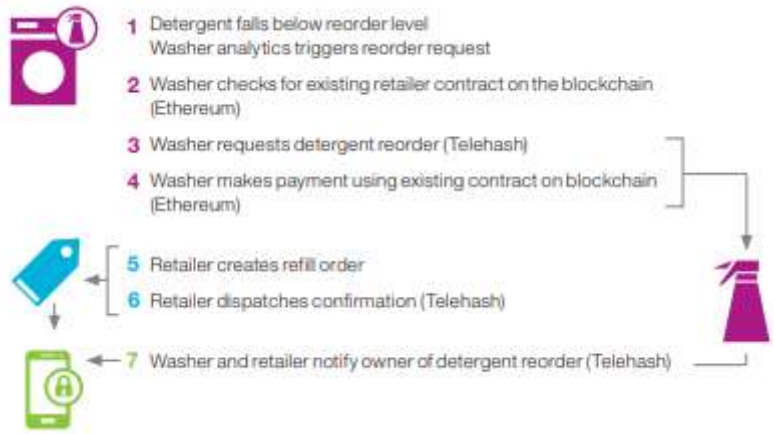

Figure 3 IoT transactions for the autonomous washer's order of a consumable [23]

The system is based on three distinct open source protocols: *Telehash* for messaging, *BitTorrent* for file sharing and *Ethereum* for device coordination functions such as recording, authentication and management of rules for initiating operations and authorising any transactions.

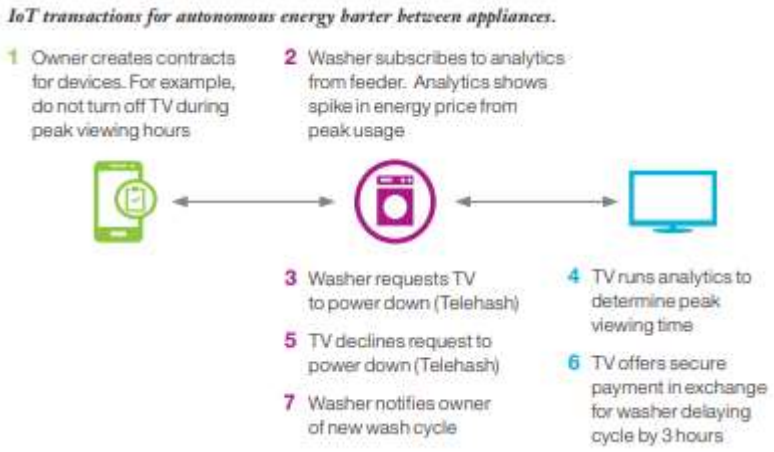

Figure 4 IoT transactions for autonomous energy barter between appliances [23]

But having a large interactive display and the connection with the specific mobile app available to the user, the machine can also display advertising messages contextual to the situation of use, allowing suppliers of services and collateral goods to fit properly into the dialogue between device and human being. All functions managed without the introduction of a central processing block that orchestrates or mediates the activities of the device with respect to the context in which it is inserted.

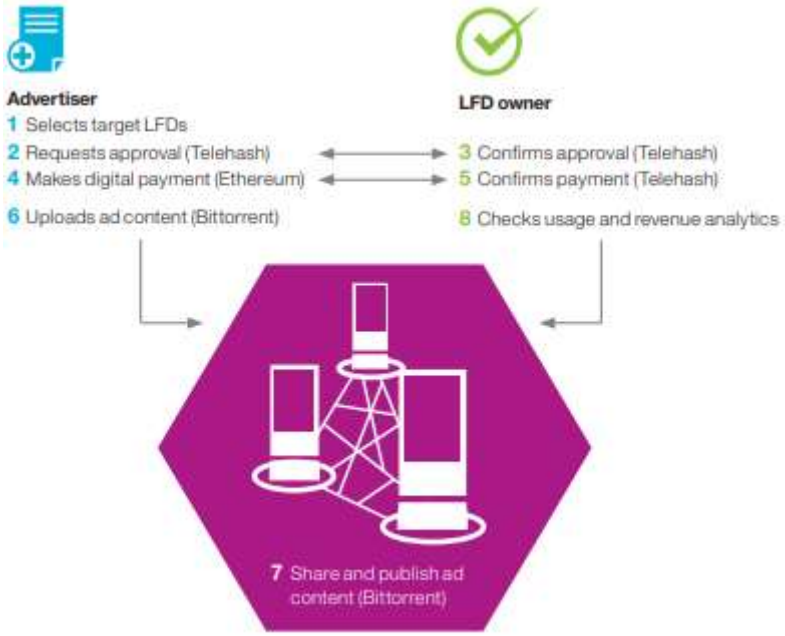

Figure 5 IoT transactions for an autonomous advertising marketplace [23]

The IoT & Blockchain combination can be used to certify the origin and routes of products sold, as in the case of safeguarding the cold chain. Let's say a shipment of ice cream is registered on a Blockchain. The individual batches containing the ice cream are equipped with IoT GPS sensors with integrated temperature and humidity sensors with the aim of safeguarding the cold chain. This shipment must reach ice-cream parlour "X". The "IoT enabled" container records locally and continuously transmits messages about the current location and temperature of the conveyor to the cloud on which the Blockchain is running as a service element. Commercial contracts specify the conditions that must be met during shipment from the factory to ice-cream parlour "X" and all parties must comply with the terms of the contract for example: "If the temperature of the container exceeds -2 degrees Celsius, the ice-cream parlour will not accept the container".

In case of violation, the supplier is liable. This data is stored on a Blockchain which is visible to all. On this ledger it is possible to follow the chronological shift of the batch of ice cream that guarantees the origin of the item as well as the maintenance of the cold chain for the correct preservation of the product.

The use of both technologies is no longer a futuristic hypothesis but already finds wide applications in the real world that allow them to be exploited not only as a simple business support but as a foundation to create important competitive advantages. Therefore, the solutions that have been developed so far allow to bring the new concept of trust characteristic of Blockchain technology and widely discussed previously, within the business operations in relation to transactions related to it.

1.4 Further relevant features

The first to use the term *disruptive innovation* were Clayton Christensen and Joseph Bower in their article "Disruptive Technologies: Catching the Wave" published in the Harvard Business Review in 1995, referring to "*those revolutionary technologies that anticipate the needs of a market, sometimes even creating new ones.*" [24]

Blockchain is a disruptive technology, however, not only because of its technical characteristics, but also because of the changes it entails in terms of transaction management. The following is a detailed analysis of the main characteristics of this technology to be assessed in order to decide whether to adopt it in a certain field or in a certain company. As already mentioned, the Blockchain is an add-only register, i.e. blocks that are part of it cannot be deleted or modified. This differentiates this new technology from a traditional database, where the data objects of records can always be updated, obviously with constraints dictated by the different levels of authorization enjoyed by those who have access to them.

Such constraints in Blockchain, at least in Bitcoin, do not exist. Immutability is not a real intrinsic aspect, but an indirect effect of the block validation process.

Each block contains a hash that recalls the previous block, so an attempt to modify a single block within the chain would necessarily involve modifying all blocks following it. Since the modification, like the creation, of a block must also be validated, the effort required to modify the single node and those after it is such that it is in itself a very powerful disincentive to counterfeiting. The presence of 5/6 blocks downstream of the block in question is enough for the transactions contained within it to be considered immutable. [12]

Two key characteristics of the Blockchain are *decentralisation* and *distribution*. The Blockchain is defined decentralized because there is no entity that controls the transaction process; while regarding the distributive property, reference is made to how the computation work is divided between the different computers. The Blockchain, in fact, is a type of *Distributed Ledger Technology* (DLT), that is a data repository shared by several entities that operate on a distributed network, intended as sites, countries or institutions. [25]

Most cloud-based services rely on a single trusted organization that controls and manages the data repository and network and controls access to associated services. This approach may be positive and desirable for some applications or sometimes necessary for the rules and business of the environment. In other cases, however, DLS (*Distributed Ledger System* or DLT if we talk about technology) can radically change certain applications in the business world, exploiting the value of DLT, which are able to offer a more efficient system. [26]

Using the Blockchain as an explanatory case, a transaction in the Blockchain network can be executed between any two peers without the need for authentication by a central agency. By doing so, the Blockchain can significantly reduce server costs and above all avoid the bottleneck phenomenon (the performance of a system or its capabilities are strongly constrained by a single component) related to centralized servers. [25]

Nodes belonging to a Blockchain can perform three functions:

- *Read*: nodes have access to transaction history, which allows them to go from as-is state to as-was state.
- *Write*: nodes can perform transactions and put them in the pending pending pool.
- *Commit*: nodes can modify the ledger, i.e. they can insert new blocks in the Blockchain validating pending transactions.

Depending on whether all nodes have permission to perform all three functions, the Blockchain is divided into *permissionless* and *permissioned*. The latter deviate from the network idea originally theorized by Satoshi Nakamoto, as they need a central authority and governance system to determine which nodes can perform what functions. [27]

In *public* Blockchain anyone can become a node in the network and consequently verify, view and carry out transactions; anyone can carry out the mining activity and for this reason participate in the consent mechanism by voluntarily offering their computing power. This system is able to offer a high level of security thanks to the presence of: a complex consensus mechanism that pushes miners to invest heavily in computational power; public-private key cryptography; a governance mechanism according to which the degree of influence of a single actor within the network is proportional, in the consensus definition process, to the amount of economic resources that he can bring. This type of Blockchain is defined as "completely decentralised". [28]

For the *private* one (permissioned ledgers), each time a data or record is added, the approval system is not bound to the majority of Blockchain participants but only to a limited number of actors who are called "trusted". According to this model, the actors can operate independently, but only one or more pre-selected actors perform the function of validators in the network. These types of Blockchain use levels of access control to specify the participants of the network and commonly use a consensus mechanism very much active. Private Blockchains have been studied lately mainly within the financial sector.

This has provoked numerous negative reactions, particularly from those who have interpreted these developments as contrary to the ideals of decentralisation proposed by Satoshi Nakamoto in 2008. Others interpreted the private Blockchain chase by financial players as a last desperate attempt to avoid a potential exclusion from the transactional system. [28]

Blockchain *consortia* are distributed databases in which the consensus mechanism is controlled by a set of pre-selected nodes. [28] Think for example of a "consortium" of 10 financial institutions, each of which manages a single node of the network. In this case the mining activity could be reduced to a joint agreement between the different participants. In these terms, the consensus mechanism would be built on a voting system with pre-established majority thresholds. For example, it could be enough that 80% of the nodes sign a block for it to be validated. As far as reading permissions are concerned, in consortium Blockchain these can be either public, i.e. issued to all or nodes of the network, or limited to some participants. This type of Blockchain for its intrinsic characteristics is defined "partially decentralized" and can be considered a hybrid between public and private solutions. [29]

Depending on the type of platform used, the Blockchain can be designed to provide different levels of data access to the Blockchain. In other words, it can provide greater data transparency while ensuring the required privacy. To protect the most sensitive information, it is recommended that such information be stored "off chain": rather than being stored and replicated between nodes within the structure ("on chain"), information and data should be stored outside and separately from the Blockchain. In addition, most Blockchain platforms cannot efficiently store large amounts of data on chain, but only the minimum amount of information and data. elements required and necessary to allow a transaction.

Specifically, in order to have confidence in the validity of the data and to share data between the silos in respect of privacy, the information to be stored in the Blockchain (on chain) are:

- *Transaction metadata* (time stamp, ID of the actors/users, type of transaction, etc.)
- *Pointers* to data stored off chain, accessible only by authorized users
- *Access control* list, listing the actors who have access to read or update data residing in the pointer. [30]

Based on the above considerations it is therefore possible to outline and summarize what are the two main features Blockchain technology.

Verifiability: in the Blockchain each transaction is validated and recorded with a time stamp. In this way, users can easily verify and track previous records by accessing any node in the network, also improving the concept of traceability and transparency of data stored in the Blockchain. [7]

Reliability and security: thanks to its decentralized and distributed structure, the Blockchain is secure, reliable and therefore immune to potential cyber-attacks. If, for example, one of the nodes were hacked or attacked, the other nodes in the network would remain active, ensuring the immutability of data and information. Security is ensured by the cryptography and distributed nature of the system, as well as the ability to encrypt and isolate data at the data element level. [31]

CHAPTER II – Supply Chain Management

2.1 Key concepts and definitions

Although there are numerous Supply Chain definitions among the different scholars, there is a consensus on its contents. This can be defined as "*a selected, durable set of autonomous and owner-independent entities, but which are united by working together through the integration of certain business processes to make available products, services and information that add value for customers, starting with end consumers and going back to raw material producers.*" [32]

In the light of the greater complexities that have characterized the competitive landscape, in recent years there has been an increase in interest on the part of companies and institutions in problems related to the strategic management of Supply Chains. The individual company therefore no longer only has to manage internal flows, but also those of the entire ecosystem in which it operates, focusing its attention on the end customer, which becomes the ultimate goal of the cooperative activity carried out by the entire network. [33]

In this new scenario the development of the Supply Chain Management concept has been fundamental. This takes the form of a new management approach in which the individual company becomes part of a network of organizational entities that integrate their processes to provide products or services to the end customer. [34]

One of the best-known definitions of Supply Chain Management identifies it as "*the management of upstream and downstream relationships with suppliers and customers with the aim of creating more value for the end customer at lower costs throughout the Supply Chain*". [35]

The success of the individual enterprise must therefore be related not so much to it as to the competitiveness of the entire value system in which it is located.

Furthermore, it is no longer the single organization that competes within the market, but the entire Supply Chain, within which there are relationships both of a logistical nature and mutual exchange of information, knowledge, skills, services that contribute to the implementation of activities and processes. [36]

The above helps us to define the Supply Chain which, in short, can be said to be the set of all the activities concerning the creation of a good, starting from raw materials to the finished product, including the supply of materials, manufacturing, storage, stocks, order management, distribution and shipment of the finished product to the customer.

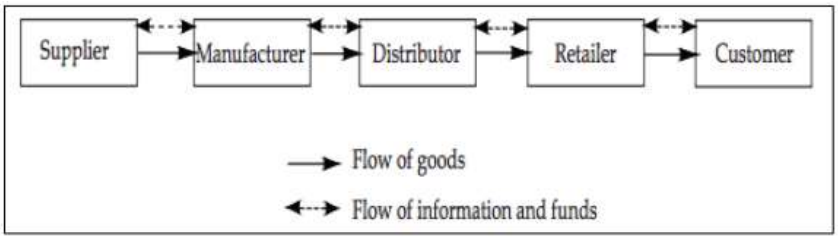

Figure 6 The basic Supply Chain, Chopra and Meindl, 2001

The SCM can therefore be summarised as the management and coordination of the three main flows existing internally and between the different levels of a Supply Chain: information, financial and physical. [37]

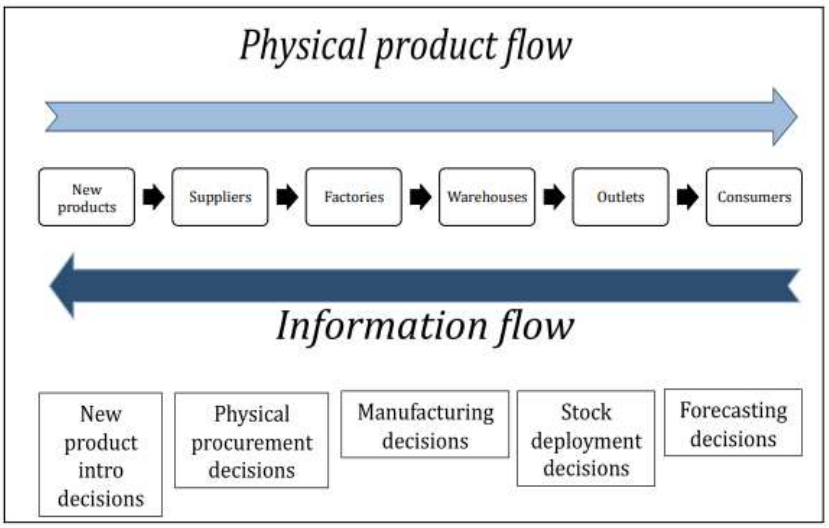

Figure 7 http://supplychaininformation.blogspot.it

2.2 Supply Chain Network and Integrated SC

In today's highly dynamic business environments, many companies are expanding, contracting or otherwise redesigning their Supply Chains. Due to rapid technological growth, classic Supply Chain models have rapidly evolved, leaving room for what we know today as the *Supply Chain Network*. The Supply Chain Network is an organic and dynamic system in which all companies are integrated with each other with the aim of improving the overall value of the entire chain. *Integration* is the process of redefining and connecting the parts of a whole, in order to form a new one. In Supply Chains the definition of the parts usually coincides with the boundaries of the enterprise itself. [38]

In the 21st century we have witnessed some changes worldwide that have contributed to the birth and development of Supply Chain networks. First, as a result of globalization, the proliferation of multinational companies, joint ventures, strategic alliances and business partnerships have proven to be critical success factors. Other practices at the production level have been adopted in order to make companies more flexible and able to react quickly to the continuous changes in the market. These include the practices of *Just in Time*, *Lean Management* and *Agile Manufacturing*. Secondly, technological changes and the dramatic fall in the cost of communication technologies have radically changed the coordination between the different members of the Supply Chain network. [36]

The search for integration, in order to be effective when applied to the entire Supply Chain, must first and foremost take place within the company itself between the various departments and segments, which in most situations require a common vision and objective. In the absence of a minimum level of internal integration, external integration risks becoming an unnecessary effort that does not speed up business processes and therefore does not bring real benefits. The evolutionary path towards Supply Chain Management is therefore composed of two main phases, the first takes place within the company and is an internal reorganization, while in the second phase this approach must be exported to the outside, with the aim of to remove those obstacles that usually prevent two companies from having and share common goals.

