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TRACING AND TRACKING WITH THE BLOCKCHAIN

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Master of Science Degree in Management Engineering

Academic Year 2017-2018

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

In the last months of 2017, a lot of investors started to buy bitcoins, to gain on the invested capital, tanks to the increase of the Bitcoin value: buying bitcoins became an alternative way to invest in the Stock Exchange. However, the Bitcoin value starts to decrease, and all the hopes of investors, who behaved to find a virtual El dorado, went wane.

Nevertheless, today Bitcoin is the coin with the highest value, equal to 5800 Euro or 7121 dollars, and the Bitcoin's success is mainly due to the technology which regulate crypto currency transactions: the Blockchain. In this thesis, there are analysed Blockchain's characteristics to understand why it is so interesting at the eyes of the financial and productive world.

First of all, it is completed a deductive analysis to hypothesise which could be the benefits that the blockchain application in supply chain management and production planning would offer to companies.

After that, an inductive analysis focuses on the pilot projects already completed or in progress, to understand, at this moment, which are the achievable advantages thanks to the adoption of the blockchain to support the supply chain management.

Finally, the adoption of the blockchain in tracking products is proposed to an Italian company operating in the chocolate industry.

ABSTRACT (ITALIAN VERSION)

Alla fine del 2017 è scoppiata la Bitcoin mania, una gran parte di investitori ha deciso di acquistare Bitcoin e sfruttare la crescita del valore della cripto valuta per guadagnare sul capitale investito: acquistare Bitcoin era diventato un metodo alternativo di investire i propri soldi in borsa. Quando però, il valore del Bitcoin ha cominciato a scendere, la speranza degli investitori che credevano di aver trovato una El dorado virtuale è andata scemando.

Nonostante questo, il Bitcoin è ad oggi la moneta che vale di più al mondo, con un valore attuale di 5800 euro o 7121 dollari, e il successo di questa moneta virtuale è principalmente dovuto alla tecnologia che ne governa le transazioni: la tecnologia Blockchain. In questa tesi saranno analizzate le caratteristiche della tecnologia blockchain per capire cosa la rende così interessante non solo agli occhi del mondo finanziario ma anche del mondo produttivo.

Verrà quindi dapprima effettuata un'analisi teorica e deduttiva, con l'obiettivo di ipotizzare quali possano essere i vantaggi che la tecnologia blockchain è in grado di offrire alle aziende se usata per supportare la gestione della filiera e del processo produttivo.

Dopodiché, saranno analizzati i progetti pilota, completati o in programma, nel quale la blockchain è stata utilizzata a supporto della gestione di filiera, per capire cosa realmente si possa ottenere già da ora dall'utilizzo di una soluzione di questo tipo.

Infine verrà proposto l'utilizzo della blockchain nella tracciatura del prodotto ad un'azienda operante nel settore del cioccolato.

EXECUTIVE SUMMARY

The thesis focuses on the potential impacts the adoption of the Blockchain technology could have on the supply chain management and on all the activities related to the manufacturing process of a company. In particular, after this work, the objective is to have an insight of the actual level of development of blockchain solutions and of the benefits achievable by companies.

In the introduction it is provided a basic explanation on what is the blockchain, which are the characteristics of the blockchain consensus algorithms and which are the differences between permissioned and permissionless blockchain. Essentially, the blockchain revolutionises the actual system of online data transfer, because the activity of verification and validation of the exactness of transactions is pursued no more by a central authority, but, it is in charge of the members of the network. This implies that the transaction is made directly by the sender to the receiver, without the need of a third party and, therefore, without paying any intermediary costs. The validation and verification of transactions is made through a consensus algorithm, actually there are different types of consensus algorithms with different characteristics, but, basically, validity of transactions is confirmed when transactions are verified by the majority of the members of the network. The validation activity is called mining and the validator nodes, members of blockchain which offer their CPU power to the mining activity, are called miners, and are compensated by the system. Transactions approved by the blockchain are registered on the distributed shared ledger of the blockchain forever, and they cannot be modified by anyone. Indeed, the decentralised ledger implies that data are no more stored in a central system, but these are stored on all the nodes, so, a malicious node would have to own the majority of the CPU power of the whole network to modify the ledger.

In chapter 2 there are listed the current practices adopted in the supply chain management, in manufacturing process and to the new product development process, and then, it is introduced the concept of Industry 4.0, in which blockchain will have to integrate. After that, there are presented some hypothesis of possible ways to adopt the blockchain to support the supply chain management and which are the expected benefits. In particular, the safety and immutability of the blockchain ledger can be exploited in two ways: a sure tracking of items along the supply chain, and a way to improve the planning of activities, thanks to the real time sharing of data.

In chapter 3, there are presented the main pilot projects concerning the blockchain solutions to support the supply chain management, and in this way, it is possible to understand which are the benefits achievable with the actual level of technology, and to have an insight of the different blockchain based solutions and their characteristics available in the market. This analysis confirms the hypothetic benefits theorised in the deductive analysis and it adds a further advantage: tracking products with a blockchain solution can make companies' supply chain transparent, therefore they can improve their customers relationships, and in this way increase revenues.

Finally, a blockchain based solution is proposed to an important Italian company in the chocolate industry, which, nowadays, is a model of Industry 4.0, but, with not very encouraging results. This experiment allows to declare that a lot of work has still to be done before the blockchain could begin the supply chain transparency revolution.

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2. INTRODUCTION

2.1 WHAT IS BLOCKCHAIN

The term Blockchain appears at the end of November 2008, in a dissertation on a peer-to-peer electronic cash system posted in an US mailing list of cryptographers, by one or a group of computer programmers under the pseudonym of Satoshi Nakamoto. Since then, the term encompasses two meanings: technically, the blockchain is a distributed replicated database that allows secure transactions between two entities without a central authority, but, in a wider perspective, experts and researchers use this term to identify the whole technology ecosystem behind digital assets exchange among participants of the same network, with no intermediaries.

Satoshi Nakamoto and his team created an open platform, called Bitcoin, where participants can exchange money, in a form of a new virtual currency called again Bitcoin. In Table 1 are presented the main differences among virtual currency, legal currency and traditional online payments.

Characterisitcs		Bitcoin	Legal currency	Traditional online payments
Management	Issuer	Issued by the system	Government or banks	E-money service providers
	Manager	Managed by P2P network	Government or banks	E-money service providers
Value	Issuance cap	21 million BTC	None	Issued within the amount deposited in advance
	Grounds for value	Trust in the system	Trust in the government	Trust in a reliable third-party
Money transfer	Required time	A block is created every 10 minutes, the blockchain is considered authentic after the creation of 6 blocks, so the finalization time is of 60 minutes	Immediately in the case of direct receipt, a long time when there is the need to transfer money	Several days to one month, until payments to member stores are completed
	Transfer fees	Small amount sustained by senders	Expensive sustained or by senders or by the receivers	Sustained by the receivers
Anonymity	Anonymity of transactions	Transaction records are explicit but anonymous	High anonymity	Low anonymity
	Disclosure of transaction records	Disclosed	Undisclosed	Generally undisclosed

Table 2.1. Comparison between Bitcoin, legal currency and traditional online payments

Usually, to transfer money to another place, maybe in a country with another currency, it was necessary to complete the operation through a reliable third-party, like banks or other financial institutions, which was in charge to control the regularity of the transaction and assumes the role of repository of information, and this service is paid through transaction fees.

Bitcoin transactions revolutionised the movement of money: no more need of trusted third party, because the information is now in an open ledger that is accessible to any participant of the network. Thus, every bitcoin can be tracked, in this way participants can identify counterfeit bitcoins. In addition, the distributed ledger increases the safety of information and transaction, preventing the double-spending and the theft of money through hack attacks, because information is not collected in one single place. To sum up, Nakamoto created a system that:

- Enable direct transactions without the need of trusted third parties;
- Enable non-reversible transactions;
- Reduce credit cost in small casual transaction;
- Reduce transaction fees;
- Prevent double-spending.

Transaction definition

The transaction is a message composed by: the public address of the receiver, a cryptographic digital signature to prove the authenticity of transaction and, finally, the value of the transaction. Transactions are created and transmitted to the network by who send bitcoins.

To avoid the falsification of data in the transaction, each one is linked with a digital value through the hash function. This function provides to modify the hash value when there is also a little change in the data of transactions.

In addition, to protect sensitive information of the participants of the network, it is adopted the "Public-key cryptography" method. Each transaction has two different keys, one private, exclusive property of each participants, used to unlock the cryptocurrency fund; and the other public, like an e-mail address. These two keys allow to encrypt and decrypt the transaction.

The digital signature proves the authenticity of the transaction and it is made by encrypting the hash value of the data transferred with the sender's public key.

Transaction authentication

The other users of the network receive the message, use the sender's public key to decrypt the digital signature and then verify the authenticity of the transaction. Using the same hash function of the sender, they create a new hash function and check if the two values are the same: if it happens, they confirm the authenticity of the digital signature. After that, transactions are collected in an updated version of the database or ledger, called block.

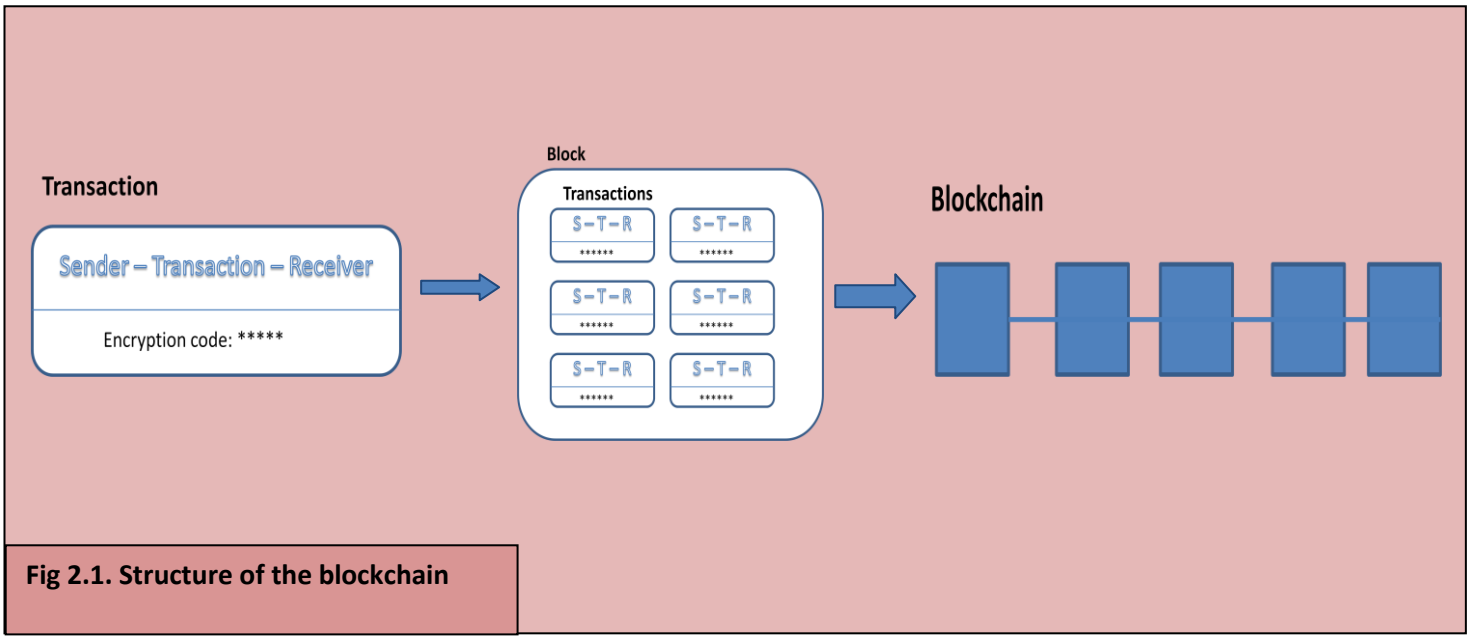

Fig 2.1. Structure of the blockchain

Block validation

Some nodes, designated for the validation phase, receive the block and start an iterative process of validation, called mining, that is a consensus algorithm which validate transactions only if the 51 % of the network approves the authenticity.

Each node of the network can be a validator node, it has to offer its CPU power to solve the Hashcash algorithm to validate transactions. Validator nodes are called miners and are rewarded with an amount of bitcoins if they succeed in the validation phase. The mechanism of validation is called Proof of Work (PoW) and consists on an iterative process which stops when the miner obtain a designated value. In detail, miners calculate a hash value by adding any given value to the collection of data arrived to them, and the process continues, adding other values to the transaction until the final hash value is smaller than the original. When a node succeed in the PoW, it transmits the block to the other nodes, and they have to confirm the correctness of the value and approve the transactions constituting the block.

Block chaining

If all transactions are validated, the new block is attached to the blockchain, and the blockchain is transmitted to the whole network.

The blockchain collects all transactions in a timely order, thanks to a timestamp, and each block contains also the hash value of the previous block, and information of transactions included in the actual block. However, if multiple nodes success simultaneously in PoW, two different blocks appear in the same time in the chain, creating a fork. In this case, the chain that becomes longer is considered authentic, generally a chain is considered authentic when six new blocks are added.

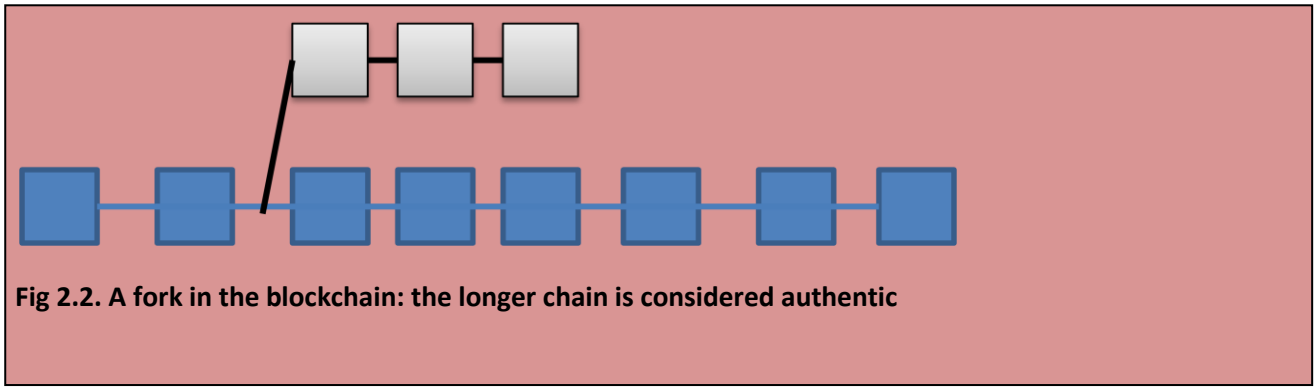

Fig 2.2. A fork in the blockchain: the longer chain is considered authentic

Problems of Blockchain

Although the Bitcoin platform and blockchain brought a new way to transfer digital assets, there are also some defects and problems: here are presented the most impactful.

Firstly, an important problem is related to the time of finality and the accuracy of the timestamp. Finality is the process of finalization, so, the process of approval of an authentic transaction. The time to complete this process could be from 10 to 60 minutes, in particular when there is the need to establish the authentic chain in the case of fork; this can reduce the possibility to apply blockchain in businesses that require responsiveness.

Then, there is the problem of the date and time accuracy of transactions recorded. In fact, the timestamp indicates the moment of creation of the new block, not the moment in which transaction begins. Thus, this time can depend on timing of the creation of previous blocks, or on timing of responses from the other nodes.

Furthermore, one block is created in 10 minutes, and the transactions processed per second are from 5 to 7, that is a very small frequency which can limit the future scalability of the solution. Indeed, for example, Visa system has a frequency of processing of 3600 transactions per second on average, and can reach a peak of 65 000 transactions processed per second, a huge difference in performances, respect to those of the Bitcoin platform.

Another limitation of blockchain is in the application of the solution to small smart devices (IoT), which, probably, will dominate our world. Indeed, the blockchain contains all past data, so its usage requires substantial memory, but, it is difficult to store and download all this information in small devices with small memory.

In addition, the safety of the blockchain can represent a limit in its application in the industry. In the platform, there is not the possibility to eliminate from the network those nodes who want to make illegal operations on transactions, but the safety of blockchain is founded on the fact that a malicious node, to pursue its objectives, should own 51% of CPU power of the entire network.

Nevertheless, this safety mechanism is very expensive and resource-consuming: in 2013, it is estimated that PoW required even 0.15 million $ per day[1].

Another characteristic of blockchain that make it difficult to apply in business environment is the impossibility to correct and change data already recorded, so in all those sectors in which happens that some modifications on data already recorded need, blockchain limits these operations. Moreover, companies could be discouraged from applying blockchain because of the excessive disclosure of the information, they could be scared of information leaking by the other nodes or by the counterparty in the negotiation.

Finally, the fluctuations of transaction fees make them difficult to be predicted by companies and this may have also some effects in complicating the taxation procedure.

[1] http://www.bloomberg.com/news/articles/2013-04-12/virtual-bitcoin-mining-is-a-real-world-environmental-disaster

2.2 HISTORY OF BLOCKCHAIN

The Bitcoin platform, conceived by Nakamoto in 2008, started its activities in January 2009, when the first block, named Genesis, was created and the first mining activity took place. To discourage dishonest behaviour of participants, miners were rewarded with 50 BTC for block; this quantity will be halved every 210 000 blocks validated, until reaching 21 million BTC. In the October of the same year, the platform performed an important step, "The New Liberty Standard" established the value of bitcoins: 1 309 BTC = 1 $. The equation was derived so as to include the cost of electricity to run the computer that created the bitcoins in the first place. Nevertheless, one main characteristic of bitcoin is its volatility, indeed, during these 10 years, often the cryptocurrency lost or gain 10% of its value in few minutes. For this reason, at the beginning, people were sceptic in using bitcoins, they did not understand the exchange ratio between cryptocurrency and real money.

In 2010, the value of bitcoin increased ten times and it was founded by Jed McCaleb, and the next year sold to Mark Karpeles, MtGox, which exchanged real money in bitcoins. Despite of these successes, Bitcoin lived a difficult period in which the value of the coin decreased a lot, because some weaknesses of the system appeared. In August, the worst event happened: an hack attack generated 184 billion bitcoins, thus, the system needed some hours to detect and erase the illegal transaction and to institute an updated corrected version of blockchain. Moreover, Bitcoin started to be perceived as a platform for illegal trade, indeed, the anonymity of transactions favoured the spread of illegal traffics. "Silk Road" was the biggest of these illegal market that used bitcoins to finalize transactions and it was closed by the US government only in 2014.

In spite of the difficulties, the platform is never been suspended and users have been increasing worldwide. In the February 2011, after a long time, the Bitcoin value reached the parity with the US dollar and the platform started to expand its business in other countries and in Europe. But after some months, in June, Bitcoin showed another time its weakness, and the most serious hacker attack was pursued: Allinvain, a Bitcoin forum founder, was the victim of a theft of 25 000 BTC (375 000 $). After this event, the value of the currency fall down from 17.5 $ to 0.01 $.

In 2013, the US Financial Crimes Enforcement Network (FINCEN) issued regulatory guidelines for "decentralised virtual currencies" and classified, for the first time, the bitcoin miners as Money Service Businesses (MSBs), that may be subjected to the registration and other legal obligations. In spite of its growth, until 2013, Bitcoin was seen as an alternative to traditional economy and a threat by banks and financial institutions; for this reason, governments and banks tried to oppose the usage of bitcoins and in some countries, like China, Bitcoin's usage was forbidden.

From 2014, et the end of the campaign against Silk Road and online black market, Bitcoin started to wash its image, and , concurrently, companies started to be interested in blockchain technology and its possible application beyond online payments. At this point, it is possible to differentiate the concept of Blockchain technology and Bitcoin platform, and companies started to be interested in the application of the blockchain technology. Thus, companies and start-ups, which

wanted to operate exploiting the advantages of blockchain technology in every industry, rose, reaching a number of 138 in 2016 and even 188 in 2017. Since 2012, over 650 equity deals to blockchain companies have totalled more than 2.1 billion $, with the highest annual growth dated back exactly in 2014, when deals grew of 180%.[2]

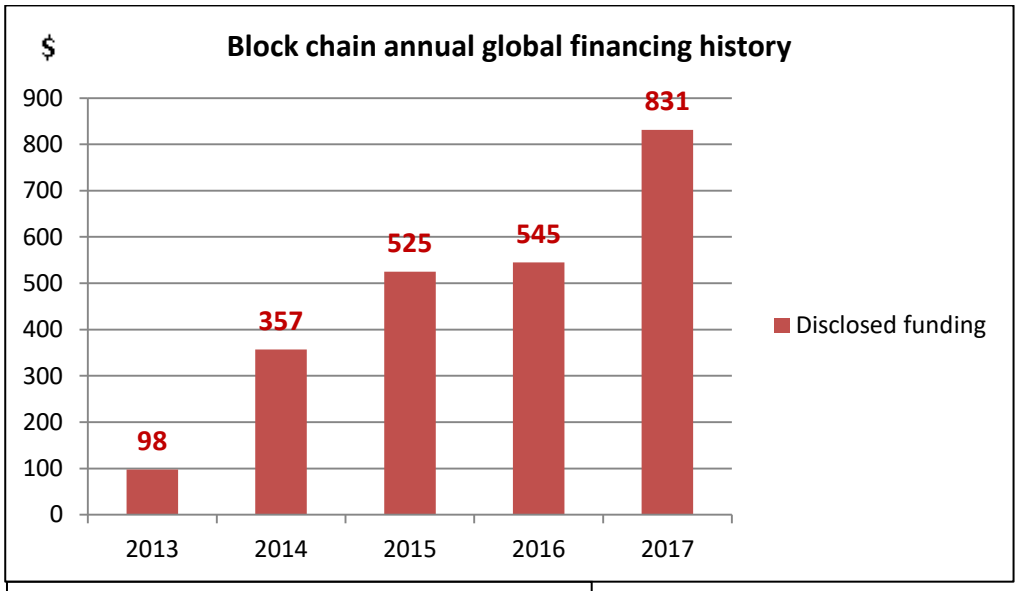

Fig. 2.3. The Blockchain annual funding

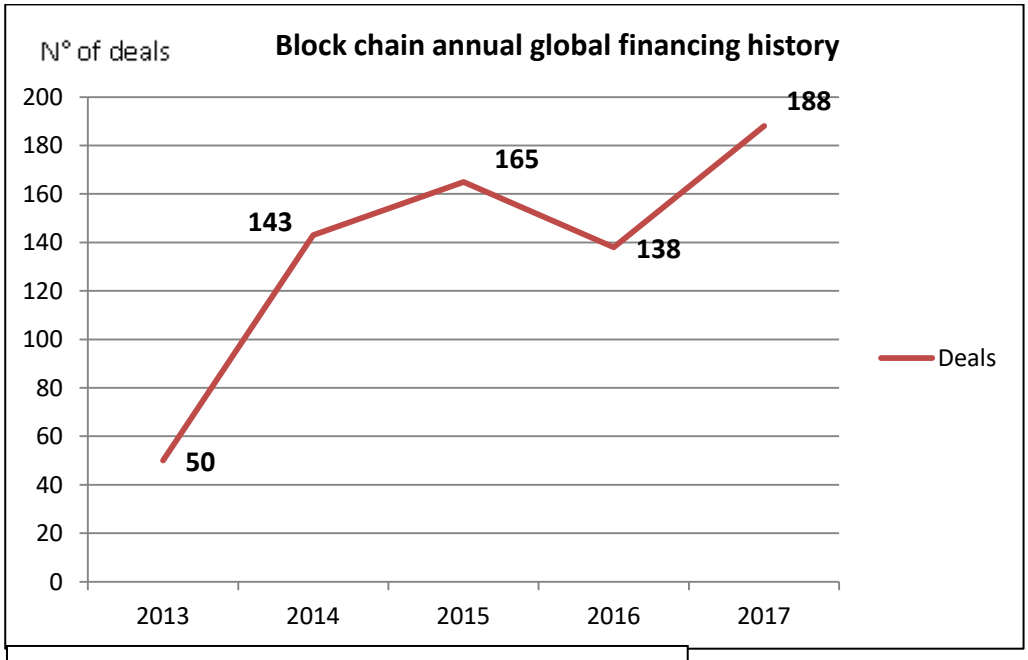

Fig. 2.4. The Blockchain annual number of deals

[2] Data taken by CB Insight, "*Blockchain investment trends in review*", (2017)

In the same year, the company Elliptic provides to bitcoin's users a storage service against the loss and thefts of digital currency and the English government eliminated the tax on bitcoin's transactions.

To sum up, since 2014, the interest in blockchain technology increases among experts of several industrial sectors. The non-reversibility, transparency and the new concept of decentralised trust are the main features technologists are interested in. Thus, blockchain technology become very attractive, in particular in tracking transactions of goods and services, in confirming the authenticity of documents, and finally in the realization of the smart contracts.

Improvements

In these 10 years, a lot of technological improvements took place; here the most important will be presented, but, before, it is reminded which are the main impactful problems:

- Pow is conducted for every 10 minutes in Bitcoin and the system is not suited to data processing that requires promptness;
- The capacity of each block is approximately 1 MB, falling short of being able to process a large volume of transactions;
- The Bitcoin blockchain requires enormous machine power and its energy efficiency is low;
- Exclusive use of machine power larger than 50% of the total of all network participants cause a risk of control of the blockchain.

To reduce the effects of these problems, new consensus algorithms have been developed: Proof of Stake, Proof of Importance and Practical Byzantine Fault Tolerance.

Proof of Stake (PoS) is a method that assigns priority in hash calculations in accordance of the holding ratio of virtual currency or randomly or on the base of the coin age. Validator nodes are required to put "at stake" a predefined amount of digital asset betting on consensus process outcome. This is based on the idea that a dishonest act committed by a node holding a large amount of virtual currency results in reducing the reliability and value of the currency and this fact works as an incentive for any participant to avoid dishonest act, malicious nodes that do not follow the protocol lose assets.

Proof of Importance (PoI) is a method that, on the basis of transaction amount and balances of individual nodes, creates clusters through transaction graph analysis, and then, assigns priority in hash calculation to more significant nodes.

The Practical Byzantine Fault Tolerance (PBFT) is an algorithm for solving a Byzantine Fault resulting from a failure in building a consensus caused by the Byzantine Generals Problem. However, the total number of nodes must be known and the maximum number of illegal nodes should be set, and such requirements make it difficult to apply this algorithm to public system.

Nevertheless, the adoption of new consensus algorithm is not enough to solve all the issues inside the Bitcoin platform; so, other practices are carried on. Firstly, to assure the accuracy of date and

time of transaction, there could be collected statistically time records, beyond this, some private-type blockchains were born to limit the participation in the network. Private or permissioned blockchains are networks in which the access is restricted to known participants. The advantages of permissioned blockchains respect to the unpermissioned ones, like Bitcoin, are to enhance reliability of participants so as to adopt a simplified version of the algorithm, that does not require a reward for building a consensus. Permissioned blockchain networks are generally preferred by the company, because they can control more careful the disclosure of the information and because the participants are reliable and identifiable.

Finally, some companies operating in the blockchain affirm that they can also design a script that allows to modify data of preceding blocks, in case of a failure in building a consensus due to the entry of a program by a specific script .

2.3 BLOCKCHAIN TECHNOLOGY ECOSYSTEM

In the previous part it was explained how blockchain technology starts to be used for solving challenges and improve efficiency in different sectors, beyond the online cash transactions. Here there is a brief presentation of the main players of the blockchain technology ecosystem, and, in Table 2, there is a classification of the platforms according to the consensus algorithm and the provided services.[3]

	Record transaction of value information	**Record transaction of property rights or rights to enjoy service**	**Registration of processes and contracts**
PoW	Bitcoin (Abra, Openbazzar, Everledger, Ascribe, BitHealth, Filament...) Altcoin (Litecoin, Monacoin...)	Counterparty (Swarm, Getgems, Storj...) Coloured Coins (Swarm, Colu, Votosocial) Omni	Sidechain (Liquid)
Improvement of consensus algorithm	Nxt (Voxelnauts) Orb Peercoin Ripple Stellar	Nem Bitshares mijin	Ethereum (Augur, Filament...) Monax (Everledger)

Table 2.2. Classification of the blockchain platforms according to the consensus algorithm adopted

Bitcoin platform and other alternative coin providers consent to record movements of digital coins or value information; however, there are various applications like Abra (remittance to Islamic country), Openbazzar (marketplace), and Everledger (proof of ownership) which provides different services, but, that use the Bitcoin blockchain too.

Furthermore, an extension of the platform's services is provided by the technology of Coloured Coins. Coloured Coins allow to fill bitcoins with asset information and to move these information between participants; unusual fields in which Coloured Coins can be used are proof of ownership of goods (Colu), cloud funding (Swarm) and electronic voting (Votosocial).

A more complex application founded on Bitcoin blockchain is Counterparty, that enables users to create their own currency and their virtual assets within the Bitcoin blockchain, indeed, Counterparty pays a fee to Bitcoin miners to record transactions.

Moreover, Counterparty offers the possibility to exploit cloud funding services (Swarm), messaging services (Getgems), cloud storage services (Storj), compensations released if users accept to leave

[3] Table taken by Nomura Research Institute, "*Survey on blockchain technologies and related services*", (2016)

part of their computational power for medical and scientific projects (FoldingCoin), items traded within online games (Spells of Genesis), the possibility to invest in US real estate (RealEst. Coin), and, finally, the possibility to sign Smart contracts.

The original coin of Counterparty is called XCP, and it was issued using a method called “proof of burn”, which derives its name by the process of creation of XCP. In fact, they have been created by destroying (“burning”) bitcoins: users had to send their bitcoins to an unspendable address that change them into the new currency. Using the “proof of burn”, the Counterparty developers decided to put themselves in the same position as every user, in the hope of eventually benefiting from their work.

In Counterparty, every user can access to four wallets that preserve security of the funds: indeed, private keys are no stored on the server, and all information sent to the servers are encrypted, and every movement made in a working session is erased when the user exits. The wallets enable users to: create and manage new tokens on the Bitcoin blockchain, distribute profits in any currency, trade, create and manage multi-signature address, store tokens online and broadcast data feeds to the Bitcoin network.

After the implementation of different blockchains with different cryptocurrencies, a technological solution to exchange digital coin between different blockchains has been developed, whose name is Sidechain. A Sidechain is a blockchain that validates data from other blockchains and enables movements of bitcoins and assets between different blockchains. Sidechain improves performance and privacy protection of the blockchain, and, in addition, it enables new extension to support myriad asset classes, like stocks, bond, derivatives, real or virtual world currencies, as well as to add capabilities like smart contracts, secure handles and real-world property registries. In Sidechain, the hard part is securing transfers of coin, so, the receiving chain must see that the coins on the sending chain are correctly locked. One of the most important Sidechain is Liquid, the commercial Sidechain developed by Blockstream company and other important partners like Bitfinex, Bitcoin China, Kraken, Unocoin and Xapo.

On the other side, there are a lot of other blockchain applications which do not use PoW algorithm but adopt PoS or other algorithms developed by themselves. NxT, Peercoin and Orbs adopt PoS consensus algorithm and make transactions of digital currencies, while, other applications like Ripple and Stellar execute the same function but in a permissioned blockchain. Finally, Ethereum and Monax offer the possibility to develop smart contracts.

Ethereum was created in 2014 by Vitalik Buterin, a programmer involved in Bitcoin, which argued that Bitcoin did not give the possibility to develop applications. Ethereum was born through a public online crowd funding, in which participants bought ethers (Ethereum cryptocurrency) exchanging with bitcoins. An important difference respect Bitcoin is in the consensus algorithm adopted: the PoS rather than PoW, then, Ethereum gives users the possibility to develop applications and, in particular, the platform defines a simple way to create smart contracts. Smart contracts are stored publicly on every node of the blockchain and run on the Ethereum Virtual

Machine (EVM). Smart contracts runs exactly as programmed without any possibility of downtime, censorship, fraud or third party interference.

The other platform, Monax, was born in 2014 and its name was originally Eris, then it was changed in 2016. The platform offers users the possibility to develop their blockchains and smart contract applications as Ethereum, and, indeed, Monax gives the possibility to its users to run smart contracts in the Ethereum Virtual Machine. Monax was designed to support multiple blockchains connected to different networks with different smart contracts' interpreters, through the application "Monax command-line interface", which provides tools and services to simplify the building, testing and running phase of the application developed by users. Moreover, Monax offers also some Software Development Kits, that help users in developing their smart contract applications, giving them the possibility to run the Ethereum Virtual Machine in the Monax permissioned blockchain.

2.4 APPLICATION FIELDS

Finance

In a standard inter-bank funds transfer if the sending and the receiving banks do not have a reciprocal account, they have to rely on an intermediary. Payment workflow, from execution to settlement, takes days, and fees have to be paid to the intermediaries: so, blockchain can be adopted as a ledger for payments between banks belonging to the same group, every bank could be a permissioned blockchain network. This solution would result, first of all, in a reconciliation between different databases, then, in an elimination of the usage of intermediaries and the related fees; basically, the blockchain access would be granted only to regulators and auditors. Furthermore, a permissioned blockchain could be created among banks belonging to different groups, but, this solution can become more attractive only if a larger number of banks participate on the network.

Ripple was born in 2012 with the objective of using the block chain technology peculiarities in the exchange of money between banks and financial institutions worldwide. The company partnered with important venture capital firms like: Accenture, Google Ventures, Santander InnoVentures, Standard Chartered, etc...

The digital asset for completing payments in Ripple is XRP, which is faster and more scalable than Bitcoin and Ether, allowing 1500 transactions per second. Ripple's technology provides real-time messaging services, and, clearing and settlement of financial transactions to its clients.

The network of banks and financial institutions using Ripple from RippleNet. RippleNet supports the activities of participants of the network with three products: Process payment through "xCurrent", Source liquidity through "xRapid" and Originate payments through "xVia". XCurrent is a standardized technology enabling banks to message and settle transactions among them with increased speed, transparency and efficiency. XRapid is an access to an on-demand liquidity fund of digital assets that eliminates the need to have accounts in destination currencies. Finally, xVia is a web service providing the ability to securely originate real-time payments with rich data attachments.

Funding

Using blockchain technology, Startups could raise money creating digital tokens and selling them in an initial coin offering (ICO). One advantage of the coin system for venture capitalists is that it doesn't stop their money for years, and then, investors can complete acquisitions quickly and without intermediaries.

Swarm is a new platform (its white paper is been written in 2017), which represents a decentralised capital marketplace. Crypto-equity is a new form of sharing that simplifies this process. Organisations installed on the Swarm platform can create their tokens, prescribe their quantitative limits and issue them to participants. All tokens live in the Swarm wallet which is built on the block chain; when a participant likes an opportunity running on Swarm, they can collect funds together with others and invest as little or as much as they want to realize the project and see the opportunity grow. Participants can buy or sell these tokens whenever they want, and they decide how long to engage. The Swarm platform uses a three-tiered token model:

- *The Swarm token (SWM) is a utility token which gives access to the Swarm network. SWM lives on the Ethereum block chain and will be tradable on exchanges.*
- *The Swarm Utility Network token (SUN) is a security token which facilitates the many financial opportunities run by the Swarm syndication partners. It lives on a private block chain.*
- *The SRC20 token is an asset-backed token. It represents the ownership of real assets and can also be traded on the internal Swarm Network exchange.*

Participants can also consult the Swarm reputation model which is based on the historical performance of members of the network. Finally, a small percentage of the money goes to the Swarm platform (a non profit organisation) for maintenance and upgrading purposes. Swarm platform accepts Ether, and BTC only through Bitcoin Suisse.

Communication

Messaging services and social networking services (SNS) have been made available using blockchain. These services are sometimes used in combination with a payment service or a reward service.

Getgems is an instant messaging app that provides messaging services together with the possibility to have a wallet of Bitcoin and GemZ and exchange them with the other participants of the network. Because of its nature, Getgems is perfect for businessmen that can use only one application to support relationships with other companies or investors.

The application was born in 2014 through a crowd funding of tokens raised up by 1251 members of the Bitcoin community with an amount of the initial funding of 780 000 $. The application exists both on the Android version and iOS one, and, as said, allows the movement of tokens between users; in addition, there is also the web browser version of the app. Getgems is created on the Telegram platform, while Gemz is the own virtual coin of Getgems and was created on the Counterparty platform, operating on the Bitcoin block chain.

Asset management

In the second half of 2013, blockchain technology starts to be used to register physical assets, giving the possibility to use the public ledger to store and validate documents, instead of rely on a central authority. In fact, a user can store the signature and the timestamp associated with a document in the blockchain, and validate it at any point using blockchain mechanisms. To register ownership of an asset, a transaction is created with a reference on the physical asset, moreover, the information is stored on a blockchain record and the owner of private key is then registered as the owner of that asset.

Factom is working in using blockchain technology to lock in data, making them verifiable and auditable. Factom can control and validate protocols instead of the clients, so companies will have an easy look of the information needed .

Factom registers transactions on blockchain following four steps:

1. *Application owner purchases Entry credits with Factoid, the Factom virtual currency;*
2. *Application records an Entry;*
3. *Factom servers create Entry Blocks and Directory Blocks;*
4. *Factom secures an anchor (hash of the Directory Block) on the blockchain.*

Factom divides roles of Bitcoin miners: recording Entries in a final order and auditing Entries for validity. The Factom servers accept Entries, assemble them into blocks and fix their orders; after 10 minutes, the Entry ordering is made irreversible by inserting an anchor into the Bitcoin blockchain. The auditing of Entry is a separate process which can be done either with or without trust. With trust, an auditor verifies the Entry was valid, the auditor submits its own crypto signature, that shows the Entry passed all the checks and the audit requirements will be part of a Factom chain. On the other side, trustless auditing is similar to Bitcoin mining.

Entries are validated client-side by users and applications, and those that do not follow the rules or that do not meet the requirements of the specified enforced sequence can be disregarded by the application and rejected. However, Entries that might be rejected by the rules or the audit program will still be recorded. Users of such chains will need to run the audit program to validate a chain sequence of this type.

Furthermore, the Factom system consists of a four-tier architecture designed to both produce verified chains of information and secure data within the blockchain.

1. *Directory layer*
   It defines which Entry chain ID have been updated during the time period covered by a directory block. Factom servers collect Merkle roots of entry blocks and package them into a directory block, this process is called anchoring. Ten successive Directory Blocks are hashed via a Merkle tree, and the Merkle root is recorded into the Bitcoin blockchain.

2. *Entry-block layer*
   Entry blocks are the second level of hierarchy in the system. Individual applications will pay attention to various chain IDs. Entry blocks are the place where an application looking for entries, can expand its search from a chain ID to discover all possibly relevant entries. The Entry Blocks intentionally contain hashes of individual Entries and not the Entries themselves. This allows the Entry Blocks to be much smaller than if all data was grouped together, and, separating the Entries from the Entry Blocks also allows for easier auditing of auditors.

3. *Entries*
   Entries are constructed by users and submitted to Factom. By hashing or encoding information, the user can ensure the privacy of entries.

4. *Chains*
   Chains in Factom are sequences of Entries that reflects the events relevant to an application. Chains document these event sequences and provide an audit trail recording that an event sequence occurred. In addition, cryptographic signatures would be proof they originated from a known source. Chains are logical interpretations of data placed inside directory blocks and entry blocks. The Directory Blocks indicate which chains are updated, and the Entry Blocks indicate which entries have been added to the chain.

Storage

Data are encrypted and stored on a P2P network, and therefore, these cannot be accessed by third parties, providing a storage service with few defects.

Storj is a protocol of a distributed network for the formation and execution of storage contracts between peers, developed in 2016. Files are encrypted client-side before they are stored on the network, so, the owner retains the complete control over the encryption key and, thus, over the access on data. Storj is built on Kademlia, a distributed hash table (DHT).

A DHT is a class of decentralised distributed systems where every node is identified with an ID number, that is useful for the identification of the node and to find stored values.

Data storage is negotiated via a standard contract format. The contract is a versioned data structure that describes the relationship between data owner and who stores data. Contracts contain all information necessary for each node to form a relationship, transfer data and arbitrate payments. Storj does not require a specific payment system, the official currency is Storjcoin, but, it is admitted also BTC, Ether and other virtual currencies.

Public

It is complicated to realize public services on blockchains, such as budget management, voting, notification management, provision of social security of local governments. Nevertheless, there are some trials: in London, during the mayoral election, one candidate ran a race promising to introduce the use of a blockchain for budget management. Furthermore, Estonia, Honduras and other countries show interest in adopting blockchain in the public system.

Estonian blockchain

Estonia provides a distributed and unalterable ledger of information with public keys which can be combined with a private key to effectively encrypt messages and authenticate digital signatures. For companies, in a country with just 1.3 million people, blockchain offers a way to more easily become global.

The customer need to know neither that they are trading in coloured coins, nor that their ID card login uses hash-function cryptography. In this sense, a blockchain acts as a silent, more efficient workhorse behind a solution that looks familiar: a mobile payments app, an online crowd founding and trading platform, or a login portal. Extent of regulation is a key issue for the Estonian authorities: they understand that hesitation and indecision can be as damaging to innovation as harshness.

At the beginning of last year, LHV bank, the largest independent Estonian bank, became the first bank to experiment with programmable money when it issued 100 000 euro worth of cryptographically-protected certificates of deposits. The experiment followed the establishment of a new LHV subsidiary, Cuber Technology, focused exclusively on Bitcoin-based digital securities. Cuber's work comprehends two sections: Cuber securities and the Cuber wallet. Cuber securities are simply bank certificates of deposits recorded in the Bitcoin blockchain. They are denominated in Euros, may pay interest and are suitable for various purposes. Cuber wallet is the first demonstration of Cuber usefulness. It is a piece of software for mobile phones, enabling instant and free peer-to-peer euro transactions, and low cost instant payments for merchants and consumers, using underlying Cuber securities. Users store their private keys on their smartphone to enhance security and mobility. To protect against server compromises, Cuber wallet decentralises trust from the server and makes the users themselves the Bitcoin clients. The app uses SPV (Simplified Payment Verification), a type of thin client security, which means the user has never a complete copy of every block in the chain, but, they download a smaller amount of data, the blockheaders, which link transactions to a place in the chain. This allows them to see that a network node has accepted the transaction, while blocks added after it further confirm that the network has accepted it. LHV is currently testing it in a few physical locations, but anticipates wider utility in online business, particularly for small payments. The use of the fiat currency undoubtedly makes the app more user friendly. The user and the merchant do not and should not see that Cuber uses Bitcoin. Cuber's open source code and application program interface are available to third

parties online, inviting other cryptocurrencies exchanges and developers to penetrate into the technology. Both LHV and its partner, ChromaWay, prefer to drive usable innovation with smaller software developers and start-ups, rather than large banks.

In addition, Funderbeam, a reputed business intelligence platform for investors, found a blockchain-based investment marketplace, to buy and sell coloured coin shares in start-up syndicates. What differentiates Funderbeam from the crowd funding alternatives is the issuance of coloured coins represented syndicate members' shares, which can be instantly bought, sold, or traded with other investors. By being decentralised and unalterable, blockchain can create more transparency in the equity market, without compromising anyone's privacy.

Since 2013, Estonian government registers have used Guardtime to authenticate the data in its databases. Their Keyless Signature Infrastructure (KSI) pairs cryptographic hash functions with a distributed ledger, allowing the Estonian government to guarantee a record of the state of any component within the network and data stores. Using their ID card, citizens order prescriptions, vote, bank online, review their children's school records, apply for state benefits, file their tax return, submit planning applications, upload their will, apply to serve in the armed forces, and fulfil around 3000 other functions. Entrepreneurs use their ID card to file their annual reports, issue shareholder documents, apply for licenses, etc.. Government officials use their ID card to encrypt documents for secure communication, review and approve permits, contracts and applications, and submit information requests to law enforcement agencies. With the blockchain, citizens can see who reviewed their data and any alteration to their personal data must be authorised. Moreover, through using hash functions, as opposed by asymmetric cryptography used in most PKI (Public Key Infrastructure), KSI cannot be broken by quantum algorithms. It is also so scalable that it can sign an exabyte of data per second using negligible computational and network expense. It removes the need of trusted authority, its signed data can be verified across geographies, and it never compromises privacy because it does not consume customer data.

2.5 BLOCKCHAIN REGULATION

One of the main obstacle for the scalability of the blockchain technology is the regulation of the transactions. In fact, governments have not make any intervention yet, to write a legal code for bock chain transactions; so, despite the clear potential of the application of this technology, blockchain is seen sometimes as something outside the traditional channels to move cash, assets and information and, for this reason, it is perceived risky and not totally reliable by companies. Indeed, Blockchain was born as an alternative respect to the current financial system, but, to exploit the potential of the technology, it is necessary to include it in the financial system, establishing standard rules that make blockchain transactions a relevant way to conclude business. Governments should begin to regulate blockchain transactions, cutting in this way any remain connections with the illegal market.

However, since its birth, blockchain was regulated through a technical code, intrinsic to the system, where all the activities which broke the rules were not allowed by the system, that return an error message. Each participant of the network is submitted to the same code, because they use the same software; in addition, to assure that data are not modified by nodes, every transaction is verified through a verification process that use a consensus algorithm, created by the developers of the platform. The integrity of the system is based on the distributed consensus: only transactions verified by the majority of nodes are attached to the blockchain, so, for an illegal entity it is necessary to collect more CPU power than the sum of all the honest nodes own. Despite the difficulty, theoretically, a malicious node who owns the majority of computational power, can pursue illegal activities within the system, without the possibility for the system to stop it or remove it from the network; thus, to prevent dishonest behaviours and assure the integrity of the system, a set of economic incentives are put in place for honest nodes.

On the other side, the current financial system is regulated both via technical code and legal code. Creation and modification of the digital records of the legal obligations between institutions is governed by technical code, while, legal code ensures that participants in the network are compliant with law. Legal code is controlled by financial regulators, who collect information by participants; furthermore, private financial networks, like Visa, have their private rules, fixed by their governance which have to regulate financial transactions.

The permissioned blockchain network is a solution closest to conventional private financial network. In this type of network, one node has the authority to preserve the integrity of the system and to control the respect of the rules by participants: this node is the “proprietor” of the permissioned network. The proprietor has legal and technical authority over the code, it determines how the code is modified.

In conclusion, legal regulation of blockchain technology will be not only a benefit for stakeholders, but there are also social interests: governments could collect taxes, limit the use of distributed ledger for criminal purposes, and exploit in this way the effects of the technology in society, aiming at creating a system resilient against systemic risks and market failures. Permissioned distributed network are easier to regulate because it is sufficient to impose legal obligations on its proprietor, while unpermissioned distributed network are more difficult because it is impossible to identify a legal entity in charge of the system. Thus, the opportunity could be to regulate the activity made on the open platform, such as exchanges and wallet providers. An example is the BitLicense, issued by the New York State Department of Financial Services.

In addition, a technical code could be issued by a government research-project, as happened for some internet protocols like TCP/IP, this allows governments to attain legitimate regulatory goals by influencing the rules built into the computer code. Alternatively, the public sector could develop a permissioned system that allows public regulatory influence to be exerted through a combination of legal and technical code, rather than exclusively through legal code. Some of the core internet technologies have shown that it is possible for governments to successfully catalyse the creation of technical code that has become foundational to private sector activity.

3. BLOCKCHAIN FOR SUPPLY CHAIN MANAGEMENT

The objective of the introduction was to give an overview of the characteristics of Blockchain, focusing on what it is the Blockchain and how it works. In addition, it has been showed which are, in these ten years' history of Bitcoin, the most important events and the impact they had in the reputation of the technology at the eyes of the economic and business world. Thus, in these ten years, there was an evolution of the opinion of business world towards the blockchain technology and the interest in its potential uses rose up vertically. In the meanwhile, there were developed some innovations in technology to modify those aspects that were a limitations to the scalability of the blockchain.

The Blockchain ecosystem is composed by the Bitcoin Blockchain, exploited not only by the Bitcoin network, but also by platforms such as Counterparty, and other blockchains such as Ethereum and Monax. On these platforms the whole amount of different applications, which use blockchain technology with different purposes in different industrial sectors, are developed. Finally, in the introduction, there was a focus on the need to regulate blockchain transactions to make the technology more attractive and reliable for companies.

Now, it is the time to introduce the real cornerstone of the study: how the Blockchain technology could improve performances in Supply Chain Management? Which are the direct and indirect effects of the use of Blockchain technology in tracking materials along the Supply Chain? To understand the opportunities offered by the use of the technology, first of all, it is necessary to list and explain which are the different processes along the Supply Chain and which are the techniques and methods used nowadays by companies to accomplish different tasks.

Then, it is important to analyse the cases in which Blockchain technology is already developed to improve the Supply Chain, and so, understand which are the areas of impact of these solutions.

Finally, it is possible to analyse the existent gap between what the actual business scenario asks, which is the immediate need of the actual Supply Chain Management Science, and what the development of blockchain technology in Supply Chain Management offers.

3.1 ANALYSIS OF THE ACTUAL PRACTICES

Nowadays, technological innovations grow so quickly that companies can no more rely only in internal resources to design and develop new products, but, they have to focus their efforts in what they do best and outsource remaining activities, relying in a network of business relationships.

Thus, the importance of Supply Chain Management has increased a lot, because the contribution suppliers and distributors is giving in the creation of value for the final product, and therefore for the company, has increased in last years. In fact, it is estimated that supply chain creates the 80% of value of the final product on average, and, in some sectors, this percentage is even higher.

In this scenario, it emerges the concept of extended enterprise, which is the totality of the players (suppliers, manufacturing plants, distributors, retailers, etc...) that concur to the creation of the final product. Thus, the competition is changed, and now, is not a company vs company game, but it is a supply chain vs supply chain one; so, the extended enterprise has to be managed as a unique company, and the integration of all nodes becomes fundamental to achieve company's objectives.

Supply chain management is "the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole" (Christopher, 1998).

Since few years, supply chain management has to face an important challenge: the increasing attention for environmental sustainability and social responsibility. Thus, the corporate social responsibility is something companies cannot postpone and the objective for organizations is now a sustainable development. Sustainable development is a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commision, 1987). Consequently, a sustainable supply chain management consists on "strategic, transparent integration and achievement of an organization's social, systemic coordination of key inter-organizational business processes for improving the environmental and economic goals in the long-term economic performance of individual company and its supply chain" (Carter and Rogers, 2008).

Thus, there will be showed, for each business function or activity under the responsibility of Supply Chain Management, the historical and classical practices, and how these are changing, thanks to new technologies, to fulfil customer requirements, also in terms of sustainability and social responsibility performances. In particular, there will be presented one at a time the activities of sourcing, planning, distribution, production and new product development (NPD); after that, there will be introduced the concept of Industry 4.0, which is the scenario in which the Blockchain technology will come into view.

3.1.1 Purchasing and Sourcing

Sourcing is "the process of searching markets for sources of goods and services identifying, selecting and developing suppliers" (Lysons and Farrington, 2012): for a company, working with a new supplier represents always a risk, because the company cannot be sure a supplier will perform according to the promises it made before. Consequently, companies use to involve, build up and maintain a base of approved and preferred suppliers.

Purchasing is "the process undertaken by the organisational unit that, either as a function or as part of an integrated supply chain, is responsible for procuring or assisting users to procure, in the most efficient manner, required suppliers at the right time, quality, quantity and price and the management of suppliers, thereby contributing to the competitive advantage of the enterprise and the achievement of its corporate strategy" (Lysons and Farrington, 2012). The purchasing department has to find suppliers through a process that includes different stages, beginning with an exploration of possible new suppliers; this process is called strategic sourcing.

The strategic sourcing is composed by three stages, presented in the Table 3.1.

Pre-selection	Selection	Choice of the preferred suppliers
It consists on supply market research made through the web or through consultant agencies, to find new potential suppliers outside the company's supply base. In the pre-selection phase, often, company's partners or other existing suppliers can be important resources of information. At the end of the process, the company attains the **list of potential suppliers**.	Potential suppliers are further evaluated, and those of them who pass the check are drawn up in the **list of approved suppliers**. In the future, the company will choose among suppliers in this list, to reduce the cost and risk involved in negotiating with an unknown supplier.	Among the approved suppliers, companies choose some with whom build a long term relationships that are called **preferred suppliers**. The company will invest in the approved and preferred suppliers to make them grow and to build a strong relationship with them; but, at the same time, the company evaluates and monitors the suppliers' performance to understand which are the weaknesses that have to be improved.

Table 3.1. Stages of the strategic sourcing

Traditionally, companies monitored suppliers on operational performances such as cost, quality, and delivery time, but, the extreme need of sustainable development forces companies to assess issues such as labour conditions and environmental risks. Many companies set a sustainability policy, in which are drawn up all the terms suppliers have to respect during the day by day activities to be conformant with the sustainable image that the company wants to maintain in front of its customers; moreover, companies starts to conduct audits to verify the behaviour of suppliers.

Despite recurring to approved or preferred suppliers is the favoured way to acquire goods, companies can have the necessity or can choose to recur to a new supplier. Basically, the reasons of this choice can be:

- The company wants to enter in a new market, or to design a new product, so it needs a supplier which can provide something different respect to the others;
- The company wants to innovate its product, so it chose to seek for a more innovative solution;
- The company wants to change its supplier to pursue cost-savings objectives, or to be nearer the plants, or the company decides to operate in another country and decides to have a local supplier pursuing political reasons.

The choice of looking for a new supplier results in a variation of the purchasing process, and so, it impacts in cost and time dedicated to the transaction. In 2010, Van Weele designed his "purchasing process model" made by six stages, the first half called "source-to-contract" and the second half called "procure-to-pay". The model represents a situation of a new purchase, so, in the cases in which a company chooses a supplier among its supply base, the process doesn't follow all the steps. The Van Weele model is composed by six phases:

1. Specifying;
2. Selecting;
3. Contracting;
4. Ordering;
5. Expediting;
6. Evaluating

Specifying

Specifying is the act of drawing the document which contains the specifications of the purchase needs. Specification is the reference document during the purchasing process, and if the supplier does not satisfy the specification, it has to repair to its error and eventually to pay penalties. Specifying is a fundamental stage because what company asks to suppliers has to be written in the document and has to be coherent with the strategy company wants to pursue and with its position in the market. Products acquired by the company has to permit the achievement of the performance promised to the final customer, so, as instance, a company which promise high quality has to make specifications coherently, looking for the most performing products and no for the cheapest ones.

The level of detail of the specification document is another important choice a company has to take, on the basis of the supplier with whom it has to confront, and on the basis of its knowledge of the technology. Sometimes, it is better to draw a detailed specification document that includes with no ambiguity what the company requires, using standard specifications and objective language. Detailed specifications are useful when the company wants to be sure that all the needs are fulfilled by suppliers, or, these are used in transactions with foreign suppliers, because the

company intends to monitor the behaviour suppliers adopt within the plant. On the other side, a too detailed specification document could limit the number of available suppliers, reducing the competition and favouring the counterparty in a future negotiation; moreover, detailed specifications limit the opportunity for suppliers to innovate.

While, when the company needs something it doesn't really know how it works and how it could be realised, so, when there is an important knowledge gap between the buyer and the supplier, the company won't draw detailed specifications because it could be in difficulty, but, it will use functional specifications. Functional specifications provide only an overall explanation of the needs of the company without indications on the production process suppliers have to follow; therefore, the supplier is free to choose the best way to satisfy company's needs. Contrary to detailed specifications, functional specifications encourage supplier innovation.

Selecting

The selecting process starts with supply market research to identify potential suppliers and then, the company invites suppliers through a Request For Information (RFI) and consequently, a Request For Quotation (RFQ).

The supply market research is the typical activity which is pursued only when the company is seeking for a new supplier; in fact, this process is a very time consuming and expensive. Thus, if the company doesn't need a new supplier, it avoids this cost, seeking in the list of approved suppliers.

The RFI process is a further stage to eliminate from the list of approved suppliers those with whom the company doesn't intend to work. The RFI is conducted through contacts and visits to suppliers plants.

The RFQ serves as the invitation to bid for suppliers and typically includes details like price and specifications. In addition, it is important that a RFQ contains: all the requirements of the company written in unambiguous language, because it is a legal document, the date and time by which suppliers must submit their quote, and some disclosure on selection criteria, to develop a collaborative relationship with suppliers.

Contracting

Contracts are essential to avoid risks of non-compliance; these include terms and conditions of payment and delivery that have to be respected during the relationship with a supplier. To assure that the terms of the contract are respected by both parties, a contract should include penalty clauses if anyone of the two parties do not respect the terms. In addition, a contract should contain also a specification on the liabilities in case of recalls or withdrawals of non-conformant products already sent to the distribution channels.

Drafting a contract is a task which requires effort and time, because the two parties have to align terms and conditions desired by both, in conformance with the local law. If customer and supplier

are in two different countries, usually, it is adopted the law of supplier's country, otherwise, the two parties can accordingly choose an international standard.

The complex relationship between buyer and supplier, the information asymmetries and the unforeseen contingencies need complex contracts to be regulated, but, some companies are discouraged by these types of contracts and, on the contrary, they prefer "framework agreements" or "umbrella contract" (Mouzas and Furmston, 2008). These types of contracts don't focused on the penalty clauses, but, they focus on the principles of the relationship between the parties. Framework agreements are more relevant in knowledge-intensive relationships, where there is the need of sharing knowledge and information.

Ordering and expediting

In some situations, the contract itself constitutes the order, otherwise, the contract provides the framework for frequent routine purchases. Ordering takes place through electronic systems that help to automate the process and reduce transaction costs. The order has to include: the order number, a brief description of the product or the service required, the unit price, the volume and the expected delivery time and place.

After that, the role of expediting is to secure the quality and timely delivery of goods. External or third-party expediters can help to track the process: they are in charge of inspection and notification about the progress of the order and any potential failure.

Evaluating

Evaluating concerns in the assessment of the performance of goods or services. If these do not respect the standard fixed in the contract, the company can ask for penalties, but, at the same time, it is advisable to provide awards to suppliers that exceed the performance agreed in the contract.

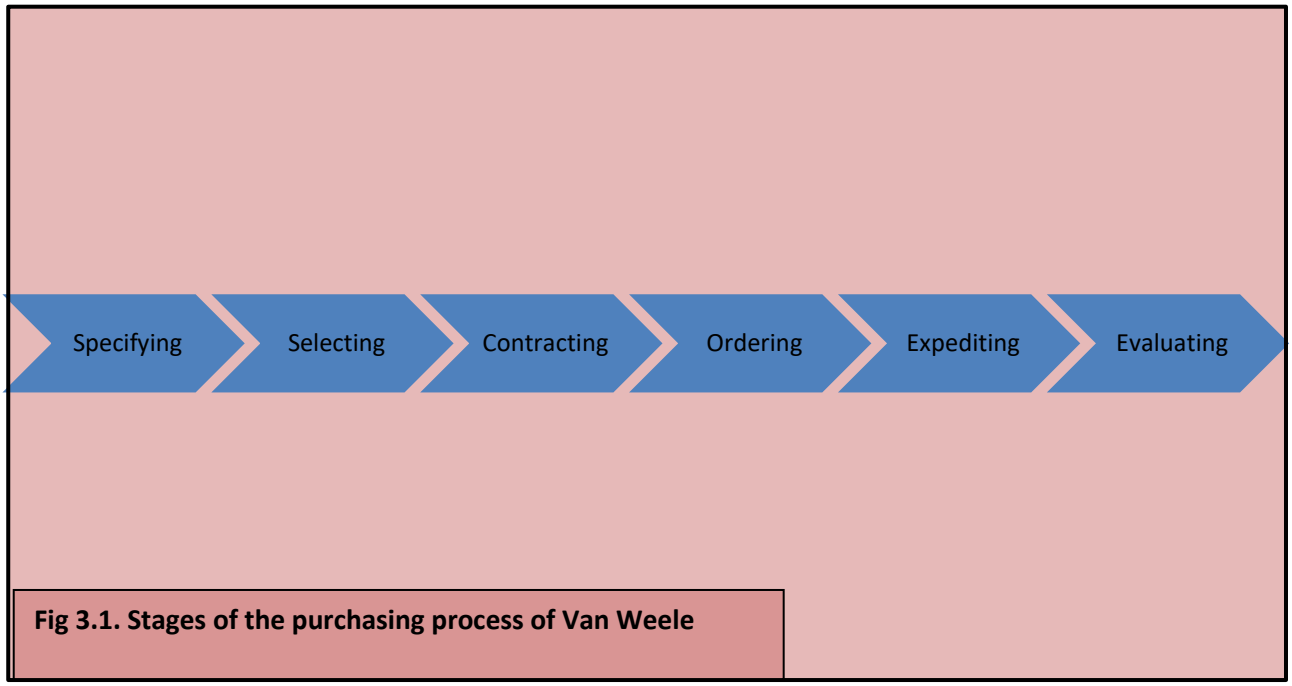

Fig 3.1. Stages of the purchasing process of Van Weele

Supplier partnership

Changes in purchasing and supply management practices have altered the way through which organizations manage supplier relationships. Nowadays, the focus is on developing and managing close long-term relationships; supplier relationships can be seen as an acquisition of supplier capabilities that are essential not only in the company's cost reduction efforts but also in its efforts to continuously improve its products and processes and to come up with innovations. The trend towards partnerships certainly indicates a growing interpretation of supplier relationships as relying on soft values, such as trust, commitment and mutuality.