Integration can take many forms. A first classification is represented in the picture [39]:

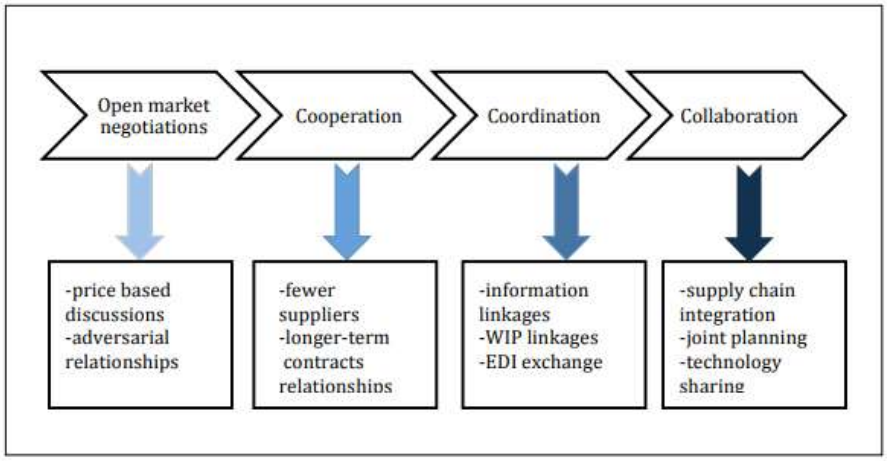

Figure 8 Integrated Supplu Chain, Spekman et al. (1998)

Negotiation: basic level of integration between two or more actors. The communication is limited to a discussion of purchase and selling prices, methods of payment and delivery of goods. At this level, little information is shared, and the objectives remain independent.

Cooperation: it presupposes the rationalisation of the supplier base and the development of long-term contractual forms. It provides for a high degree of cooperation between the actors, which takes the form of a minimum level of integration and sees communication as its focal point.

Coordination: intermediate level of integration, where the constant exchange of information makes most interorganisational relations more fluid and efficient.

Collaboration: maximum level of integration, in which the companies involved have the same objectives and the same vision, and above all, they are characterized by a continuous exchange of information and data and incessant communication

Van der Vart and Van Donk in 2004, instead, studied the level of integration on the existence of three different moments characterized by distinctive elements. [40]

Transparency: a phase in which a Supply Chain may be in the case of a actors participating in it are able to share relevant information in in an organized way. This stage is characterized by the almost total autonomy of every single actor in proceeding and acting, in fact, every function you will behave as you see fit based on the information obtained from the others. Supply Chain actors. At this stage the greatest danger is the incompatibility of the information systems of different companies, which could lead to an exchange of information that is too slow and therefore ineffective. Phase still characterised by a certain independence and autonomy of the individual actors, and by individual and uncommon objectives.

Commitment and coordination: companies exchange relevant information on a continuous basis, but unlike in the previous phase, they do not act autonomously and independently, but rather seek integration at the decision-making level and not only at the information level. The objectives become partly shared, trying to satisfy all the actors who become part of the integration process.

Integrative planning: integration is achieved through the progressive centralization of decision-making and control processes by a single actor in the Supply Chain, which will have the task of coordinating and managing it in the best possible way. This company will be the one with the greatest responsibility in terms of leadership and with a focal importance within the Supply Chain. In this phase there is a maximum level of integration, given by intense relationships, a continuous exchange of information and a high degree of communication.

2.3 Current challenges and criticalities

Harrison believes that companies currently compete through the Supply Chain and is therefore increasingly seen as a necessity and a competitive advantage for all companies. [41]. The competition that distinguishes most industrial sectors today is represented by important and substantial innovations compared to the past. First, the customer holds a more and more central position, and, from a passive subject, he transforms himself into an active player by directing his preferences towards companies able to satisfy them.

Moreover, the customer's choices are no longer based solely on price but also on other factors, both material and immaterial, associated with the quality of the product or service provided. [42]

Gattorna even believes that nowadays the Supply Chain is the business itself, the fundamental element for success. [43] What characterizes the market and its environment today is globalization and the consequent vulnerability of an increasingly demanding demand, which creates uncertainty and an extreme need for flexibility.

Within this complex ecosystem conditioned by an increasingly rapid evolution of environmental variables, the Supply Chains have experimented with new configurations able to guarantee the flexibility and dynamism necessary to compete in an environment characterized by high uncertainty. [44]

The focus has moved from managing internal activities to the search for a stronger integration with all external actors in order to better satisfy the end customer. The progressive increase in variety, variability and uncertainty of the context have in fact, as outlined above, pushed companies to adopt models characterized by an increasing degree of openness to the outside world, allowing individual entities in the *value chain* to focus on distinctive skills and acquire complementary ones from third parties. [36]

As early as 1985, Michael Porter introduced the value chain concept in which he considered internal and external logistics to be one of the focal points in a value chain, as well as much more popular functions such as marketing and sales, customer services and operations. Only if a company manages to implement these activities in an efficient way will it gain a competitive advantage.

Porter believes that a company's value chain is a part of a broader value system that includes suppliers and consumers, and for this reason, he says that a company's success depends not only on its value chain, but also on the value system of which it is part. [45]

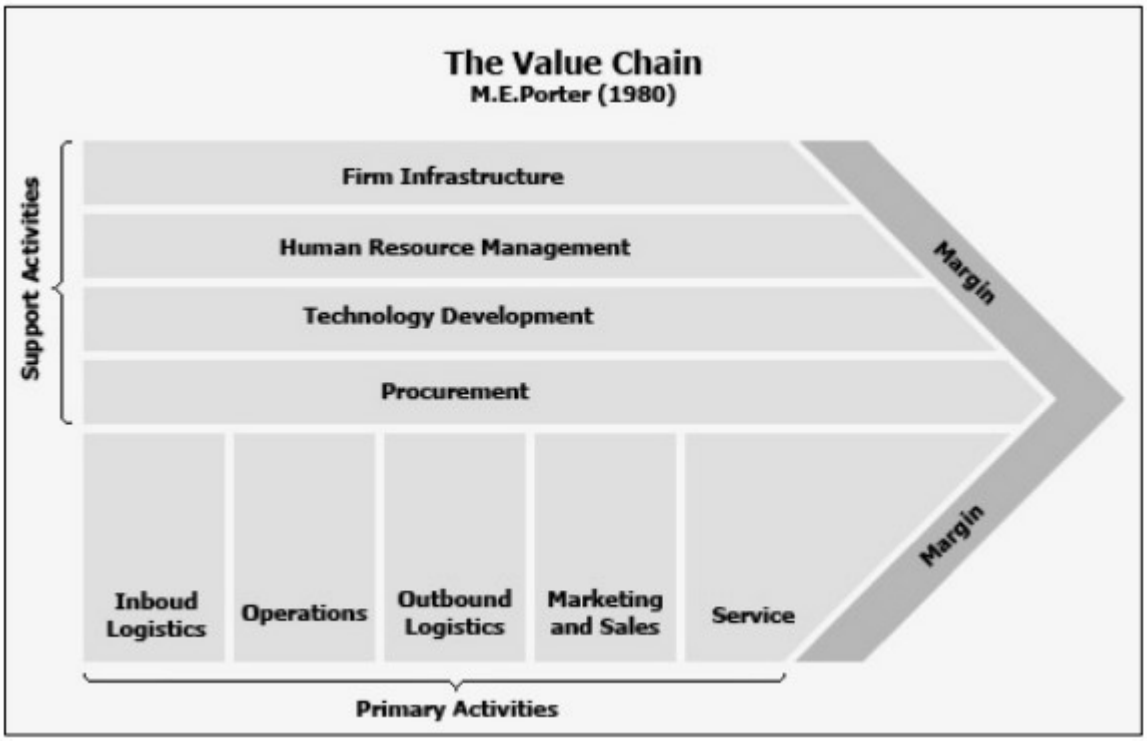

Figure 9 Michael Porter, Competitive Advantage: Creating and Sustaining Superior Performance, 1985

In support of this, a report made out by Accenture, INSEAD and Stanford University, which shows that leading Supply Chain Management companies are also more profitable and rewarded in the financial markets. The study, carried out between 1997 and 2002, includes an accurate analysis of more than 600 "global 3000" companies operating in 24 different industrial sectors. [46]

The study agreed that the stock market should act as a judge of the company's performance and strategies, and labelled as "leaders" those companies with efficient Supply Chain Management and as "latecomers" those that did not seem to have an organized Supply Chain; the study then evaluated the financial performance of the various companies, comparing them with what had previously been established on the basis of their "labelling".

The results that emerged are quite eloquent, the average annual growth composed of the market capitalization of the companies considered "leaders" exceeded the "latecomers" by between 10 and 30 percentage points.

The "leaders" had a higher share growth rate than the "latecomers", in the order of 20% more. Of course, these results were not found in all the cases analysed, in fact, about 12% of the companies considered "latecomers", however, observed growth rates. high, but, given the limited number of cases (only 12%), it can be assumed that the study is quite truthful and that indeed companies with a shrewd management of the Supply Chains are, on average, more profitable.

2.3.1 Sustainability

Corporate sustainability is one of the key themes of this new millennium and is one of the great challenges of today's Supply Chains. Within this context, the companies that are part of the supply network, as the main players in the world ecosystem in which we live, have found themselves having to deal with the great issue of corporate sustainability.

A 2015 research promoted by Nielsen and titled "*Nielsen Global Survey of Corporate Social Responsibility and Sustainability*" has shown the increasing attention of the end-customer to the origin of the product and sustainability along all stages of the Supply Chain and throughout the product lifecycle. *The Easy Way* advertising monitoring agency, in collaboration with the Politecnico di Milano, in the first four months of 2019 showed a 34% greater use by the media of keywords related to sustainability compared to the previous year. [47]

It is not only end consumers who pay more attention to the level of sustainability adopted by companies in the pursuit of business activity: similar behaviour can also be observed by investors. Some research shows that Venture Capital in their investment choices no longer only investigate the economic and financial performance of a company, but increasingly consider the social aspects and the impact that companies have on the reference environment. [48]

The commitment made by companies on the subject of sustainability is considerable: according to the *GreenItaly 2019* report, carried out with the patronage of the Ministry of the Environment and Protection of Land and Sea, the share of so-called eco-investments by companies in 2018 was 21.5%, compared to 14.3% in 2011. [49]

Based on the above considerations, sustainability has become so fundamental for companies today that it undermines their survival. Within this context, in order to compete, companies must adopt a transition towards the green economy, i.e. towards the creation of a circular economy that: minimizes waste, improves the living and working conditions of employees, promotes social and environmental policies that are not destructive for the planet.

Within this ecosystem, even in modern Supply Chains, the concept of sustainability has taken on vital importance, giving rise to the so-called *Green Supply Chain*. Rettab and BenBrik defined Green Supply Chain Management in 2008 as "*a managerial approach that seeks to minimize a product or service's environmental and social impacts or footprint*." [50]

Finally, in addition to the attention paid by governments and institutions, the issue of sustainability has been the focus of many international programmes and projects. In this regard, it is important to mention here the work proposed by the *World Economic Forum* on *Sustainable Development Goals* (SDGs). The Swiss foundation has developed seventeen objectives for the period 2016-2030 that must be achieved worldwide in order to make the planet we live on a suitable place to continue to host the human species. Compared to the previous document of the *Millennium Development Goals* (MDGs), addressed to the period 2001-2015, the document is characterized by the universality of the defined objectives: these are in fact valid for the whole world, not only for developing countries and not only for governments, but for all the subjects operating in the 183 States that have signed them, i.e. civil society, voluntary organizations and companies.

2.3.2 Tracing and transparency

Globalization has dramatically increased the trans-national commodity movement, exponentially complicating global Supply Chain Management. Today it is in fact very difficult for companies to trace the information related to every single step that takes place in the passage of a single product from the producer to the final consumer or in the opposite direction from the customer going up the entire production chain.

The presence of multiple actors, each of which contributes to production even beyond national borders, makes the traceability of current Supply Chains a very complex activity. The direct consequence of the inability of companies to keep track of information is the lack of transparency within the Supply Chains. [44]

One of the dimensions that make tracking information within Supply Chains complicated is the difficulty for companies to deal with a wide variety of different regulatory systems that are constantly evolving. There are still overlapping or conflicting requirements within individual national systems. For example, in relation to the food sector, different and conflicting rules exist in different jurisdictions in relation to allergens, tracing of ingredients, declaration of nutritional values, use of pesticides and much more. [51]

Another aspect to highlight is that global Supply Chains need to be digitized in order to support full traceability of products and related information. Today, the lack of appropriate technical solutions aggravates rapid response times and generates inefficient data flow. The transfers of materials and finished good between the various companies highlighted the need for alignment between the various item identification systems in place in the various companies through the establishment of a common standard.

In the 70's different companies, in order to facilitate collaboration, introduced the *barcode* traceability system following the guidelines defined by the *GS1* association. The barcode is a graphic representation of data; the most common one is composed of a set of parallel lines, which differ in thickness and space between them, and an alternation of alphanumeric characters. This string has variable composition and length according to the GS1 standard. However, due to its small space and character size, the barcode has a reduced storage capacity. The barcode has limits in terms of operability as it needs to be physically read by a scanner at a close distance. In addition, this technology is critical for its ease of reproduction. A photograph and a reprint of the barcode is enough to obtain a duplicate identical to the origin code. To make up for these deficits, a new technology has been developed: *RFID*.

RFID tags dialogue with the reader through electromagnetic waves, so they do not need to be physically scanned and maintain a high level of operability even at longer distances. Thanks to these features they can be inserted inside the product, a condition that reduces the risk of tag duplication and consequently counterfeiting. In addition, the RFID tag has a high storage capacity, additional information about the item can be saved and can be updated over time. The operational features of RFID technology have enabled it to be widely used. An analysis by Statista shows the expansion of the market size of this technology over time: from a global annual revenue of about 9.56 billion dollars in 2014, it is estimated to reach 41.3 billion dollars by 2027. [52]

In any case, due to the obstacles described above, in a complex and extensive Supply Chain, characterized by numerous intermediaries and lack of visibility on processes, many of the challenges on traceability and transparency of the Supply Chain are not solved thanks to the use of these systems. Moreover, automatic data capture tools are very expensive, complex to implement and difficult to apply both for large volumes and bulk goods. In many cases, therefore, the traceability challenges result in the lack of product registrations with enormous damage to the entire Supply Chain. [51]

In addition, the increase in complexity both in the degree of customization and in the functionality of the products causes an exponential increase in the complexity of traceability systems, from which it follows that many processes are still paper based. Manually written documents are characterized by human errors, slowing down product reordering and the ability to track and trace information. [53]

Track and trace processes cannot ignore the massive use of the technologies described above. For perfect operability, compatibility between the various company systems is of fundamental importance. Every company must be equipped with devices able to support the reading of the various unique identification codes of the product, a condition that can be achieved through the development of a common strategy and a governance system in order to ensure integration within the Supply Chain and consequently increase efficiency and return on investment. In these terms an important contribution can be made by Blockchain technology as will be described in detail in the next chapter.

2.3.3 Digitalization

One of the most obvious aspects of the general change that has taken place in modern society is the spread of digital technologies. It is a phenomenon that is stimulating a broad debate about the implications of this for government in both large and small and medium-sized enterprises. [32]

One of the key factors that has enabled the spread of digital technologies has been the rapid fall in their cost to the market. Not only have the costs of individual products and technical solutions been reduced, but there has also been a significant decrease in infrastructure costs such as those related to network connectivity. Computational and storage costs have also fallen dramatically compared to the past, and trends show that these are set to fall even further in the years to come, with the same technical performance. Within this context, companies have been able to obtain, with the same investment, or in any case following low investments, increasingly significant benefits from the implementation of digital technologies. [54]

Within this context, many Supply Chains are rapidly changing from static activity sequences to dynamic and interconnected systems that incorporate partner ecosystems and new technological solutions. The transition from linear and sequential operations to an open and interconnected system is the key element to allow Supply Chains to continuously optimize their configuration and above all to compete in the future. [38]

This open and dynamic system in which information between the different states of the Supply Chain is integrated and connected is called the *Digital Supply Network* (DSN). The Digital Supply Network is a new, highly interconnected business system that includes both isolated applications for individual companies and integrated solutions for the entire Supply Chain. [54]

Some companies, maintaining the objective of satisfying customer demand in a short time and with minimum costs, in order to adapt to the "new normality", have taken the path of transformation of the Supply Chain. The first step to transform their organization into a new Supply Chain model based on collaboration is understanding and adapting to the new digital world.

It is clear that new approaches to business are having a profound impact on global trade. And while these new models are not yet fully understood by all business leaders, their impact on traditional Supply Chains is already underway. Successful companies will need to take advantage of new management practices, an ever-expanding data reservoir and new technologies relevant to the Digital Supply Chain.