Partnership could be defined as "an ongoing relationship between two firms that involves a commitment over an extended time period, and a mutual sharing of information and the risks and rewards of the relationship" (Ellram and Hendrick, 1995).

Basically, the identifiable features of a partnership between two companies are:

- Shared goals;
- Mutual benefit: mutuality concerns the extent to which a company is prepared to relinquish its own goals for the sake of a relationship, and implies common goals and interests that bind firms in a shared purpose;
- Long-term commitment;
- Trust and open sharing of information.

In particular the last attribute of a partnership, the trust, is difficult to define and its development takes long time. Suppliers have to demonstrate they are able to deliver according to the specified performance objectives, over a period of time. On the other side, to develop a trusty relationship with suppliers, customer has to:

- Increase two-way information sharing;
- Expand the scope of interaction;
- Create a context promoting mutual investment in the relationship;
- Develop a culture of respect for supplier capabilities;
- Maximize consistency and predictability of behaviour towards suppliers;
- Focus on making key suppliers successful.

Moreover, trust implies the absence of opportunistic behaviours of the parties, so, none of the two has to take advantage from any knowledge gap and supplier does not have to over-charge the customer.

Despite the advantages of a trusty relationship with suppliers, a survey reported in CPO Agenda (Hughes and Weiss, 2007) showed that only eight per cent of sourcing and procurement managers were 'extremely satisfied' by the value they realized through their key supplier relationships, and just under a third were quite satisfied. The customer companies do not capture sufficient value from their supplier relationships, because of a short-term focus, a lack of transparency, a lack of

commitment and respect for supplier expertise, a too rigid bidding processes and one-sided contracts.
The conclusion of a subsequent larger scale survey of more than 300 companies in North America, Europe and Asia-Pacific was that the tremendous value potential of supplier relationships was not exploited:

"Companies generally treat their most important suppliers in ways that are only marginally or intermittently different from the way they treat their arms-length commodity vendors. They may sporadically work with key suppliers to develop new technology or jointly analyze opportunities to improve supply chain efficiency, but they have not institutionalized new ways of working with these suppliers as partners rather than vendors."
(Hughes and Weiss, 2007)

Supplier assessment and development: monitoring and mentoring

Companies use supplier evaluation to identify areas where performance is below the expected level and issue penalties accordingly, then, if supplier performance doesn't improve, companies can decide to fire the supplier and choose another one.

Usually, companies evaluate supplier performances using a range of criteria, that include measurable performances such as quality, delivery price, service and flexibility, aspects of internal processes including for example defects, schedule realization and cost, and, finally, process-based evaluation methods.

Table 3.2 provides a summary of the supplier balanced scorecard of Hughes that shows different ways to measure supplier performance. The outcome measures are those that result from the supplier performance and, these are divided into strategic and financial value measures. The former focus on ways in which the supplier can contribute to critical value-adding activities of the company whereas the latter are measured in financial terms. The predictive, or process, measures are divided into operational and relationship quality measures: operational performance measures are all important but those that are critical are those that are aligned with overall business (and purchasing/supply strategy). The final dimension "Relationship quality" suggests a very different perspective as it focuses not on the performance of the supplier but on the performance of the relationship between the two parties.

Outcome measures		Predictive measures	
Strategic value	**Financial value**	**Operational performance**	**Relationship quality**
Contribution to product innovation Contribution to process innovation Reduction in supply risk Contribution to entering new markets Contribution to CSR goals Contribution to brand equity	TCO Price stability Cost avoidance Asset utilization ROA ROI Incremental revenue generated Incremental profits generated	Quality Delivery Flexibility Service level Administration processing	Level of trust Frequency and quality of communication Degree of mutual understanding Degree of strategic alignment Quality of joint problem solving and conflict Level of mutual commitment

Table 3.2. Huges's supplier balanced scorecard

Nevertheless, defining performance measures is not sufficient to improve performance, but, many times, the process of defining the measures and how you use these, are more important than the measures themselves. Measures could be defined jointly with suppliers and used collaboratively, showing the data with suppliers, so that suppliers know where they are. Thus, the results can be used to address the problem areas and to improve rather than simply penalize suppliers when performance is below the parameters. Supplier assessment should be used to identify areas of improvement and it is the prerequisite for successful implementation of supplier development programs.

Nowadays, to assess the relationship buyer-supplier, suppliers evaluate customers too. Thus, they issue evaluation surveys to the customers to highlight areas in which the customer should improve; in fact, often, it is due to the customer inefficiencies that supplier does not achieve the promised level of performance.

Make or buy analysis

The make or buy analysis is a strategic evaluation of the activities that should be made in-house and those that should be bought. The technology improvements in every sector increase the need for companies to acquire and exploit specific knowledge of suppliers, becoming in this way dependent from them; so, it is essential for a company to identify properly which are the external resources that can contribute to create a competitive advantage in the market.

There are three main theories which explore the internal and external dynamics of the firm related to make-or-buy decisions: Transaction Cost Economics, Resource-based View, Extended Resource-based View.

Oliver Williamson developed the Transaction Cost Economics (TCE) theory, which determines the choice of producing internally or outsource on the basis of the effect of the choice on the economical structure of a firm. The theory takes into consideration only the transactions between two companies, not the relationship, and considers transaction costs as unit of measure of the convenience to make or buy something. According to this theory, each firm has the objective to minimize transaction costs, and in this direction, it takes its decisions. Transaction cost is the cost incurred in making any economic exchange in addition to the acquisition cost; examples of transaction costs are: collecting market information, writing a contract and negotiating with the counterparty. However, transaction cost is not the only characteristic taken into account by the TCE theory to establish whether outsource the component or service, but the choice is related also to the asset specificity and the opportunism. The asset specificity measures how much the investment sustained to conclude a transaction is specifically related to that transaction, and on the contrary, how much of this investment can be re-used for other purposes. Then, opportunism describes the environment in which companies operate: companies in their strategic choice of make-or-buy have to take into account that each enterprise could try to deliberately act opportunistically to increase its profits. Transaction cost, asset specificity and opportunism are the three drivers in the TCE theory to establish if it is convenient to complete a transaction to acquire products or services or to look for internal alternatives.

The resource-based view theory (RBV) was proposed in 1980 and it focuses on the sources of "sustainable competitive advantage" of a company. The logic under the RBV is that the company's success is determined by the resources it owns and controls; so, every company should understand which are these resources and keep them within the company, while, all the others can be acquired by external suppliers. Following this theory, companies can optimize their efforts and resources in doing what they are able to perform better, focusing all their strengths, without losing efforts in other non-central activities that suppliers can accomplish easily; in this way, companies can improve their performances and increase their competitive advantage. However, on which are those resources, analysts had different opinions. One opinion is that the resources originating a sustainable competitive advantage have to be found between the activities pursued by the company and these are called "core-competences". A "core competence" has to be: valuable, rare, inimitable and not substitutable. A successive interpretation takes into consideration the dynamicity of the market environment, so, the "dynamic capabilities" theory considers also the evolution of the competences of a company and the resource which creates a sustainable competitive advantage is the ability to maintain and adapt core competences, integrating, building and reconfiguring the internal and external processes.

Nevertheless, the two interpretations of the RBV theory are focused internally and do not consider the firm as a part of a network of firms connected by relationships. Thus, the extended resource-based view (ERBV) theory reconsiders the role of a firm as a node in a network and looks for

sources of competitive advantage something that overcome the borders of the firm; so, relationships with other nodes of the network are the unique and difficult to imitate resources which consist on the real competitive advantage. After that, another interpretation, called Natural Resource-based View, focuses on the capability of a company to establish relationships with stakeholders developing politics of sustainability; in fact, according to this theory, this ability constitutes an important competitive advantage in the market.

To sum up, it is possible to note how different theories analyse different aspects and take into consideration different drivers to guide the make-or-buy decision. The natural consequence is that different theories could lead to different actions in the same scenario. The TCE theory suggests to maintain within the company those activities with an uncertain outcome, that occur with a higher frequency and that involve a high amount of specific investment. On the other hand, RBV theory focuses on the identification of strategic core competences to maintain them within the company, while the remaining activities have to be outsourced. Last, the ERBV theory focuses on the capability of a company to establish unique relationships with its strategic partners.

3.1.2 Planning

Supply chain planning consists on taking strategic, tactical and operational decisions along the supply chain, from the procurement to the distribution, to accomplish the objectives of the company. The main success for planning is fulfilling the demand to maximize revenues, and, at the same time, aligning the demand and supply to optimize costs.

Basically, the supply chain planning is a complex task, which concerns in managing different variables (level of stocks, make or buy decision, production capacity) to realise the operations and capacity plans. The planner, in his activity, starts from the information he owns about the forecasted demand, the positioning strategy of the company, and also, technical information concerning the realisation of physical products; and then, he plans all the different activities, considering constraints of production capacity, financial availability, geographical disposal and law obligations.

One of the first and most important choices is where to put the decoupling point. The decoupling point identifies the moment in which the forecasted demand meets the real demand; this moment corresponds with the location of inventory necessary to fulfil the demand. The position of the decoupling point impacts a lot on the performances of the supply chain, and this is strongly related with the strategy pursued by the company to reach the consumer, and with the image that the company wants to transmit to the external world. In particular, the position of the decoupling point affects the inventory level, the flexibility and the lead time of a company.

For some years, the success of Japanese automotive industries made popular the Lean manufacturing strategy, which consists in focusing on efficiency during all the production process, reducing in this way costs and wastes. Indeed, the goal of Lean thinking is to eliminate all sources of waste in the working environment, not only physical wastes such as excessive stocks or excessive scraps, but, the lean strategy focuses on a mental approach in which each worker tries

to reduce the waste of efforts and time, to be more productive. Moreover, another important concept of the lean thinking is the devotion to the continuous improvement idea, which aims at eliminating sources of wastes to redeploy the dedicated resources to more value-adding areas; moreover, this could be considered an approach that gives back centrality to humans work in the production process.

However, for what concerns supply chain, lean strategy focuses mainly on: Just In Time (JIT) inventory management strategy and the target of zero inventory. Actually, the two concepts are strongly linked, because excessive inventories are considered, according to lean perspective, unnecessary resources and avoidable costs, and JIT is the inventory management method that assures the reduction of inventory. The Just In Time approach suggests to place an order too close as possible to the delivery date, to reduce inventory costs and errors in forecasting demand, that would lead to unsold products.

Despite of the lean thinking, inventories are necessary in a company for several reasons. First of all, inventories allow a company to offer a better service level to customers, because they do not have to wait for satisfying their desire; then, inventories are fundamental to respond quickly to unexpected events that could cause stock outs and loss of sales. Moreover, despite the lean thinking, inventory keeping can also concur to the reduction of production and logistic costs; in fact, inventory can allow company to pursue strategies of collecting speculative stocks, or, in those markets characterised by seasonality, this allows to optimize the scheduling production over the entire year.

To manage the inventory replenishment, there are two traditional approaches: the requirements based, in which information is transmitted upstream the production chain and the first player push the material into the chain, and, then, the stock management approach, in which information goes upstream the chain one stage at a time and each player decides when issuing the order to its suppliers. There is not a preferable approach, but it depends on the scenario in which each company operates, so, the company chooses among these two different strategies, and in addition, it has to consider to use different inventory management strategies for different products. The stock management method is preferable when inventory keeping is risky, cheap and the inventory replenishment is easy, otherwise, it is preferable to adopt a requirements based approach.

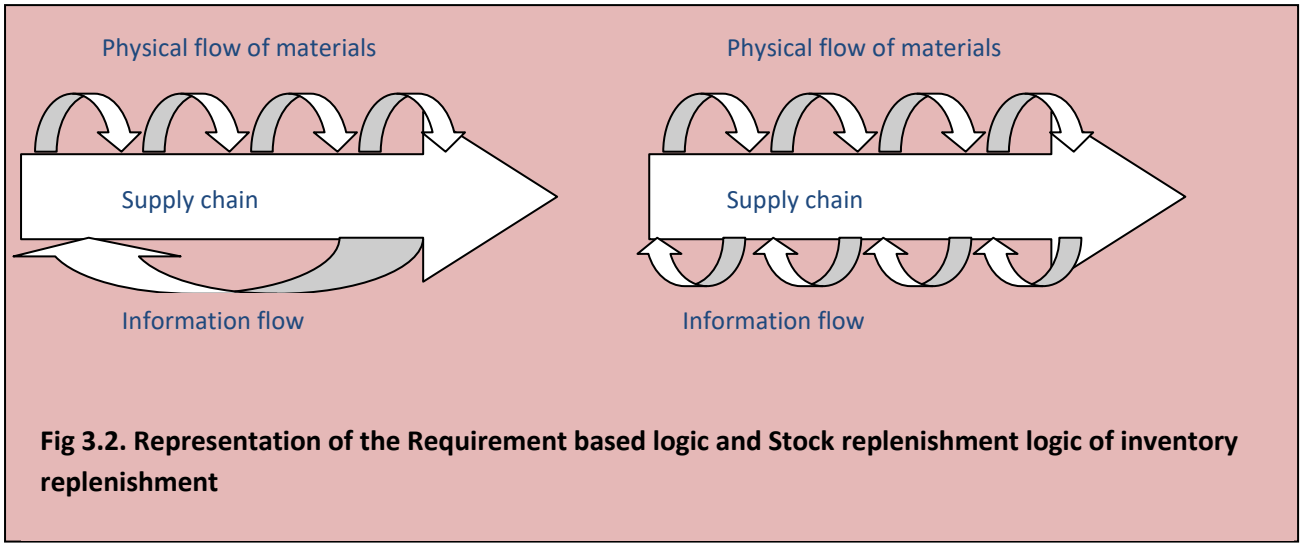

Fig 3.2. Representation of the Requirement based logic and Stock replenishment logic of inventory replenishment

Inventory management, choice of the position of the decoupling point, managing the workload of humans and machines, managing the distribution, managing the materials supply, are some of the activities that constitute supply chain planning; and to manage all these activities, since the '60s, supply chain planning is conducted with the support of a set of data processing functions which, relying on company databases, support decision making.

The first planning activity supported by IT was the material replenishment: a software was developed able to disaggregate the components of an item, and so, useful to support the purchase orders of all components, knowing the needed number of final products. Then, the distribution planning was supported by a software too, and in the '90s it was developed the ERP (enterprise resource planning) software, that allows companies to manage both the material replenishment and the distribution. The software is divided into modules, but, a small integration between them allows to avoid redundancy and duplication; moreover, the database is unique but shared by all modules, and independent processes are synchronized.

Although the ERP software improves during the years, the supply chain planning requires something more reactive and fast in updating plans, then, it needs more computational power to support an integrated plan of global supply chains, eliminating the department barriers. Thus, it is used a new tool, the Advanced Planning and Scheduling (APS). APS is a Decision Support System (DSS), capable to support complex supply chain planning tasks by simultaneously addressing materials and capacity planning, so as to optimally balance demand and supply. This is divided in modules too, as instance SAP is divided in four modules: planning, which includes the planning of all the supply chain stages, execution, which is focused on the management of the operations during the production process, co-ordination and, finally, collaboration.

The APS allows to create a virtual model of the real supply chain of a company acquiring data from ERP and, through some advanced algorithms, it is able to make simulations and give solutions on the basis of the planner choices, to show which are the effects of different choices on the supply chain of the company. The features of an APS are presented in Table 3.3.

	Procurement	Production	Distribution	Sales
Design	Strategic network design			
Planning	Master Planning			Demand Planning
	Materials Planning	Production Planning	Distribution Planning	
		Scheduling	Transport Planning	Demand fulfilment
Operations				

Table 3.3. Structure of an APS software

- Strategic Network Design: APS supports decisions on the location of production, on the capacity of the plants and distribution centres and, in addition, on the product-facility allocation choices.
- Demand Planning: APS is able to create a demand forecast for long term planning taking into account the historical demand, promotional events, product life cycle, similarity between old and new products and cannibalization, competitive products. Moreover, it supports the decision on the moment in which enter in the market with a new product, or launch a promotional event.
- Master Planning: APS supports the building of the Master Production Schedule (MPS);
- Materials Planning: APS section dedicated to the Material Requirement Planning (MRP).
- Distribution Planning: APS section dedicated to the Distribution Requirements Planning (DRP).
- Transport Planning: APS optimizes the material flow to minimize transportation costs.
- Production Planning: APS defines the production plan considering materials and capacity constraints, with objectives of cost minimization.
- Scheduling: APS defines the optimal order release, sequencing and routing using heuristics and other methods taking into account constraints and setup times; finally, it realizes a detailed production schedule.
- Demand Fulfilment: APS supports the company in planning delivery dates and delivery quantities.

Nevertheless, nowadays, the real innovation is in exploiting all the software needed for supply chain planning without owing those. This is the most important advantage of the usage of the cloud computing in the working environment and along the supply chain of a company. Briefly, the cloud computing is a model for enabling ubiquitous, on-demand network access to a shared pool of configurable computing resources such as networks, servers, storage, services and applications.

Using software on cloud needs only an internet connection, there is no need to acquire softwares, or to control that the machine can support the softwares installed, or to occupy memory of the system, etc... The company pays only when it uses the application on cloud and it doesn't take care of anything else; this means a reduction of maintenance cost, of costs to update the software, and in addition, this will imply a reduction of time spent in the management of these software, that could be used in a more productive manner.

Furthermore, the cloud offers three types of service:

- Infrastructure as a Service: The cloud provides customers a virtual hardware in which the customer can create its personal IT solutions.
- Platform as a Service: The cloud provider gives to the customer the platform accessible via web and the preset tools to create applications on the platform. In addition, the cloud provider gives assistance to customers during all the phases of the development of an application.

- Service as a Service: In the Service as a Service, the provider offers a certain amount of software or applications, that customers can use on demand, via web.

3.1.3 Logistics and Distribution

Logistics

Logistics management concerns in the coordination and control of the direct and reverse flow of materials along the supply chain, from the movement of raw materials through the delivery to end customers. Logistics decisions consist in the disposal of inventory or stock and in the way to transport this inventory from one stage to another. Furthermore, logistic decisions impact a lot on the sustainability of a company, the easiest example is the different environmental impact that depend upon transportation choices.

The most important decision in transportation planning concerns the mode of transport used to move goods through the supply chain: this choice has significant effects on the costs involved, but also on the service level offered to customers. Typically, the fastest or most flexible modes of transport give the highest service level but also the highest cost. Indeed, there is a trade-off between minimizing the transportation cost and maximizing the service level, which is often translated as speed and reliability of service. The primary factor, which affects the transportation mode choice, is the capacity, most often in the form of trucks, trailers or containers: higher capacity implies greater investment in transport resources.

However, decisions on the appropriate method of transportation will not only depend on cost and capacity, but, there are other performance measures which are increasingly taken into account for transportation, such as flexibility and reliability.

Road transport

Road transporters or motor carriers offer the comfort of point-to-point access with flexibility and, in spite of it is not the most cost efficient form of transport, this mode offers many advantages that shippers prefer. The scope of road transport depends on various geographic factors but in general these services range from local and regional through to continental deliveries. Regarding the issue of capacity, there are two types of road transport offers, truck load (TL) or less than a truck load (LTL).

An important activity of road transportation planning is the calculation of costs for a given service level. Basically, the costs can be thought of as related to the human resources (drivers), the physical assets (vehicles), running materials (fuels), and the time needed. Typically, the transportation cost is divided into fixed costs such as depreciation of the vehicle and insurance, and variable costs such as driver wages and fuel.

While variable costs tend to be directly related to reducing fuel use, other costs can increase when attempting to reduce environmental effects, indeed, when considering how to reduce the emissions, improved technologies may increase investment costs. The principal development in

road transport technology regarding emissions has been in the improvement of engine efficiency and exhaust treatment. One of the barriers to reduce the impact of road transport is that the costs for new engine technology are not always affordable, especially for small logistics companies operating on low margins. Another option for reducing the impacts of road transport is to modify routing and timing of transport, and in this way, companies can reduce both costs and impacts. In 2010, Palmer and Piecyk suggest that, rescheduling deliveries to the early morning for short journeys or during the night for long journeys can lead to a reduction of 3% of CO2 emissions.

Sea and inland water transportation

The majority of global trade is transported by sea. The reason is that it is well suited to high volumes because the unit transportation cost is lower, but on the other hand, it is not suitable for time-sensitive shipments because of long lead times and also many possibilities of delay. This mode of transport is seen as one that leads to the least emissions for carbon. While water is seen as the most environmental-friendly form of transport, there are impacts that need to be considered, such as the risk of accident and the resultant pollution. Although seagoing freight dominates the world's trade flows in terms of volume, inland waterways also provide savings in cost and a direct access to urban areas; both rivers and canals can provide useful modes of transit for freight.

Other transport modes

Rail and air freight play a very important role in logistic flows that tend to fill specific needs. In particular, air freight is clearly better when speed is fundamental, but also the relative value of the products has to be high enough to justify the costs. Rail has often been cited as a preferred alternative to road transport, particularly in Europe, but the structural inflexibilities still limit the use so far.

	Rail	**Road**	**Water**	**Air**
Cost	Medium	High	Very Low	Very High
Speed	Medium	High	Low	Very High
Flexibility	High	Very High	Low	Medium
Capacity	Medium	Low	Very High	Very Low
Accessibility	High	Very High	Low	Medium
CO_2 emissions	Medium	High	Very Low	Very High

Table 3.4. Comparison between different transportation modes (Source: Adapted from "Purchasing and Supply Chain Management, a sustainability perspective", Johnsen, Howard and Miemczyk, 2014)

Reverse logistics

Reverse logistics is the process of bringing products back from the distribution channel or final customers in order to recuperate value or to meet regulatory demands, such as recycling or avoidance of disposal in landfill. Reverse logistics provides a number of opportunities to improve profits ranging from building customer loyalty, to developing secondary channels and having fewer

discounts in retailers by repositioning stocks. In parallel to these profit opportunities, reverse logistics also increases cost reduction possibilities.

One obvious area of cost reduction is in raw material purchasing, whereby materials recovered and recycled from end customers can return back into the manufacturing process, thereby avoiding buying virgin materials.

Although reverse logistics shares many of the same characteristics and objectives as forward logistics, there are some specific challenges that have to be addressed. The first challenge is product acquisition: as the product itself is often held by the end consumer, it is difficult for the reverse logistics organization to locate the product, especially, if the sellers of the product have been out of touch with the end customers. Then, another difficulty with acquisition regards the achievement of information on location of the products when these have been passed on to other customers, for example in the second-hand product market.

A second difficulty in reverse logistics is the assessment of product quality. Where products require high amounts of work to render the product saleable again, the potential value is reduced, so, a reverse logistics process requires a stage whereby quality is evaluated. Often this process also includes a sorting stage where the products are categorised according to the quality; finally, depending on the work needed to bring the product to saleable quality, a company can decide whether to recycle or simply to dispose the product, if allowed by law.

Distribution system

Companies, according to their strategy, decide how to reach the customer. Clearly, to meet end-customer demand, it is crucial to hold inventory in a distribution channel or, if there are no stocks in the channel, time becomes the main constraint to meet customer demand.

Distribution can be pursued through to indirect channels or direct channels. In indirect channels, the manufacturing ownership is low, but, the majority of channels are owned by the owners of the distribution centres, that, often, design also the route of delivery from the suppliers of products. Recently, the transportation and distribution centre management has been outsourced to logistics specialists, although the overall control still depends on the retailer. Furthermore, wholesalers have remained in place in channel structures which serve multiple, smaller, often independent retailers. The main advantage here is that the wholesaler can obtain a price reduction by ordering large quantities; in many cases, the wholesalers own the physical distribution part, including warehouses and transport capacity, which is often dedicated to specific types of products.

In addition, third-party logistics providers have started to create specific channel structures for those particular market segments or products that require specific assets in material handling.

The last main channel structure is the direct to customer channel, which bypasses physical retailers and has developed significantly due to the ubiquitous use of internet. Typically, the virtual retailer has regional warehouses served by their manufacturers, and then, uses delivery companies to make the final delivery. There are a number of advantages to this type of

distribution channel. In particular, internet-based companies can offer a large range and have high-product availability performance as well as being very reactive on pricing and promotional activities, according to changing demand. Downstream, customers have a completely different experience, as they have to wait for delivery and have additional transportation costs, but they can receive objects at their home.

One of the distribution network design factor consists in the customer expectation of delivery times, compared with production and delivery lead times. Where products are standard, customers are typically unwilling to wait for delivery; on the contrary, if products are more customized or exclusive with limited supply sources, customers are more likely to accept or even expect a delivery delay. The main distinction in the design of the physical distribution network is related to stockholding and transportation costs. If the shipment took place from the manufacturer directly to the customers, there is the possibility to save a lot of money in terms of inventory holding, because the manufacturers can aggregate all the demand from retailers or end consumers: this is particularly useful if products have high value, with a low but unpredictable demand. But, on the other side, the transportation costs are relatively high, especially where carriers are used to deliver products directly to end users.

Thus, in order to reduce the transportation cost, when there is more than one manufacturer, shipments are grouped together at a distribution centre, however, this structure is sensitive to disruptions and has an increased likelihood of stock-out situations, so the risks need to be minimized.

The last option minimizes the transportation cost, because it collects small quantities from suppliers and deliver small quantities to retailers or end consumers. This traditional distribution centre is able to hold stock to buffer the differences in supply and demand. However, it is clear that the coordination costs and requirements for integrated information systems are higher in this case. This method is particularly useful where the demand is variable, so planning of deliveries is challenging, and where products have a high value or are perishable, such as fresh foods.

In summary, the choices over different delivery methods depend on a number of decisional factors, that are based primarily on the value of the product and the nature of the demand. Volatile, unpredictable demand lead to fast replenishment systems either at retailers or distribution centres, generally resulting in smaller collection and delivery batch sizes. At the same time, the shift towards increasing number of consumers buying over the internet implies that final destinations have increased exponentially, requiring even greater levels of distribution flexibility. Therefore, the continuous trend in product proliferation and e-commerce means that it is likely that the use of these more flexible, responsive and rapid distribution systems will continue in the future. The challenge ahead is to design systems that can maintain this level of reactivity, at a reasonable cost financially and environmentally.

Supply chain traceability

Successful supply chains rely on transparency of supply-and-demand information. Technology helps supply chain actors to track stocks as it moves in and out of warehouses. Tracking and tracing of items within the supply chain is therefore integral to supply chain management. Tracking is the capability to locate a specific product wherever it is in the supply chain, in order to be able to withdraw it, or recall it, whenever necessary. While, tracing is the capability to identify the origin and characteristics of a product at each point of the supply chain, in order to be able to determine the identity and source of products received, whenever necessary.

Nevertheless, some scandals such as the horse meat in beef products, the high level of lead-based paint in Mattel toys, the Palm oil etc.. rose the problem of the visibility that companies have on their complete supply chain.

The paradox is that although supply chain technologies have evolved to an extent where companies should be able to keep track of moving goods throughout their supply chains, the complexity of global supply networks rose so much that companies in reality often do not have perfect visibility in what their products actually contain. In fact, supply chains often become less transparent as product complexity increases: a large number of components means a wide supply base, both direct first-tier and sub-tier suppliers.

Some companies place the responsibility on first tier suppliers to manage the second tier suppliers and so forth, but a more interventionist strategy, where companies personally engage in and take responsibility for analysis beyond the first tier, may be required to ensure compliance within the extended supply network.

In any case, existing enterprise resource planning (ERP) systems are not sufficient to capture the required data. The use of product labels has traditionally given consumers a minimal amount of information, such as the country of origin. Showing barcodes (or numbered product codes) on labels provides a further way to allow not only companies to trace their products through the supply chain, but also consumers to trace the product they have bought.

Nowadays, using mobile phone applications, consumers can scan a code to learn more about products or services. California winemaker, the Blankiet Estate, labels their bottles with a code − BubbleTag™ − that, when entered at the company's website, authenticates the wine. Consumers can access detailed information about each bottle via internet or mobile phone. Asda, the UK subsidiary of Walmart, uses webcams at selected supplier factories to allow people to see the conditions at, for example, textile factories in Bangladesh. New Zealand-based Icebreaker uses a "BAA Code" to enable consumers to trace their merino wool garments to specific sheep farms.

However, there is the need of something capable to bridge the gap between physical and digital world, capable to give a unique identity to every single object and automatically acquire this identity, effectively bringing the data acquired to the digital world and making physical objects talk and work with each others. This is possible thanks to the combination of smart objects operating

in smart networks. Smart objects are related to the concept of Internet of Things, that would be a system of interrelated computer devices, mechanical and digital machines and objects in general, that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

A recent development aimed at creating efficiency in distribution systems is the use of RFID technologies. An RFID tag is a chip with a radio antenna that can store data related to manufacturing date, delivery destination and shelf-life information, and it is attached to products or packaging. The information on the chip is collected by a reader, which is connected to an information system such as a warehouse management network. RFID tags can be either passive, active, or battery-assisted passive. An active tag has an on-board battery and periodically transmits its ID signal. A battery-assisted passive has a small battery and it is activated in the presence of an RFID reader. A passive tag is cheaper and smaller because it has no battery; instead, the tag uses the radio energy transmitted by the reader.

Tags may be read-only, having a factory-assigned serial number that is used as a key into a database, or may be read and write, where object-specific data can be written into the tag by the system user.

Cost has been the main barrier to RFID adoption so far, and so, the complete replacement of barcode systems is still a future aspiration.

RFID	Barcode
Does not need a “line-of-fight” so orientation of the reader does not matter if within range	Requires line-of-sight
Many tags read simultaneously	Only one read at a time
Durable	Easily damaged
RFID tags can be automatic and can collect and store information	Only a static label
Expensive	Less expensive
Liquids and metals near or around the tags cause read problems	Can be used on or around water and metal with no performance loss
RFID tags must be added to the product during the production process	Can be printed before production or directly on the items

Table 3.5. Comparison between RFID and Barcode (Source: Adapted from “Purchasing and Supply Chain Management, a sustainability perspective”, Johnsen, Howard and Miemczyk, 2014)

RFID have only been used where they can be justified, usually in JIT delivery systems or for valuable assets such as reusable containers, and within internal company operations, such as inside warehouses where they can be reused easily. Indeed, the major difficulty is in recovering tags from the end consumer, when RFID is used to track items in open supply chains.

Moreover, RFID is particularly useful for products with many stock keeping units (SKUs), which are difficult to track leading to stock inaccuracies. Indeed, Walmart is working with its main suppliers to ensure the tags are attached to clothing from the moment of manufacture, and helping

suppliers incorporate RFID data into their own warehousing and inventory management systems, so that the investment pays off for both parties. At the retailers, the tags give Walmart information about the location of products throughout the store, from goods in inventory to checking the items are in the right shelf area. The main benefits of RFID are: labour cost savings thanks to an increased efficiency and accuracy of auditing inventory levels, reduction in shrinkage, because this technology discourage theft and improve the recovery of products missed, improved visibility avoiding sales loss due to inaccurate replenishment. There are also challenges related to the use of RFID, mainly concerning the management of the data received. Finally, this technology can also be used to detect when food products may have changed temperature, leading to bacterial development risks.

An alternative to RFID is constituted by the wireless sensor network: this relies on wireless connectivity to transport sensor data. Wireless sensor networks are spatially distributed autonomous sensors, which monitor physical or environmental conditions, such as temperature, sound, pressure, etc... and which cooperatively pass their data through the network to main locations. The more modern networks are bi-directional, also enabling control of sensor activity. The WSN is built of “nodes” connected to several sensors, each sensor network node is composed by: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting.

WSNs are used a lot in the healthcare sector, and in the monitoring of area or environment conditions. In industry WSNs are used to:

- Monitor the functioning of machines;
- Monitor conditions of working environments;
- Monitor resources;
- Monitor wine production.

In many applications, a WSN communicates with a Local Area Network through a gateway. This enables data to be stored and processed by devices with more resources, for example, in a remotely located server. A wireless wide area network used primarily for low-power devices is known as Low-power Wide-Area Network.

Operating systems for wireless sensor network nodes are typically less complex than general-purpose operating systems.

3.1.4. Manufacturing

Industrial production consists in a set of activities required to produce goods or services delivered to the market. Moreover, the subsystem of the company which uses resources as inputs to provide products and services in order to satisfy the customer needs and objectives established by the company's strategy is called production system. The production system has to be designed on the basis of how the company chooses to fulfil the demand from the market, how the production is managed to make the required production volume and how the product is made through the production process.

Now, it will be presented the main manufacturing system design:

- **Job Shop:** Machines are grouped on the basis of technological processes involved, similar machines in the same department, workers are skilled on the basis of the technological processes involved. Each product has its own routing in the system. The main characteristic of a Job Shop is the flexibility, which makes this system suited to production of customised and different objects in low volume. Furthermore, high flexibility lead to a low impact of breakdowns and low obsolescence of the system, but, at the same time, job shop has efficiency limits and it is complex to manage and to size capacity.
- **Manufacturing Cells:** Machines are grouped into cells, on the basis of the process requirements of the part families and each product has its own routing within the cell. Respect to the Job Shop, Manufacturing Cells system reduces work in progress (WIP), lead time and setup times, then, it allows to estimate more reliably delivery lead times and finally, it allows a rationalisation of material flows which make easier the production management. Moreover, workers within a cell are more related to the realisation of a product and so, they have to work in team with people of different skills responsible for the quality of the final product: this expertises' exchange means the possibility of job enlargement and enrichment for employees. On the other hand, it is more difficult balancing the work load between cells and managing technological operations outside the cells, and then, because breakdowns have higher impacts, this system requires more machines than in a job shop. However, there is an alternative to traditional manufacturing cells, with the purpose to be more responsive to production mix variability: **Virtual Manufacturing Cells**. In **Virtual Cellular Manufacturing** the machines that belong to a cell are not physically located together, but, they are identified as a group only by the Production Planning and Control system.
- **Transfer lines:** A transfer line consists in a series of machines where flows of a single product type or of a limited number of product types within the same family result in a routing through the machines. The transfer line is usually a highly automated manufacturing system which realises objects characterised by a high and stable demand. Transfer lines allow company to further reduce WIP and lead time thanks to an easier production management, but it is not very flexible, setup times are long, and, because the line is designed to realise only one particular product, the risk of obsolescence is high and failures impact a lot on the production. The last important characteristic of a transfer line,

which is to be taken into consideration during the design choice, is the cost of a line which is higher respect to manufacturing cells and Job Shop.

- **Process plants:** A process plant is formed by a series of production equipment used to make non reversible chemical-physical transformation of materials through a fixed technology routing. Plants are designed to operate a continuous flow of production process, or a batch production process. Process plants are characterised by an high investment in automation and in sensors which have to control automatically the technological parameters of the production process, beyond this, a supervisor is ready to intervene whereby the sensors fail. The high automation of the process plants make these easy to manage (both production and logistics), with a lower need of workforce, but, at the same time, the low flexibility of the system is the reason of the high impact of failures in the production process and the high risk of obsolescence.

Here it will be presented the main assembly system design:

- **Fixed position assembly:** The product is assembled in a single site, rather than being moved through a set of assembly stations, and materials, equipment and tools are brought to the site. It is a system characterised by a skilled workforce who are able to complete different operations and so, it is a system that assure high flexibility and the possibility to realise a wide range of product types. On the other hand, it is not suited for high production volume because of the risk of intertwining of material flows and high WIP; the main investments needed are for the labour training of the employee and for the space of the site, that has to be large enough to contain all equipments necessary for the assembly phase.
- **Assembly line:** an assembly line consists in a series of stations where the product is progressively assembled. In an assembly lines system, the space is rationalised on the basis of the routing of the product to optimise material flow and reduce WIP. Here, workers skills are limited to those needed to complete their own operation; the architecture of assembly lines does not allow easily change in material flows, so, the system is not flexible and it could be difficult to balance the lines workload, then, in this system, setup times are longer. Moreover, there are different types of assembly line, on the basis of the way the material handling system works. **Machine-paced lines** are characterised by a timer that starts the movement of materials when the cycle time of the line arrives. This system assures a perfect control of the cycle time and production capacity of the line, but, otherwise, increases the probability of no completion of products and the problems of unfinished pieces. Thus, in **operator-paced lines**, the operator has to give the consensus to the movement of pieces, and, the material handling system moves the pieces only after all operators have finished, so, cycle time is variable and it is determined by the slowest operator, but, any problems of unfinished pieces is avoided. Then, there are **unpaced lines**, where each assembly position owns a buffer in which are collected pieces in queue: the operator gives the approval to the movement of the piece that go ahead to the buffer of the next station. Finally, in the **continued flow lines**, the material handling system moves

at a constant speed and operators following the piece on which they have to perform the assembly tasks. In the continuous flow lines too, there is the double alternative of controlling the cycle time or controlling the unfinished products: if the company wants to focus on the cycle time control, the operator can't stop the line, otherwise, the operator can stop the line in the case he did not have finished its task.

- **Assembly shop:** An assembly shop consists in a series of stations and each station is assigned a phase of the assembly process of a product type, a mix of product types can be produced within the assembly shop and its stations. The assembly shop is a flexible system able to realise different product types, and the assembly phase is characterised by the absence of any cycle time constraints because each station is decoupled by buffers.

3.1.5. New Product Development

In the last ten years, companies increasingly consider suppliers as critical sources of innovation and try to involve suppliers of key components into design and development processes.

During the new product development, it is in the early stages that the project hold the 80% of its value, and it is in the early stages too, that significant changes in product design and specification cost less. In Figure 3.3 there is a representation of the new product development process.

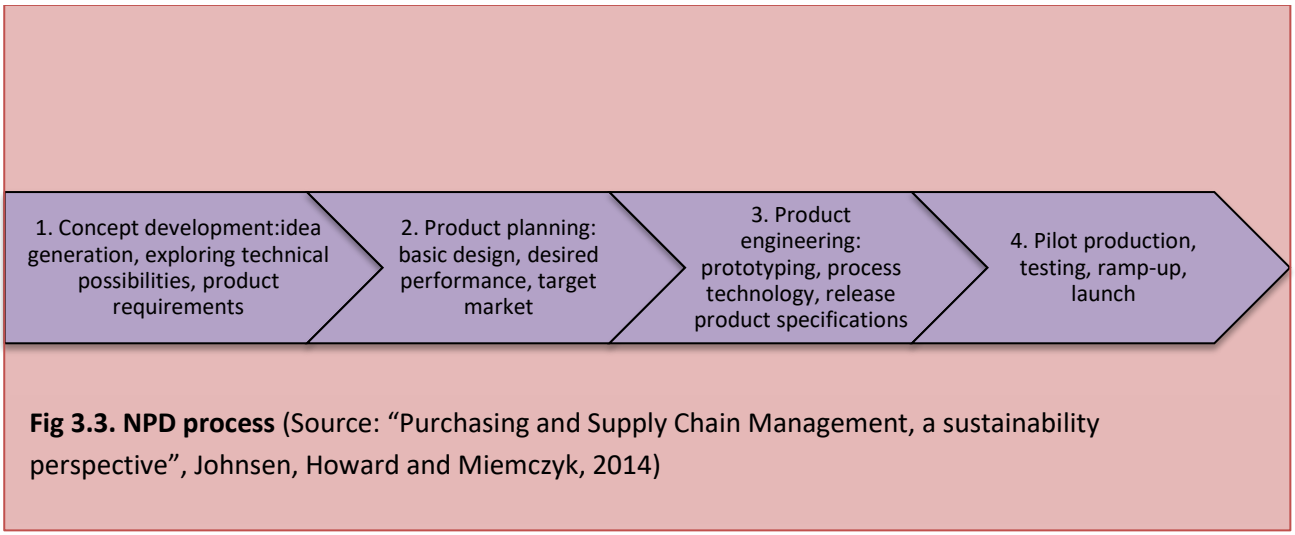

Fig 3.3. NPD process (Source: "Purchasing and Supply Chain Management, a sustainability perspective", Johnsen, Howard and Miemczyk, 2014)

Early Supplier Involvement (ESI) means involving suppliers of key components as early as possible in the process. Involving suppliers in the first two stages of new product development processes enables design for manufacturing and helps to prevent, to reduce, or to introduce earlier, costly design changes.

Nevertheless, ESI is not always beneficial for projects, because it contains a lot of challenges that make the process difficult to be applied successfully. Indeed, ESI implicates the difficulty to involve different partners at the same time in the project, controlling that the desired level of quality of each component is achieved, that the deadlines are respected by all players, that each component or part respects the specifications and that is conformant. In addition, ESI includes also the necessity to control that each supplier behaves honestly and respects the code of conduct and the

agreements taken, and, moreover, it needs the capability to face unexpected events, that can force companies to change something of the project or of the development process.

To manage all this complexity, it is fundamental the selection of the right suppliers and, the choice of the moment in which involving each supplier into the project. Since the stages which hold the majority of the value of the final product are the first and the second, concept development and product planning, so, suppliers of high-value and complex parts that represents high risk should be involved in these two first stages, and for them it is necessary to postulate either a black-box or a grey-box responsibility.

The terms grey-box and black-box derive from the Le Dain model, proposed in 2010: the model aims at identifying and classifying different levels of supplier involvements, based on two dimensions:

- The **degree of development risk**, which depends on the number of subcomponents used in the building block, on links between the individual component and other components, and whether it is on the critical path;
- The appropriate **degree of supplier autonomy** or responsibility, which depends on the nature of the supplier technologies and capabilities the company's own, and on supplier's capabilities in proportion with those owned by the company, and on supplier's availability and interest in working with the company.

Moreover, different levels of supplier involvement in the process correspond with different types of specifications provided to suppliers, ranging from entirely customer driven (white box) to supplier driven (black box); the grey-box situation requires joint development of specifications. Strategic co-design and development require close cooperation and extensive communication between the two parties, but a significant amount of responsibility is delegated to the supplier who is viewed as the real expert, therefore, he takes the lead role in the development of the detailed design solutions. Critical co-design and development is similar but the balance of knowledge of the component being developed is more counterbalanced, consequently the grey-box situation. Therefore, specifications need to be jointly developed by the two parties and extensive collaboration is required for this solution. White-box collaboration resembles classic sub-contracting; in any case, it is the customer that should provide detailed technical specifications to the supplier, leaving him as little space as possible for misunderstanding of buyer needs and requirements. This situation involves less intensive collaboration and communication and suppliers can be involved at a later stage in the NPD process.

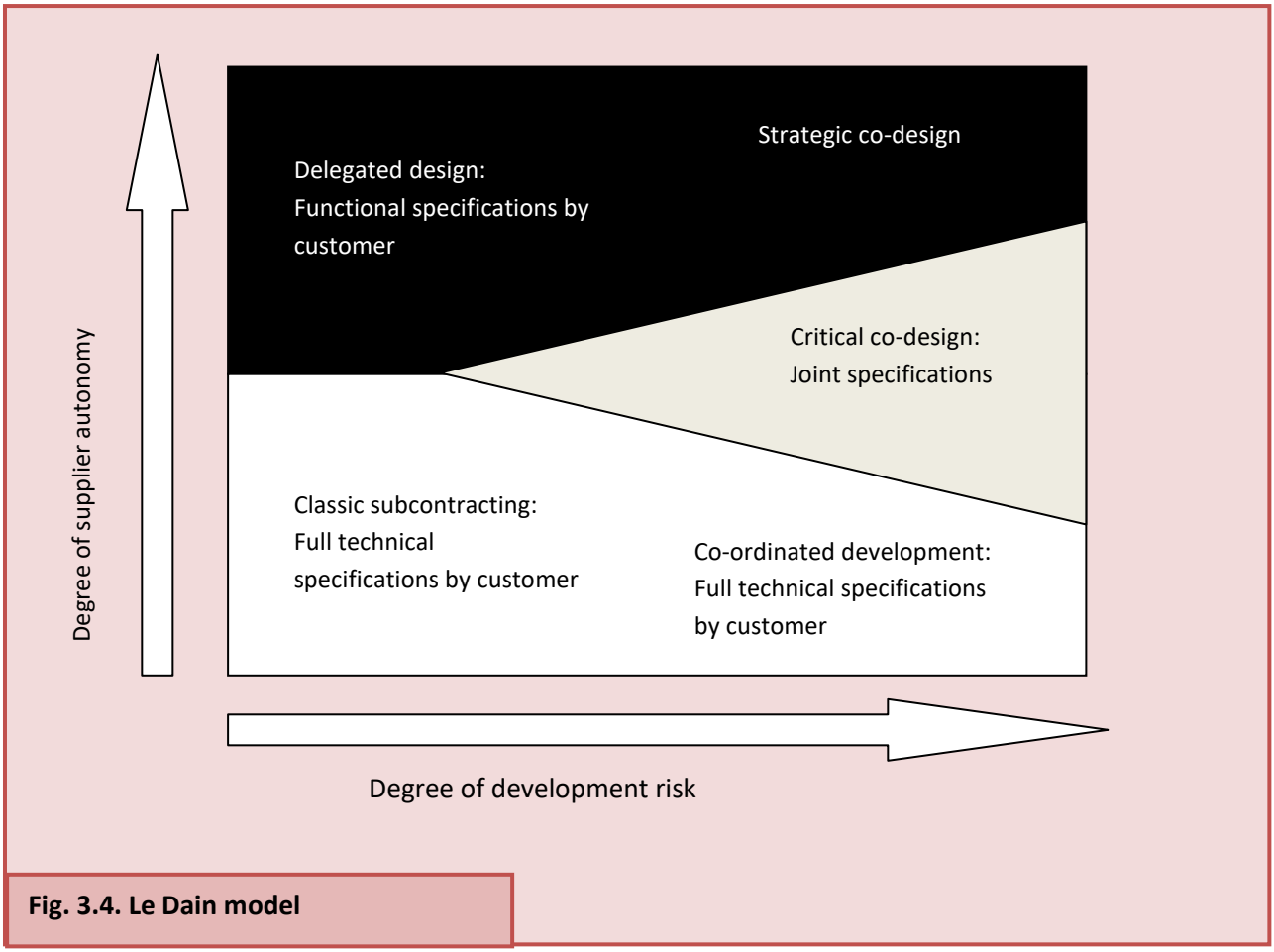

Fig. 3.4. Le Dain model

In addition, successful ESI requires long-lasting supplier relationship development and adaptation, and the internal capabilities of the company need to be adapted to fully benefit from ESI. Top management within the company needs to be supported and engaged in ESI, and cross-functional coordination between different internal functions, such as purchasing, logistics, production and marketing, is critical.

However, ESI is only appropriate for incremental NPD projects and not for radical, or discontinuous, innovation. Thus, when companies get involved in projects characterised by high technological uncertainty, ESI may no longer be useful. Indeed, discontinuous innovation implies that existing technological capabilities and markets become obsolete, and are therefore replaced by new technological and market capabilities. The problem for companies that succeed at collaboration with long-term existing suppliers (ESI) is that such partnerships have limited innovative potential. If you always only search for ideas, knowledge and technologies from the same old partners, it is difficult to change drastically the competences of suppliers and so, to change drastically the product, that, probably will remain always the same product, but, improved. Therefore, to create discontinuous innovation, it is necessary that a firm acquires competences outside the supply boundary, contacting new suppliers. Two organisational options are created to source for new resources outside the supply chain boundary: either the foundation of a special sourcing department, who search for potential new technologies, or each sourcing staff has the dual task of searching for existing and new potential supply market.

Furthermore, the increasingly interest to sustainability in the production process rose the new concept of “Design for environment” (DFE) or eco-design, which focuses on:

- **Design for environmental manufacturing**, including raw material extraction, processing and manufacturing using non-toxic materials and processes. This includes the minimization of waste and hazardous by products, air pollution and energy expenditure.
- **Design for environmental packaging**, ensuring that materials used in packaging are environmentally friendly. Materials and also pallets used for transportation are reusable and recyclable, and unnecessary paper and packaging products are eliminated.
- **Design for disposal or reuse**, involving reuse or refurbishing of a product when it reaches the end of its life.

Design for sustainability, or D4S, is an eco-design concept that expands the focus to include not only the environmental dimension of sustainability but also the social and economic dimensions. The concept of D4S is being promoted by the United Nations Environment Programme (UNEP) to encourage companies to develop long-term innovation strategies that will alleviate the negative environmental, social and economic impacts within the supply chain and throughout the product life-cycle.

3.1.6. Industry 4.0

In the actual business scenario, traditional productivity levers have been exhausted. In the past, companies used to outsource and offshore production to exploit the economic advantages of low-cost countries, but, nowadays, wages and taxes in those countries increase and also the transportation cost rise up. Thus, companies are redesigning their manufacturing networks on the basis of the new key success factors. Fundamental to achieve a competitive advantage now, there are factors, such as short time to market and a quick customer response, which have to affect the customers’ sensations more than reducing company’s costs. Thus, to improve their performances in these fields, companies have to move back the production sites near their customers and near R&D department. At the same time, to not lose the advantages of offshoring, companies start to invest in automation and robotics technology to make the production process more cost efficient.

In particular, Industry 4.0 is based on four clusters of technologies (Table 3.6). Different drivers are leading to an acceleration of use on a large scale for each of these clusters.

Data, computational power and connectivity	Analytics and intelligence	Human-machine interaction	Digital-to-physical conversion
Big data/open data: significantly reduced costs of computation, storage and sensors	**Digitization and automation of knowledge work:** Breakthrough advances in artificial intelligence and machine learning	**Touch interfaces and next-level GUIs:** Quick proliferation via consumer devices	**Additive manufacturing:** Expanding range of materials, rapidly declining prices for printers, increased precision/quality
Internet of Things/M2M: Reduced cost of small-scale hardware and connectivity through LPWA networks	**Advanced analytics:** Improved algorithms and largely improved availability of data	**Virtual and augmented reality:** Breakthrough of optical head-mounted displays	**Advanced robotics:** Advances in artificial intelligence, machine vision, M2M communication and cheaper actuators
Cloud technology: centralization of data and virtualisation of storage			**Energy storage and harvesting:** Increasingly cost-effective options for storing energy and innovative ways of producing energy

Table 3.6. Disruptive technologies enabling the digitization of manufacturing sector (Source: McKinsey)

- *Data, computational power, and connectivity*

  This cluster, which comprises big data, the Internet of Things (IoT), and cloud technology, is mainly driven by a significant reduction in costs, that makes possible the ubiquitous use of sensors and actuators and allows for affordable and powerful storage, transmission, and processing. For example, in the IoT, sensors and actuators, embedded in physical objects, are interconnected via wired and wireless networks. These networks produce large volumes of data that move to computers for analysis, while all physical objects are able to both detect their environment and communicate autonomously among each other. Today, interoperability is made possible by new communication protocols designed especially for seamless machine-to-machine (M2M) interaction. Connectivity is enabled by LPWA technologies that provide the wireless infrastructure to connect thousands of IoT nodes.

- *Analytics and intelligence*

  Advances in artificial intelligence and machine learning as well as the exponential increase in available data and improved statistical techniques enable digitization and automation of knowledge work and advanced analytics. For example, Watson, the IBM cognitive system, is able to answer complex questions through the analysis of unstructured data and information collected by research literature, case histories, etc...

- *Human-machine interaction*

  The interaction between humans and machines is a cluster in continuous growth; consumers are accustoming to new ways of interacting with machines that come from the growing use of smart personal devices. Touch interfaces are already ubiquitous in the consumer world today, and movement recognition as well as virtual and augmented reality devices are increasingly in use. The familiarity with these devices will favour the implementation of human-machine interaction as a natural feature in the manufacturing environment. Indeed, companies such as the German start-up Ubimax have already experimented apps that run, for example, on smart glasses, to pursue warehouse, assembly, and service processes more efficiently, exploiting live instructions that are loaded on the visual field of the worker wearing the device. Another dimension is the increasing physical interaction between machines and humans, where machines and humans both work in closer physical proximity and where machines can help humans in hard tasks. An example is the Festo ExoHand, which functions as an exoskeleton emulating the anatomy and physiology of the human hand. This is worn as a glove and can support hard manual works by transmitting human hand movements, to a robot's hand. As a result, the worker can conduct a given task for a longer period of time and faster than before.

- *Digital-to-physical conversion*

  It allows to decrease costs and to expand range of materials, improving in the last years the precision and quality. For example, 3D printing was applicable only to polymers and metals, while, right now, it is applicable to a broad range of materials, including glass, biocells, sugar, and cement. At the same time, the maximum size of 3D printing has increased by more than ten times from the 1990s. It is not just additive manufacturing that is becoming more relevant, but also technologies like advanced robotics and increasingly cost-effective options for storing energy and innovative ways of producing energy.

Despite these disruptive innovations are at the basis of the fourth industrial revolution, this is a revolution based on cyberphysical systems that won't require a disruptive approach to implement new technologies, but, Industry 4.0 will require that existing equipment will have to be updated, mainly for what concern sensors and connectivity.
Thus, this change won't be disruptive, but incremental. Unlike previous industrial revolutions, Industry 4.0 is not about replacing the existing assets with new ones, but about understanding the managerial challenges posed by the disruptive technologies along three different dimensions:

1. The next horizon of operational effectiveness;
2. New business models as a result of shifting value pools;
3. Foundations for the digital transformation of the company.

Industry 4.0 constitutes a shift from optimizing physical assets to optimizing how data and information are leveraged along the product lifecycle. The digital optimization is built on a end-to-end information flow, which starts with the digital design of the product, passes on through the digitally driven and controlled manufacturing process, leads to the digital monitoring of the end products, and finally concludes in the recycling of products, where digitally stored information can help in the identification of parts to reuse.

At each step, the process can be visualised and controlled by digital tools (tablets, smartphones) and interaction can be carried out via digital channels. Furthermore, using and sharing information across the digital path, will enable stronger cross-functional integration and closer cooperation along the complete product lifecycle. Managing the digital path comprehends four prerequisite activities for the creation of value from data:

1. *Information capturing and recording*

   Inefficiencies can only be eliminated if they are detected and documented, so the physical production process needs to be mapped along the digital path, based on the collection of real-time data in an automated way and, with historical data points. This requires moving from selected, sampling-based measurements, mostly for quality control purposes, to a full coverage of the production process, using sensors and measurement devices to collect information for every single piece.

2. *Information transfer*

   Data collected at a specific point in the value chain might be more useful at another point, so, to make information available at a specific point, it is crucial to share, even in real time, information collected across the value chain. Therefore, companies need to integrate disparate sources of data from different applications, and, moreover, the data integration should not stop at the company borders.

3. *Information processing and synthesis*

   Captured information need to be processed to obtain ideas from data collected. Conclusions can be right or not, depending on two things: causal relations between factors that are hypothesized, and the use of data collected.

4. *Turning information into outcomes*

   The last step needs to close the loop from the digital sphere back to the real world by translating conclusions from the data analysis into recommendations and, then, actions. A lot of decision making processes still require human involvement, while data analysis are often performed and automated in real time. Therefore, opportunities are

associated with speeding up and potentially automating these decisions, and beginning the required actions.

Value drivers of Industry 4.0

Here, there will be showed the impact Industry 4.0 could have in traditional value drivers of the actual business scenario.

- **Process:** Industry 4.0 improves the process effectiveness thanks to the possibility of optimizing in real time the production. Typically, real time process optimization yields an improvement in throughput of up to 5 percent.
- **Asset utilization:** This driver is particularly important in asset-heavy industries with expensive machinery, where every minute a machine does not produce causes losses in terms of capital expenditures and lost revenue. Here, Industry 4.0 can decrease costs associated to planned machine downtime, unplanned machine downtime, or setup times, leveraging on the predictive maintenance. Typically, predictive maintenance decreases the total machine downtime by 30 to 50 percent and increases machine life by 20 to 40 percent.
- **Labour:** Advances in human-machine interaction allow to increase labour productivity, reducing the strain of workers and the complexity of their tasks. A Canadian manufacturer of warehouse furniture, Etalex, was able to increase the production volume of 40%, without increasing the workforce.
- **Inventories:** Industry 4.0 acts on the main causes of excessive inventories, such as inaccurate stock collection, unreliable demand planning necessitating safety stocks, or overproduction. An example could consists in the use of intelligent cameras to capture the actual fill level of a supply box; then, this box will be wirelessly connected and automatically will reorder components. Typically, Industry 4.0 can reduce inventory cost by 20 to 50 percent.
- **Quality:** Products with a low quality need to be re-worked, so the low quality in the production process is an extra cost. The quality inefficiency is caused by unstoppable processes in manufacturing, deficient packaging in the supply chain or distribution, and unskilled installation; the elimination of those issues during the value creation process can create value. Industry 4.0 leverages on statistical process control (SPC), advanced process control (APC), and digital performance management to eliminate the quality inefficiency along the production process. Real-time data analytics and APC enable real-time error corrections to minimize reworks and scraps, and typically, it leads to a reduction of quality costs of 10 to 20 percent.
- **Supply/demand match**: Industry 4.0 optimizes the match between demand and supply, through crowd forecasting, which, based on advanced analytics, can increase the accuracy of demand forecasting to 85% on a weekly basis. One automotive OEM can identify the product options that customers are willing to pay a premium for, by gathering information

via the online configurator on its web site and actual purchasing data. As a result, the products offered could be reduced, obtaining in this way a significant decrease of development time and production cost.

- **Time to market:** Reaching the market with a new product earlier creates additional value through increased revenues and potential early-mover advantages. Therefore, the capability of Industry 4.0 to reduce the development process thanks to the conversion between the digital and the physical world, can shorten the time to market by 30 to 50 percent.
- **After sale service:** Typically remote and predictive maintenance bring about 10 to 40 percent of cost reduction.

Plants of Industry 4.0

The fourth industrial revolution will see a change of the plants which will produce goods, there are three archetypes of future Industry 4.0 plants:

1. **Smart automated plants**, which address the need for mass products at low cost and are fully automated, digitized and highly cost efficient. These plants produce large volumes and commodities. The supply chain will be integrated end to end, enabling full transparency and optimization of the digital path, resulting in automated and mostly uninterrupted processes and end-to-end material flows. In addition, robots, which already offer the potential for significant increases in labour productivity, will not only be smarter but also more collaborative and safer. The plant will provide very high productivity per machine due to the ability to use predictive maintenance to reduce unplanned downtime and high throughput from real time yield optimization. Managing the digital path will also facilitate information sharing with suppliers and distributors, enabling further operational effectiveness through approaches such as real-time supply chain and data-driven demand prediction, which will reduce inventory costs and improve service levels. Finished products from the smart automated plant will go to the mass market, while WIP could be raw material for customer-centric plants or e-plants in a box.
2. **Customer-centric plants**, which address trend markets. These are ultra responsive plants producing highly-customized products at affordable cost to address the trends to mass customization. Customers will design their products online, and the models will be sent directly to the most suitable factory once the order has been placed.
3. **E-plant in a box**, which addresses niche and remote markets. These small-scale, low-capex mobile plants can quickly be set up at new locations at competitive costs to produce small series of products. The e-plant in a box is a prefabricated facility, agile and mobile, and potentially delivered in containers, that could have customers stopping by to design their own-products on-site with the help of specialists. Therefore, the e-plant in a box will be highly adaptable to local trends due to its proximity to customers and local ecosystem, and time to market will be reduced thanks to this proximity.

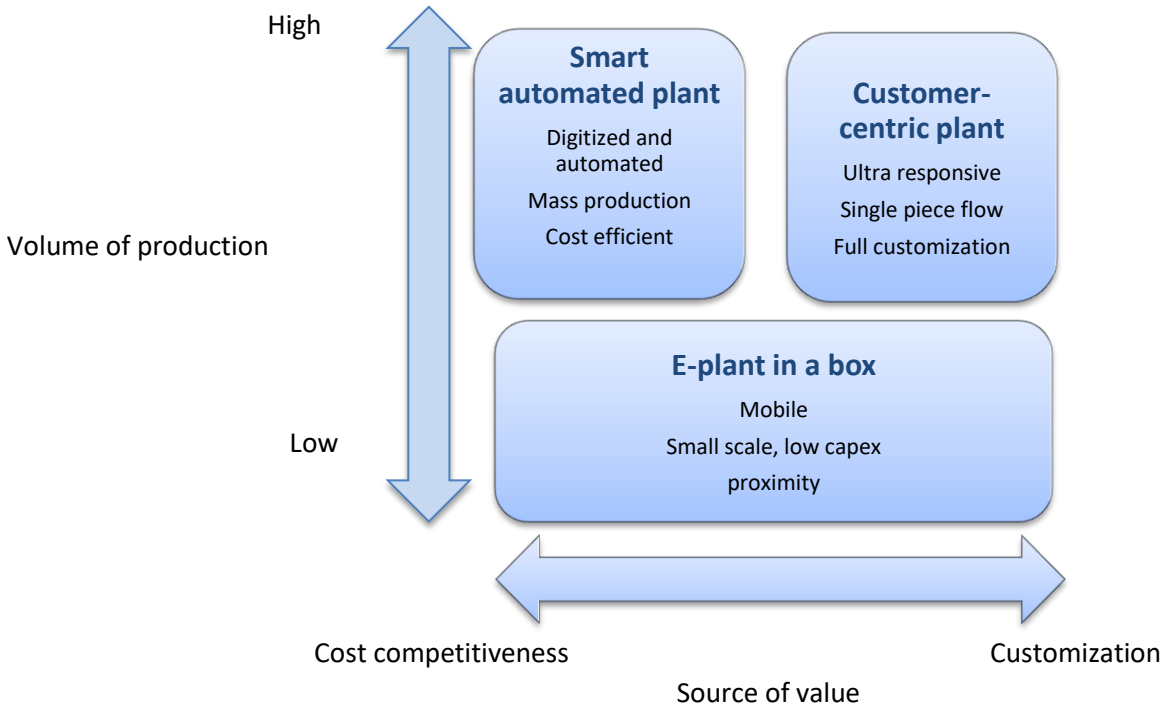

Figure 3.5. The three archetypes plants of Industry 4.0 (Source: McKInsey)

3.2 DEDUCTIVE ANALYSIS

After the presentation of the main activities that compose the supply chain management, the manufacturing process and the new product development, and the presentation of the new concept of Industry 4.0, it is possible to detect which could be the possible applications of Blockchain in the industrial sector and which could be their benefits.