The Boston Consulting Group has developed a map of the main areas of action to be considered as strategic starting points for a digital transformation of the Supply Chain. [55]

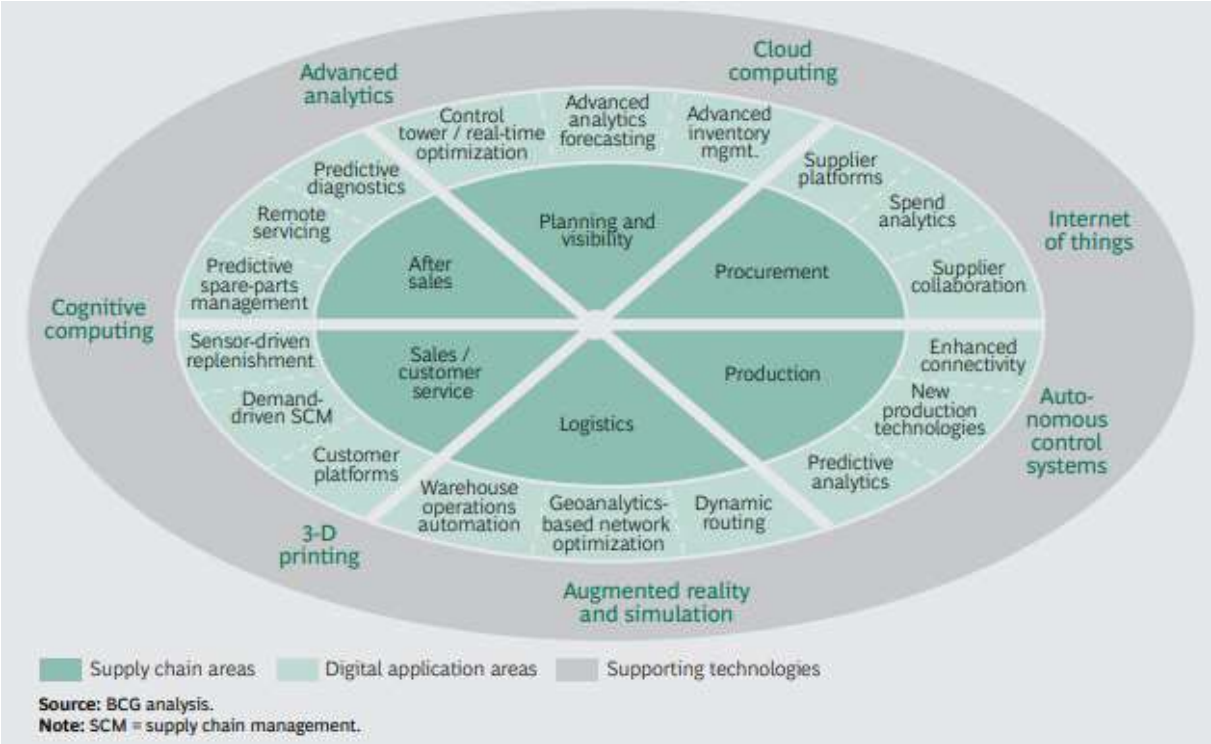

Figure 10 The Landscape of Digital Supply Chain Management

Three dimensions are distinguished:

- *Supply Chain areas*: planning, procurement, production, logistics, sales / customer service, after-sales services. They correspond to the functional silos of traditional chains, which must be reshaped, centralized and revisited according to the new organizational logic.

- *Digital areas*: each functional pillar of the Supply Chain is associated with new concepts and tools to be used to improve and simplify traditional processes. These tools take advantage of the potential offered by digital to speed up and simplify operations. Examples are advanced analytics for forecasting, collaboration between suppliers, predictive analytics, automation of warehouse processes, customized platforms for customers.

- *Supporting technologies*: the use of new digital tools is allowed by some supporting technologies born with the 4.0 industry revolution, some examples are cloud computing, the Internet of Things, augmented reality.

There are different definitions of Digital Supply Chain. The Digital Supply Chain Initiative for example describes it as "*a customer-centric platform model that captures and maximizes the use of real-time data from a variety of sources. It enables demand stimulation, demand sensing, and management to optimize performance and minimize risk.*" [56]

Another definition of Digital Supply Chain was formulated by Alicke, of McKinsey & Company, which defines it as Supply Chain 4.0, namely "*the application of the Internet of Things, the use of advanced robotics and the application of advanced analysis of large data in Supply Chain Management: inserting sensors into everything, creating networks everywhere, automate everything and analyse everything to significantly improve performance and customer satisfaction.*" [57]

The figure below schematically represents the transition from a traditional Supply Chain to a Digital Supply Network. The interconnected grid of the new DSN model is clearly visible and within the new configuration and each node is potentially connected with every other link in the chain. In this new ecosystem the communication is multi-directional, and this allows the generation of new links between activities and links that in traditional Supply Chains were non-existent.

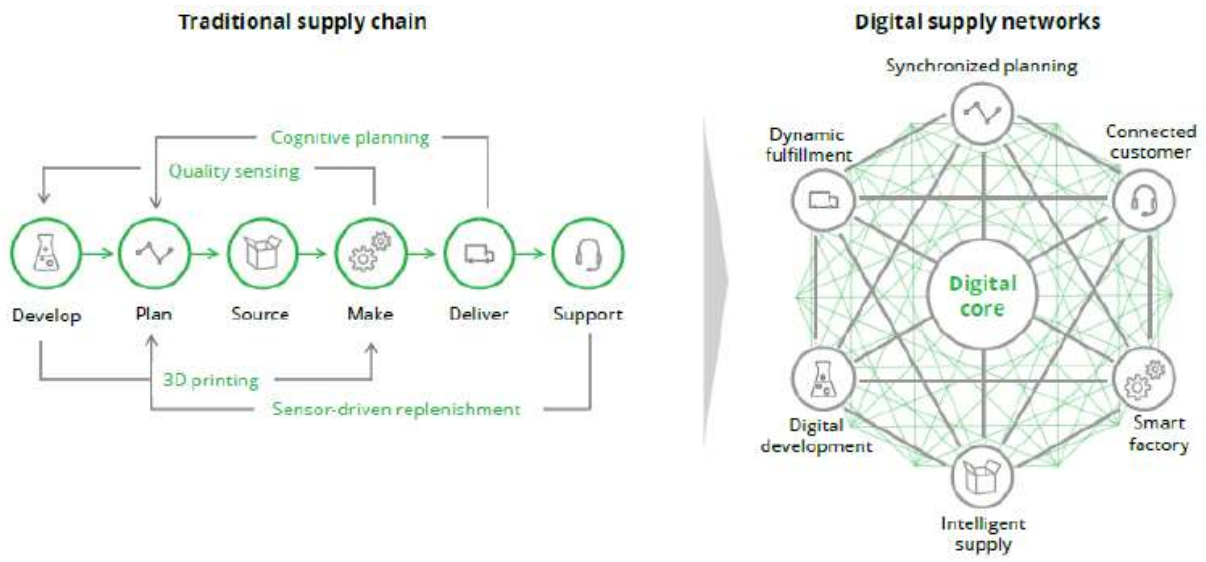

Figure 11 From Supply Chain to Digital Supply Chain [54]

As shown in the figure, the transition from traditional Supply Chains to DSN requires the development of new transversal skills. In fact, the adoption of new technologies presents the Supply Chain Management with the challenge of having to develop new management practices able to govern and control innovation from this scope. The evolution of management models necessarily involves an evolution of the language associated with them. So, for example, we will no longer talk about *Plan* but *Synchronized Planning*, i.e. synchronized planning processes between all the nodes of the network. Or we will no longer talk about Support, i.e. management of support activities to the final customer, but about Connected Customer, i.e. a system in which the customer becomes the main actor and protagonist within the network and is actively involved in the Supply Chain Management process. [54]

Finally, the involvement of the final consumer possible thanks to the support of digital technology allows to obtain a direct contact with the demand, to rethink the customers' purchasing experience and finally to anticipate the changes in consumer tastes, adapting the supply to the changes, even sudden, of the final demand.

2.4 Hype cycle

A tool to assess the growth of interest in new technologies over time is the Hype Cycle theorized by the consulting firm Gartner, engaged in research and analysis in the field of Information Technology. [58]

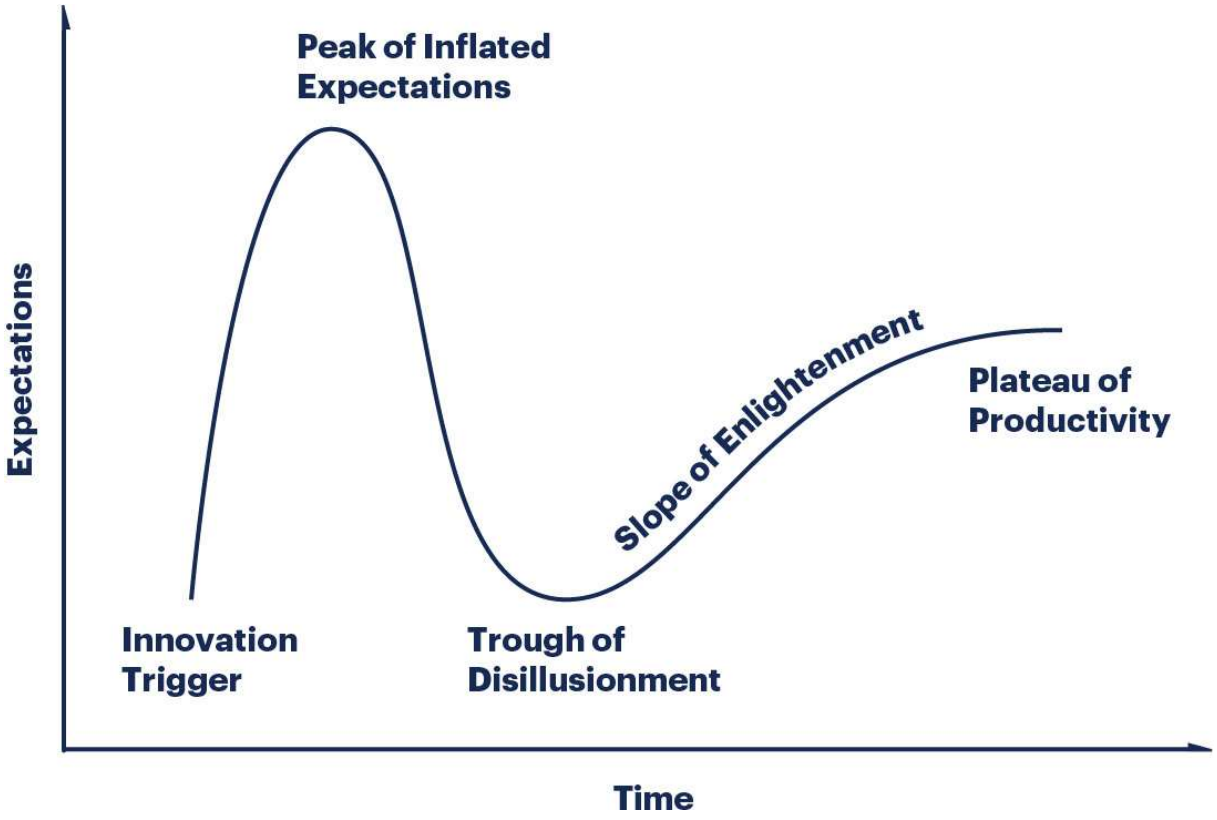

Figure 12 Hype Cycle [58]

On the horizontal axis is represented the time variable while on the vertical axis the visibility of the technology in terms of popularity and interest by companies. Along the curve every technological solution pass from the conception or discovery phase, to the phase in which it becomes an integral part of the production system and is widely used on the market. It is important to underline that the speed with which the technologies make this path is not constant and/or equal for each technology: some take a few years to cross the curve while others remain in it for long periods of time.

Gartner, in support of its research work, highlighted some disruptive technologies that can radically change the management of operations in today's Supply Chains. [59]

Artificial intelligence: AI aims at replacing machines in tasks generally performed by human resources as they require the use of reason. Unlike traditional applications that are designed to perform a specific task, artificial intelligence aims at progressive machine learning. The same often has initially limited information and perfection of its knowledge through training phases based on the concept of learning by doing. The new frontier of machine learning is deep learning, a field in which the learning process is realized through neural networks (ANN - Artificial Neural Network) composed by different layers in which each layer aggregates the data of the previous one and returns the new input data of the next layer.

Industrial Internet of Things: The IoT consists in the networking of objects in order to interact between them and at the same time a better collaboration with human resources, through sensor systems and data processing. Technological evolution pushes the IoT towards the Internet of Everything (IoE). It consists in expanding the connection to the network from objects, processes, people and data. The fields of application could potentially be the totality of sectors. Through the support of a smart network, for example, energy savings could be ensured by switching on public lighting systems.

Robotic Process Automation (RPA): This technology concerns the engineering of robots aimed at collaboration and gradual replacement of corporate human resources. The robots are in fact programmed to respond to certain inputs by performing precise tasks, thus reducing the error rate. Moreover, it is possible to replace robots in hostile or dangerous environments for human beings, in order to guarantee, in addition to an increase in efficiency, an improvement in safety conditions.

Predictive analytics: This tool uses statistical modelling methods combined with machine learning in order to analyse historical data, identify trends and make forecasts. In particular, the input is made up of huge amounts of data that are difficult to process because they are derived from the aggregation of information related to different factors, such as political, economic, social, environmental and operational. Through the techniques of predictive analytics, scenarios characterized by similar boundary conditions are compared and alternative final statistics are deduced.

Blockchain technology, as already extensively described in Chapter I, has the potential to radically change Supply Chain Management. The use of smart contracts to manage Supply Chain relationships, product and information tracking at every level of the Supply Chain, the emergence of decentralized marketplaces is just some of the disruptive applications of this technology.

In 2019, again the consulting firm Gartner, published an entire Hype Cycle dedicated to Blockchain Technology and its possible applications. [60]

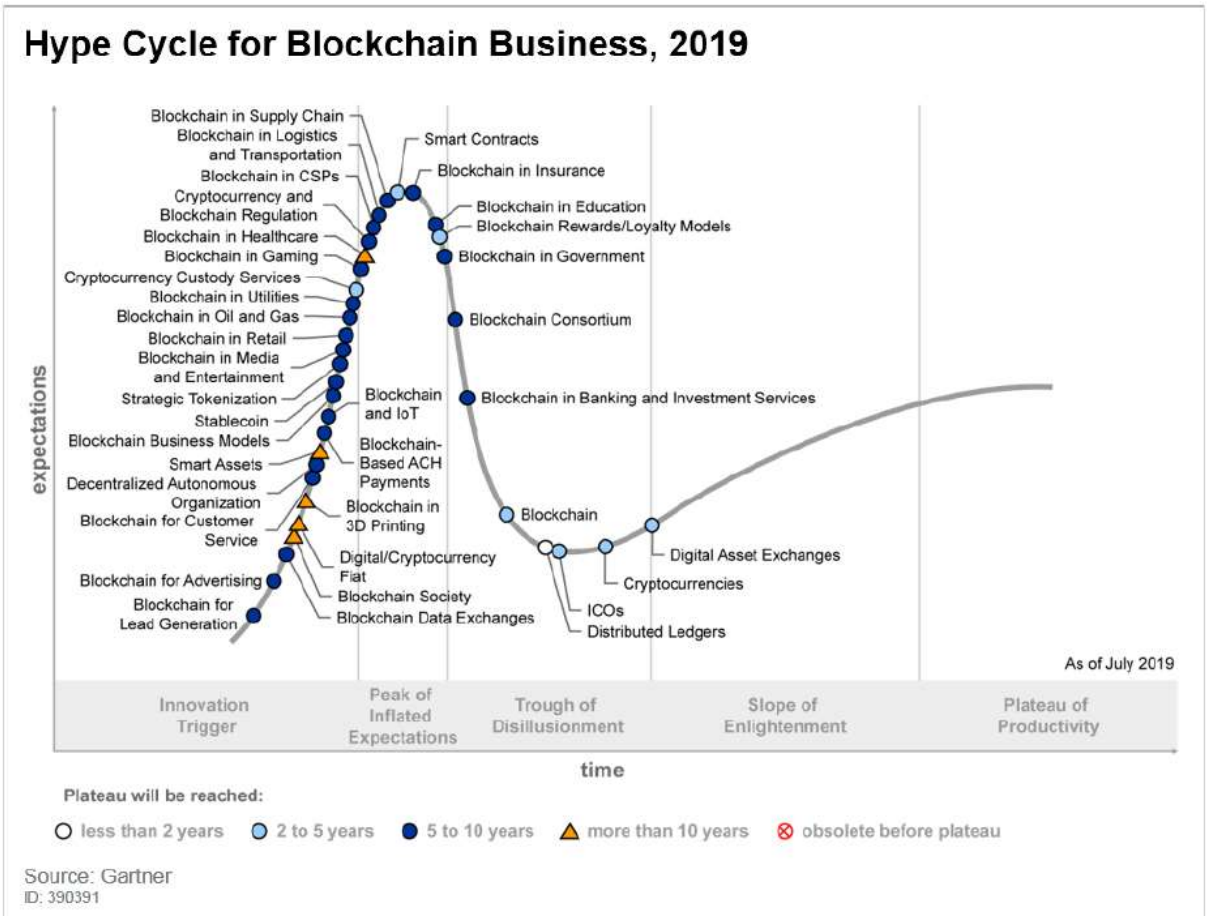

Figure 13 Gartner's Hype Cycle for Blockchain Business, 2019

Concerning the application of Blockchain to the Supply Chain, the subject of this thesis, it can be observed that it is currently at the moment of greater hype: it is assumed that it can solve or in any case improve the critical points of the existing Supply Chains.

The first implementation tests have been carried out and more and more case studies are being added to the reading that highlight the difficulties, but at the same time the benefits that can be found in the Supply Chain thanks to Blockchain applications. The proliferation of numerous application cases is the typical scenario present at the same time as the spread of an emerging technology, however, as usual, only a few projects are successful: it is estimated that only 8% of the pilots concerning Blockchain Technology can be considered successful, while the remaining ones will soon be completed. [61]

CHAPTER III – Blockchain's role in Supply Chain dynamics

3.1 Implementation areas

As mentioned in the previous pages, the Blockchain can be used to record different types of data, from transactions to any type of information, without relying on an intermediary or having to interact with other users.

The technological advances that have characterized the economic and industrial landscape in the last twenty years have led to the end of the Linear Supply Chain giving rise to dynamically connected Digital Supply Networks (DSN), able to better respond to market dynamics. The introduction of these new configurations has substantially transformed the way companies exchange and share information, leading to the emergence of complex ecosystems in which processes are integrated with each other. [62]

Although digital technologies have facilitated and simplified the sharing of information and made it possible to address at various levels some of the major issues that characterize the manufacturing ecosystem and Supply Chain, their implementation is not without challenges. In fact, in relation to digital transformation, among the difficulties faced by companies, there is the understanding of which technologies to invest in and at what time. This choice can dictate both the rapid progress of the company and its differentiation and its collapse and/or exit from the market. [63]

The Blockchain is a tool that enables consensus to be reached in the execution of a collective activity involving entities that do not necessarily trust each other, but which have a common goal. Trust, which is the essential tool used by companies, when they make an exchange or transaction, up to the creation of the Blockchain, was achieved thanks to the involvement of a centralised intermediary; i.e. a central authority in which the parties placed their trust and assumed the burden and responsibility of verifying the integrity and truthfulness of the transactions.

In other words, the Blockchain is *trustless* and, thanks to its distributed nature and consensus mechanisms, allows participants in a community to trust each other without recourse to a middleman: it is not necessary for individual participants to trust a particular node but, it is sufficient, that they place their trust in the system. [19]

Supply Chain Management is a fertile, but still largely unexplored, ground for possible applications of Blockchain Technology. In order to verify the state of the art of the interaction between the new technology and the logistics chain, a team from the University of Hassan (Morocco) in collaboration with the Institute for Forecasting and Futuristic, has analysed the literature on the subject, identifying the trend topics. [64]

The study showed that the aspect considered most innovative and characterizing Blockchain Technology is the traceability, its application in the Supply Chains of the food, pharma and luxury sectors. It is clear that the need for accurate identification of origin, location and boundary conditions is all the more important as the goods transported have special requirements related to the security of all actors in the Supply Chain, such as manufacturers, carriers and end customers.

The big challenge is to understand when to capitalize on the Blockchain and how to combine it with other digital technologies to generate important benefits within the supply networks. [55]

3.2 Tracking of goods in the food industry

Nowadays, the food reputation has become a central driver in consumer and purchasing choices for consumers. The numerous food contamination scandals that many companies have had to face have spurred them, or at least the most innovative of them, to adopt technological solutions to try to respond, but above all to avoid, this phenomenon.

According to a report by the *Grocery Manufacturers Association*, most of the companies that are recalled because at serious risk of causing damage to consumer health, they risk a negative financial impact of up to $ 10 million and almost one in four companies reported a loss of more than $ 30 million for a single recall.

Although relatively new, Blockchain is already generating excitement among some companies in these sectors. This is because it offers many advantages that are valuable for different players in a Supply Chain. In the food sector, however, a major challenge in product traceability is often due to ambiguity of product information, vague registration of product characteristics or whether the goods are difficult to trace. Many companies in this sector have started to invest more and more in automated food safety software that allows them to see where the food in question is located. and where they come from within the Supply Chain.

The Blockchain can be a significant turning point for product traceability within the Supply Chain. Supply Chain as it provides a single solution for all entities operating in the same Supply Chain without the latter being forced to integrate directly with each other or being influenced by the technology and/or the business decisions of others. It allows data sharing without the need to modify the systems of each entity and therefore greater product traceability across multiple partners, locations and facilities. Each stakeholder can view the same product lifecycle data.

In fact, by enabling access to the same set of data, the Blockchain can provide greater transparency to multiple stakeholders in the Supply Chain, benefiting also from a commercial/economic perspective: for the farmer or small producer, it can be an opportunity to have greater visibility of upstream demand to win the best prices, better control of production (to avoid by-production / overproduction) or potentially direct revenues. Suppliers can also use this information to view items in the production process and improve delivery times, and compliance with them, in their store.

The positive aspects of applying the Blockchain can improve communication and increase customer satisfaction as retailers can choose to increase customer engagement by making some information about the Blockchain directly accessible to consumers. For the consumer, this can provide greater visibility into the product's origin, manufacturer, quality and similar aspects - all factors that contribute to loyalty. and to strengthen the company-consumer relationship.

Food tracking not only brings benefits in terms of transparency, but also offers the opportunity to create new business models and long-term sustainable product differentiation. Some of the most significant technological advances have led to a complete reinvention of a sector and the creation of new ones. The disruptive effect on current business and operational models that Blockchain can have should not be ignored as if products could be more easily identified and monitored more effectively, ensuring greater transparency in the way they are produced, actors would have more incentive to improve their processes.

A transparent, real-time view of product movements could create a more responsible and collaborative approach to global trade, reducing costs and time and increasing efficiency. For example, manufacturers who often have a limited view of global markets and demand can benefit from reliable customer demand data: they can leverage the data to reduce the risk of overproduction and waste and improve profitability.

3.2.1 Case History "A" - IBM Food Trust

At a time when issues of safety and food safety in general have taken on a central role in consumer behaviour and choices for the world of the agri-food industry it seems crucial to have new tools to respond to the growing demand for quality and reliability that underpin consumers' propensities and purchasing decisions.

Within Agri-Food, the US group has launched *Food Trust Chain*, a platform through which companies can register and interface. IBM is a founding member of the Linux Foundation Hyperledger Project, and collaborated in the development of *Hyperledger Fabric*, the well-known framework of authorized Blockchain networks, whose interface is proposed in the picture.

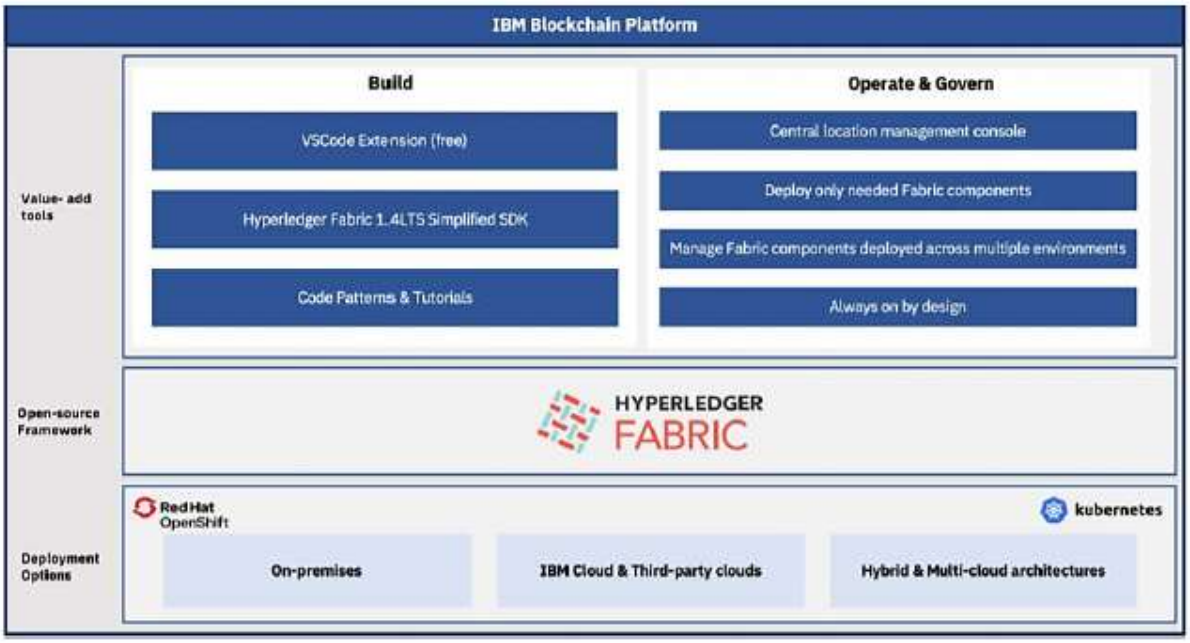

Figure 14 IBM Hyperledger platform interface (www.ibm.com)

The IBM Blockchain platform provides its users with a complete set of software, services, tools and example code to help them quickly create a Blockchain application. The following figure illustrates how users of a generic Blockchain developed with IBM tools interface with its registry.

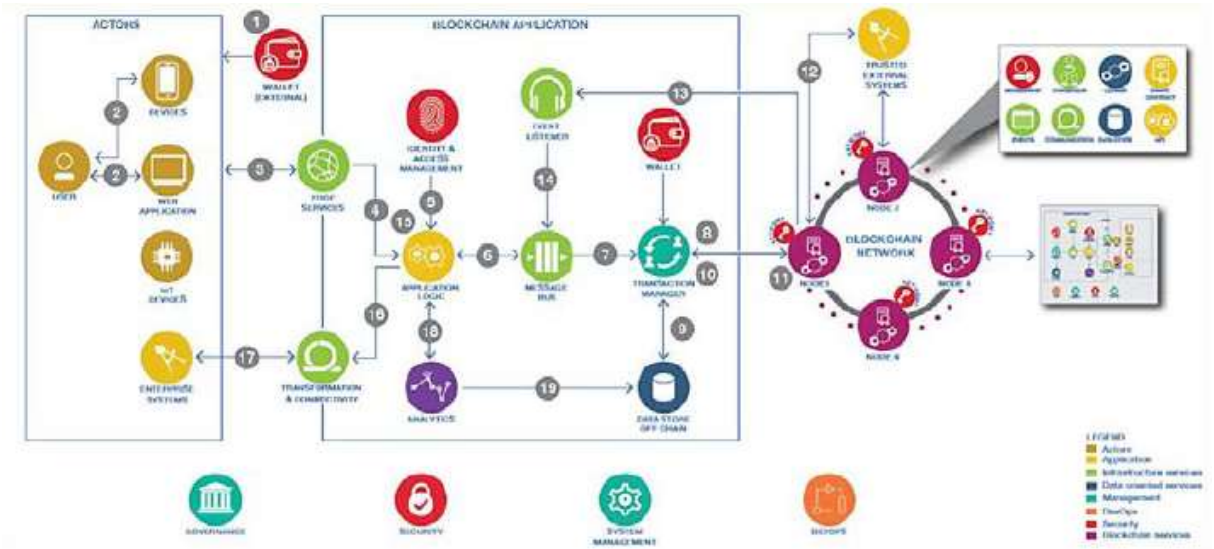

Figure 15Interconnection of platform components (www.ibm.com)

As can be seen, through IoT devices and ad hoc interfaces, Supply Chain actors can receive and send messages to the Blockchain log. In fact, a special logical application can verify the authenticity of each message through fingerprint matching for example. It will then translate the message into a string of code and, through the *message bus*, a special service of the Blockchain infrastructure, will share it with the *transaction manager*, a management system that allows to activate the transaction between the participants involved.

The data of this operation are historicized in memory units outside the chain, and then inside the nodes the conditions to activate the transaction are verified. When the block is validated by the nodes, a special service (*event listener*) will update the register with the execution of this new event, while the logical application will translate the relative code in a string written in simple language that will be transmitted and written on the company's own systems (ERP), updating the process in question.

The IBM Blockchain Leader Europe, *Andrew Darley*, underlines how the need for a new, much more aware and informed relationship with food and production methods has been growing among consumers for some time. This path of knowledge has become more sophisticated and richer in content and needs: the consumer starts from the "basic" question and asks *What am I putting on my plate? Is it safe food, has it been made with controlled ingredients and reliable manufacturing processes?* Darley recalls how consumers also question whether food is organic, whether it is produced with respect for the environment, but also with respect for the workers involved, and he still wonders whether with this choice he is supporting local business, whether it contributes to the growth of values that he considers fundamental and that he wants to support with his choices.

All questions that translate concretely into data and information that must be as reliable and secure, open, shared and verifiable as possible. All information therefore - observes Darley - which, if correctly collected, managed and represented, makes it possible to guarantee the identity of each product and of all its dimensions and allows those who invest in these values of knowledge to have a competitive advantage, that is to say to respond clearly and precisely to consumer demand.

Darley also speaks explicitly about the crucial role played by Supply Chains in creating new consumer confidence and draws attention to how this role is increasingly close to business today. In the last two, three years, in addition to the new questions that accompany the choices about food, a real new feeling towards the food world has grown: food is not only bought to satisfy a need and to gain pleasure from it, but to "feel good" also in terms of conscious choice towards the environment and society. In this sense, the competition "on the shelf" to win the attention and choice of consumers is more complex and sophisticated: it is always obviously a price issue, but it is balanced with values linked to the origin and the storytelling (reliable, certified and verifiable) of the product linked to traceability. For this reason, more and more supermarkets have chosen to dedicate more space, more shelves to products that arrive enriched with these values, with labels able to tell this reliability. The weight of sustainability and adherence to a new scale of values is a fact and IBM's research shows that 71% of consumers agree to pay extra for information on origin and therefore on traceability and transparency.

Darley adds that consumers feel much more engaged. Confirming this reading of consumer behaviour is also a research by *Carrefour* in France which shows that consumers spend almost a minute reading the information on the origin of the product on the label before putting the product into the shopping cart. Bringing the chicken Supply Chain to the Blockchain to ensure that consumers always have access to all the information on how the animals are bred, fed and treated that are then sold on the shelves of the large-scale retail trade. To guarantee complete traceability throughout the entire Supply Chain with the participation, thanks to the Blockchain, of all the players to define a model to be extended to other Supply Chains, starting with citrus fruit.

The aim is to enhance, for its customers, the main feature of the Blockchain: security in the certification of the data provided by all operators for the benefit of information to be made available to consumers on the quality of the product they find on their shelves in Carrefour stores. With the Blockchain project, Carrefour customers will be able to check whether the chickens are reared without the use of antibiotics, outdoors, with an information window opening onto a chain consisting of 29 farms, two feed mills and a slaughterhouse.

The chicken will then move on to citrus fruits for the chain that produces fruit and vegetables under the Carrefour brand.

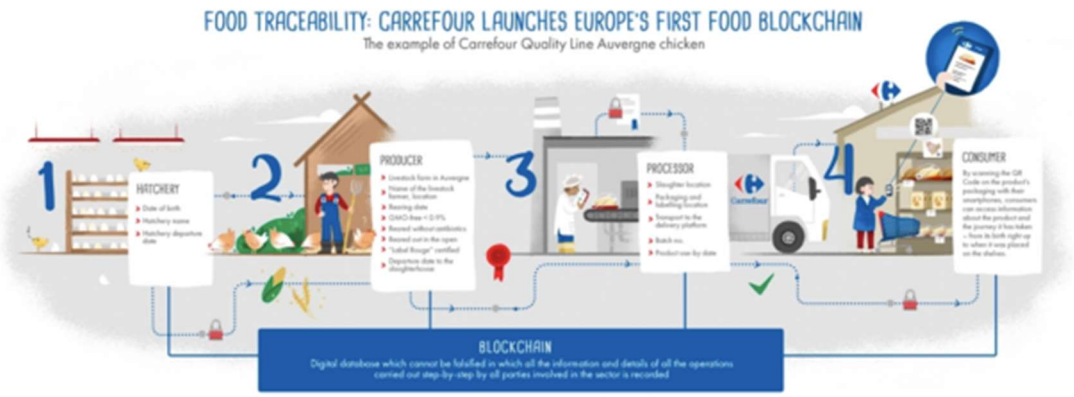

Figure 16 https://www.agrifood.tech/sicurezza-alimentare

Thanks to a *QR Code* on product packaging, consumers will be able to access the data of each product and consult it with the support of an interface created by Carrefour. The code can be nimbly read by a smartphone, such a scan will link to a URL. The traditional QR code consists of a fixed string, specific to each product category, but not to each individual item. The web page resulting from the scan is therefore generally the manufacturer's website or a platform for online purchases. With the spread of the consumer's desire to know exactly all the stages of the route taken by a product, from raw materials to the customer's home, and the consequent spread of *Track and Trace* systems, there has been a significant increase in the use of QR codes by companies.

Thanks to IBM Food Trust the conditions are created to validate all the information that makes up the food Supply Chain. Starting of course from the origin of the raw materials, but also including all the values and characteristics that contribute to determine the value of a producer such as the quality of processes and activities related to packaging, storage, transport quality.