To sum up, basically, the blockchain technology allows to create a distributed shared ledger among participants of the same network and it let participants to complete on-line transactions without any intermediary, because the validity of transactions is controlled by the network. Essentially, the technology represents a new concept of trust, based no more on a central authority, but more democratically, a decentralised trust based on the control of every node of the network. The ledger is not owned by someone, but, this is accessible to every user, that can download it and control information on transactions; none transaction can be modified when it is already registered on the blockchain, and every asset moved is traced by the system. Indeed, if a malicious node would try to corrupt the system, this should be able to own the 51% of CPU power of the entire network to change the ledger in each node; while, in traditional systems, it is enough to attack the central entity which manages the access and the safety of information.

In the following paragraphs there are presented hypothesis about which can be possible usages and applications of blockchain technology in the supply chain management.

3.2.1 Blockchain in the sourcing process

At the beginning, it could be interesting to start asking which could be the effect of the application of blockchain technology in the companies' purchasing behaviour: how much companies could be affected in the outsourcing decisions? How much companies could be stimulated to build partnership with their suppliers?

The main theories which analyse companies' behaviour in making economical exchanges with suppliers are three, introduced in the previous "make or buy analysis" (pag. 39-41). In particular, two of them focus on maintaining in-house those activities which create competitive advantages, core competences for the RBW theory, while the capability to build inimitable relationships with its own supply base for the ERBW theory. Thus, for what concern the Resource-based View theory and the Extended Resource-based View theory, likely, the introduction of the blockchain to complete transactions would not change a lot in the companies' inclination to outsource, because the blockchain would not impact neither in the core competences nor in the capability to build good relationships with other companies.

But, a substantial change in the companies' inclination to trade, there would be considering the "Transaction Cost of Economics" theory by Williamson. Indeed, the TCE theory declared that the objective of each company in make-or-buy decisions, was to reduce at maximum the transaction costs. The market analysis, according to the TCE theory, is based on these three factors affecting the business environment:

- Transaction costs;
- Asset-based specificity;
- Opportunism.

Firstly, transaction costs are composed mainly by: costs to collect market information, costs to write the contract and costs to negotiate with the counterparty. The blockchain would reduce the contracting costs, because every type of intermediaries in drafting the contract would be eliminated by new smart contracts; so, companies should not pay third parties to support the contracting phase.

Then, companies would have to subscribe on blockchain platforms, and also invest in training courses of blockchain for those employees and managers who will have to record transactions and use the blockchain. In particular, for supply chains regulated by permissioned networks, these investments have to be considered specific, because the company cannot use the same platform to conclude transactions out of the specified network. Nevertheless, companies do not have to acquire durable and big machineries, do not have to set their production line in conformance to the specifics of the client; but, these need only to adopt an on-line platform to complete and verify transactions, so, this is a little specific investment.

Finally, the blockchain technology paradigm and its algorithms, the PoW and all the following variations, assure a high level of safety for transactions, and constitute an important barrier to malicious nodes. Indeed, the blockchain is governed by a technical code impossible to bypass; this means that the blockchain would reduce at most the scenario of opportunism imagined by Williamson.

After that, it is interesting to estimate which can be the impact and which are the areas and the activities that could be addressed by the use of the blockchain technology. Thus, considering the purchasing process, how this process would change with the use of blockchain technology to complete transactions.

In the specifying stage, a company draws the specifications of the purchase needs: everything the company wants to obtain by its suppliers has to be written in the specification document. Thus, this means that a company which wants to exploit the advantages of blockchain will have to fill the specification document with the request that the supplier has to be available in adopting blockchain, to complete transaction.

In the selecting stage, a company selects suppliers through processes such as RFI and RFQ; probably, these kind of approach to select right suppliers is compatible with a supply chain managed through a blockchain platform, so this stage won't face any important change. But, a strong improvement in the purchasing process is related to the potential use of blockchain in the contracting phase. Indeed, the blockchain, as it is been introduced before, allows the constitution of smart contracts that would substitute traditional ones, introducing a lot of advantages and savings.

Actually, the idea of smart contracts is not new and it is originated several years before the birth of Industry 4.0; in fact, already in the 90's Nick Szabo described smart contracts as the possibility to use electronic protocols to make contracts and business practices. Blockchain allows to record a lot of information (contract terms, performed obligations, procedures and work processes), and to build applications which execute automatically when related conditions are satisfied. Then, in addition, blockchain assures the safety of transactions, thanks to the consensus algorithm, and the ability to trace every asset moved in the transactions, and, last but not least, blockchain allows to avoid the need of third parties to preserve the validity of the contract.

Nevertheless, using blockchain to draft smart contracts needs also some attention. First of all, it is important to establish who has the authority to update the contract, in order to avoid that unauthorised entities modify any contract details. Moreover, there is the need of a careful management of transactions, which means to manage the change of ownership of goods, the transaction of rights on assets from the sender to the receiver, and then, the transaction of money between the two parties. In addition, transactions completed on the blockchain need the capability to manage credit cards' information of the nodes. Finally, drafting a smart contract requires high attention, because entities have to keep constantly in mind that information recorded on the blockchain are difficult to modify, so they have to be prepared, and they have to try to anticipate which could be possible needed adjustments.

To sum up, smart contracts could substitute a lot of those back-office activities that require companies efforts, time and costs. Indeed, smart contracts could execute automatically transactions, payments and settlements; moreover, at the same time, these would control the validity of transactions and the correctness of the counterparty without the need of any third party, and without discriminations, or differences, related to the counterparty structure or power. As consequence, smart contracts would reduce contract disputes and lawsuit costs.

Coming back to the purchasing process, it has been explained where blockchain can enter in the first three stages, in the "source-to-contract" part; now, moving to the "procure-to-pay" part, the structure of smart contracts makes them useful also to support the final stage of the purchasing process, "evaluating", in which performances of suppliers are assessed and penalty clauses or rewards are issued. Smart contracts would execute automatically this process.

While, for what concern the fourth and the fifth stage of the purchasing process, whereas the ordering activity would not face any important change, because orders would continue to be issued thanks to the support of ERP software, the expediting could be supported by blockchain in the traceability of goods moved.

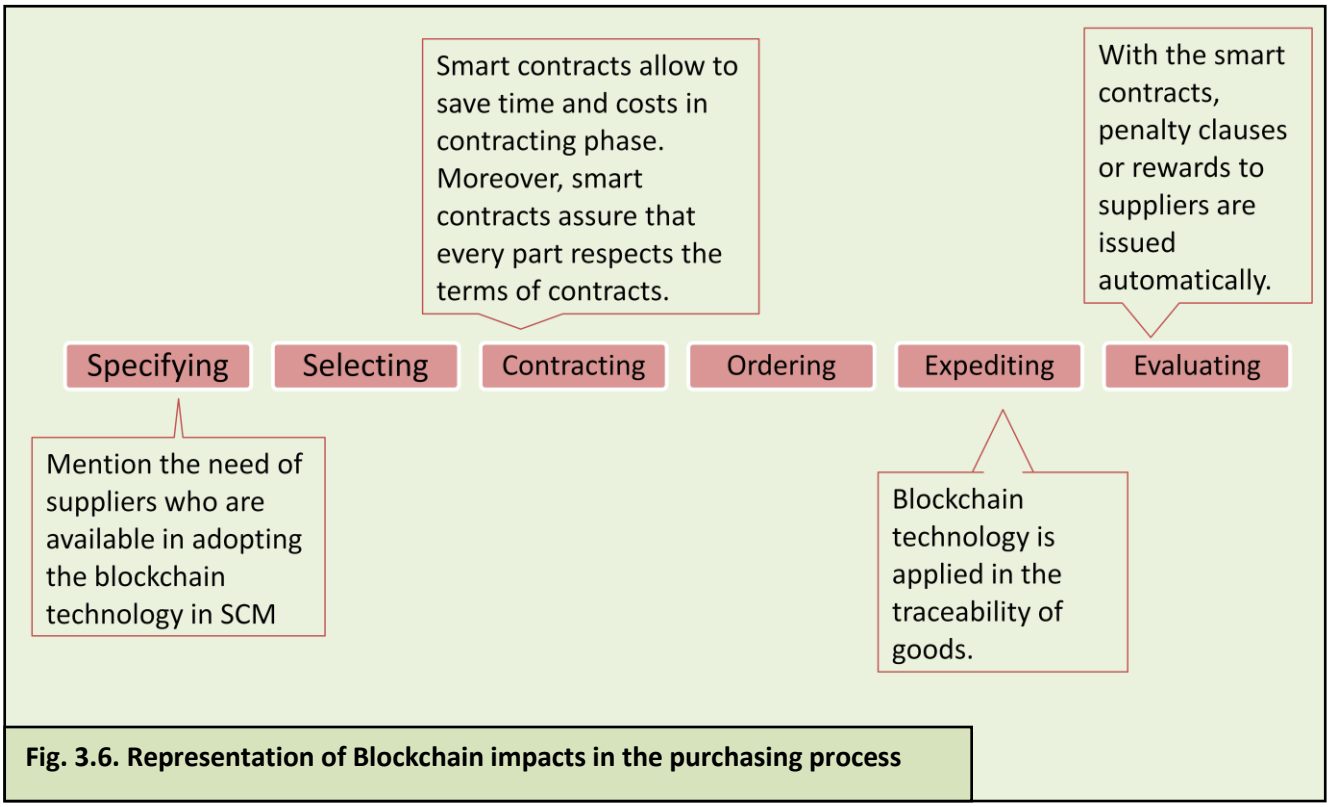

Fig. 3.6. Representation of Blockchain impacts in the purchasing process

But, now, which are the cases in which there could be advantageous to adopt blockchain?

Wüst and Gervais, from the Department of Computer Science in Zurich, developed a framework to determine when adopting blockchain, and which type of blockchain networks are more suited to different situations. In general, multiple entities, or companies, can decide to complete transactions through a distributed ledger or a centralised system, which provides to validate transactions and to assure the safety of information or asset traded. The distributed ledger is feasible thanks to the blockchain technology: so, data are not stored and managed by any central authority, which has to validate transactions and regulate the access to information, but, the ledger is accessible by every node of the network which can contribute in the validation phase. Otherwise, in a centralised system, a third party stores all data and assures the safety of transactions, validates them and manages the access to information stored.

Thus, if companies want to trade, but, they are not agree in trusting in third parties or centralised systems, they can use a blockchain ledger, developed by itself or maybe by third parties. Talking about business relationships and about the use of blockchain in a supply chain, in the majority of the cases, companies prefer to complete transactions within a permissioned network. Reasons why companies prefer permissioned networks are:

- The identity of all members is known;
- Validation of transactions is faster, and no remuneration is needed to validator nodes.

In a permissioned blockchain, every node has to show its identity when it asks to join the network, however, it can manage the disclosure of all the rest of information. Often, companies consider

permissioned blockchain a better solution to preserve some information respect to the permissionless one. Then, usually, participants of the network do not trust each other and the blockchain technical code assures the safety of transactions and the absence of any opportunistic behaviour by the nodes of the network. In a permissioned network nodes are less, so the consensus takes less time, and, moreover, there is no need to compensate validators, because they are all members of the network, whose interests is that transactions are valid and safe.

After that, companies can decide to use a public permissioned blockchain, in which only the validator nodes need to be authorised, while anyone can make transactions, or a private permissioned blockchain where all the nodes have to be authorised to be part of the network. Altough a public permissioned blockchain would favour a scenario more open and it would encourage competition of suppliers and development of innovations, the private permissioned blockchain is easier to manage and, maybe for this reason, generally preferred by companies.

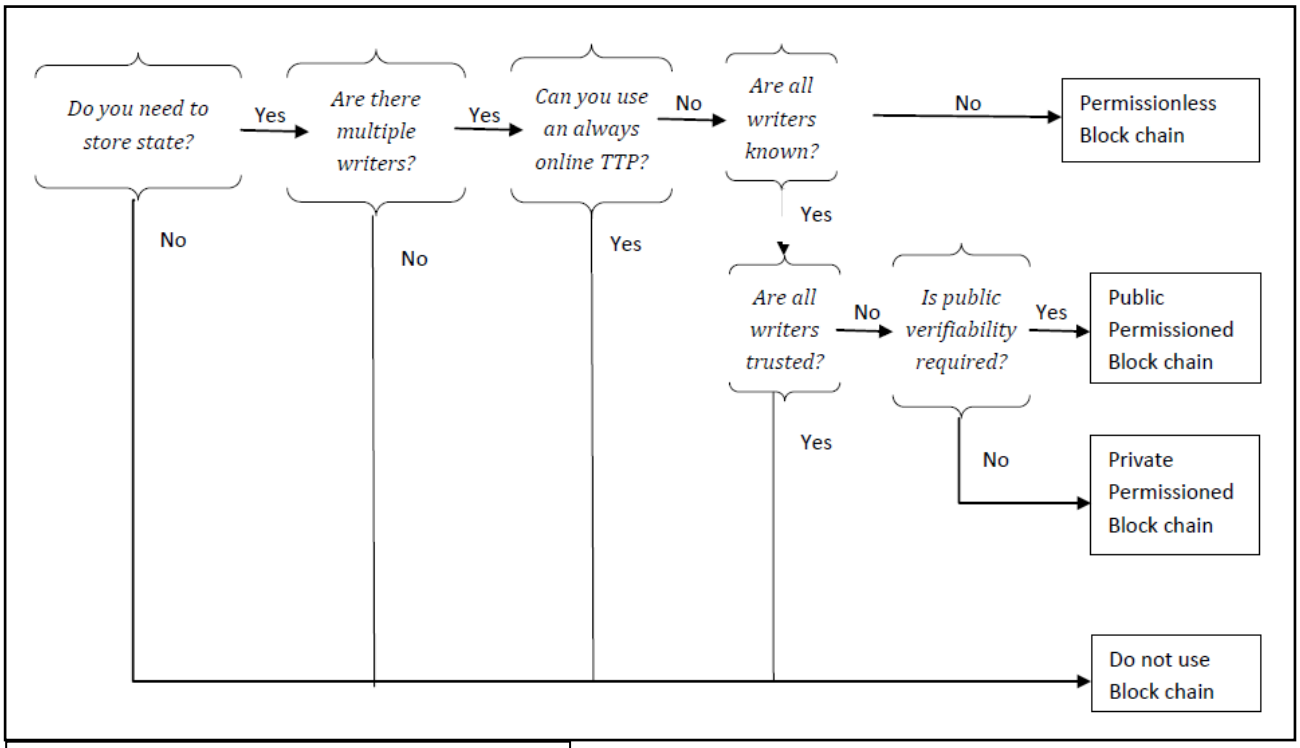

Fig. 3.7. Wüst and Gervais model

3.2.2 Blockchain impact in planning activity

It is been explained in the previous section the importance and the complexity of the planning activity within a company, and, for this reason, this activity is supported by IT since a long time. Currently, companies can plan their activities using APS software or applications available on cloud and the blockchain technology would not substitute these types of software because it fulfils different needs. Indeed, a blockchain platform is not able to represent reality and to run simulation on the basis of the actions chosen by managers; but, it can affect inputs of an APS software.

Typical inputs of the planning activity are: forecasted demand, the strategy of the company and technical information about the manufacturing of physical products. In a supply chain, there could be two opposite scenarios:

1. The nodes of the supply network do not have any type of partnership or agreement between them, and so, they plan their activities on their own, pursuing personal objectives. If the supply chain is composed by five stages and the final forecasted demand is equal to 800 units the scenario is the following:

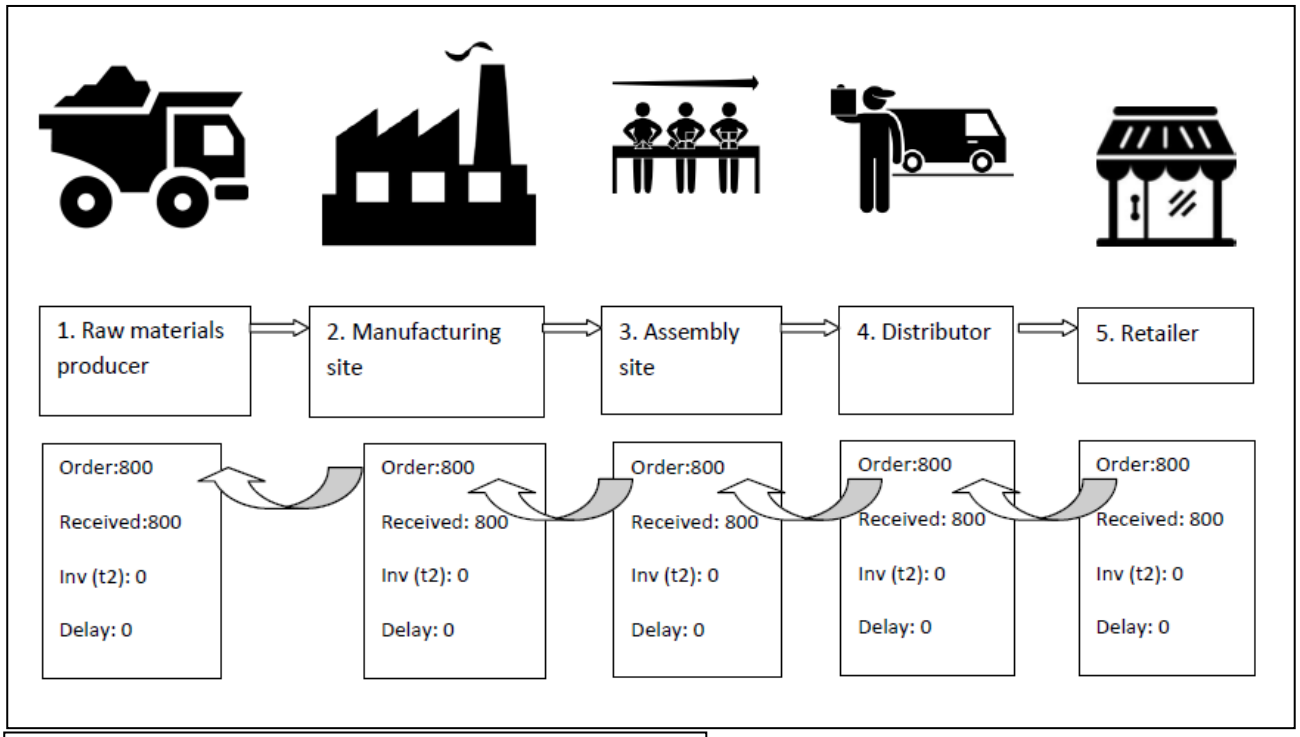

Fig 3.8. Non-collaborative scenario: stable demand

The inventory replenishment method adopted is assumed to be the stock management, because each node has a relationship only with its direct supplier. Thus, the result is that every node makes an order equal to the final forecasted demand, therefore, there will be no inventories at time 2 in the system and companies do not face extra-costs for delivery delays . However, if, suddenly, the retailer wants to buy more units for every reason, as instance because it wants to launch a promotional activity to make the demand grow, or because it wants to collect stocks for peaks of demand, what would happen?

The distributor would see an order bigger than the usual and it is not able to fulfil this order, because it has planned the production for 800 units and not, as instance, for 1000; so, the distributor will incur in extra-costs for deliveries in delay. Moreover, the distributor will increase the order to its supplier because it is going to collect stocks, to avoid any further delays if another time the demand will still grow. The same scenario will appear at every level of the supply chain.

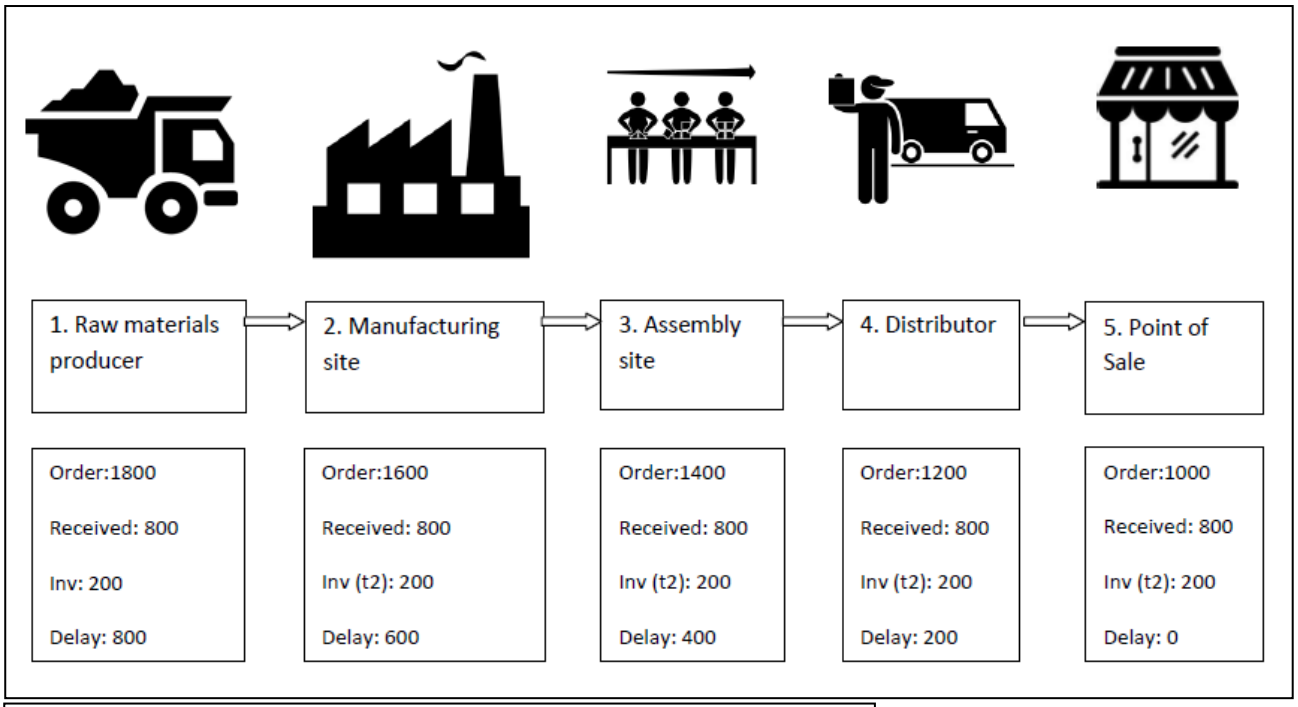

Fig. 3.9. Non-collaborative scenario: variation in the final demand

In this alternative scenario, the supply chain is very inefficient, because suppliers are not able to send materials on time to customers, and so, they have to consider exceptional deliveries which correspond to extra-costs; in addition, at each stage there are some inventory holding costs that could be avoided. In the Figure 3.10, it is showed the variation of the demand at each stage, to understand which are the stages that pay more the lack of coordination in planning production and delivery.

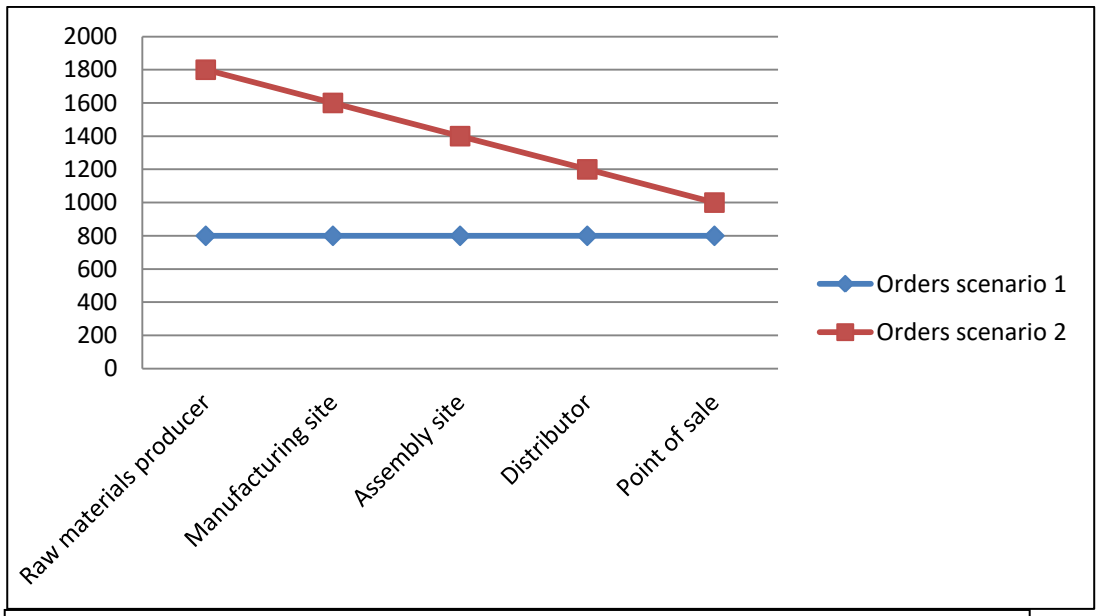

Fig. 3.10. Variation of orders' quantity along a non-collaborative supply chain

Companies, which see a high variation in the demand, are those more far from the market. This is the known bullwhip effect which causes the extension of the impact of an error along the supply chain, going far away from consumers' requests.

2. In this scenario, nodes of the network share information on forecasted demand or level of inventory and, in this way, they can collaborate to plan the production and distribution activities. Information arrives at the first stage, following a requirement based logic of replenishment and, as instance, if there is an immediate need of increasing the production, the situation is:

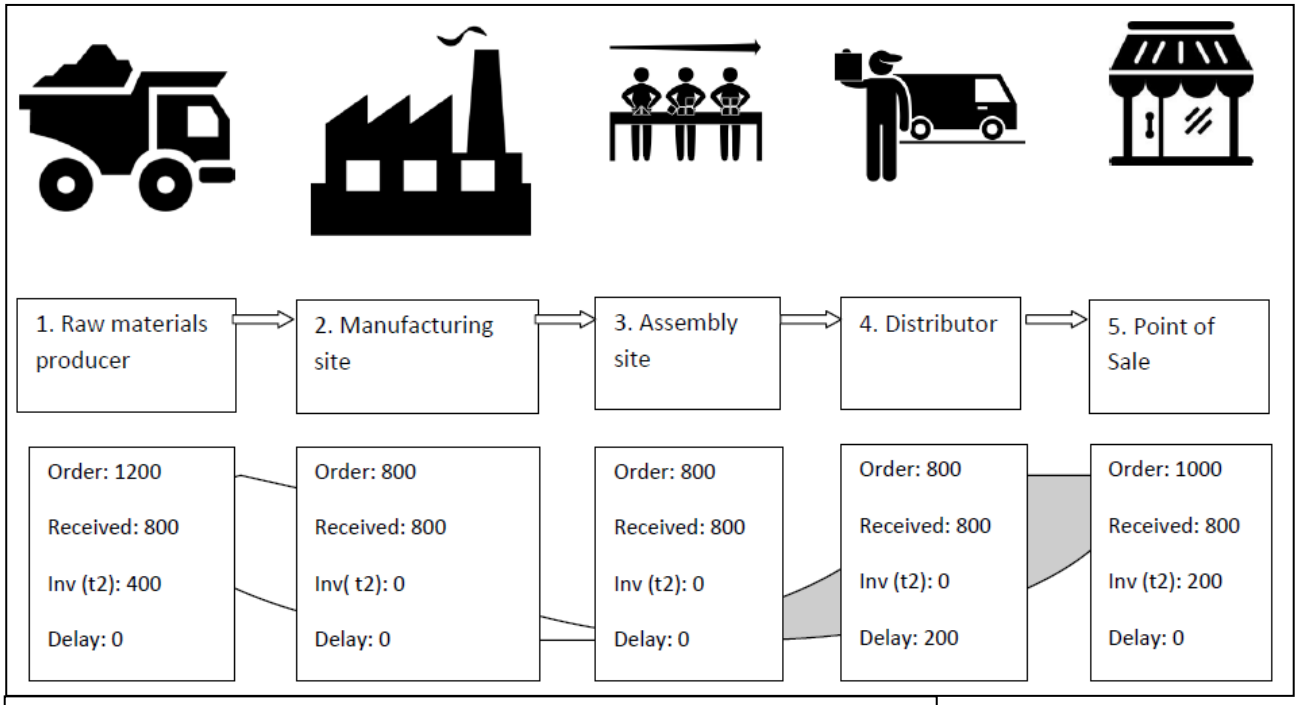

Fig. 3.11. Collaborative scenario: variation in the final demand

In this case, the nodes of the chain avoid to increase their orders because they know their suppliers cannot fulfil these; so, information goes upstream and, as the order delays as inventories of the whole supply chain decrease respect to the non-collaborative scenario. This means that a coordinated planning in a supply chain reduces the bullwhip effect.

Certainly, a coordinated and integrated planning is not a common situation, but, blockchain is important in sharing information. Indeed, the blockchain ledger is available to everyone, not only to verify transactions, but also to see, exploiting the traceability potential of blockchain, where are singular items that a node awaits. Thus, for sure, the use of blockchain favours and improves the coordination of the supply chain, giving more detailed information about the position of each items and the state of transactions; in this way, a node can exploit this information as inputs for its planning activity.

3.2.3 Blockchain along the distribution

Now, focusing on the distribution, the growing need of consumers to know what they buy stressed the necessity for companies to have visibility on the whole supply chain of an item, along the entire distribution channel; so, investments were done to implement traceability system that can assure a strict control on items lifecycle. Information companies will have to disclose concerns the origin of products, the materials used, the steps these have passed through during the manufacturing and assembly phase, and then, the ethic, and the conduct of companies involved in the supply chain both towards the environment and towards workers.

The blockchain allows to register on the ledger the transfer of goods, including related information such as the parties involved, the price, date, location, quality and state of the product; moreover, as Bitcoin is able to track each bitcoin moved, as the blockchain would be able to trace every digital asset moved, so, to trace the journey of any item from the birth to the arrive at the point of sale.

Traditionally, companies have information of items only when these pass through some points, in which are installed repeaters that read information stored on the sensors of the items, and transfer them to the hardware or software middleware. Thus, actually, companies are not able to trace constantly items, but they have information in silos, corresponding with points in which are located repeaters. Otherwise, with the blockchain, it is possible to trace constantly the journey of items, and the timestamp function assures the precision of information stored in the ledger. The blockchain creates and encrypts records of transaction containing the serial number, or barcode or tag representing physical goods and moves these to the other nodes of the network, that have to verify the validity of the block containing the transaction: if the block is valid, it is added to the ledger and each node can know where a particular object is.