This is an approach based on quality and data security and transparency that allows different forms of valorisation. Obviously, as already widely pointed out, there is a valorisation towards final consumers, who look for guarantees in terms of quality and safety, there is valorisation in terms of efficiency and quality of the Supply Chain and uncertainty related to the issues of data and information management in emergency conditions such as the Covid-19 lockdown.

Finally, Darley recalls that IBM Food Trust is at the base of relevant projects with companies that are responding to these consumer needs with more and more important information on traceability and here Darley mentions actors like *Walmart* that are increasing the number of products they want to trace; but also the extension to new types of products. Based on this trend, the amount of data that can be accessed about the origin and thus all the Supply Chain routes to which ingredients and foods are subjected before they reach the consumer will become more and more extensive. An increasingly relevant trend that counts on data that is available and with the values of transparency and immutability offered by Blockchain.

Walmart, the world's largest chain in the large-scale retail channel, was one of the first to want to exert total control over food safety in the Supply Chain through Blockchain technology, conducting a pilot study in the Chinese food market. In 2016, Walmart established the *Food Safety Collaboration Center* in Beijing, where it plans to invest $25 million over five years in research into better global food safety. Using Blockchain technology, implemented by IBM and based on Hyperledger Fabric, Walmart successfully completed two pilot cases: the first on pigs in China, the second on mango fruit in the Americas.

Through a *farm to table* approach, i.e. from producer to consumer, Walmart's solution through Blockchain in the second pilot study significantly reduced the time needed to trace the origins of mango from seven days to 2.2 seconds, while allowing for greater transparency in Walmart's food chain.

In fact, mangoes are found in many parts of America and are shipped all over the world; greater transparency has made it possible to reduce, if not zero, the possibility of contracting listeria or salmonella, both bacteria contained in mangoes. In simple terms, what Walmart wanted to invest in is complete *end-to-end* traceability, as well as was defined by IBM.

3.2.1.1 Barilla and the "pesto" certification

The aim of this project is to create an integrated and transparent food Supply Chain capable of guaranteeing greater food safety and a new approach to the ethics of consumption and production. This case study is based on documents available on the Barilla and IBM Italy websites, and is an excerpt from a thesis previously drafted about Blockchain in support of Supply Chain Management.

The platform developed by IBM, first, allows developers to use programming tools and languages to model, build, test and develop business applications on a distributed network. Moreover, one of the most appreciated features of this platform is the possibility to create a flow within the network built on the Blockchain and then test it in a virtual environment that simulates how the various actors could react and behave in a series of different scenarios, with the possibility to actually invite some of the participants to take part in the simulation to make it even more realistic.

Within this Blockchain network all the actors in the process are concentrated: the production and packaging of pesto according to the traditional Genoese recipe. In detail, there are four main nodes: the farmer, who manages the cultivation of the main ingredient, the basil, the producer, the transporter and finally the final consumer.

The farmer sows the basil field in March, irrigates and fertilises it and in June the mowing of the seedlings begins, carried out by means of digital devices and locators that collect a series of data and send them automatically to the Blockchain register.

The transporter arrives at the farm, starts loading the prepared basil and then transports it to the production plant where he delivers it; also, in this case, GPS trackers and sensors allow the crucial information detected to be written on the Blockchain register.

The quality control makes an inspection of the arrived load, the conformity to the standards is checked and then the basil is stored in a cold room at constant temperature until the transformation of the ingredients into pesto according to the traditional recipe of the brand takes place; all the ERP and tools used both during the production phase and during the quality acceptance record the data on the Blockchain and all the actors can display them indelibly.

The end consumers by scanning the QR code on the pesto jars, will be able to know all the information collected along the Supply Chain starting from the name of the company where the basil was grown and the mowing period up to the production according to the traditional recipe.

If, during one or more of these phases, some of the conditions provided for in the contracts are not respected, Barilla will decide whether or not to accept a variation of the terms and establish the desired flexibility, which will then be translated into digital terms through Smart Contract. The choice of basil as a product to test this pilot project is linked to the image that is transmitted of the product, freshness and quality are in fact the two most publicized attributes.

After a year of experimentation and installation of the project and a few months of actual operation, the conclusions reached by the company recognise the Blockchain as a firm and secure structure, a sort of spine that can hold up even highly articulated business. However, its value would collapse if there were no incorruptible entry point devices, i.e. IoT tools that allow to read and enter a series of information, so a renewal from this point of view is necessary first.

3.2.2 Case History “B” - EY OpsChain Traceability

Provide the company with a completely digital solution to verify the work of suppliers, enhance Supply Chain controls and monitor the entire Supply Chain, from raw material to product delivery to the final consumer, ensuring the highest standards of transparency and quality assurance. At the same time, deliver in the hands of the customer a QR code present on the packaging that, framed with the smartphone or inserted on the site, allows you to access the history of the products you buy and then check all the stages of processing to which they have been subjected, from the origins to the arrival on the plate.

This is the *EY OpsChain Traceability* solution developed on Ethereum's Blockchain and adopted by one of Italy's best-known frozen food companies, *Bofrost*. All the data and information collected are shown to consumers in a simple and immediate way: by framing the QR code on the packaging with your smartphone, or by entering the code on the website, you arrive on the web page that tells the whole story of the product, from its origin to the various steps of the production chain, until its arrival on the plate.

Conveniently from a smartphone, there you go:

- Know the entire history of a pack of frozen cod, from the moment the fish is caught (with the name of the vessel, fishing method and location) to the sale, through storage and packaging, with temperature tracking and data on quality control and certification.
- Find out everything about frozen artichokes: supplier, growing area, storage temperature. And then learn about the laboratory tests to which fish and vegetables are subjected and, why not, get some suggestions for preparation in the kitchen.

The defence and enhancement of Made in Italy goes digital and Blockchain can give new answers to the major issues of anti-counterfeiting, certification and quality control for the benefit of consumers and producers.

With the *Wine Blockchain* project in defence of Made in Italy wine EY wanted to propose a solution for quality certification in Smart Agri-food key that allows to defend and enhance the quality and excellence of our country's wine production. The project was developed in collaboration with the startup *EZ LAB* and *Cantina Volpone* and represents a response to the very strong need for protection that comes from the Made in Italy agri-food as a tool to defend the quality of cultivation and as a solution to support the transparency of the production cycle.

Cantina Placido Volpone is the first winery in the world to certify the wine chain, *Falanghina* wine through Blockchain. The technology guarantees the company to implement a self-certification system that cannot be modified by parties external to the manufacturer, so as to show greater reliability of the data and strengthen both the certification processes of the bodies in charge but also the verification of the individual consumer and the entire ecosystem: retailers, wholesalers, companies in the tourism sector.

The basic idea is the same that we find in the realization of the increased labels in supermarkets, that is to create a "virtual KM-zero", the continuous research of the relationship between producer and consumer "as in the past", a digital relationship between producer and consumer that, through an intelligent label placed on the bottle of wine, allows to know the entire process of production and transformation of this, maximizing trust between them.

Consumers are increasingly attentive to the origin of the products and raw materials used and to the issues of sustainability and the quality of the methods used to grow the food that arrives on our table. The research "*Attitudes and behaviour of the wine consumer and the relationship with large-scale retail trade*" carried out by *VeronaFiere* shows that 74% of consumers explicitly declare that they are influenced in their purchase by the availability of information on product traceability issues.

The Volpone winery with the Falanghina inaugurates this methodology and this service and makes available the first product traced and certified in shape from the vineyard to the table.

Wine Blockchain EY creates a public and unchangeable register directly linked to the digital signature of the producer, and at the same time allows to map every single production process guaranteeing, thanks to this information, the values of territoriality, authenticity and quality of the product and more generally of Made in Italy.

In this way Wine Blockchain EY creates a digital identity card for wine (applicable in the future to other products) and represents a value for the entire Italian agri-food sector both as a fight against counterfeiting and to combat price dumping created by foreign products in the form of fake Italian products.

It should also be noted that a significant proportion of consumers have become accustomed to checking the product label and looking for increasingly reliable and precise information on the product to verify its quality.

If attention is focused on the wine sector, it must be stressed that in Italy the market is characterized by companies that are struggling to bring the values of the territory, method and professionalism to the end customers, as a testimony to the genuineness of the product and more generally to the value of Made in Italy. Values that are at the same time a guarantee of quality and a business lever compared, for example, to the offer of wines that do not have the same tradition and that often compete using the price lever. So much so that it is estimated that the losses of the Italian wine sector in the face of different phenomena of counterfeiting of the products of our Supply Chain amount to almost € 2 billion per year.

Consumers are more and more sensitive to the issues of knowledge about both the products and the territory and the method used for production and this need is particularly relevant to Italian wine products. The research *Ricerca Vino & Giovani*, promoted by the *Istituto Marchigiano* di *Tutela Vini*, notes that more than 70% of consumers consider the possibility of paying a higher price when this represents an effective guarantee of quality, transparency and origin.

3.3 Fashion & Luxury revolution

One possible application of the Blockchain is certainly in the tracking of products in the luxury sector; product tracking is more relevant in an industry with a high counterfeiting rate and where maximum transparency is required from companies by consumers, who are willing to pay a premium price.

Precisely, how large the counterfeit goods industry is difficult to calculate, since it is an industry operating on the "black" market. A rough estimate shows that counterfeiting accounts for more than 6% of world trade and generates $450 billion annually, with around $100 million worth of counterfeit goods entering the United States seized each year. Today, it is estimated that the black market for counterfeit goods is worth more than $3 trillion worldwide and can be found in any luxury sector, from jewellery, artwork, clothing, accessories, and alcohol. [65]

One dramatic example of counterfeiting that has caused a significant drop in sales is the one of Louis Vuitton in the Italian market in 1970: in that year the famous brand withdrew completely from the market their products because they are aware of not being able to compete with their imitations. [66]

In one scenario, the consumer is not aware that it is a fake product at the time of purchase. This is often because the quality of the good is not easily observable and distinguishing a copy from the original product requires an expert and critical eye. This type of scenario is usually typical in markets for car parts, electronic products such as computers or stereos or medical or pharmaceutical devices. The luxury sector, by contrast, is characterised by non-deceptive counterfeiting.

However, sometimes consumers are fully aware that the products purchased are fake products and imitations of the original product. Grossman and Shapiro (1988) describe that the public is aware of the availability on the market of fake products such as branded watches, leather goods, fashion clothing, perfumes and designer sunglasses and so on.

According to the two authors it is the label and identifying design features (e.g. logo or distinctive fabric patterns) that are of value to consumers, as in the case of status goods.

When buying these types of counterfeit goods, the risk is much lower than when buying technically advanced or medical counterfeit goods. Counterfeit status goods often offer product qualities like those of the original goods and the consumer of such products is not at risk of personal injury or "serious" risks. Consumers of these goods, however, are subject to a different risk, namely social risk because luxury goods are of high symbolic value and social visibility. [67]

Efforts to combat counterfeiting come in many forms, and Nill and Shultz (1996) argue that conventional remedies against counterfeiting on the supply side, some are effective while others are less effective, which is why the company's focus should also be on the consumer demand side: i.e. placing an emphasis on ethical consumer decision-making, understanding what drives them to seek out such products.

3.3.1 Case History "C" – LVMH and Microsoft announce AURA

In 2016, the OECD estimated the value of imports of counterfeit and pirated goods at almost half a trillion dollars, or 2.5% of global imports. In Europe this figure is closer to 5%. Footwear followed by knitwear and leather goods are the three main groups of counterfeit goods seized.

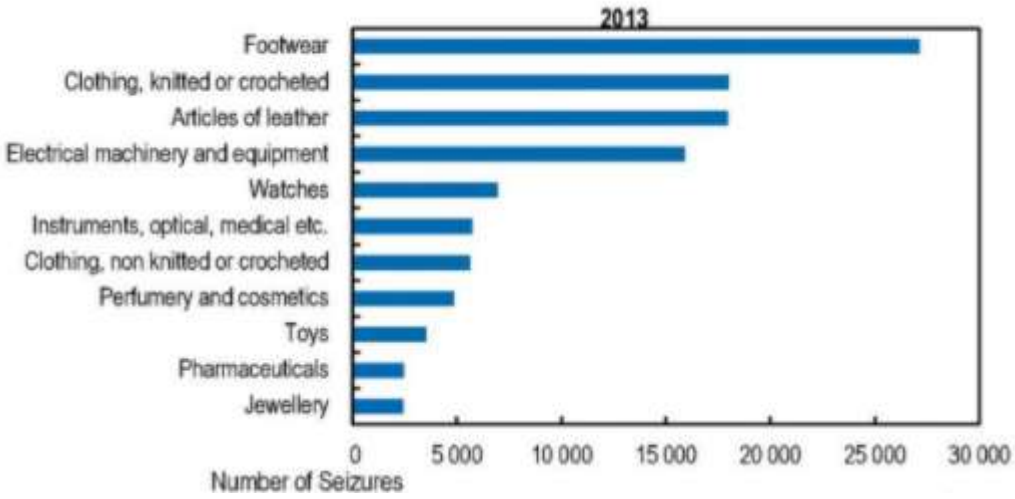

Figure 17 Source: Organisation for Economic Co-operation and Development

In July 2019, *ConsenSys*, in partnership with LVMH and Microsoft, announced *AURA*, a platform aimed at providing the entire luxury industry with powerful product tracking and tracing services based on the Ethereum Blockchain technology and using *Microsoft Azure*.

AURA gives consumers access to the product history and proof of authenticity of luxury goods - from raw materials to the point of sale to the second-hand market. The goal is to create a unique system that cannot be tampered with and at the same time ensures that the LVHM group is acquiring original raw materials that will make up the final product.

In the luxury sector, given the high-end prices, the success and survival of a company depends very much on the authenticity of the products: through AURA, LVHM can have 360-degree control over its Supply Chain and, at the same time, ensure that customers who buy Louis Vuitton branded products pay for original, quality products. [68]

Several brands of the LVMH Group, such as Louis Vuitton and Parfums Christian Dior, are currently involved and advanced discussions are underway to add other brands of the LVMH Group and other luxury groups worldwide. For Louis Vuitton, the development of the AURA project is the culmination of its Track & Trace programme, which was launched more than three years ago.

The luxury goods industry involves many specialised players - design, raw materials, manufacturing and distribution. LVMH products have a unique story to tell throughout the product lifecycle, which can now be revealed using Blockchain technology. During production, each product is recorded in a common ledger, which is non-reproducible and contains unique information. At the time of purchase, a consumer can obtain the AURA certificate with all product information by applying for the brand. The decentralised and unalterable Blockchain technology provides transparency and a single source of truth for the consumer: it ensures the authenticity of the product, provides details of the product origin and components, instructions for product maintenance and the available after-sales and warranty services. [69]

In addition, the product timeline also shows the raw materials used to manufacture the product, processing, shipping data, etc., making it an integral part of the sales process.

Investing in Blockchain brands such as LVMH enables them to demonstrate the authenticity of their products. In this regard, Blockchain aims to remove doubts about the identification of authentic products in a transparent and unalterable register using a *digital twin*, i.e. a virtual representation of a physical product that cannot be duplicated or altered. Since the digital twin cannot be associated with more than one physical product and, above all, cannot be fiddled with, the use of Blockchain and its protocols will greatly improve the transparency of the Supply Chain and of the product itself. [70]

3.3.1.1 Script of the interview with David Teruzzi, CTO of LVMH

Mr. Teruzzi is an expert in applied maths and AI and is currently playing several roles: CTO at the Aura Blockchain project (LVMH Paris); Blockchain Conseil Founder (www.Blockchain-conseil.com); Co-Fondateur TokenInvest (tokeninvest.ch); Blogger blogchaincafe.com; Blockchain Senior Advisor (BTU-protocol, FieldCoin, NaviAddress, DomRaider...); Multi-Blockchain consultant/developer (LVMH, Carrefour, TokenInvest ...); Conseiller en investissement crypto: OLI Invest (CH); Speaker Blockchain for the french magazine Journal Du Net.

He was kindly available to give a brief telephone interview concerning Blockchain world and offering some interesting insights. As already mentioned above, the AURA project consists of the creation of a Blockchain Consortium that allows players in the luxury sector to cooperate by exploiting the immutability and private keys that technology provides.

In the current context of a health emergency where human interactions and activities must be limited, the Blockchain can certainly help to fluidise and certify those processes that will be increasingly robotic. To make an example, there are already three ports in China based on this concept and extremely advanced in terms of automation. Rail-mounted overhead travelling cranes are remotely controlled and there is practically no human presence in the loading area, as everything is automated.

From the moment the container is unloaded from the truck, its movement to the depot, the crane and finally to the ship is managed automatically. This is done by the overhead cranes that pick up the container from the trailer and place it in the storage area. In this way it is possible to guarantee the continuity of the Supply Chains by renouncing the human contribution. In addition, thanks to the trustless Blockchain, the timing of cross-border controls can be reduced.

Loading/unloading efficiency is a fundamental parameter for shipping companies, whose costs are measured in days in the case of ship rental and mooring hours. A few hours or even days waiting in port for container handling operations translates into out-of-pocket expenses.

During his experience, David has also worked with Carrefour on the chicken chain traceability project, which has been extensively described in section A dedicated to the food industry. In this circumstance the data are available on a public ledger among poultry producers until the information reaches the wholesale customer via the last hash. However, this poses the problem of making sensitive information easily accessible to competitors that could predict a drop in sales, for example. For this reason, companies are faced with a trade-off between increasing consumers' trust and confidence, not disclosing at same time data that could harm their business.

To overcome this dilemma, privacy features should be integrated by encrypting private data within the public Blockchain. The Consortium's model is the most widespread now precisely because companies are reluctant to expose and widen the spectrum of their data to ensure the trust of end users.

3.3.2 Case History "D" – International Logistics at Luxottica

The description of this case study is an adaptation of an earlier thesis work that does not focus on the counterfeiting of luxury goods, but on a pure logistics problem.

The company in question, leader in the eyewear market, owes its successful strategy to the vertical integration choices made over the years: the main processes integrate all the manufacturing and logistics phases of the Supply Chain.

Therefore, the entire distribution process is directly controlled by the company, both to increase the level of service and to reduce the overall lead-time.

Starting from the date on which the product must be delivered to the store, all other activities are scheduled and organized backwards.

- *IN-DC Delivery Date*: is the date of deposit of the product at the distribution centre.
- *Ex-Factory Date*: corresponds to the date when the goods must be ready and available for pick-up by the shipper.
- *Production Date*: corresponds to the production date of the good, once the purchase order for its components has been completed.

The AS-IS process, i.e. before the Blockchain was designed, is illustrated below.

Ideally, about a week before the planned date of the Ex-factory, the vendor sends to the logistic team all the general documentation regarding the shipment. Once the documentation is received, the team can approve the shipment and specify the transport methodology that must be applicable within the specified time frame. These communications between the forwarder and the vendor are mostly offline, without including the logistics team, making this part of the process extremely opaque. Ultimately, therefore, all stakeholders will not have visibility into the entire process.

Once the shipment has been approved, the forwarder will send the logistic team a sort of scheduling including the estimated date of departure and arrival. At the port/airport-station/arrival point of destination. When the goods have been collected by the forwarder, he will transport them to the nearest port or station or collection point, where the loading operations on the chosen means of transport will be completed. Operators will ask to see the documentation attached to the cargo, especially the Bill of Landing, which gives them temporary possession of the cargo. Upon arrival at destination, the container is inspected, its gross weight is checked again as before transport, legally confirming that the cargo has not been compromised during the journey.

The control process can be delegated to an external company and concerns the inspection of all the documentation mentioned above, which must be sent by express courier to the company in charge of the control, causing another inefficiency and delay in the handling of the cargo.

After the check has been completed, the goods are reloaded to the courier that makes last-mile deliveries, who, in order to deliver the goods to the prescribed distribution centre, will have to book a sort of appointment at this one. Once the load has been deposited at the centre, a document, the Proof of Delivery, is signed and sent by the courier to the forwarder, who is then able to ask the logistic team to pay the agreed rates. The same process has been rethought with the help of a Blockchain platform and distributed registry technologies.

The solution was based on the use of a Blockchain platform provided by Ethereum, whose Solidity programming language gives the advantage of a detailed structure that can also be supported by the so-called oracles, i.e. data sources external to the platform but that must be considered as variables within the project.

The implemented platform consists of a web interface directly connected to the Ethereum Blockchain so that all data produced and collected from the Blockchain register can be presented in a user-friendly way via the interface.

The documents physically present in the initial process were replaced by digital signatures, obtained through a special program that processes files of any type and calculates the encrypted code in text format. The redesign of the process is shown in the figure.

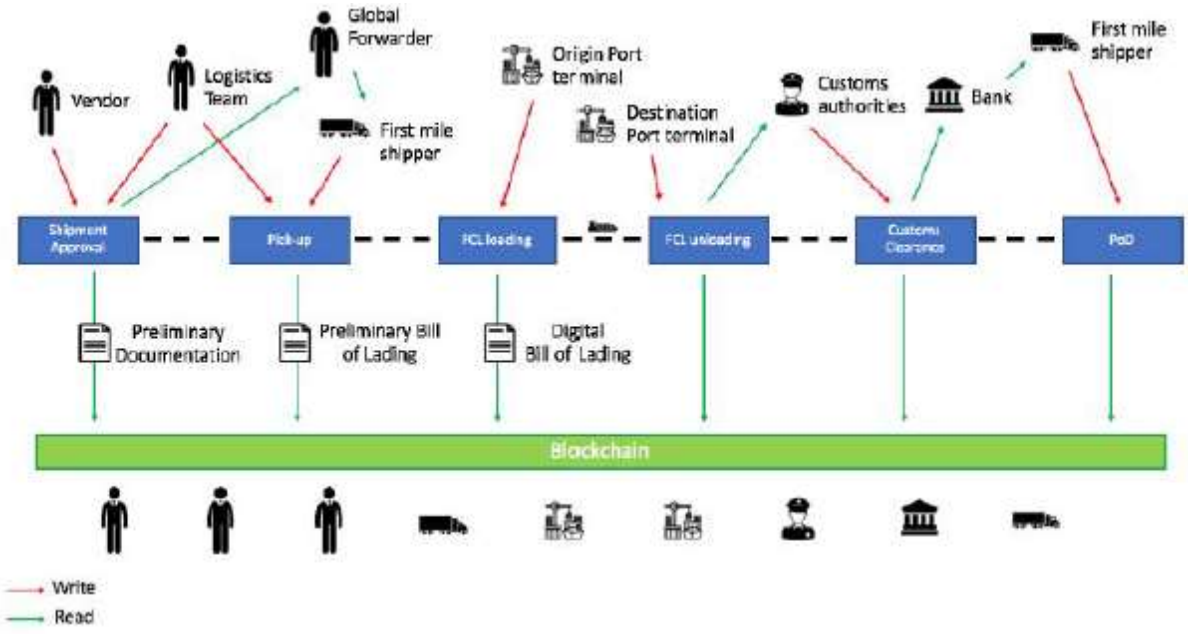

Figure 18 Structure of the new Blockchain-based process [71]

a) *Shipment Approval*: the list of materials that are sent for shipment is encrypted by the vendor and uploaded to the platform. Within 5 days from the file upload, the approval table discussed above on the platform will be able to automatically calculate the optimal parameters of Ex-factory date, in-DC date, etc., using the criteria previously entered by the team.

   The vendor will then upload the shipping documents, the tracking code, documents that will be used to automatically generate a sort of preliminary Bill of Landing.

b) *Pick-up*: different actors can be involved from the pick-up phase of the materials to the loading on the means of transport. The key to maintaining visibility on all movements is to have given each actor access to the platform in order to load the necessary information. The algorithm uses some of the variables previously entered, such as the total weight of the load or the code of one of the items contained, to create a first version of the Bill of Landing.

Each actor, when receiving the load, will have to fill in a form with a random subset of data and will automatically generate the same code of the Bill of Landing previously written on the Blockchain. Consequently, the status of the goods is updated, and its possession passes to this actor.

c) *FCL loading and unloading*: the cargo is then loaded and unloaded from the means of transport, and some sensors placed on the container allow to continuously monitor parameters such as temperature, humidity and position of the goods, writing these data on the Blockchain logbook.

d) *Custom Clearance*: at this stage, it has been explained how several authorities are involved, resulting in the passage of documents between them, generating inefficient flows of information, as well as delays. The platform illustrated so far can automatically generate and provide information such as the commercial value of the goods transported, the details concerning the goods transported, the information concerning the logistic flows suffered by the goods. If no data has been previously modified, the various logistics operators will be able to display exactly all this information, which is usually the information required to validate the unloading of the goods, completely automating this operation.

e) *Proof of Delivery*: the last phase concerns the last mile transport, which will be operated by a special provider through the Bill of Landing that will prove its possession of the property. From this moment on, no form of Bill of Landing will be necessary, only the preliminary one, consisting of a code string, will be required to update the status of the cargo.

At the destination, a timestamp will be sent on the Blockchain which will confirm that the goods, represented by their hashes, have arrived at the delivery point, also confirming that the quantities previously recorded match exactly those physically present at the end. The completion of the shipment will automatically activate the Smart Contract responsible for the payments of the various players involved, as negotiated in the terms of the contracts stipulated.

In conclusion, it can be said that the solution, if evaluated through some factors commented below, is mostly beneficial compared to the traditional process. However, this theoretical study was not followed by a subsequent phase of implementation as it had lower priority, given the non-immediate monetary savings, than other more urgent projects.

- *Lead Time reduction in the Customs Clearance phase*: availability of all information to validate the load directly on the platform;

- *Punctuality of the shipment compared to the date of IN-DC*: the use of the Blockchain would encourage compliance with deadlines by establishing bonus or penalty policies;

- *Cost of all activities related to administrative documentation*: elimination of redundant documents and information asymmetries;

- *Resolution of misunderstandings in assigning responsibility*: each plaintiff transmits information such as an update of the status, proof of possession of the goods, etc., so the resolution of any disputes is facilitated by greater clarity in the allocation of responsibilities.

- *Safe exchange of information*: as opposed to the previous system, where information was exchanged via email, the proposed solution represents a substantial improvement.

3.4 Benchmark analysis of case studies presented

Modern Supply Chains have many critical issues that lead to loss of efficiency, waste, high costs or lost profits. Some of the main frictions existing in modern Supply Chains have been identified based on the most challenging objectives identified in the papers dedicated to technological innovation. [64]

In comparing the projects illustrated above, it was decided to limit the analysis to only two case studies, representative of the food and luxury industries. Although the characteristics of the product are different among the various cases, the *objective* at macro level is very similar: the search for greater control over the process, obtaining improved levels of visibility and transparency also and above all in the management of disputes and disputes with other actors.

When this objective is then declined at the micro level, i.e. at the specific Supply Chain level, it takes on somewhat different connotations. For Barilla it means bringing greater added value to the end consumer, thanks to the renewed transparency acquired through these processes it can immediately take on enormous and positive value also for the customer with a minimum of effort for the company. While Luxottica's end customer will derive no benefit from the process itself, other than the added value of an improved stock situation at the points of sale, resulting from the efficiency of the process.

As far as the *time and costs* of the processes are concerned, only for Luxottica was it possible to obtain an estimated valorisation of the whole project, which depends on many factors, the main ones being: the portion and complexity of the Supply Chain involved, the percentage of change with respect to the AS IS status, the need to adopt tools and technologies not previously implemented, the development time.

As pointed out in the Barilla case, the absence of IoT technologies within the processes causes a slowdown in the implementation of Blockchain technology as it is a priority to equip oneself with these tools and train operators in their use. While time can be used as an indicator of complexity, the duration Barilla's projects seems to suggest that they are more complex implementations.

This consideration is supported by the fact that in this case the change made to the processes had to involve them even to the point closest to the end customer, thus implementing a series of further applications which have impacted the packaging, delivery to points of sale and monitoring of customer reactions.

This is therefore the design of projects that have had high visibility from the outset, conducted with the aim of strengthening the brand's image; therefore, a more cautious and precise evaluation and design of the process and all its appendices was necessary.

At the level of the *portions of the Supply Chain* involved, it is evident how the logistics team of each company presents itself as the protagonist of the various companies; the component that varies from case to case is linked to the ownership percentage of the logistics chain. If we examine the Luxottica case, in fact, internal logistics is responsible for coordinating the operations of vendors, forwarder and intermediate couriers. For Barilla, on the other hand, the process, being conducted entirely on Italian soil, allowed for a faster alignment with a smaller number of actors than in other situations.

The *choice of the platform* and its technical characteristics has seen Barilla focus on a Permissioned register, in which access is restricted to a predetermined number of actors, whose visibility on processes and the number of operations they can conduct depends on the role. It is therefore a system, although decentralized, potentially asymmetrical, in which the different actors will have different access to information. This allows the central company to maintain a high level of secrecy and security, but at the same time to gain visibility into many operations that were previously opaque or took place in the background, far from its control. The solution adopted by Luxottica seems to go in the opposite direction, using a public register, where all nodes can have the same level of visibility and reactions using their private keys.

Coming now to the *documentation* reduction associated with the various phases of the processes has been perceived in both cases as significantly improved. Documents such as the Bill of Landing or loading/unloading certificates are automatically generated by Smart Contract in the form of digital tokens and recognised as valid and authoritative. Traceability, the goal of this implementation, has also been satisfactorily perceived in all cases.

As far as the reduction of the *costs of intermediaries* is concerned, on the other hand, it was uniformly perceived as a non-decisive advantage.

For Barilla, re-designing of processes and the use of new tools has led to a change in the routines of the various players, but this has not translated into a reduction in the number or time dedicated to the various activities. In the other case, the process itself consisted of a series of steps in which different phases of drafting documents or manual verifications were necessary and with the introduction of the Blockchain a significant reduction in the time dedicated to them was perceived, thanks to automation.

Among the cost items, the redesign of the existing process structure also stands out. As pointed out by Barilla, the as is process foresees a very limited use of Artificial Intelligence tools and IoT devices, the change made will be much greater and will impact the Supply Chain both at a strategic level and at a more micro-operational level, investing the routines of all the actors. As far as the license for platforms and tools is concerned, in general the cost depends on the provider and the type of solution and therefore, especially in the case of Barilla, which used the tools provided by Microsoft and IBM, the cost was significant.

What has been observed through these two projects is that Blockchain has so far been used as a tool to support initiatives to redefine existing processes. The primary business objective is to restructure the chain of steps and actors, at least for a part of the Supply Chain if not for the whole structure, and, only once a better flow is achieved, an additional element, Blockchain technology, is introduced to add a new property to this process, the unchangeable writing of all transactions on the public register.

In both cases, the need that led to the redefinition of existing processes and procedures was to resolve disputes between actors. If for Luxottica it manifests itself as a need to keep under control also the operations that took place in the background between forwarder and couriers, of the treatment and transport conditions agreed with partners; indicators such as storage temperatures or mowing time of the basil are key variables for obtaining a finished product that respects the values communicated to customers.

From what emerges from the cases illustrated, it seems that the adoption of the Blockchain has produced an impact only at the level of adaptation of the physical tools and interconnection platforms used by the actors and has promoted little change in the flows. The operator will therefore only be responsible for that part of the training related to the use and maintenance of the new tool; instead, the team of analysts and IT specialists will be responsible for the design of the entire background structure that will have to be designed ad hoc to support the Supply Chain processes.

That's why this second task is entrusted to providers who have developed solutions that have already been tested and tried by different realities. This is the reason why, in addition to being able to manage very complex and articulated Supply Chains, it has allowed the platforms of industry leaders such as IBM and Microsoft to be the most popular today, despite the wide network of start-ups that is growing more and more around the topic.

It therefore seems that the objectives of efficiency and visibility over the entire process, have guided the choice of Blockchain technology and only secondarily for some companies have translated into external objectives, bringing value also to the end customer and thus strengthening the brand. This is, however, a possible consequence only for those cases where the consumer can benefit from the acquisition of this information, therefore mainly for the consumer goods sector such as food and fashion products for example.

In conclusion, the following considerations can be deduced from the analysis of these cases. Blockchain is considered a valid tool to replace the more traditional communication and integration systems along the Supply Chain, or modern alignment strategies. [72]

However, when compared to these fewer avant-garde tools, it seems to emerge that the greatest benefit it can bring is the indelible digitisation of all the steps taken by a product, so its use is more appropriate if the objective is precisely this.

The management of the logistics Supply Chain is therefore the area where the greatest benefits can be perceived; the impact on the other macro-areas is still very questionable and now the costs would outweigh the benefits. [73]

CHAPTER IV – Coronavirus impact of Supply Chains

4.1 Supply Chains in the wake of the pandemic

Since December 2019, companies have been experiencing the major extraordinary outbreak of the severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2), also known as Coronavirus Disease 2019 (COVID-19). The current impact of this outbreak on manufacturing companies is already very serious and it is predicted that the medium to long term impact will be greater than that of all other previous major outbreaks such as SARS 2003 and H1N1 2009. [74]

A survey published on March 28 by the *Chartered Institute of Procurement and Supply* revealed that 86% of Supply Chains are affected by the COVID-19 pandemic and the *Institute for Supply Management* found that between early March and late March, the number of companies affected by Supply Chain impacts rose from 80 to 95%. [75]

Firms around the world have faced unprecedented challenges due to the disruptions caused by the Coronavirus outbreak and the resulting major lockdown. Some companies, mainly in the hospitality industry, have not survived due to the slowdown in trade, while others have struggled hard to meet the needs of the population, including farms, retailers, logistics providers and members of health care Supply Chains. [76]

The design of a resilient Supply Chain requires the development of five principles [77]:

- *Engineering* the structure of a Supply Chain that includes all its members, including first- and second-tier suppliers, distribution channels and end users, is important to identify likely bottlenecks that may limit the flow, capacity and visibility of production.

- *Collaboration* is a key aspect of a resilient Supply Chain that needs to be adaptable and flexible. Sharing information is the best way to increase visibility and reduce risk in a Supply Chain. The purpose of Supply Chain collaboration is to create a common understanding of Supply Chain strategy, because when there is a clear understanding, relationships can make sense.

- *Visibility* refers to the monitoring of the flow of materials and information in a Supply Chain to ensure that procurement, production, delivery schedules and orders are met. Collaborative planning and forecasting are also important to provide a clear common view of the processes within a Supply Chain.