Moreover, the decentralised structure of the ledger makes impossible for anyone to own the ledger and manipulate data.

The collaboration between traditional traceability tools and the blockchain guarantees a continuous monitoring of item conditions during the distribution, constituting in this way an important barrier against the grey market. To develop a complete traceability system, there is the need to transfer the physical object into the blockchain, to give each item a virtual identity. Thus, objects has to be linked with a sensors, a tag, able to store information about items and transfer them to the platform; examples of possible tools are: Qr code, Wireless sensor networks, RFID, etc...

Solutions that trace items thanks to an interaction between RFID tag and software already exist, but are all centralised, one of the most important is provided by GS1 *(solution described in detail at the end of the section)*.

Nevertheless, in centralised systems there is a problem of trust, because an organisation has to assume the role of controller for the management and access of data stored. Indeed, in this case,

the possible alternatives are two: either a company of the chain will collect and manage data of the whole supply chain, or a third party. The first alternative is not feasible in the majority of the cases, because, unlikely, all industries of the same supply chain have a so high level of trust in one member to give him this power and responsibility, but, also the second case could be not so sure. Indeed, companies of the supply chain should choose very carefully the third party who will manage their data, because they have to assure that the external company is not closed to any other company of the chain, and that it is prepared to pursue that task.

Beyond the problem of trust, in a centralised structure there remains another weakness, the security. Information are stored in a single point, so, for an hacker could be easy to enter in the system and change, remove or take data.

Otherwise, blockchain allows companies to afford on a technical code that no one can bypass, and this makes this solution perfect to trace transactions between parties with little trust in each other. In the blockchain, the algorithm which validate transactions assure that no one can corrupt the ledger, unless it owns the 51% of CPU power of the entire network.

To sum up, it is possible to identify three main advantages of adopting blockchain in traceability of supply chain:

1. **Non localization:** each user can access to the state of the system, without the need to pass by a single particular authority but applying independently common rules.

2. **Security:** as said before, the blockchain ledger is not stored in a central server, but it is distributed by all nodes and every node has a copy of the ledger. Thus, to change data in the ledger it is not enough to attack one node because the other nodes quickly recognize the hacker attack and do not validate the new updated database.

3. **Auditability**: the blockchain ledger is easily auditable because each transaction is recorded in the chain. Instead, in centralised systems, auditing can require a lot of time and money, because data of transactions typically come from a wide variety of sources.

The GS1 EPCglobal architecture

GS1 is a federation of more than 110 business organisations, which creates standards adopted by industries and companies in driving their businesses.

Nowadays, 2 million companies use GS1 Standards, and the most common standard is, without any doubt, the barcode; in fact, it is estimated that 5 million GS1 barcodes are scanned every day around the world. Moreover, 10 million products are registered in "The Global Data Synchronization Network" (GDSN), used by a lot of retailers to share information.

GS1 Standards allow different companies to speak the same language in the identification of products or documents, in capturing these information through data carriers and in sharing those among them.

The Electronic Product Code (EPC) is a language for unique identifiers assigned to physical objects, unit loads, locations, or other identifiable entity. EPCs have multiple presentations, including binary forms suitable for use on RFID tags, and text forms suitable for data sharing among enterprise information systems. When EPCs are encoded onto individual RFID tags, radio waves can be used to capture information at extremely high rates and at distances of more than 10 metres, without line-of-sight contact. These characteristics of RFID can be exploited to intensify supply chain visibility and improve inventory management. The traceability process consists of the implementation of three key sub-processes:

1. *Identification and labelling of the products to facilitate and optimise product identification;*
2. *Data capture and recording: scanning capabilities combined with electronic information flow to optimise reception and despatch operations;*
3. *Linkages and communication to optimise data sharing between supply chain partners and support recall, or withdrawal procedures.*

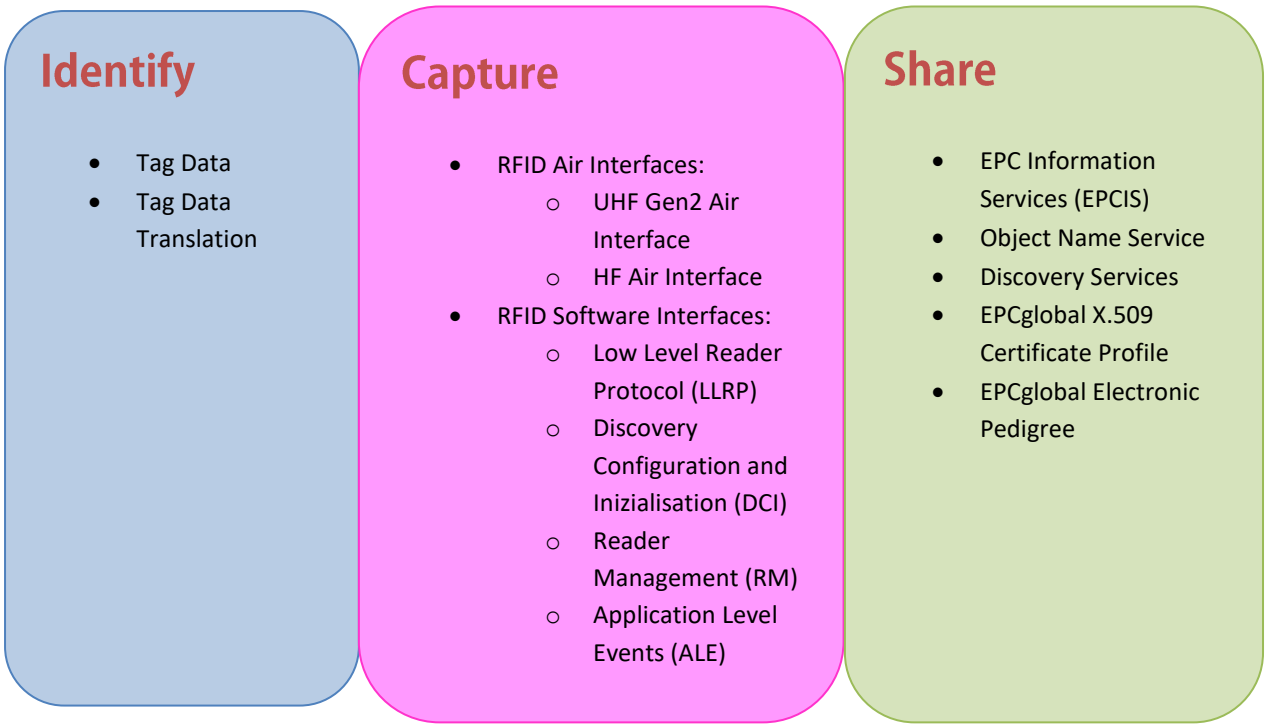

Fig. 3.12. EPC traceability process

Identification

The identification stage includes Tag Data Standard (TDS) and Tag Data Translation (TDT).

TDS defines the EPC, including its correspondence to GS1 keys and other existing codes. In addition, it specifies data that is carried on Gen 2 RFID tags, including the EPC, User Memory data, control information, and tag manufacture information. Thus, the TDS includes two different things: the EPC identifier and the RFID data carrier. EPC is a string having the following form:

urn: epc: id: scheme: component1. Component2. ....

The structure of the EPC guarantees worldwide uniqueness of the EPC across all types of physical objects and applications. The action of allocating a new EPC and associating it with a specific physical object is called "commissioning". Thus, applications and business processes that commission EPCs are responsible to ensure that the same EPC is never assigned to two different physical objects.

First of all, EPC contains the company prefix, to identify the company who produce the items, furthermore, each EPC scheme provides a namespace of identifiers that can be used to identify physical objects of a particular type.

- *Serialised Global Trade Item Number (SGTIN): It is used to assign a unique identity to an item;*
- *Serial Shipping Container Code (SSCC): It is used to assign a unique identity to a logistics handling unit, such as the aggregate contents of a shipping container or a pallet load;*
- *Global Location Number With or Without Extension (SGLN): It is used to assign a unique identity to a physical location, such as a specific building or a specific unit of shelving within a warehouse;*
- *Global Returnable Asset Identifier (GRAI): It is used to assign a unique identity to a specific returnable asset, such as a reusable shipping container or a pallet skid;*
- *Global Individual Asset Identifier (GIAI): It is used to assign a unique identity to a specific asset;*
- *Global Service Relation Number (GSRN): It is used to assign a unique identity to a service relationship with service providers and service clients;*
- *Global Service Relation Number Provider (GSRNP): It is used to assign a unique identity to a service provider;*
- *Global Document Type Identifier (GDTI): It is used to assign a unique identity to a specific document.*

Moreover, Tag Data Translation (TDT) standard concerns in a machine-readable version of the EPC TDS specification. TDT can be used to validate EPC formats and to translate between the different levels of representations in consistent way. In addition, TDT contains details of the structure and elements of the machine-readable files and provides directions on how it might be used in automatic translation or validation software, either standalone or embedded in other systems.

RFID Air Interfaces

The RFID Air Interfaces of the EPC system are: the Ultra-high frequency (UHF) Gen2 Air Interface and the High frequency (HF) Air Interface.

The Gen2 Air Interface protocol was published in 2004, and it defines the physical and logical requirements for an RFID systems of interrogators and passive tags, operating in the 860 MHz-960 MHz UHF range. The protocol was then updated in 2008.

On the other side the HF standard defines the physical and logical requirements for a RFID system operating at 13.56 MHz frequency. The system comprises readers and tags.

RFID Software Interfaces

RFID Software Interfaces comprehend: Low Level Reader Protocol (LLRP), Discovery Configuration and Initialisation (DCI), Reader Management (RM) and Application Level Events (ALE).

LLRP is a low level protocol between software and a reader that provides very precise control over the operation of a single reader. It is composed of almost 100 standard commands and provides an

interface to low level functionality that is uniform across different reader vendors. Thus, reader vendors don't have to throw away their existing command language; instead, many reader vendors support LLRP commands in parallel with their vendor-specific interface.

Instead, the DCI standard specifies an interface between RFID readers and access controllers and the network on which they operate. It specifies the necessary and optional operations the reader and the client can pursue to use the network to communicate with other devices, to exchange configuration information, and initialise the operation of each reader; so that, the reader operations protocol can be used to control the operation of the readers to provide tag and other information to the client.

The Reader Management (RM) protocol is used to monitor the operating status and health of EPC global compliant RFID readers.

Finally, the Application Level Events (ALE) standard specifies an interface through which clients may obtain filtered, consolidated data capture information for physical events and related data from a variety of sources. In particular, ALE clients do not need to know which model of reader is being used or even how many readers or antennas are in use, but, they only need to specify its information requirements, allowing in this way ALE implementation to determine the best way to fulfil requests. This function is implemented by running an "ALE filtering and collection engine", which can be obtained from certain reader vendors and also software vendors, who are specialised in RFID middleware. At the end, ALE delivers to clients decoded data.

EPCIS

EPCIS is a G1 standard that allows companies to share information about the physical movement and status of items during their journeys all over the supply chain. The goal of EPCIS is to enable different applications to create and share visibility event data, both within and across enterprises. This aims at enabling companies to obtain a shared view of physical or digital objects within a relevant business context.

Object name service (ONS)

The ONS is an automated networking service that discovers data and services associated with a GS1 Identification Key, and after that, it leads computers to sites on the World Wide Web. Information included in the EPC pass to the ONS of a local network, which leads the middleware to a server where a file about that product is stored. After the authentication, the middleware retrieves the file and information about the product can be sent on a company's inventory or supply chain applications.

Discovery services

Discovery Services provide a tool to authorised clients, useful in detecting multiple sources of information. It is the same function of the ONS, with some differences: first of all, Discovery Services provide information only to authorised users, while the ONS does not require any authorisation, and then, while with the ONS a company is able to know information of an item related to the first stage of the production, Discovery Services allow to know information about the whole lifecycle of an item.

EPCglobal X.509 Certificate profile

The Certificate Profile produced by the EPCglobal standard, is the X.509 Certificate Profile. The certificate profile works to interpret and narrow functionalities that already exist. Moreover, the certificate profile provides a minimum level of cryptographic security and defines and standardises identification parameters for users, server and devices.

EPCglobal Electronic Pedigree

The electronic pedigree provides a standard platform with state, regional and national drug pedigree laws. Each state law specifies the data content of the electronic pedigree, but none of them specifies the actual format of the document, so, the need for a standard electronic document format that can be updated by each supply chain participant, is what has driven the creation of the specification.

3.2.4 Blockchain in the production process

It was just explained how blockchain could be useful in tracking goods and what is its potential in this field, so, a possible further step could be the application of blockchain to track the flow of materials during the production and assembly phases too.

Indeed, the different machines or departments that an item has to pass through to complete its travel into the production or assembly site could be integrated in the blockchain. In this manner, when an item pass from one assembly or production station to another, the movement is recorded in the blockchain and it is possible to track the routing of each item also during the production process. Thanks to the timestamp, it is possible to date back to the batch of production of the product or the moment in which it finishes a manufacturing operation, to study more carefully the characteristics of each item; moreover, the blockchain could be used also in coordination with tools of statistical process control to improve the quality control within the company, facilitating the detection of defective lots during withdrawal or recall processes.

The operation of filling the transaction in the blockchain would be pursued by the operator in line which has to make the transaction before the piece is moved to the next station. The scenario could be very similar to an unpaced line in which the operator, at the end of the operation, moves the piece ahead, but, this time, he has to put the transaction on the blockchain to move the piece.

3.2.5 Blockchain for NPD

The characteristics of blockchain makes it useful in the coordination of new product development processes. In particular, the capability to share instantaneously information regarding transactions and date and time of transactions among different companies can be used in NPD projects, which often see difficulties in respecting deadlines.

In the first stages of the NPD process, via blockchain, companies can share documents about the design of the new project or the different available designs on the basis of the technical characteristics of the products and the performances it could achieve.

The strong relationship about the accuracy of date and time of blockchain transactions recorded and the need to respect deadlines and to choose the right moment to involve suppliers in the NPD process is an important feature that could lead to the use of blockchain in the NPD process. Blockchain helps the NPD process in: involving suppliers at right time, control the quality level of components, and that suppliers respect deadlines and specifications thanks to the smart contracts. Moreover, on the other hand, thanks to the blockchain, suppliers can access to the updated ledger of the project and understand when they will join in project, to plan adequately its actions.

In addition, a permissioned blockchain would be the most suitable solution for the problem of trust between companies involved in NPD projects.

3.3 THEORETICAL BARRIERS TO BLOCKCHAIN ADOPTION

After some proposals of possible applications of blockchain in the supply chain management, and the presentation of the related benefits, it is the moment to analyse which could be the possible theoretical barriers of the introduction of this technology in the supply chain management.

In the Sourcing process, the blockchain enters in two way: the necessity in the specifying stage to fill the specifications with the pre-requisite that suppliers must be available to adopt blockchain, and the substitution of the traditional contracts with the smart contracts, regulated by the technical code of the blockchain. For what concern the specification, an effect of the introduction of the blockchain pre-requisite in the specification document is the limitation of available suppliers, and this reduction can cause a lack of competition between suppliers, which, in this way, will have a higher bargaining power in the negotiation phase. Concurrently, there could be the possibility to lose an optimum supplier only because it does not accept to use the blockchain, maybe because it is scared of the adoption of this new technology. Indeed, in particular in those industries in which the final product has a low technological complexity, and suppliers are composed by a lot of small or family companies, which are little familiar to the digital technology, there is the necessity to make the transition of information to the blockchain as easiest as possible, adopting some simplified user interfaces of the software to allow suppliers adopt the new technology without any fear. At this point, it can be useful to remind the Estonia case, in which the bank Cuber provides to users an online payment service, that appears to users as an app through which they can complete online payments, with the possibility to download a simplified version of the blockchain ledger (containing only blockheaders), which allows users to verify that the network has accepted the transaction and that the block has been attached to the chain; nevertheless, users do not see that Cuber makes payments in Bitcoins.

On the other hand, the adoption of the smart contracts rises two types of problems: a security problem and a responsibility problem. The security or safety problem is caused by the fact that the blockchain assures a high level of security, but, theoretically, frauds and thefts are possible; in fact, these happened in the past, and also recently. The most serious theft concerning the smart contracts occurred in the 18th June of 2016 in the Ethereum blockchain, until that day never hacked. The hacker succeeded in collecting 3.6 million ether, stolen by “The DAO” structure, which is the most important DAO of Ethereum. In the Ethereum blockchain, DAO stands for Decentralised Autonomous Organisation and it codifies the rules and decision making apparatus of the organisation, creating a structure with decentralised control. The most famous DAO of the Ethereum blockchain is called “The DAO”, which was created by a German start-up on the 30th April 2016, and it makes “smart locks” to allow people share their things in a decentralised version of Airbnb. “The DAO”, in the moment of the attack, grew so quickly to own the 15% of all the ether of the blockchain, indeed, consequently to the attack, the ether’s value fell from 20$ to 13$. In addition, the event showed the weakness of the system and rose another important problem related to smart contracts: is it possible to consider The DAO theft a theft?

The hacker was able to move ether in a "child DAO", that has the same characteristics of the parent DAO, and, despite all nodes are able to see the ethers in this DAO, no one can access to remove the ethers immediately.

Moreover, the nature of the smart contract is constituted in order to be itself the ultimate judge of the deal, and theoretically, if someone is able to pursue an operation within the limits of the technical code, which governs smart contracts, there could be very difficult not only to identify the attack and repair its effects, but also, to prove the crime.

It is possible to link this limit to the other important barrier to the adoption of smart contracts: the transfer of responsibility and decision power from human to machine. This limit is not easy to overcome, indeed, while there are possibilities to link technical and legal codes, as it was showed in the introduction, here there is also a psychological problem: people do not afford to leave the decision power to a machine governed by a code. Indeed, although the code constituting the contract assures the observance of terms by each party, otherwise, smart contracts cannot be modified neither bypassed; so, each error or inattention, during the building of the smart contract, will result in a weakness of the contract. If someone is able to act within the code of the contract to pursue malicious purposes, or if something needs to be changed, or if an error does not allow to complete an operation, the two parties cannot act on the execution of the contract, and people are scared of this.

Furthermore, the application of blockchain technology to support traceability of items in the distribution channel and within the company has two main barriers: implementation costs and time asymmetries. The implementation costs are simply related to the adoption of a complete traceability program which comprehends tools and the blockchain platform, while the time asymmetries' effect is more complex. In the Bitcoin blockchain, the assets moved are bitcoins, which live in a digital world, and they are moved to the receiver until the validation of the block is completed: the finalisation time takes normally from 10 to 60 minutes. Otherwise, in a blockchain which represents the supply chain, transactions regard physical objects with a virtual identity, so the delivery time of the physical items cannot correspond to the finalisation time. If assets are moved only after the validation of the block, the time asymmetry can cause an increase of the time needed to complete transaction: indeed, if T is the time to complete transaction, it will include both the time of the virtual transaction (finalisation time) and the time of the physical transaction.

$$T = T_v + T_p$$

T= transaction time;

T_v = time of virtual transaction;

T_p = time of physical transaction.

Thus, the validation time affects seriously the performance of the supply chain and, in particular in a manufacturing or assembly line where operations take usually short time, delays could become

relevant. Permissioned network can attenuate this effect, because the consensus algorithm last less due to a reduced amount of validator nodes; however, the increase of the transaction time adopting the blockchain in supply chain management is quite inevitable and its effects can be more or less impactful depending on the situation. A possibility to maintain the efficiency and the speed of the supply chain in those cases in which time asymmetries affect a lot performance of the supply chain, could be to begin the physical transaction before the validation of the block, in the meanwhile, transactions are visible anyway in the blockchain although not validated yet.

Finally, in the NPD process, the adoption of blockchain could cause a limitation of the open innovation opportunities. In fact, the creation of a blockchain network for a NPD project can result in a strong link between companies, that, in the future, could choose to maintain these networks of relationships for NPD projects; however, this behaviour will have a negative effect on the inclination of companies to look for external sources of innovation.

The last barrier to the adoption of blockchain technology in supply chain management regards again a security aspect. Indeed, the security of blockchain is founded on the consensus algorithm and the shared ledger, which guarantee the validity of transactions because, as it was said before, a malicious node should own the 51% of CPU power, or it should have a CPU power higher than the sum of all the remaining honest nodes; but, theoretically, the crime is possible. However, in permissioned blockchain, characterised by a lower amount of nodes, this chance is more likely, because for some companies would be easy to appropriate of the majority of CPU power of the network and find an agreement to discriminate another company, or to create cartels, using the blockchain.

This possibility reveals the necessity to establish standard and legal rules in the adoption and use of blockchain in the business, to favour the scalability of this powerful technology.

Role in SCM	Activity involved	Benefits	Barriers
Blockchain as a requirement in the specifications	Sourcing	Help in identifying suppliers who want to adopt blockchain	Limit the available suppliers with consequences on the internal competition
Smart contracts	Sourcing	• No need of third party in charge of notifying the contract; • Automatic execution of transactions, payments and settlements; • Assure the observation of the terms by the parties; • Reduce contract disputes and lawsuits costs.	• Possibility of frauds and thefts; • Transfer of responsibility and decision power from men to machine.
Traceability	Distribution/Production	• Capability to trace instantaneously the journey of each item, form the manufacturing site to the point of sale; • Safety of data stored in the ledger; • Availability of a shared ledger of information not owned by any companies of the chain; • Complete tracking of all items recorded.	• High implementation costs; • Time asymmetries between virtual and physical transactions.
Coordination of the NPD	NPD	• Sharing instantaneously information about the project; • Support the NPD project in: involving suppliers, control quality and respect deadlines and specifications; • Help the planning activity of participants of the network.	• Risk to focus on old partners loosing in this way open innovation opportunities.

Table 3.7. Theoretical benefits and barriers of the adoption of Blockchain technology in the supply chain management

Interview with the IoT Expert Valerio Vaccaro

Valerio Vaccaro is the IoT Expert, working for the Italian Start-up Eternity Wall, which started three years ago as a solution to allow users to write eternal and anonymous messages in the blockchain, and now, is one of the most important consultancy company for blockchain solutions. In particular, the company developed the OpenTimestamps, a standard for data certification through the blockchain. This protocol allows:

- *Independent verification of timestamps by the users without any external intervention;*
- *Aggregation of data;*
- *Reduction of costs;*
- *Guarantee of privacy, because the server do not receive the original copy of the document, but only the hash of the file;*
- *Possibility to easily change standard protocol, because it is open source.*

Essentially, the blockchain adoption in data certification of digital documents is a proof of integrity for regulators offering incontestable data for customers and, in addition, it guarantees transparency between supplier and customers. Among the clients of Eternity Wall there were: Intesa Sanpaolo, Deloitte and Cerved.

In the interview with Eng. Vaccaro it is possible to find some clarification on doubts about possible barriers of the blockchain adoption, and to understand which could be the future applications of blockchain in the industrial sector.

1. *Which are the label tools (QR codes, Barcode, WSN, RFID, etc...) more suited to be put in communication with a blockchain platform?*
   Every label tools can be used together with the blockchain, in particular QR codes at this moment are the most adopted.
2. *Is it possible to adopt the blockchain in tracking products also after sale, to improve the efficiency of the reverse logistic and favour the recycling activity and a closed-loop supply chain?*
   Yes, but it would not add anything to a solution which already exploit a distributed ledger, however increasing the development costs.
3. *Could the blockchain support the sorting activity?*
   It depends on data that I want to record on the blockchain, but, as in the previous case, now, it is more advantageous to use a distributed ledger.
4. *Is it possible that the blockchain finalization time affect the supply chain performances?*
   It could be, if, as instance, I want to wait the validation of 6 blocks in the Bitcoin blockchain I have to wait for one hour, but if it is enough to see transactions on the blockchain, they are immediately visible on the ledger.
5. *Is it possible to put into communication different blockchains among them maybe representing different supply chains? If yes, through the Sidechains?*
   Basically is NOT possible for different blockchains to communicate among them, because their previous story is different. Sidechains can be used for offline modifications with a limited timeframe.

3.4 INDUCTIVE ANALYSIS

At this point, it is the moment to identify which are the potential uses in the short term of the blockchain in the supply chain management, referring to the actual situation of projects already completed or currently underway. Actually, the main scope of these projects regard exactly the improvement of the traceability along the supply chain. In the following section, there will be presented some cases of application of the blockchain technology in the supply chain management, highlighting which is the state of the different projects, in which industry and how they apply the technology, and the benefits that those application produced or aim at producing in the future.

3.4.1 Everledger

Everledger is a british sartup based in London, founded in 2015 by Leanne Kemp, that aims for ensuring transparency of journey of items along the supply chain, by building a digital verification system that helps in the reduction of fraud, black markets and trafficking. The company identifies assets creating a permanent record on the blockchain which contains information about characteristics, history and ownership: the first application field is in the diamond industry.

Particularly, in the jewellery sector, frauds cost 2 billion $ every year, and Everledger aims at providing dealers and insurers in the industry with a service to monitor the provenance of jewels and find stolen diamonds or items coming from conflict zones. Since the beginning of its activity, Everledger recorded 1 000 000 diamonds on the blockchain, and each diamond is identified on the basis of forty unique characteristics.

The company tries to exploit advantages of both permissionless and permissioned networks, recording diamonds in the Bitocoin blockchain, and, at the same time, providing to users a permissioned blockchain developed by IBM. Everledger leverages the security of the Bitcoin blockchain, through the connection of the diamond's ID to the smallest quantity of bitcoin available, which becomes, consequently, the substitute of the diamond on the Bitcoin blockchain ledger. After that, every time the diamond moves along the supply chain, or changes its ownership, the virtual identity, the "virtual diamond", moves on the blockchain. Moreover, as introduced before, Everledger provides also a permissioned blockchain to enable transactions within the industry, developed by IBM, with whom Everledger established in 2016 a partnership.

IBM's blockchain platform is delivered to its clients through the IBM Cloud, in what there can be called as Blockchain-as-a-service (BaaS); in particular IBM blockchain is built on the Hyperledger Fabric and Hyperledger Composer.

Hyperledger is an open global collaboration, hosted by "The Linux Foundation", among some companies leader in industries that comprehend finance, banking, IoT, supply chains, manufacturing and technology. Hyperledger aims at assuming the role of a trusted source of innovative open source development community about the constitution of blockchain permissioned networks. Composer and Fabric are two projects of the Hyperledger community: in

particular, Composer consists in a set of tools for building blockchain business network to create smart contracts and blockchain applications for business owners and developers of start-ups, while Fabric is a blockchain framework implementation that allows components to be plug-and-play. In addition, Hyperledger Fabric enables companies to build different channels, allowing to create a separate ledger of transactions: this is an important opportunity for networks where some participants might be competitors and they do not want every transaction they make, known to every participant. Moreover, Fabric allows companies to communicate among themselves in a private way, without sharing information with the entire network, and to act on modifications to the consensus algorithm, that can be set either PBFT or without consensus.

Everledger aims at becoming "a permanent, digital, global ledger that tracks and protects diamonds and other valuable goods on their lifetime journey"; in fact, the Everledger's founder, Leanne Kemp, declared that their technology can be applied to all sectors in which knowing provenance of items is important. Thus, the company is beginning to become interested in the application at the wine supply chain, and, in addition, it has signed recently an agreement with Vastari, an art and exhibition database.

3.4.2 Provenance

Provenance is another British organisation based in London, founded in 2013, which works with databases and open data to help companies gather information from their supply chain. But, actually, the main activity of the company is in applying the blockchain technology to provide a digital "passport", which proves authenticity and origin of physical products. Applying blockchain in the traceability of products implies two important benefits for society and environment: preventing the selling of fake goods, and the "double spending" of certifications.

Moreover, the use of blockchain allows virtuous companies to demonstrate their ethical and environmental conduct, and to defend themselves by any claims regarding the safety or the authenticity of products. Indeed, the Provenance solution allows companies to share with the external world the impact of processes constituting their supply chain management. The benefits, for companies, of using blockchain technology in the traceability of items are:

- Trust;
- Collaboration: the Provenance platform provides an opportunity for actors of supply chain to collaborate, sharing information about the lifecycle of products;
- Integration: Provenance allows to create a digital identity of physical products;
- Authenticity;
- Security: data are protected by the consensus algorithm of the blockchain;
- Creation of a loyalty relationship with customers.

In addition, to enforce the relationships with NGOs or auditors who are interested in assessing the sustainability of supply chains, Provenance allows these entities a free use of the platform.

Until now, traceability was in charge of centralised systems, sometimes managed by neutral or non-profit organizations, but, the blockchain allows to overcome the limits of centralised systems. Indeed, a centralised system implies that a third party is able to be trusted by every actors of a supply chain, or better, of more supply chains, to collect and manage all data. Actually, situations in which a NGO organisation manages the traceability of a supply chain are very few, because, usually, the company which takes care of the items' traceability is either the most important company in the chain, or an external provider. However, even if a company is really neutral in the management of the traceability system, there would be another problem: the centralisation of data constitutes a single point of weakness, attractive for malicious entities.

Instead, as it was showed before, the blockchain technology guarantees a high level of certainty over the loyalty of the information.

The Provenance system provides to the registration of virtual identities of products in the blockchain, and after that, every transaction with the connected information is recorded on the shared ledger. This allows actors of a supply chain to transfer the characteristics of their material products to any other actor along the chain. Nevertheless, certain companies might be concerned about their privacy or the privacy of their suppliers; so, Provenance uses the Public-Private Key Infrastructure to allow companies transfer information, without revealing their identity. In this manner, manufacturers can safely pass an authentic certificate downstream keeping their identity private, while, customers can check characteristics of purchased goods, without seeing the whole complexity of the supply chain.

Blockchain technology makes the Provenance platform:

- Auditable;
- Cost-efficient, because it eliminates the need to audit "handling companies";
- Real-time and agile;
- Public;
- Guaranteed continuity, because the elimination of any central operator ensures inclusiveness and longevity.

Now there will be presented the pilot projects completed with the use of the Provenance solution. On the basis of different needs related to the different situations, the company decides to adopt either Bitcoin or Ethereum public blockchain platforms, but, differently from Everledger, no permissioned blockchain networks are provided. Provenance decides to use Bitcoin, when it wants to exploit advantages of a more developed and mature system with the possibility to develop very basic smart contracts; while it decides to use Ethereum when there is the necessity to make confirmations, certifications or ID transformation.

Tracking fresh products with Co-op

The UK Co-op is the fifth biggest food retailer of the country, with more than 2500 stores. The Co-op is a particular organisation, not owned by any big investor, but composed by individual members and other co-ops that govern over the organisation. Indeed, each member of the Co-op can vote on key business issues at the annual general meeting, elects representative members at the council or being elected to the member council.