- *Speed* refers to the reduction of the "end-to-end" time for the production and delivery of products and services. Thus, value stream mapping can help identify activities or processes that can be reduced or eliminated to improve material flow. Digital technologies such as cyber-physical systems, sensors, barcodes, Internet of Things, collaboration portals and cloud computing can enable both the visibility and speed of Supply Chains. [76]

- *Risk assessment management* should be developed as part of the routine of a company and its Supply Chain to develop the ability to anticipate and respond to incidents. The collection and storage of data and information on past events would help to systematize the knowledge gained over time and especially after COVID-19 has been overcome. The analysis of large amounts of data and Blockchains are means to collect and record the information to be analysed.

Blockchain systems can help to retain the data needed for recovery, such as information and data on production capacity, staffing requirements, and information on supplier capacity and emergency suppliers. Therefore, managers can use the data and information to take action to implement the recovery model they have developed. [74]

4.2 Blockchain solutions to face COVID-19 disease

The outbreak of the Coronavirus (COVID-19) at the end of 2019 poses a serious threat worldwide. The spread of the virus is causing the global economic shock with massive disruptions in many sectors such as supply chain, industry, insurance, agriculture, transportation and tourism, forcing governments and owners to shut down their operations. [78]

According to the Organization for Economic Cooperation and Development, the global economy could grow this year at the lowest rate since 2009 due to the Coronavirus outbreak, as the forecasts in the chart illustrate. [79]

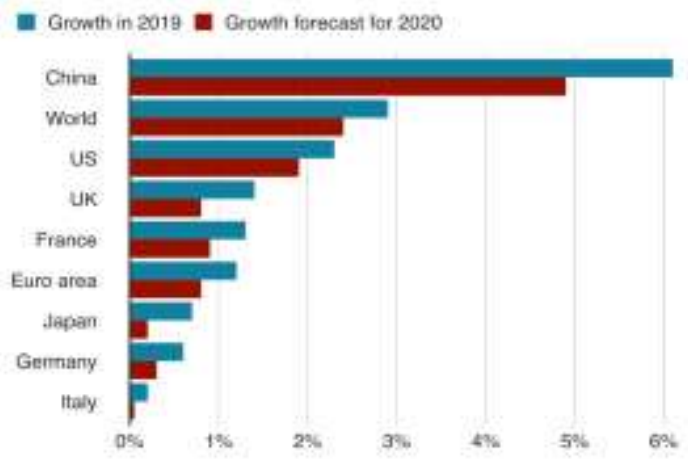

Figure 19 The impact of COVID-19 on global economic growth [79]

According to Walmart, several industries and categories have faced massive panic buying as a result of the COVID-19 pandemic, and the world's largest 1,000 companies had over 12,000 factories, warehouses and operations in quarantine areas by early March. [80]

Unfortunately, existing research on Supply Chain resilience may not have realized its full potential for understanding Supply Chain risks in the industry. A survey conducted by *Bassware* with over 700 respondents found that 60% of responding procurement managers identified a lack of transparency in their Supply Chain. [81]

Beroe, a procurement market intelligence service, released survey data on March 22, based on 450 companies from around the world, showing that only 49% of respondents had developed business continuity plans for the COVID-19 crisis and only 57% had identified critical supplies and suppliers. [82] Globalization of the Supply Chain can indeed provide a manufacturing cost advantage through economies of scale and by locating production in regions with factor cost advantages.

However, globalization also lengthens the logistics pipeline, bringing with it the risk of delivery delays and dependence on distant sources. [83] A reduction in the number of suppliers can create a lever in the negotiation of payment terms and prices, but also increases the dependency on these suppliers for further supply.

In this segmentation, it is recommended that companies focus on securing supply rather than cost savings during critical bottlenecks, and for more strategic deliveries, companies should adopt a more collaborative approach. Moreover, the literature suggests Supply Chain Risk Management techniques that involve active information sharing throughout the Supply Chain. [84]

In addition, executives can take advantage of digital technologies, as these technologies can play a significant role in implementing the strategies and remediation plan. For example, better collaboration in the Supply Chain is proposed in this research, which requires the timely exchange of accurate information between buyers and suppliers to improve the supply of raw materials. [85]

Technologies such as RFID and Blockchain can accelerate the exchange of information and improve the transparency of warehouse positions and logistics flows. This is especially true when information exchange changes from a partial and sequential (one level at a time) to a completer and more immediate. [86] As a disruptive technology, Blockchain could lead to a major change in the design and operation of Supply Chains. This is closely related to features such as reliability, traceability and intelligent contracts for trusted relationships across the network. [87]

Several specific applications of Blockchain technology for Supply Chain Management have recently been developed by researchers and industry, which can be assigned to certain primary categories, including product origin (traceability), advanced SC operations (in terms of security, transparency, visibility), trade finance, disintermediation, data security and smart contracts. [88]

Some companies have worked to rebalance supply lines to reduce dependence on single global sources by adding local and nearshore suppliers and facilities to their Supply Chain. In the past, *Nike* may have been a figurehead for sourcing from a limited number of low-cost global locations to reduce the cost of goods sold and provide leverage in controlling supplier relationships.

Nike is increasingly incorporating nearshore factories and suppliers and even in-market sourcing into its Supply Chain. This has enabled the company to respond more quickly to consumer demand, introduce new products more frequently and deliver them more quickly to regional markets. It also reduced the company's dependence on a few global factories and suppliers. [75]

Furthermore, Nike uses RFID in its Supply Chain to track demand and product availability throughout the Supply Chain closer to real time. This enables faster response to demand shifts and reduces the risk of over-ordering in response to bottlenecks. Newer technologies such as Blockchain can also be used to promote the immediate and complete dissemination of information in the Supply Chain, replacing the traditional partial and sequential dissemination. [89]

In the shipping area, for example, *Maersk* uses the Blockchain to send shipping documents to future shipping destinations not just when a shipment arrives, but as soon as the shipment leaves, and these documents are immediately forwarded to all downstream steps and actors in the Supply Chain. The collaboration between Maersk Line and IBM dates to 2016, when they started to carry out several pilot projects to analyse the potential benefits of Blockchain in tracking containers during water transport. Following a hacker attack that led to congestion in 76 ports around the world, Maersk sees the need to invest in Blockchain technology.

Maersk estimated the losses caused by the cyber-attack at around $300 million. Various pilot projects were related to food or agricultural products: in 2014, Maersk tracked avocados and roses from East Africa to Europe; in September 2016, Maersk and IBM tracked a container of flowers from the Kenyan coastal city of Mombasa to Rotterdam in the Netherlands.

The pilot project was a success, and Maersk and IBM subsequently used the system to track containers of pineapple from Colombia and mandarins from California.

Newer technologies can enable more autonomous Supply Chains where control towers can use new levels of visibility to manage demand and supply risks. But in the Nike example, we saw the introduction of RFID, a much less new technology. Blockchain is not used as a stand-alone technology at Maersk; it uses and complements existing technologies. This provides the opportunity to approach technologies in terms of how they complement existing technologies, and to evaluate existing technologies for their potential contribution to Supply Chain problems, as well as newer technologies. [75]

4.2.1 Case History "E" – Genuino: Made for Evidence

Genuino, an Italian start-up, founded in 2018 in the United States and later in 2019 as an innovative start-up in Italy, is a decentralized certification protocol that enhances the quality and authenticity of products of excellence, certifying their ownership and subsequent transfers of ownership, tracing the production chain, eliminating counterfeiting and, finally, connecting the brand with an active, aware and remunerated consumer. The following excerpt was taken from a telephone interview with Eleonora Mulas, CEO and Co-Founder of Genuino.

Blockchain's ability to bring confidence and implement increasingly reliable forms of certification is also finding increasing attention in the world of sport and football. *ACF Fiorentina* and Genuino have chosen to start a collaboration that allows to certify unequivocally the official shirts of the Club and this is the first time that a football team decides to use Blockchain technology to obtain the certification of the uniforms that are worn by their players.

The shirts worn have been fitted with a special chip (IoT) and each of them is now combined with a unique unchangeable code that irrefutably confirms their authenticity and are thus certified by Genuino on the Blockchain. This certification makes it possible to attribute a secure value to the jerseys that will be made available on the market to all those, fans, enthusiasts and collectors, who wish to have a unique object closely linked to a sporting performance and the team. All this with the activation of a charity auction.

The first part of the project was developed in the quarter September - December 2019, including the anti-counterfeiting and certification part, while now the focus is on the marketplace design. The sports collectible market does not see the presence of many technology providers; however, it is very attractive due to its large size and high growth rate, together with adequate profitability.

The type of Supply Chain considered are not particularly large and this simplifies the relationships with the single actors, being these in a limited number. Therefore, there was no need to analyse complex management and data sharing systems integrated at ERP level, as they are short chains more oriented towards services than industrialization.

For the client, in this specific case the football team, if not already in possession of internal know-how and technological expertise, the support of partners such as Genuino represents the highest cost fraction. Training is especially necessary for the aspect related to the transactions of the cryptocurrency used, i.e. Ethereum.

In the context of the Covid-19 epidemic emergency in which it is difficult to blindly trust the genuineness of information based only on what is communicated, the catering sector requires particularly careful measures to contain the contagion. The group specializing in Japanese catering *Daruma* has decided to form an alliance with Genuino to increase knowledge of all data relating to the management of raw materials and production and to guarantee greater transparency to Supply Chain companies and end consumers.

In this specific case, the aim is to enhance the quality and authenticity of the production chain of Japanese cuisine, but also to automate the process by making it more efficient and, at the same time, give exclusivity to the products, offering the consumer a personalized, easily accessible experience, making him an active protagonist of the value story. Through the application of the Genuino certification protocol, Daruma is able to offer its clients the opportunity to personally verify, understand and collect evidence of the rigorous implementation of risk mitigation measures in the production, processing, marketing and administration environments, in order to guarantee the safety of the food consumed and protect consumer health.

4.2.2 Case History “F” – Medical Supply Chain: VeChain and Alipay

In this pandemic crisis, maintaining a continuous supply of medicines and food has become a challenge for the health sector. Blockchain technology can help Supply Chain companies to achieve rapid delivery flows by tracking the flow from origins to destinations in a trusted and reliable way.

An interesting application for Blockchain is *VeChain*, a Blockchain-based platform for monitoring vaccine production in China. [90] All activities related to vaccine production, from materials and codes to packaging, are recorded and stored on distributed books. This project also provides a reliable method to reduce the risk of possible changes in vaccine information. VeChain will also ensure that vaccine records are unalterable and permanent in order to achieve high vaccine quality, which is of great importance in the health sector as in the COVID-19 epidemic.

In addition, VeChain and *Mastercard* are among the heavyweights supporting the new *APAC Provenance Council*, which has already secured millions in Supply Chain tracking and funding pilots across the Asia Pacific region. The Consortium will provide comprehensive solutions for the authentication and traceability of food, wine and products using Blockchain, with emphasis on Australia's $76 billion exports to China. [91]

Payments are made outside China with Mastercard and for goods going to China with *Alipay* Australia. Products can be tracked using VeChain as a public Blockchain or Mastercard Provenance as a permitted accounting system. Supply Chain tracking was a key application identified in the Australian government's recent *National Blockchain Roadmap*, and Australia's share of the value of exports to China reached a record 38% in 2019 - more than any other country.

Recently, Alipay, together with the *Zhejiang Provincial Health Commission* and the *Department of Economy and Information Technology* in China, launched a Blockchain platform that allows users to track the demand and Supply Chains of medical supplies. [92]

This consists of recording and tracking materials used to combat Coronavirus epidemics, such as masks, gloves and other protective equipment. The company claims that Blockchain can ensure a high level of trust for the medical Supply Chain by securely linking blocks and transactions, protecting data in the Supply Chain thanks to Blockchain encryption and ensuring fast data flow thanks to Blockchain decentralisation. When an outbreak occurs, a rapid response and a fast Supply Chain is the most important thing that the arms authorities must tackle the problem. By using Blockchain, the problems in the Supply Chain can be solved, saving thousands of lives and billions of dollars. [93]

In summary, Blockchain can offer five main solutions to support the medical Supply Chain in the Coronavirus crisis:

- *Product requirements*: providing a solution to update real-time requirements and medical factories for rapid response, i.e. Supply Chain rate adjustment.

- *Eligibility of the offer*: offer a solution to control quality of the goods from the factory side, i.e. product specification, delivery quantities.

- *Transport tracking*: goods, medical goods must be traced in order to ensure transparency in the medical Supply Chain. This can be done through a Blockchain network with transaction recording and monitoring capabilities.

- *Financial payments*: Blockchain can be used as payment platform between suppliers and customers. All digital payments are recorded on the Blockchain with time stamp and signature without being changed or modified.

- *Customs certificates*: customer behaviour such as purchasing, and payment transactions can be reproduced on the Blockchain with digitally signed certificates showing the negotiations between the providers and the users.

CONCLUSIONS

This thesis was shaped primarily with the aim of clarifying the concept and applications of Blockchain technology within the Supply Chain. Secondly, it has been conducted a state-of-the-art study on the use of Blockchain to combat the Coronavirus (COVID-19) epidemic, as this is an exceptional event with a global impact on the Supply Chains. We have introduced a conceptual architecture that integrates Blockchain and Supply Chain Management. Some important use cases and projects were also highlighted. Finally, we pointed out some potential Blockchain investigations for the fight against COVID-19.

The number of projects launched is very small, and even more so when only those cases are considered where, within the Supply Chain, the adoption of the technology has reached sufficient levels of analysis and design to be able to describe it in terms of benefits and costs detected or estimated. Some of the projects mentioned concern a purely theoretical study or in any case experimental but limited only to part of the network. Despite this, it has been possible to detect for the cases considered a lively interest in sharing and comparing the results achieved, as evidenced by of a general climate of enthusiasm and cooperation.

However, the management of interactions along the Supply Chains and the involvement of actors can represent very strong barriers, especially if not everyone perceives the win-win aspects of the system. Another limitation of this research concerns the aspect of process analysis induced by technology. Indeed, this technological choice has led, for those cases in which it has been possible to analyse, to a minimum redefinition of the processes involved, producing instead substantial changes in the approach used for the notarization of transactions, which therefore becomes largely automatic.

Since the study has been limited to these cases, it is not clear whether the technology itself can introduce a substantial change in the way processes are set up and organised. Within the limits of this research perimeter, it seems that, at least for the time being, it is not a new disruptive approach in this sense. What is confirmed by the results, however, is the undoubted advantage produced in making activities more efficient, especially in terms of speed in resolving blockages and disputes.

Moreover, the riskiness of the technology does not allow companies to rely on it at all today and therefore it is used more as a support tool on an operational rather than a strategic level. However, if this aspect is resolved in the future, in a probabilistic scenario, the way of managing individual businesses could be strongly impacted by a decentralisation logic, and the initial inclination towards a permissioned register could only be a transition phase towards a public logic in which access to information by any of the nodes can activate transactions and certify changes of hand without the need for manual action.

Finally, as COVID-19 is a new experience for Supply Chain decision makers, they would face many challenges in deciding on recovery planning. Some journals in this area, which have published research calls on COVID-19 and Supply Chain Management, have helped to create a possible avenue for research on the resilience of Supply Chains. Nevertheless, more focused, less conceptual and more empirical research on the events surrounding the pandemic can help managers to address the challenges related to risks in the Supply Chain and can help reduce the risk that they will have to draw further lessons from the research they have already done during the next crisis.

Some Supply Chains should be put in the spotlight because they are crucial to society and require special attention from the government, e.g. pharmaceutical, especially those dependent on biodiversity, food retailing, logistics and transport, and the health and safety sector. [76]

Society can reassess its decision-making processes in relation to consumption patterns due to isolation and changing habits. According to the *EY Future Consumer Index*, consumers tend to change their behaviour after the COVID-19 crisis. A survey conducted by Ernst and Young shows that 34% of respondents would be willing to pay more for local products, 25% for trusted brands and 23% for ethical products. [94] And Blockchain technology can play a fundamental role in that direction, as proven by this thesis work.

While this study is essentially based on the literature on Blockchain applied to Supply Chain dynamics, future studies could consider collecting real data from specific food and medical device Supply Chains to develop and analyse a global Supply Chain Network that takes into account the impact of a global pandemic such as COVID-19. Therefore, full empirical studies, such as in-depth case studies or a large-scale survey, can be carried out to gain an in-depth understanding of how Blockchain technology contributes to the recovery or validation of the proposed strategies and their impact on Supply Chains.

REFERENCES

[1] D. Ivanov and A. Dolgui, "Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. A position paper motivated by COVID-19 outbreak," *International Journal of Production Research,* vol. 58, no. 10, pp. 2904-2915, 2020.

[2] D. Ivanov, Structural Dynamics and Resilience in Supply Chain Risk Management, International Series in Operations Research & Management Science, 2018.

[3] S. Leible, S. Schlager, M. Schubotz and B. Gipp, "Frontiers in Blockchain," 19 November 2019. [Online]. Available: https://www.frontiersin.org/articles/10.3389/fbloc.2019.00016/full. [Accessed 20 September 2020].

[4] "Blockchain for Technology, Media and Telecom (TMT) Companies," 2019. [Online]. Available: https://assets.kpmg/content/dam/kpmg/us/pdf/blockchain-for-tmt-2019.pdf. [Accessed 20 September 2020].