Co-op in UK is an important business which rose in 2016 34 billion £[4], and Provenance has conducted a pilot project with The Co-op site on Manchester. The project has consisted in providing to fresh products, a digital passport, and in tracking in real time the journey of products all along the supply chain. Provenance has collected data from farms, factories, Co-op distribution centres and retailers, and, in addition, it has integrated ERP systems of all these players, to allow every actor of the chain to gather, every moment, information about suppliers and their environmental and social impact. The final result has been a digital history of the product, readable also by final users.

The main benefits of this project were:

- Risk reduction: Every product in the chain has a digital passport, this means the possibility to know where are the goods, and, in addition, product claims have not been duplicated or adulterated.
- Growth of customer trust: Interactive labels, that link physical goods to their digital journeys, transform marketing and product claims in trusty information.
- Efficiency increase: The Provenance platform provides a single source of truth for product claims and certificates, which are traditionally stored in separate silos.

Tracking tuna on the blockchain

This further pilot project was conducted by Provenance in 2016. It took six months, since May to November, and consisted in tracking fish with the use of blockchain and smart tags.

The project took place in Indonesia, which is the main producer of tuna, and concerns two types of tuna: the Skipjack and the Yellowfin.

The fishing sector is characterised by an high percentage of unregulated and illegal activities, including human rights abuses, frauds, overfishing and illegal fishing. Furthermore, bad effects of illegal fishing in Asia affects the whole fish market; in fact, the NOOA (National Oceanic and Atmospheric Administration) Fisheries estimated that 24 million tons of fish is traded illegally annually. In addition, it is estimated that between the 20% and 32% of wild-caught seafood imports of US is caught and sold illegally ("Estimates of illegal and unreported fish in seafood imports to the USA", British Columbia University), in spite of trials by United Nations to control and monitor fishing boats. In Indonesia, the tuna fishing is one of the major source of

[4] https://www.uk.coop

employment, but, who operates responsibly is not rewarded for his effort. Indeed, overfishing and illegal fishing practices reduce increasingly the catches of who fish within the rules, that, as consequence, have to spend more time in the ocean, consuming in this way more fuel. Therefore, higher costs of sustainable fishing are not compensated by premium prices because it is difficult to have complete traceability and transparency along the supply chain, which would justify a market premium.

Provenance wants to make more transparent the supply chain of tuna and avoid the double-spending of certifications, through the support of the blockchain, which allows to constitute an open platform that can deliver neutrality, reliability and security. In particular, the blockchain makes impossible the double spending of certifications, because no third parties are involved in the certifications process, and smart contracts represent those unbreakable rules.

Although permissioned blockchains are more scalable, faster and guarantee companies more privacy, Provenance decided to invest only in permissionless blockchains: in this case, the application was created in the Ethereum blockchain. A permissionless blockchain do not have any pre-determined nodes which own the responsibility of the validation phase, so, this gives more possibilities for customers to access data and strengthens the level of trust in the traceability system, because there would be impossible for the supply chain members to collude in limiting the disclosure of information about products' journeys.

Before the beginning of the project, Provenance met eight companies which catch tuna sustainably, and tried to understand the peculiarities of the tuna supply chain, and which are the digital systems in charge to track products. Actually, only one company used a digital tool for fishes accounting, called "ThisFish Tally-O system" by Ecotrust Canada, and Provenance decided to maintain this system and integrate it with the application created in the Ethereum blockchain. The application links the identity, location, characteristics, certifications and audit information with a specific item. The project is composed by three phases.

1. Registration and data collection

The first step was to provide local fishermen with the Provenance app, through which, they had to send SMS messages to register their catch: each SMS issued a new asset on the blockchain. Then, assets were transferred from fishermen to suppliers in both the physical and the digital

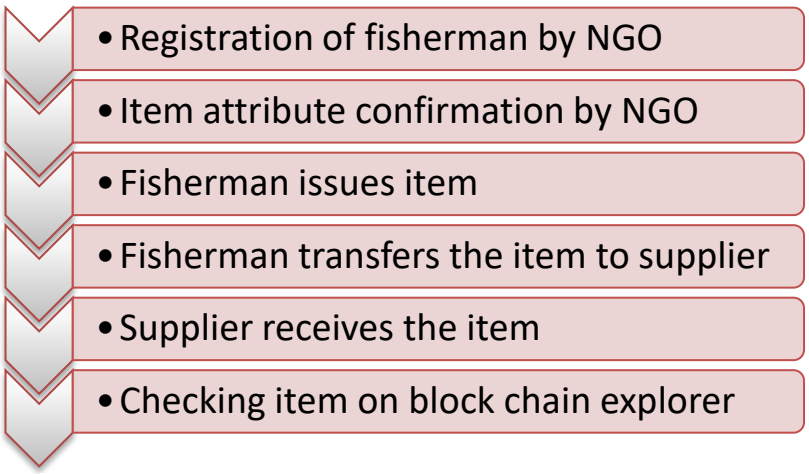

Fig. 3.13. Steps of the fishes' registration on the Blockchain ledger

world, and, at this point, even the ownership of the asset moved from the fisherman to the supplier; however, the fisherman remained saved in the digital history of the product. Previously, a NGO organisation had verified the social and environmental condition of fishermen, and its audit was fundamental in the election of fishermen which participated in the Provenance-validated chain of custody.

2. Linking the blockchain with the existing systems

   As said before, Provenance maintained software for database management adopted by different companies, and integrated these with the Provenance app. Among others software, Tally-O showed an important potential in tracking fish: in particular, data were encoded and printed on the label, and then, imported in facilities that use Tally-O.
   In the Provenance solution, each node of the chain corresponds to a blockchain address; in this manner, everyone can access and control information about products stored in each single address, therefore, the entire supply chain achieves transparency and interoperability.

   The blockchain platform raises itself as single source of truth for verifying the validity of actors' identity and of any certifications or features they declare; in addition, the blockchain consensus algorithm assures the validity of any certification attributed to different items.

   Thus, tunas were identified with a digital record held on the blockchain, and a unique identifier (QR code, or RFID) was attached to each fish.

   Then, when tunas are processed and turned into the final products, the corresponding assets on the blockchain need to be updated and modified accordingly.
   Digital assets on the blockchain are moved when starts the physical transaction, in the meanwhile, Tally-O is connected to scanners that enable shipping management: the blockchain provides an audit layer over an existing data management system, like Tally-O.

3. The consumer experience

   Finally, Provenance replaced the traditional printed labels with NFC-enabled smart stickers, through which customers can see the journey of products on their smartphones or tablets.

Limitations of these pilot project stand in the easiness for illegal organisations to copy QR codes or NFC stickers used to track tuna, undermining in this way the validity of the physical product associated with the blockchain ledger. Actually, there would be possible to adopt NFC tags that allow to store cryptographically information, but, this solution is too expensive, so there are two other alternative approaches to avoid duplication of tags: one high-tech, and the other, low tech.

- High-tech: some technologies such as Prooftag, or nano spirals enable to create NFC tags more difficult to be copied.
- Low tech: actually, low-value products do not encourage illegal entities to copy tags, because this activity is not so advantageous.

Tracking coconut on the blockchain

In Indonesia, Provenance used the blockchain technology in the coconut's supply chain for another pilot project. This time, the project was more focused in verifying the ethic of the coconut's trade, in particular in making financial transparent the supply chain. Traditionally, there was difficult to prove the amount of money local farmers received for their coconuts, but, Provenance aimed at tracking payments with the blockchain.

Basically, Provenance worked with the NGO, Fairfood, to track ethic claims of 1000 coconuts. The process was similar to that adopted in the tuna case: coconuts are registered after the harvest via SMS, and then, all modifications and transactions are registered on the blockchain ledger, even payments.

The adoption of blockchain in tracking coconuts provides customers a proof of the ethic of the supply chain.

Transparency in fashion industry

Provenance presented in May 2017, at the Copenhagen Fashion Summit's "Solutions Lab", the result of a project started in April, about the adoption of the blockchain technology to track products in the fashion industry. The company collaborated with the fashion designer Martine Jarlgaard, who develops and produces Alpaca yarn jumpers in small scale.

The product is made in England, the supply chain is smooth and composed only by three nodes, all of them English companies:

- The "British Alpaca Fashion Company": a family company which breeds alpacas;
- "Two Rivers Mill": a small company which is specialised in the production of yarns 100% alpaca;
- "Knitster LDN": the studio of Jarlgaard set in London.

First of all, in the "British Alpaca Fashion Company", different types of alpacas were registered on the blockchain; records contained also information on each alpaca sample. Moreover, in the blockchain was recorded also the production phase to obtain fleece and, subsequently, the transfer of this fleece to "Two Rivers Mill". It registered the production of yarns' cones, with the details about the type of fleece used for each cone, and then, sent them to the Jarlgaard studio, where the design and the manufacturing of jumpers took place.

All the operations of the supply chain were recorded with a unique ID on the blockchain and the customer can access to information about the journey of the product, about the protagonists of the chain and characteristics of components and production processes, through a smart label.

This pilot project wants to show how could be advantageous the use of blockchain in the fashion industry: with a unique ID for each single operation along the chain, and the use of a decentralised system like blockchain, there is the possibility to provide customers sure information about characteristics of final products, certifications owned by the company and its suppliers, avoiding risks of false claims. In particular, the consumer's trust in the company is fundamental in a sector strongly affected by counterfeiting, and a transparent supply chain can justify the request for a premium price for those products, whose supply chain is ethical and sustainable.

In addition, the blockchain platform would increase the involvement of suppliers in the development process, because they feel more important and appreciated. Indeed, while in centralised systems information are stored and managed by a central authority, which is often close to the most important company of the chain, with distributed ledger information are available equally to every participant, that is now part of a peer-to-peer network.

3.4.3 Cargill

Cargill is an important American multi-national company, which operates in different industries to provide products and services to food and beverage companies, large and small farmers, energy providers and retailers.

In November of 2017, the multi-national started a pilot project to examine the potential of the use of a blockchain platform in tracking turkey products. Cargill decided to use a public blockchain platform, without revealing which, to provide customers information about origins of the products.

The project wants to study the impact of the adoption of blockchain in two areas: food safety and sustainability. Often in the past, the turkey and chicken industry was under accusation for diseases caused by virus carried on turkeys and chickens: last time, in 2015, over 50 million birds were destroyed in US due to the Avian flu, which involved 230 farms ("Cargill's Blockchain Pilot: Turkey Tracking Gimmick or "Hot-to-Trot" Agricultural Revolution", Drew Johnson, November 2017).

In these cases, there was difficult to identify quickly the cause of the contamination and which were really the contaminated products, due to a lack of a system able to track the entire supply chain. Blockchain could play the role of a common distributed ledger useful to track products and, moreover, to plan production activities to reduce consumption of resources (water) necessary to grow turkeys, thanks to the information sharing possible on the blockchain platform.

Therefore, the object of the experiment was the "Honeysuckle White" brand, one of the brands owned by Cargill, which operates in the turkey's industry. The project concerned 60 000 turkeys deriving from four voluntary farms, that were sold in Texas.

At the point of sale, customers found an ID code on the labels of turkey's products and, inserting it on the Honeysuckle White website, they could access information about turkeys and farmers who bred them. In detail, the turkeys' supply chain was not completely transparent, but, consumers

could access information only about the first node of the chain, about what turkeys ate, or the time they spent in the farm, or the location in which they were butchered.

After the analysis of the project's results, Cargill declared that it will decide if enlarging the level of disclosure in future uses.

3.4.4 ZonghAn Technology

ZonghAn Insurance is a Chinese company which operates in digital insurances online, it was born in 2013 by the synergy between three Chinese companies: Ping An, Tencent and Alibaba. ZonghAn became soon a giant, indeed it was able to sign, in the first year of life, 630 million insurance policies stipulated by 150 million clients.

Inside the ZonghAn Insurance company, ZonghAn Technology represents the subsidiary focusing on research and development of latest technology. One of the projects of ZonghAn Technology concerns the use of the blockchain technology in tracking the journey of chickens along the supply chain, from farms to the point of sale. Despite the project seems similar to the Cargill one, here, the execution is very different and the integration of other high technologies make this project more promising and innovative.

Indeed, ZonghAn provided customers the possibility to know not only the characteristics of the farms in which chickens grew, but also to have information about all the nodes of the supply chain they passed through, before arriving on the shelves. The real-time monitoring of the life of birds is possible thanks to the union between IT and OT. Indeed, ZonghAn applied an anklet to each chicken since its birth, that is an IoT device connected via wireless to the blockchain platform, which send real-time data on movements and activities of each sample to the platform.

ZonghAn Technology collaborated for the IoT devices with Wupu, a company based in Hangzhou, that provided IoT devices attached to the ankles of chickens and checked each transaction record on the blockchain with the mobile application. Otherwise, for what concern the development of the blockchain application, ZonghAn Technology used internal start-up Anlink.

Anlink is a cloud service platform, through which the company provides services, and between these, also blockchain-based services, BaaS (Blockchain-as-a-Service). Anlink used Ethereum blockchain to create its blockchain protocol called Ann-Chain; therefore, on this blockchain it can create different applications.

In May 2017, Anlink developed Ti-Packet, the blockchain based system used to track chickens for the pilot project.

The project is pursued in collaboration with other companies like Shanghai Lianmo Information Technology and Guoyuan Agricultural Insurance Company, and it aims at creating and promoting a new brand "Bubuji", which will be an ecological brand providing chickens bred in organic and free-range farms. The pilot project begun in June 2017, and it is called "gogochicken": more than 200 farms coming from different provinces of the country wanted to join in the project, from the

beginning. Chickens grow up on organic and free-range farms, with an average life of four to six months rather than 45 days as in factory farmed chicken. Now, the "gogochicken" project involves 100 000 chickens, but, the aim of the company is to continue the project and increase investments in this way: the objective, targeted by 2020, is to reach 2500 farms and more than 23 million chickens tracked with the anklet and the blockchain.

Nevertheless, this is not enough, the company wants to offer the possibility for customers to buy the chicken when he is still a baby and follows his growth on the blockchain. The company is thinking about using a facial recognition tool to allow customers identify chickens in the farm.

3.4.5 Walmart

The American multi-national Walmart, which is the largest retailer in the world with 11 695 stores in 28 countries, is exploring, through different pilot projects, the possibilities offered by the blockchain in tracking fresh products from the producers to the shelves of the stores, along the supply chain. The last project, it is going to undertake, will be placed in China, in collaboration with IBM and the Laboratory for E-Commerce Technologies by Tsinghua University National Engineering; the project will be pursued also in collaboration with the Chinese online retailer "JD.com".

IBM will provide its blockchain permissioned platform, while Tsinghua University will act as a technical advisor sharing its expertise in the key technologies and in the China food ecosystem. Blockchain adoption in tracking food products represents an opportunity to monitor closer and in real time the processes, that items passed through along the supply chain, and to assure the safety of products and the validity of certifications.

The final goal of this project was declared to be the creation of a "standards-based-method" to collect data about the origin, safety and authenticity of food, assuring real-time traceability throughout the supply chain, thanks to the adoption of the blockchain technology.

Furthermore, the blockchain can accelerate tracing of contaminated foods because the system can track the original source of products through the supply chain. Thus, in cases of contaminated products, it is possible to identify the responsible batch and recall this, avoiding to recall the whole production. In addition, Walmart behaves that, using properly information shared on the blockchain, retailers can plan better the replenishment planning, providing customers more fresh products and saving perishable products from waste; in particular, according to Walmart, blockchain massive adoption in the supply chain management could reduce the waste of food in US from 30 to 40 %.

Actually, Walmart already made two pilot projects on items tracked on blockchain: one which took into consideration pork meat in China, and the other on Mexican mangoes sold in US. In both cases, IBM collaborated with the retailer, providing the blockchain platform, Hyperledger Fabric.

The first project saw the collaboration of Walmart and IBM, with also Tsinghua University of Beijing, and, as said, focused on the tracking of pork. The project started in January 2017 and

lasted four months, tracked pork products were sold on Walmart stores, where each individual item was authenticated using the blockchain system to create a transparent and secure record. In the blockchain, were recorded information about the farms from which pigs come from, about batch numbers, about the factory and processing data, about the expiration dates, about the storage temperatures, and other shipping details, and customers can access to these information through a code on the product package.

The other project is made on mango sold in US: pallet of mangoes were tagged with numeric identifiers and filled in the blockchain. Then, every time mangoes completed an operation in the supply chain, the blockchain record was updated: information about the entire journey of the products were accessible inserting a code on a web portal. The mango project involved 16 farms, two packaging house, two import warehouses, and one processing facility for one month. During this project, about 10 000 slices of mango were recorded in the blockchain.

The Walmart's projects show how it is possible to access any information about the origins and the history of food products in few seconds, but, at the same time, for the company, the visibility of the supply chain allows to forecast with more accuracy consumers' demand and so, this could help the company in its planning activity. Thus, the enhancement of tracking techniques lead to a reduction of time needed in cases of product recall, while the improvement of the replenishment planning lead to a more efficient shelf life management. The adoption of blockchain in tracking items on supply chain could: save time, remove cost of intermediaries, reduce risks of frauds, tampering and cyber crime, and, finally, increase trust.

Walmart expects that the massive adoption of the blockchain technology in tracking of the supply chain will increase trust and transparency between the company and the customer, minimizing fraudulent products and promoting a sustainable food system. In addition, the adoption of blockchain will both reduce costs due to wastes of expired products, thanks to a more efficient replenishment, and increase revenues, thanks to premium prices customers are available to pay for validated organic products.

Incentives of block chain usage in the supply chain management			
Traceability and visibility across the value chain Increasing speed and flexibility of supply chain drives demand for real time tracking across partners	**Fraud and provenance transparency** Customers want to know where goods come from	**Redundant and incomplete data** Existing data systems are based on messages between silos, with different organisations having different or incomplete data	**High friction enterprise integration** Transactoions volume and speed of the business lead to a highly disputed environment and eroding trust and exposing cash

Table 3.8. Reasons to adopt the blockchain in the supply chain management (table adapted by David Galvin report of IBM)

3.4.6 Vechain and Babyghost

Vechain is a permissioned blockchain platform based on Ethereum blockchain, it was developed by the Chinese BaaS company BitSe, based in Shanghai and founded by ex-managers of IBM, Louis Vitton and Alibaba. Developers of Vechain aim at completely eliminating the threat of the market of counterfeit goods, using the potentialities of smart contracts and blockchain technology.

The US Chamber of Commerce estimated that the counterfeit goods' market reached about 450 billion $ in 2016, equal to the 2.5 % of the world's whole trade volume, and, the 86% of these products came from China and Hong Kong. Furthermore, the report of Chamber of Commerce showed that the most afflicted sector by the counterfeit market is the fashion industry, and exactly in this way, Vechain has moved.

Indeed, at the beginning of 2017, the company started a pilot project in collaboration with a Chinese fashion company, named Babyghost, to protect original products by counterfeit market. Although it is based in New York, Babyghost is a Chinese fashion company which target young girls, and in latest years, it is one of the most growing fashion companies in China. Original garments of the brand were recorded on the Vechain blockchain, in the meanwhile, the articles were identified by a chip developed by Vechain and a QR code. The Vechain chip is similar to a NFC tag, but, it is linked directly to the blockchain, so, it uploads autonomously information on the ledger. The chip is encrypted by the system of the two ID keys, one public and the other private: the public key is stored in the blockchain and it can be verified by the VeChain app.

Furthermore, QR codes can be scanned through the Vechain app by consumers: the app verifies the public key with the VeChain servers to determine if the public key is genuine, then, customers can access information about the story of the interested piece. As a result, product safety and quality assurance are maintained, therefore, customer satisfaction is complied.

Finally, with the help of VeChain, Babyghost reached an elevated level of interaction with their customers through their garments. Indeed, interested people had already the possibility to try the Vechain solution at the "Shanghai's Fashion Week: Spring and Summer collection", where the company presented 20 models of clothing and 80 eco-friendly handbags.

In addition, Vechain is carrying on other pilot projects to apply the same technology for the supply chain management in other industries. One of this project is pursued in partnership with Liaoning Academy of Agricultural Sciences and it is focused on the support that blockchain can bring in the storage of data and in interaction in the smart green agriculture. VeChain is developing a permissioned blockchain cloud platform for organic agricultural products, while, on the other side, Liaoning Academy of Agricultural Sciences can provide data, IoT equipment, scientific farming methods and scientific fertilizers for greenhouses, to achieve accurate farming and management of the growth process of agricultural products.

Within vegetable greenhouses, sensors and digital cameras will provide data to Vechain, that, in this way, it will be able to provide news regarding the data of climatic change, soil regime agriculture, crop growth status, water and fertilizer use status, equipment operation status, and even remotely controlling the process of irrigation, ventilation, and cooling of their products. Currently, there are twenty-four research institutes in Liaoning Academy of Agricultural Sciences, with fifteen research and testing institutes, eight national-level original seed bases, five agricultural science observation and experiment stations of Ministry of Agriculture, sixteen provincial key laboratories and nine agricultural engineering technology research centers involved in the project, that aim at improving the quality control and product tracking transparency.

Moreover, VeChain has also attracted Automobile Industry; recently, the company announced the collaboration with Group Renault to provide the car manufacturer with a digital car maintenance book. Thus, VeChain worked with VISEO and Microsoft on the proof of concept for a 'Digital Passport' for Renault cars: their first stage of POC was successful and now they are moving onto the next stage.

Therefore, VeChain started to hold meetings with Daimler Mercedes and BMW in Germany to deploy smart contract.

3.4.7 Foodchain

Foodchain is an Italian project developed by the collaboration between the engineering start-up Block Srl, and the softwarehouse Kaboom Srls. Foodchain company is focused in the food industry, and, in particular, it is interested in providing a good instrument to allow Italian companies to leverage on the "Made in Italy". Indeed, the company is sure that in a scenario in which the need of consumer to know more information about what they buy is increasing, but, in most of cases, the supply chains of food companies are not very transparent, the blockchain could be the tool to be more honest and transparent with customers, and this could become an important competitive advantage. Moreover, information recorded on the blockchain are immutable and no malicious entity can change these, so, the trust between consumers and company increases, therefore the relationships between them improves, and a company could increase its loyal customers. In addition, customers will have the possibility to have information also about raw materials' suppliers and other nodes of the chain, that usually have no visibility.

The first phase is the identification and the registration on the blockchain of producers of raw materials, after that, each item is recorded on the blockchain and identified by a unique QR code or NFC tag, guaranteeing in this way the authenticity of the products. During their journey, sensors inside products send information to Foodchain, which provides to update the record on the blockchain: the monitoring of the supply chain through the blockchain improves the quality control and the planning of the production process. Moreover, in case there is the need to recall or withdraw some products, the operations would be accelerated thanks to the immediate identification of the responsible batch of production, through the blockchain.

Finally, at the point of sale, customers can scan the QR code through their smartphone, and with the Foodchain application, they can access to a lot of information, photos and videos, about the production process of each piece, and then, they can share their purchasing experience with other customers or with producers.

Nowadays, Foodchain collected two pilot projects: one in the coffee supply chain, and the other in the agriculture industry.

Foodchain for coffee San Domenico

The roasting company "Caffè San Domenico" is one of the most important Italian roasting industries, and it is specialised in the production of all the main types of coffee, including specials coffee coming from other parts of the world, and including also all the coffee "Presidio Slow Food".

The coffee type considered in the pilot project is one of the types selected by the "Presidio Slow Food", and it comes from the Sao Tome island, which is placed in the Guinea gulf. The coffee is farmed by 12 producers, and then collected by the Cooperative Me-Zochi that guarantees the authenticity of the product. After that, coffee has to travel to the roasters, in this case to the "Caffè San Domenico" company. All the documents which guarantee the origin and the transportation conditions of the coffee are controlled both at the departure and at the arrival, when further health analysis are pursued: results of these analysis will be sent to the buyer of coffee.

Then, the coffee has to go to the roaster "Caffè San Domenico", that creates and delivers the quality coffee to consumers. Finally, the consumer can access to the story of the coffee through the Foodchain mobile app, scanning the QR code on the package.

Foodchain collaboration with T18 Group

The traceability process begins with the certification of farms which produce agricultural products, then, Foodchain starts the collaboration with the T18 Group which prepares the products, records them and their related information on the blockchain, and delivers also products to nearby shops in the surrounding cities.

Focus on Foodchain: interview with the head of communication Antonio Iannone

1. *The solution proposed by Foodchain is a permissioned or permissionless blockchain network?*
   Nowadays the solution adopted by Foodchain in its pilot projects is based on the Ethereum platform: companies can decide to make the ledger accessible by every users, only by someone or only by one user. However, this summer the company will launch its own permissionless network, called Quadrans, constituted on the Ethereum platform. In Quadrans companies will have to sign the Quadrans smart contract and can constitute their own applications and use two new cryptocurrency.
2. *In the Foodchain solution, which are the nodes who participate to the validation of transactions?*
   Foodchain provides companies the nodes of the network, that are composed by IoT devices, a SaaS and a PaaS. The mining activity happens through asymmetric coded validators provided even by Foodchain.
3. *In which way data are recorded on the blockchain ledger?*
   Nowadays, data are recorded on the blockchain by the operator, so the truth of information recorded depends on the honesty of operators and companies, but, in the next future, the blockchain will be able to communicate autonomously with smart labels and sensors attached to products and placed along the supply chain. In this way, the truth of information won't depend more on the honesty of the participants of the network.
4. *Which companies of the supply chain were involved in the pilot project with the roasting company "Caffè San Domenico"?*
   There were involved in the project:
   - ***ME-ZOCHI COOPERATIVE: each coffee sack was provided by an international ID code, and transport documents were registered;***
   - ***PORT: there were registered the Bill of Landing and all documents which assure the origin of the coffee;***
   - ***IMPORTER: there were registered documents concerning the quality control on coffee sample;***
   - ***CUSTOM AUTHORITY: it was registered data concerning custom inspection;***
   - ***CARRIER: it was registered the transportation document;***
   - ***ROASTING COMPANY: it was registered the final report;***
   - ***CONSUMER***
5. *Is it possible to put in communication the blockchain with common barcodes?*
   No, because barcodes can store a limited amount of information, not enough to store all data recorded in the blockchain.

6. *Which are the main KPIs that highlighted in pilot projects an effective reduction of costs and an improvement of the efficiency thanks to the adoption of the blockchain?*
   Unfortunately we do not have official report yet, but, KPIs depend mainly by the company that we serve.
7. *Which is the cost of the solution?*
   It is difficult to estimate an average cost of the solution, because it is originated by a lot of different factors, as instance the number of nodes of each supply chain. However the cost of the solution can be distinguished in two components: the installation costs and the packaging costs. Installation costs for small companies can go from 2 000 to 12 000 Euro, while packaging costs less, it contributes for the 0,05% of the total product cost, and it depends on the ID codes, QR codes and smart labels that are provided by Foodchain. In addition, Foodchain solution can be easily integrated with the traditional ERP software such as Oracle and SAP.
8. *Which is the degree of knowledge that a company need to implement the Foodchain solution along its supply chain?*
   It is not necessary any particular knowledge of the blockchain by the company because the solution is implemented by Foodchain.

3.4.8 EY Italy

The Italian subsidiary of the EY Group, in collaboration with the startup EZ Lab developed a blockchain solution, based on the Ethereum blockchain, to track the wine supply chain. The application of the solution is similar to those seen until this point: bottles of wine are identified simultaneously by a QR code in the physical world and by a record in the blockchain. Then, all along the supply chain, each activity or process the piece undergoes is recorded on the blockchain, and at the end of the supply chain, customers can scan the QR code and see the story of the journey of the products.

The object of the pilot project was the “Falanghina” wine by “Cantina Volpone”, produced in 2016. The project aims at protecting the Italian wines from counterfeited products; in fact, a survey conducted by EY reveals that nine persons among ten would want to know more information about Italian wines, and the 70% would be available to pay more for products with a transparent supply chain.

3.4.9 Maersk

The A.P. Moller-Maersk is the largest transportation company in the world, indeed, one of seven containers shipped globally is controlled by Maersk.

Currently, the shipping industry is characterised by a lot of paperwork and bureaucracy that take a lot of time, increasing in this way the delivery time. Moreover, in June of the last year, a malware called NotPetya attacked the communication systems of more than 7 000 shipping companies, among which Maersk, and terminal operators, exploiting a weakness of the Microsoft Windows operating system. The hack attack caused congestion at 76 ports around the world, resulting then in delivery delays and in losses for shipping companies. In November, Maersk estimated around 300 million $ the losses caused by the cyber attack.

To sum up, the shipping industry is a field which is trying to innovate itself through the use of both IT systems to support operations, and OT devices to monitor the containers' journey, but, the actual system presents still some inefficiencies and points of weakness, as showed by the hack attack.

Thus, Maersk decided to start the collaboration with IBM to constitute a joint venture with the objective to launch a permissioned blockchain platform to track the shipping of containers and to provide an international standard of communication, which could reduce cost and time caused by the bureaucracy. Indeed, Maersk estimated that bureaucratic activities like the writing of contracts and documents stand for a fifth of the total shipping cost of a container. The Maersk project could start in the March 2018, and the two companies want to market firstly, two types of solution:

- Shipping Information Pipeline: it will guarantee the visibility of freight all along the supply chain;
- Paperless Trade: it will digitize and automate documents through the usage of smart contracts.

The blockchain platform is provided by IBM through the IBM Cloud and based on Hyperledger Fabric 1.0.

Actually, the collaboration between the two companies was dated on 2016, when they started to drive some pilot projects to analyse possible benefits of blockchain in tracking containers during the water transportation; in these pilot projects the companies partnered with: Dupont, Dow Chemical, Tetra Pak, Port Houston, Rotterdam Port Community System Portbase, the Customs Administration of Netherlands and US Customs and Border Protection.

In addition, it was pursued a similar solution by an important port operator of Singapore, in collaboration with IBM, and Maersk itself already tried the solution for a trans-Atlantic shipment of goods from Schneider Electric, a French energy management and automation company. In this pilot project, only Maersk and IBM managed the nodes, while the other parties of the chain could

only access to the platform to see data; instead, in the new application, each company will manage its node.

Moreover, in the new blockchain based service, IBM and Maersk deploy also other cloud-based open source technologies such as artificial intelligence, IoT and analytics: manufacturers, shipping lines, freight carriers, port and terminal operators, shippers and customs authorities will be able to access to the platform's virtual dashboard, using their credentials.

Nowadays, some important companies have already showed their interest in adopting the solution such as: General Motors, Procter & Gamble, Agility Logistics and the global terminal operators of APM Terminals in New Jersey. The 18% of Maersk containers are already recorded on the blockchain, the company says each node of the supply chain could see different benefits from the usage of the application.

Manufacturers and retailers could leverage an improved supply chain, due to an increasing of the forecasting accuracy, a promptly notification of issues and the possibility to improve the inventory management thanks to a higher amount of available data.