[5] D. Insights, "Deloitte' S 2019 Global Blockchain Survey - Blockchain Gets Down to Business," 2019. [Online]. Available: https://www2.deloitte.com/content/dam/insights/us/articles/2019-global-blockchain-survey/DI_2019-global-blockchain-survey.pdf. [Accessed 20 September 2020].

[6] S. Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," 2008.

[7] H. Treiblmaier, "The impact of the Blockchain on the supply chain: a theory-based research framework and a call," *Supply chain Management: An International Journal,* vol. 23, no. 6, pp. 545-559, 2018.

[8] L. Lee, "New Kids on the Blockchain: How Bitcoin's Technology Could Reinvent the Stock Market," *Hastings Business Law Journal,* vol. 12, no. 138, 2016.

[9] "Ensuring Data Integrity with Hash Codes," 30 March 2017. [Online]. Available: https://docs.microsoft.com/en-us/dotnet/standard/security/ensuring-data-integrity-with-hashcodes.

[10] Z. Zheng, S. Xie, H. N. Dai, X. Chen and H. Wang, "Blockchain challenges and opportunities: a survey," *International Journal of Web and Grid Services,* vol. 14, no. 4, pp. 352-375, 2018.

[11] S. Ølnes, J. Ubacht and M. Janssen, "Blockchain in government: Benefits and implications of distributed ledger technology for information sharing," *Government Information Quarterly,* vol. 34, no. 3, p. 355–364, 2017.

[12] N. Vyas, A. Beije and B. Krishnamachari, Blockchain and the Supply Chain, 2019: Kogan Page Limited.

[13] D. Lee Kuo Chuen, "Handbook of digital currency: bitcoin, innovation, financial instruments, and big data," *Academic Press,* p. 47–51, 2015.

[14] W. Suberg, "Cointelegraph," 28 June 2019. [Online]. Available: https://cointelegraph.com/news/bitcoin-mining-is-now-more-competitive-than-ever-new-data-shows?fbclid=IwAR2JG4wmXXdzV9_HWvuDVyD7JMevtlLtO4Mo6Jfd1qqRlgQl-TqukP3JxJw. [Accessed 4 July 2020].

[15] F. Hasse, A. von Perfall, T. Hillebrand, E. Smole, L. Lay and M. Charlet, "Blockchain – an opportunity for energy producers and consumers?," 2016, PwC Global Power & Utilities.

[16] C. R. Harvey, C. Moorman and M. Toledo, "How Blockchain Will Change Marketing As We Know It," *SSRN Electronic Jounal,* January 2018.

[17] P. Christy, "Smarter with Gartner," 2018 February 2018. [Online]. Available: https://www.gartner.com/smarterwithgartner/the-irrational-exuberance-that-is-blockchain/. [Accessed 5 July 2020].

[18] R. D. Boroujerdi and C. Wolf, "What if I Told You…," Equity Research, Goldman Sachs, 2015.

[19] C.Catalini and J. S. Gans, "Some Simple Economics of the Blockchain," *National Bureau of Economic Research,,* no. 22952, 2016.

[20] M. Swan, "Blueprint for a new economy".*O'Reilly Media.*

[21] W. Reijers, F. O'Brolcháin and P. Haynes, "Governance in Blockchain Technologies & Social Contract Theories".

[22] M. Gray and C. Hajduk, "GitHub," 17 April 2017. [Online]. Available: https://github.com/Azure/azure-blockchain-projects/blob/master/bletchley/AnatomyofASmartContract.md. [Accessed 5 July 2020].

[23] V. I. I. f. Business, "Empowering the edge: Use case abstract for the ADEPT proof-of-concept," IBM GLOBAL BUSINESS SERVICES, 2015.

[24] T. Economist, "What disruptive innovation means," *The Economist Explains,* 25 January 2015.

[25] D. C. d. Leon, A. Q. Stalick, A. A. Jillepalli, M. A. Haney and Frederick T. Sheldon, "Blockchain: properties and misconceptions," *Asia Pacific Journal of Innovation and Entrepreneurship,* vol. 11, no. 3, pp. 286-300, 2017.

[26] G. Wood, "Ethereum: A secure decentralised generalised transaction ledger," *Ethereum Project Yellow Paper,* vol. 151, pp. 1-32, 2014.

[27] A. E. Alunni, "Medium," 14 May 2019. [Online]. Available: https://medium.com/@angelaevaalunni/tipologie-di-classificazione-delle-blockchain-2-di-3-64b4c94e0feb. [Accessed 4 July 2020].

[28] V. Buterin, "Blog Ethereum," 7 August 2015. [Online]. Available: https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains/. [Accessed 4 July 2020].

[29] N. Sullivan, "The Cloudflare Blog," 24 October 2013. [Online]. Available: https://blog.cloudflare.com/a-relatively-easy-to-understand-primer-on-elliptic-curve-cryptography/. [Accessed 4 July 2020].

[30] Accenture, "Blockchain – reengineering the media value chain Accenture 2017," 2017.

[31] A. T. Vision, "Redefine Your Company Based On The Company You Keep. Intelligent Enterprise," 2018.

[32] R. Pinna, L'evoluzione nella dimensione organizzativa della Supply Chain: Dalla gestione di un flusso alla gestione di una rete, Franco Angeli, 2006.

[33] A. Tunisini, Supply Chains e strategie di posizionamento, Rome: Carocci, 2003.

[34] R. Ganesan and P. Terry Harrison, An Introduction to Supply Chain Management, Penn State University: Department of Management Science and Informaztion System, 2002.

[35] M. Christopher, Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service, London: Financial Times: Pitman Publishing, 1998.

[36] D. Lambert, M. Cooper and J. Pagh, "Supply Chain Management: Implementation Issues and Research Opportunities," *The International Journal of Logistics Management,* vol. 9, no. 2, 1998.

[37] S. Oz and H. E. Goren, "Application of Blockchain technology in the supply chain management process: case studies," 2019.

[38] H. A. Awad and M. O. Nassar, "Supply Chain Integration: Definition and Challenges," *Proceedings of the International MultiConference of Engineers and Computer Scientist,* 17 March 2010.

[39] R. Speckman, J. Kamauff jt and N. Myhr, "An Empirical Investigation into Supply Chain Management: a Perspective on," *Supply Chain Management Review,,* pp. 53-62, 1998.

[40] D. Van Der Vart and P. Van Donk, "Buyer Focus: Evaluation of a New Concept for Supply Chain Integration," *International Journal of Production Economics,* pp. 18-32, 2004.

[41] A. Harrison, Competing Through Supply Chains, Athens: Athens University of Economics and Business, 2003.

[42] G. Trish, J. Matt and N. Sabina, "The challenges ahead for supply chains," McKinsey Global Suervey result, McKinsey Company Report, 2010.

[43] J. Gattorna, "Supply Chains are the Business," *Supply Chain Management Review,* 2006.

[44] R. Geissbauer, J. Roussel, S. Schrauf and S. M. A., "Next-generation supply chains Efficient, fast and tailored," Report Pwc, Global Supply Chain Survey, 2013.

[45] M. Porter, Competitive Strategy, New York: FreePress, 1980.

[46] R. J. R. Chase, A. Grando and A. Sianesi, Operations Management, nella Produzione e nei Servizi, Milan: McGraw-Hill, 2011.

[47] C. Bertoletti, "Mark Up," Ottobre 25 2019. [Online]. Available: https://www.mark-up.it/la-sostenibilita-comunicazione-brand-marketing/. [Accessed 14 July 2020].

[48] V. D'Angerio, "Sole 24Ore," 27 September 2017. [Online]. Available: https://www.ilsole24ore.com/art/un-fiume-denaro-aziende-sostenibili-AEiXr3XC. [Accessed 14 July 2020].

[49] "Funding Aid Strategies Investments," Ottobre 29 2019. [Online]. Available: https://www.fasi.biz/it/notizie/studi-e-opinioni/21216-sviluppo-sostenibile-crescono-gli-investimenti-green-delle-imprese.html. [Accessed 14 July 2020].

[50] B. Rettab and A. BenBrik, "Green supply chain in Dubai," Dubai Chamber Centre for Responsible Business, Dubai, 2008.

[51] C. Sachs, R. Exman, Nohrstedt, P. Göthberg and M. Kempe, "Blockchain use cases for food traceability and control: A study to identify the potential benefits from using blockchain technology for food traceability and control," Axfoundation, SKL Kommentus, Swedish Country Councils and Regions, Martin & Servera, and Kairos Future, February 2017.

[52] "RFID (Radio Frequency Identification) technology market revenue worldwide from 2014 to 2025," Statista.

[53] L. David, "The path to supply chain transparency: A practical guide to defining, understanding, and building supply chain transparency in a global economy," Deloitte University Press, 2014.

[54] A. Mussomeli, D. Gish and S. Laaper, "The rise of the digital supply network," Deloitte University Press, 2016.

[55] A. Ganeriwalla, G. Walter, L. Kotlik, R. Roesgen and S. Gstettner, "Three Paths To Advantage With Digital Supply Chains," BCG Perspectives by The Boston Consuling Group, 2016.

[56] D. S. C. Initiative, "Digital Supply Chains: A Frontside Flip - Building Competitive Advantage to Optimize Performance and Customer Demand," The Center for Global Enterprise, 2010.

[57] K. Alicke, "Supply Chain 4.0 – the next-generation digital supply chain," 27 October 2016. [Online]. Available: https://www.mckinsey.com/business-functions/operations/our-insights/supply-chain-40--the-next-generation-digital-supply-chain. [Accessed 19 July 2020].

[58] Gartner, "Gartner Hype Cycle," [Online]. Available: https://www.gartner.com/en/research/methodologies/gartner-hype-cycle. [Accessed 19 July 2020].

[59] Gartner, "Gartner Top 8 Supply Chain Technology Trends," 27 February 2018. [Online]. Available: https://www.gartner.com/smarterwithgartner/gartner-top-8-supply-chain-technology-trends-for-2018.. [Accessed 19 July 2020].

[60] C. STAMFORD, "Gartner.com," 12 September 2019. [Online]. Available: https://www.gartner.com/en/newsroom/press-releases/2019-09-12-gartner-2019-hype-cycle-for-blockchain-business-shows. [Accessed 20 July 2020].

[61] G. Perboli, S. Musso and R. M., "Blockchain in Logistics and Supply Chain: a Lean Approach for Designing Real-World Use Cases," Turin, 2018.

[62] M. Raab and B. Griffin-Cyran, "Digital Transformation of Supply Chains," Capgemini Consulting, 2011.

[63] A. Ganeriwalla, M. Casey, P. Shrikrishna, J. Bender and S. Gstettner, "Does your Supply Chain Need a Blockchain," Boston Consulting Group - MIT Media Lab, 2018.

[64] Y. Tribis, A. El Bouchti and H. Bouayad, "Supply Chain Management based on Blockchain: A Systematic Mapping Study," 2018.

[65] M. Della Volpe, "Le strategie di marketing come strumento di difesa dalla contraffazione nelle imprese del lusso: il caso Pandora," Tesi Luiss, Roma, 2016.

[66] J. Kaikati and R. LaGarce, "Beware of International brand piracy," *Harvard Business Review,* vol. 2, no. 58, pp. 52-58, 1980.

[67] A. Nill and C. J. Shultz, "The scourge of global counterfeiting," *Business Horizons,* vol. 6, no. 39, pp. 37-43, 1996.

[68] S. Toshendra Kumar, "Louis Vuitton Owner To Use ‘Aura’ Blockchain To Track Luxury Goods," Blockchain Council, 2019.

[69] "ConsenSys," 16 May 2019. [Online]. Available: https://content.consensys.net/wp-content/uploads/AURA_ConsenSys_Press-Release_May-16-2019-2.pdf. [Accessed 31 August 2020].

[70] "CERTILOGO," 26 April 2019. [Online]. Available: https://brands.certilogo.com/hubfs/Downloadable%20Content/Making%20Blockchain%20Real.pdf. [Accessed 31 August 2020].

[71] R. Caneve, "Applications of Blockchain Technology in International," Università degli Studi, Padova, 2018.

[72] F. Casino, T. Dasaklisy and C. Patsakisz, "Enhanced Vendor-managed Inventory through Blockchain," in *The 4th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference*, Atene, 2019.

[73] D. T. Research, "Blockchain in Logistics. Perspectives on the upcoming impact of blockchain technology and use cases for the logistics industry," 2018. [Online]. Available: https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/glo-core-blockchain-trend-report.pdf. [Accessed 6 September 2020].

[74] P. Sanjoy Kumar and C. Priyabrata, "A production recovery plan in manufacturing supply chains for a high-demand item during COVID-19," *International Journal of Physical Distribution & Logistics Management,* 2020.

[75] R. v. Hoek, "Research opportunities for a more resilient post-COVID-19 Supply Chain – closing the gap between research findings and industry practice," *International Journal of Operations & Production Management,* vol. 40, no. 4, pp. 341-355, 2020.

[76] A. B. L. d. S. Jabbour, C. J. C. Jabbour, M. Hingley, E. L. Vilalta-Perdomo, G. Ramsden and D. Twigg, "Sustainability of supply chains in the wake of the coronavirus (COVID-19/SARS-CoV-2) pandemic: lessons and trends," *Modern Supply Chain Research and Applications,* vol. 2, no. 2, 2020.

[77] M. Christopher and H. Peck, "Building the resilient supply chain," *International Journal of Logistics Management,* vol. 5, no. 2, pp. 1-13, 2004.

[78] L. C.-C., S. T.-P., K. W.-C., T. H.-J. and H. P.-R., "Severe acute respiratory syndrome coronavirus 2 (sars-cov-2) and corona virus disease-2019 (covid-19): the epidemic and the challenges," *International journal of antimicrobial agent,* p. 105924, 2020.

[79] E. O. 2020, "OECD," June 2020. [Online]. Available: https://www.oecd.org/economic-outlook/. [Accessed 28 August 2020].

[80] T. Linton and B. Vakil, "Coronavirus is proving that we need more resilient supply chains," *Harvard Business Review Digital Article.*

[81] M. Forde, "SUPPLYCHAINDIVE," 6 February 2020. [Online]. Available: https://www.supplychaindive.com/news/procurement-leaders-transparency-risk/571847/. [Accessed 29 August 2020].

[82] S. Prasad, "BEROE Advantage Procurement," 22 March 2020. [Online]. Available: https://www.beroeinc.com/blog/beroe-live-survey-global-bcp-coronavirus/. [Accessed 29 August 2020].

[83] A. Harrison and R. a. S. H. Van Hoek, Logistics Management and Strategy, Harlow: Pearson Education Limited, 2014.

[84] S. Wagner and C. Bode, "An empirical examination of supply chain performance along," *Journal of Business Logistics,* vol. 29, no. 1, pp. 307-325, 2008.

[85] P. Chowdhury, K. Lau and S. Pittayachawan, "Operational supply risk mitigation of SME and its impact on operational performance: a social capital perspective," *International Journal of Operations and Production Management,* vol. 39, no. 4, pp. 478-502, 2019.

[86] R. Van Hoek, B. Fugate, M. Davletshin and M. (. Waller, Integrating Blockchain into Supply Chain Management, London: Kogan Page, 2019.

[87] S. Saberi, M. Kouhizadeh, J. Sarkis and L. Shen, "Blockchain technology and its relationships to sustainable supply chain management," *International Journal of Production Research,* vol. 57, no. 7, pp. 2117-2135, 2019.

[88] C. R., S. M. and A. J., "Blockchain technology: implications for operations and supply chain management," *Supply Chain Management,* vol. 24, no. 4, 2019.

[89] R. Van Hoek, "Exploring blockchain implementation in the supply chain: learning from pioneers and RFID research," *International Journal of Operations and Production Management,* vol. 39, no. 6/7/8, pp. 829-859, 2019.

[90] "Nasdaq.com," 16 August 2018. [Online]. Available: https://www.nasdaq.com/articles/vechain-announces-blockchain-vaccine-tracing-solution-china-2018-08-16. [Accessed 29 September 2020].

[91] A. Fenton, "Cointelegraph.com," 4 May 2020. [Online]. Available: https://cointelegraph.com/news/vechain-mastercard-and-alipay-join-australia-china-supply-chain-consortium. [Accessed 30 September 2020].

[92] L. Odera, "Coinpage.com," 8 February 2020. [Online]. Available: https://coingape.com/alipay-launches-blockchain-based-platform-to-help-combat-corona-virus-as-china-shuts-down-mining-farms/. [Accessed 29 September 2020].

[93] N. Degnarain, "Forbes.com," 22 March 2020. [Online]. Available: https://www.forbes.com/sites/nishandegnarain/2020/03/22/5-ways-blockchain-can-unblock-the-coronavirus-medical-supply-chain/#327a32fe1380. [Accessed 29 September 2020].

[94] M. Vautier, "EY Future Consumer Index," 23 April 2020. [Online]. Available: https://www.ey.com/en_gl/news/2020/04/four-consumer-behavior-trends-emerge-during-the-covid-19-pandemic-the-first-ey-future-consumer-index-finds. [Accessed 7 October 2020].

[95] L. Odera, "Coinpage.com," 8 February 2020. [Online]. Available: https://coingape.com/alipay-launches-blockchain-based-platform-to-help-combat-corona-virus-as-china-shuts-down-mining-farms/. [Accessed 29 September 2020].