Carriers and logistic providers could reduce costs and delays thanks to a higher visibility on the chain, providing customers a better service at moderate price.

Customs authorities would have a better insight of the flow of goods, and, in this way, they could improve the allocation of resources and the accuracy of the inspections.

Ports and terminals could improve document flows and higher cargo throughput rates, thanks to the increased transparency, while banks would exploit the visibility of the chain.

Finally, not only the nodes of the chain, but the whole market will benefit from the scalability of blockchain based solutions to manage the supply chain; in fact, according to the World Economic Forum the standardisation of the supply chain practices would lead to a global market growth about 15%.

3.4.10 Microsoft

In 2016, Microsoft started a collaboration with the start-up Mojix, which operates in OT and IT services for Big Data applications. The project is called "Project Manifest", and it aims at ensuring origins of products and the ethic of companies' production processes. The objective of the project is to integrate the blockchain platform, based on the Ethereum blockchain, and the RFID devices to track freight across factories, distribution centres and retailers.

The new blockchain solution was presented in January 2017, and it integrates the ViZix blockchain platform with an application through which companies can compose smart contracts. In addition, the new platform is able to communicate with RFID, Bluetooth and GPS sensors; in this way, companies can have complete visibility on the entire supply chain of items. The Project Manifest will become a permissioned blockchain similar to the Microsoft Azure BaaS platform, where every

interested entity can join in the project and increase the potential commands that can be written into the contract.

The visibility on the supply chain will drive to reduction of costs about auditing, insurance, supply chain financing and risk-mitigation.

Furthermore, the Project Manifest started also the collaboration with the Auburn University analysing seven brands and three retailers to study electronic proof of delivery, vendor scorecarding, anti-counterfeiting, anti-grey market, and data exchange data.

3.4.11 Almaviva

Almaviva is an Italian company based in Rome, which provides IT solutions globally. The company considers the blockchain a possibility to lead production system to the establishment of a model in which interconnected companies can share a large amount of information in a transparent and decentralised way. In addition, smart contracts can help in making automatic transactions between different companies, while, the integration between the blockchain platform and IoT devices can make possible for objects to talk with the platform and to give it immediately information about the item's status in a secure, transparent and fast way.

Almaviva already completed some pilot projects: as instance, at Vinitaly 2017, it presented in collaboration with the AGEA (Agency for Agricultural Subsidies) and MIPAAF (Ministry of Agriculture, Food and Forestry) a permissionless blockchain platform constituted on Ethereum, to trace bottles of wine, from producer to end consumer. Nodes of the networks and customers can access information about the origins and production process of the wine, scanning the NFC tag on the bottle. The blockchain platform is accessible to: the farmer, the producer, the winemaker, the bottler, the carrier, the retailer, and consumers too, which can see information about the harvest characteristics, the transportation of grapes and the production phases of winemaking and bottling process.

Furthermore, Almaviva has collaborated with the Campania region, to create a permissioned network called I.Ter. I.Ter is a geographic cloud that unifies all the regional databases of the offices and entities and also provides tools, data and shared services to citizens, professionals and businesses. It allows complete digitisation of administrative actions relating to governance and territorial supervision, ensuring accessibility, transparency and aggregation of information. Moreover, the integration of the IoT component and the blockchain technology allows to vehicles, which monitor the Campania territory, to send data directly to the platform, and these data are certified and immutable thanks to the blockchain, and accessible only to Campania regional offices and entities, because this is a permissioned network.

3.5 TAXONOMY OF EXISTENT CASES

Here, the previous cases of adoption of blockchain are classified on the basis of the information found about the typology of blockchain platform.

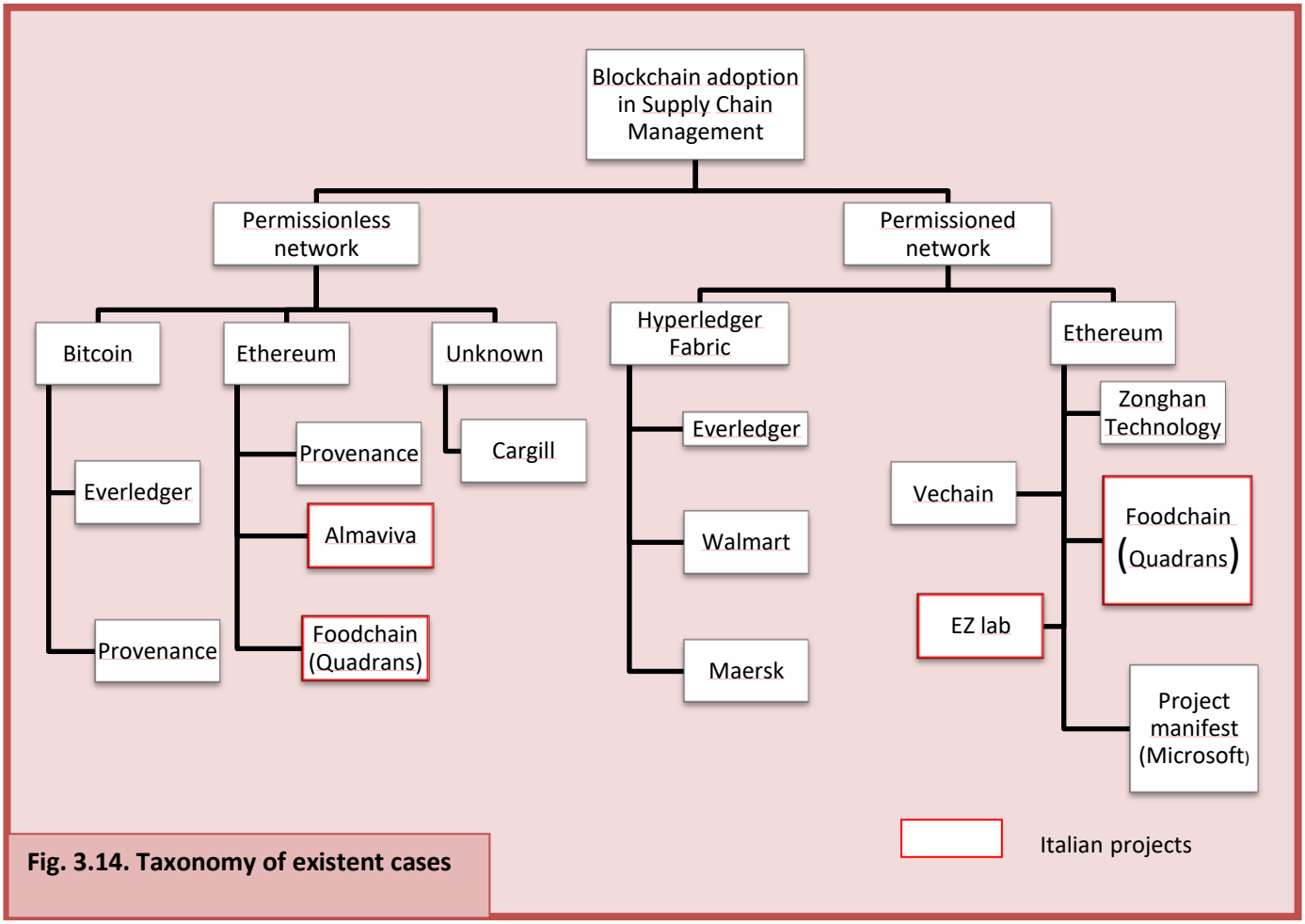

Fig. 3.14. Taxonomy of existent cases

From the taxonomy, it is possible to notice that companies preferred to use permissioned blockchain to support their supply chain management, to have an higher control on disclosure of information of their supply chain. Indeed, only three projects chose to afford exclusively to permissionless blockchain platforms: Almaviva, Cargill and Provenance, and in particular for Provenance this was a meaningful choice to express the objective of full transparency of the supply chain.

3.6 PRACTICAL BENEFITS AND BARRIERS

In this section, there are summarised which are the main common benefits of the adoption of blockchain in the supply chain management, taking into consideration the experiences described above. Benefits could be grouped in two clusters: one includes benefits brought by blockchain to

the company's activities, while the other, benefits blockchain brings to the whole industrial sector, and consequently to each company operates in.

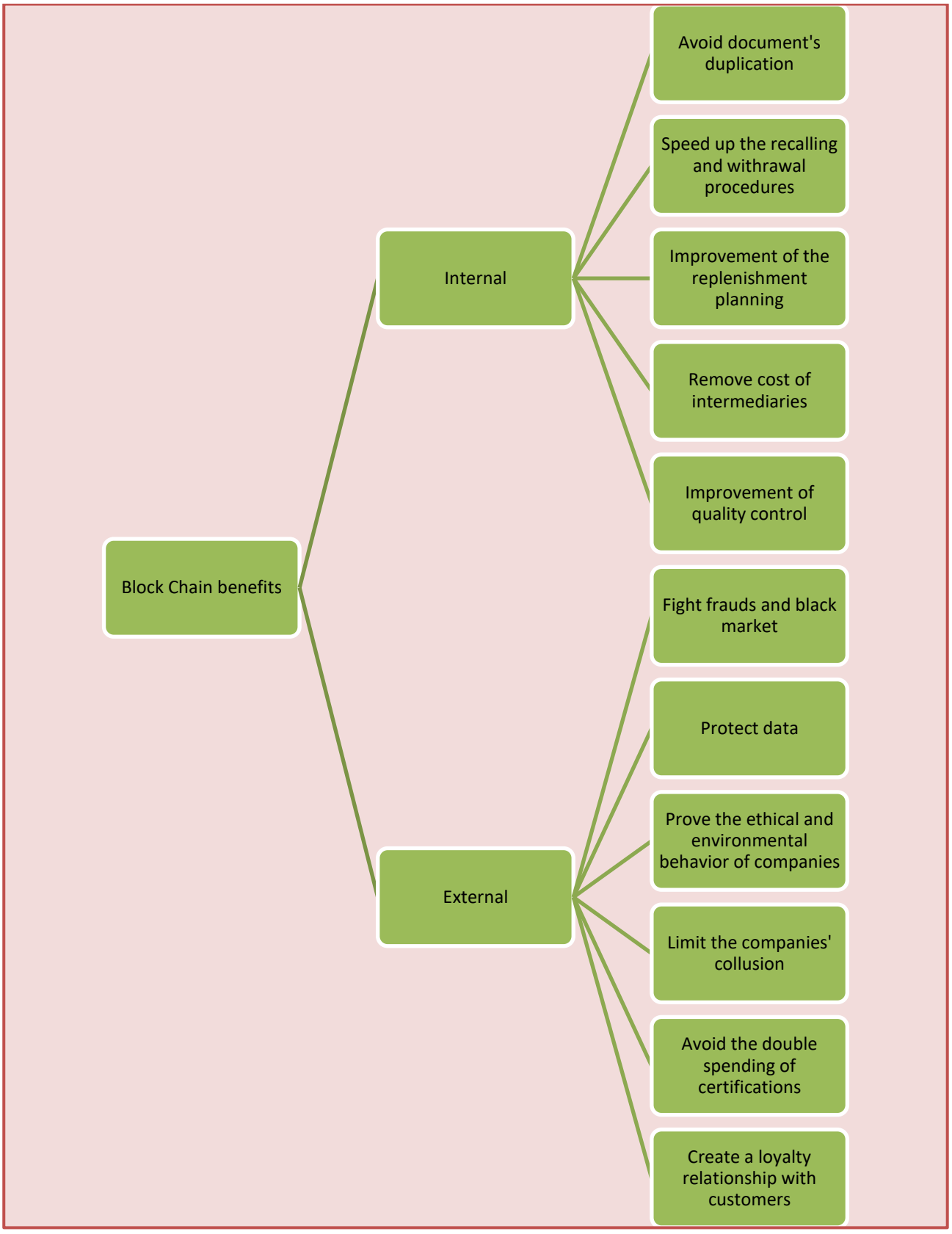

Fig. 3.15. Framework for the classification of benefits brought by blockchain

The first cluster is composed by internal benefits of the blockchain, which impact on costs of the activities inside the supply chain. Indeed, thanks to the real-time traceability of the products and the possibility, using the blockchain platform, to access to information stored on the ledger about components' movements along the supply chain, companies can collect more information useful to pursue internal activities more efficiently. In particular, the involved activities are: replenishment planning, quality control and recalling or withdrawal procedures.

The improvement of the replenishment planning derives from the possibility to share data about forecasted demand, state of orders, cycle time, eventual unexpected events or breakdowns that can affect the production volume of suppliers, delivery delays, etc. This information affects the inventory management and replenishment of companies, that can manage better the level of stocks, avoiding stock outs and overstocks, protecting in this way themselves both from potential sales' losses and useless inventory holding costs. Moreover, in case of perishable products, a good inventory management means from one side avoiding the throw off of expired products, and from the other, offering customers more fresh products, and so, a better service level.

Then, the real-time traceability of the items along the supply chain and the capability of the blockchain to constitute a digital and unique "passport" for each item, recording its characteristics, history and ownerships, favour a more accurate quality control of the production process and of companies' performances and, in case of non-conformance products, a faster identification of the causes responsible of defects. Even in this case, the improvement of the quality control and the acceleration of the activity of recognizing the causes of problems allow companies to save time, efforts, and finally costs.

Moreover, the real-time traceability of items and their unique identification on the blockchain allow also a more rapid procedure of withdrawal or recalling in case of non-conformance products or dangerous products, allowing further to identify the exact lot of production and avoiding in this way to eliminate or to withdraw good products.

Cost entries	Effects of block chain
Inventory related costs	Reduced thanks to an improved replenishment planning activity
Costs of unsold products	Abundantly reduced: the sharing of information allow companies to plan better the inventory replenishment avoiding to collect overstocks
Costs of withdrawal/recalling	Reduced thanks to an easier and faster identification of the defective lots, therefore, this allows companies to not risk to recall right lots
Cost of quality	Reduced thanks to the real-time traceability of items

Table 3.9. Cost entries reduced by the blockchain adoption

Furthermore, the blockchain eliminates also the need of intermediaries in the transfers of goods, cutting in this way also related costs, and in addition, it favours to reduce the duplication of documents along the supply chain, thanks to the easy access of online information.

Furthermore, the Blockchain consensus algorithm makes the platform the only source of truth about the items' story and so, it assures on the validity of information stored on the platform and reported to clients. In an environment in which consumers are more and more interested in knowing what they buy, the blockchain has the final effect to enhance a climate of trust between companies of the same supply chain, or companies and the external stakeholders, among which customers, NGOs, authorities and interested companies. This is one of the reason to prefer tracking items through a blockchain based solution, rather than relying on third parties with centralised solutions. Indeed, centralised systems can be able to track efficiently products during the entire journey along the chain, but they are less safe than the distributed shared ledger of the blockchain. In centralised systems, information are collected and stored in a single point which manages also the access to them, this results in a system more closed to information sharing between nodes, and in a system weaker, in which it is easier for a malicious entity to enter and alter information.

Therefore, the Blockchain could contribute to create loyalty between customers and the company, and in this way, it could become a competitive advantage respect to those companies which maintain traditional tracking systems. A survey conducted by Ernst & Young (EY) showed that customers are available to pay 70% more for products with a transparent supply chain. Thus, not only from customer perspective, but from the perspective of all stakeholders, important benefits of blockchain include the capabilities: to limit collusion, to avoid double spending of certification, to fight frauds and black market and to prove the ethic responsibility and environmental sustainability of the supply chain.

Nevertheless, from the analysis of pilot projects, there arise also some common barriers to the adoption of the technology. Even in this case it is possible to differentiate practical barriers into two groups: operational barriers and strategic/tactical barriers.

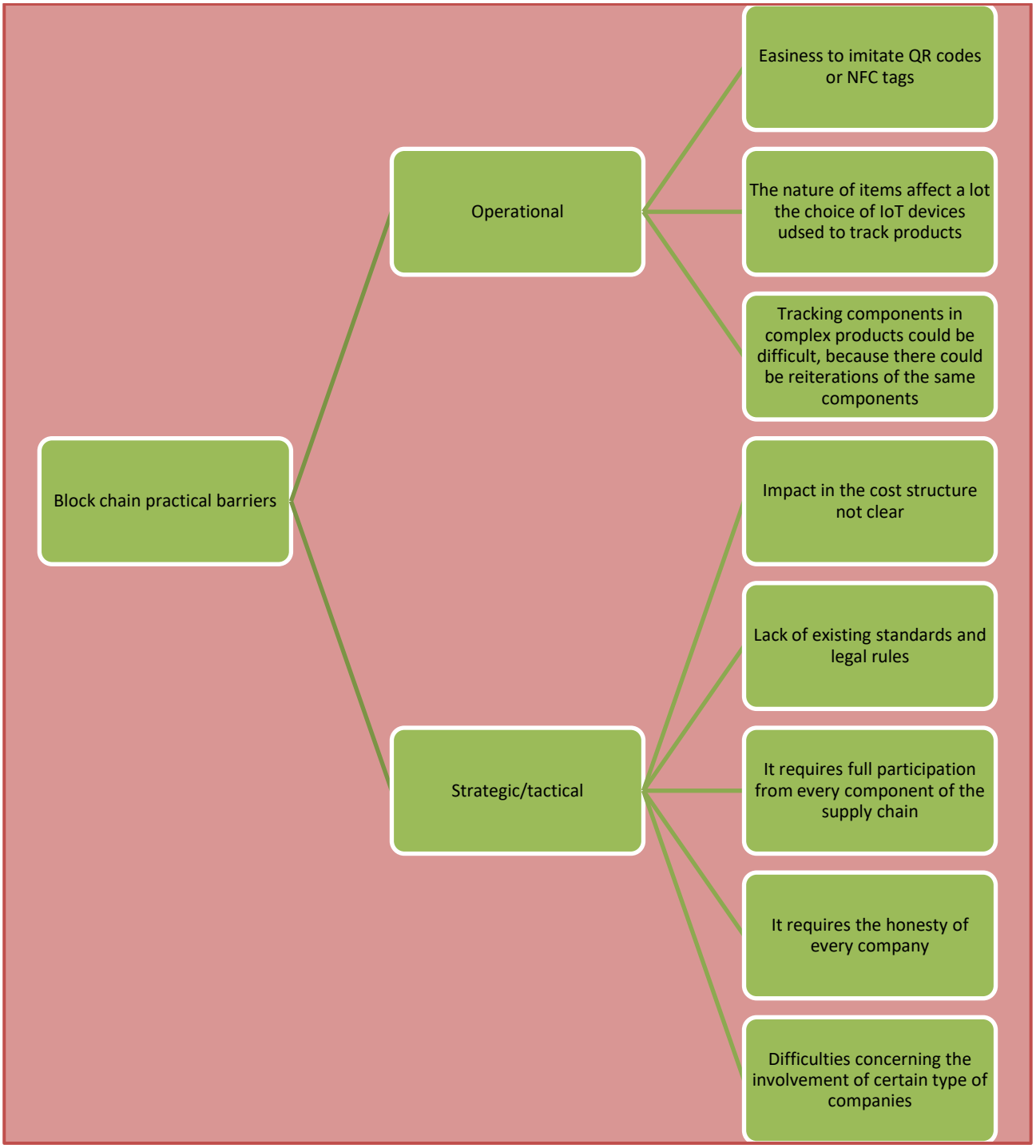

Fig. 3.15. Framework for the classification of barriers to the Blockchain adoption

The operational barriers are originated mainly by difficulties in linking physical items with the digital world; in fact, it becomes complicated for products that require important assembly stages, and so, that are composed by several components, to track each singular component. In this case the identification on the blockchain of the physical object could be more complex due to the risk of reiterations present in different objects that have inside the same components. Then, the nature of products can sometimes limit the choice of the IoT devices used to send information to the blockchain, and sometimes it could lead to the usage of devices easy to be replied. Thus, in

those cases, information recorded on the blockchain ledger can be altered without bypassing the safe algorithms of the technology, but replying the IoT tracking tools.

On the other side, strategic or tactical barriers include difficulties in involving every companies of the supply chain and in convincing supply chain nodes about the benefits of the blockchain adoption. Indeed, the adoption of the blockchain in the economic world and in particular, in tracking the items' journey along the supply chain, is something new and not regulated yet, that leaves doubts in companies about the economical convenience of this type of investment; in fact, it is different deciding to conduct a pilot project, or deciding to revolutionize the whole supply chain management.

Blockchain shows a lot of advantages, but, as it is possible to foresee, the real challenge is not the application of the technology in tracking one product type, but in the scalability of the solution to substitute the traditional tracking system for the whole range of products managed by a company. For this reason, it is necessary to remind that, currently, the consensus algorithms of different blockchains, with performances that are not the same for all solutions, are able to process only 5-7 transactions per second, with a cost close to 0.15 million $ per day (referring to the PoW consensus algorithm adopted in Bitcoin): so, how would this impact in the cost structure of a company?

Moreover, the application of the blockchain technology in tracking the supply chain requires a full and honest participation from all the nodes, in particular in those permissioned networks where it could be possible to make collusions among companies. However, if collusions or thefts happen inside the network, which are the laws that could protect companies from these crimes? Until now, blockchain network are regulated only by technical codes: the ultimate judge is the code, and "The DAO" theft was an important example to see effects of this. Thus, if someone succeed in bypassing the technical code to pursue malicious objectives, who can punish him, who can safeguard victims?

Finally, the last limit of the blockchain adoption is related to the need of a full participation of every node of the chain: indeed, this means that it is enough one contrary node to create difficulties in the blockchain adoption. As instance, is it convenient for a transportation service provider which compete on price to use the blockchain technology, sharing in this way its pricing policy with all members of the chain?

Blockhain existent solutions: perception map

In the previous section there are presented the main benefits provided by the blockchain existent solutions, divided into two groups, one which collects benefits involving the improvement of internal activities of the company, called "internal benefits", and the other, which collects benefits involving a growth of the whole industrial sector, called "external benefits". However, blockchain projects analysed are very different one from the others, both for the blockchain platform and technical solutions adopted and for the objectives they aim; in fact, any blockchain project has different priorities and wants to act on particular characteristics of the supply chain to achieve desired advantages.

In this section all blockchain projects are inserted on the basis of a qualitative analysis about their ability to achieve benefits presented in the previous section in a perception map, which wants to show the actual scenario of the blockchain solutions offered by the market.

On the x-axis projects are evaluated for their capability to achieve external benefits, while on the y-axis it is evaluated the capability to achieve internal benefits. Each company is evaluated in the capability to achieve all the benefits listed before, assigning a score from 1 to 5, for a maximum overall score of 25 reachable in the capability to achieve internal benefits, and 30 in the capability to achieve external benefits.

Everledger solution is very focused on the war to black market and frauds in the diamond industry: the history, characteristics and ownership of items are collected on the blockchain ledger, and every change of ownership is updated on the ledger. The use of both permissionless and permissioned blockchains guarantee the safety of information stored.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	1	Fight frauds and black market	5
Speed up the recalling and withdrawal procedure	1	Protect data	4
Improvement of the replenishment planning	1	Prove the ethical and environmental behavior of a company	3
Remove cost of intermediaries	1	Limit the companies' collusion	1
Improvement of quality control	1	Avoid the double spending of certifications	3
		Create a loyalty relationship with cutomers	5

Table 3.10. Evaluation of Everledger solution

Provenance is the company which collected more pilot projects in the field, but, although they were different, the objectives are mainly the same, confirmed also by the choice to adopt only permissionless blockchains: Provenance aims at giving total transparency to the supply chain to create a loyalty relationship between companies and customers and to prove the ethical and environmental behaviour of companies. In the Provenance solution, protected data can be shared by companies of the same supply chain to collaborate, to avoid documents' duplication and to trace at every moment items along the chain. Moreover, the blockchain ledger plays the role of single source of truth to fight illegal market, companies' collusion and the double spending of certification.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	3	Fight frauds and black market	5
Speed up the recalling and withdrawal procedure	1	Protect data	5
Improvement of the replenishment planning	3	Prove the ethical and environmental behavior of a company	5
Remove cost of intermediaries	4	Limit the companies' collusion	4
Improvement of quality control	3	Avoid the double spending of certifications	4
		Create a loyalty relationship with customers	5

Table 3.11. Evaluation of Provenance solution

Cargill adopts the blockchain in an industry affected by difficulties in facing problems of food safety when occur. Indeed, unfortunately, often, the turkeys and chickens industry is damaged by virus carried by goods, due to errors in the quality control. Until now, the insufficient capability to track responsible products caused loss of image of companies in the sector, also for innocent companies, and high costs to recall the whole production volume. Thus, the blockchain solution developed by Cargill wants firstly to prove the ethical and environmental behaviour of the company, and then, the complete traceability of turkeys would allow the company also to improve the quality control and to speed up the recalling and withdrawal procedures whereby it is necessary, recalling only the responsible batch of non-conformancy. In addition, the company wants to use the blockchain for improving the planning of activities to save costs.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	1	Fight frauds and black market	3
Speed up the recalling and withdrawal procedure	3	Protect data	1
Improvement of the replenishment planning	2	Prove the ethical and environmental behavior of a company	5
Remove cost of intermediaries	1	Limit the companies' collusion	1
Improvement of quality control	5	Avoid the double spending of certifications	1
		Create a loyalty relationship with customers	3

Table 3.12 Evaluation of Cargill solution

The ZonghAn Technology pilot project is very similar to the Cargill one, but, it focuses more on relationships with customers, that can access to more information about products they buy and, in the future, they can also choose chickens when they are still in farms.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	1	Fight frauds and black market	2
Speed up the recalling and withdrawal procedure	1	Protect data	2
Improvement of the replenishment planning	1	Prove the ethical and environmental behavior of a company	4
Remove cost of intermediaries	1	Limit the companies' collusion	1
Improvement of quality control	5	Avoid the double spending of certifications	1
		Create a loyalty relationship with customers	5

Table 3.13. Evaluation of ZonghAN Technology solution

Walmart made two projects on the adoptions of the blockchain, one on pork meats and the other on the slices of mangoes, and in these projects it exploited the advantages originated by the real time traceability of goods in improving the efficiency of internal performances such as: the quality control, the recalling and withdrawal procedures and the limitation of paper documents to certificate origins and characteristics of items. Walmart understood how the blockchain adoption can improve the management of the replenishment planning and of the shelf life of products, providing customers more fresh products and avoiding the waste of expired products. Customers can verify the quality declared by companies accessing to information on the journey of the products through a code attached on the product package.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	5	Fight frauds and black market	5
Speed up the recalling and withdrawal procedure	5	Protect data	5
Improvement of the replenishment planning	5	Prove the ethical and environmental behavior of a company	5
Remove cost of intermediaries	4	Limit the companies' collusion	1
Improvement of quality control	5	Avoid the double spending of certifications	3
		Create a loyalty relationship with customers	5

Table 3.14. Evaluation of Walmart solution

Babyghost applied the blockchain in the fashion industry, presenting at the "Shanghai's Fashion Week: Spring and Summer collection", 20 models of clothings and 80 models of eco-bags tracked through the blockchain. The company gave customers the possibility to access to information about the story and the characteristic of the product scanning the QR code attached to the garments.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	3	Fight frauds and black market	4
Speed up the recalling and withdrawal procedure	1	Protect data	4
Improvement of the replenishment planning	4	Prove the ethical and environmental behavior of a company	3
Remove cost of intermediaries	1	Limit the companies' collusion	2
Improvement of quality control	5	Avoid the double spending of certifications	1
		Create a loyalty relationship with customers	5

Table 3.15. Evaluation of Vechain solution

Foodchain wants to protect the origins of Italian products in the food industry, therefore Italian companies can exploit advantages of a complete transparent supply chain and improve their relationships with customers.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	1	Fight frauds and black market	3
Speed up the recalling and withdrawal procedure	2	Protect data	4
Improvement of the replenishment planning	2	Prove the ethical and environmental behavior of a company	5
Remove cost of intermediaries	1	Limit the companies' collusion	2
Improvement of quality control	5	Avoid the double spending of certifications	3
		Create a loyalty relationship with customers	5

Table 3.16. Evaluation of Foodchain solution

EY Italy provide a solution similar to food chain applied at the wine industry.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	2	Fight frauds and black market	2
Speed up the recalling and withdrawal procedure	1	Protect data	1
Improvement of the replenishment planning	1	Prove the ethical and environmental behavior of a company	1
Remove cost of intermediaries	1	Limit the companies' collusion	1
Improvement of quality control	2	Avoid the double spending of certifications	2
		Create a loyalty relationship with customers	3

Table 3.17. Evaluation of EY Italy solution

Maersk made already some pilot projects concerning the adoption of the blockchain technology in the shipping industry and in 2018 it wants to launch in collaboration with IBM a permissioned blockchain platform to track the shipping of containers and to provide an international standard of communication. Indeed, the shipping industry is traditionally characterised by long waiting times and high costs originated by a lot of bureaucratic activities which stands for a fifth of the total shipping cost of a container. The blockchain and smart contracts allow to share data and improve the integration of all players operating in the industry, and in this way, companies can save time and costs thanks to a better planning of activities. Moreover, the solution assures an higher protection of stored data by hacker attacks, that in August 2017 caused a loss of $300 million to the company.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	5	Fight frauds and black market	2
Speed up the recalling and withdrawal procedure	1	Protect data	3
Improvement of the replenishment planning	5	Prove the ethical and environmental behavior of a company	1
Remove cost of intermediaries	2	Limit the companies' collusion	2
Improvement of quality control	4	Avoid the double spending of certifications	1
		Create a loyalty relationship with customers	1

Table 3.18. Evaluation of Maersk solution

Microsoft started a collaboration with the start-up Mojix to launch a permissioned blockchain platform able to communicate with RFID, Bluetooth and GPS sensors to trace in real time goods along the supply chain and prove the social responsibility and environmental sustainability of companies in pursuing internal operations, moreover smart contracts limit the role and the cost of intermediaries.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	3	Fight frauds and black market	4
Speed up the recalling and withdrawal procedure	1	Protect data	3
Improvement of the replenishment planning	1	Prove the ethical and environmental behavior of a company	5
Remove cost of intermediaries	4	Limit the companies' collusion	1
Improvement of quality control	3	Avoid the double spending of certifications	3
		Create a loyalty relationship with customers	1

Table 3.19. Evaluation of Microsoft solution

Almaviva made two pilot projects exploiting the blockchain technology: one in the wine industry, where customers, scanning a NFC tag, can access information about the characteristics of the Italian wine, and the other in the public sector, where the distributed ledger of the blockchain was used to coordinate the activities of all the regional offices and entities of Campania region.

Internal benefits	Score	External benefits	Score
Avoid documents' duplication	3	Fight frauds and black market	2
Speed up the recalling and withdrawal procedure	1	Protect data	4
Improvement of the replenishment planning	1	Prove the ethical and environmental behavior of a company	4
Remove cost of intermediaries	5	Limit the companies' collusion	1
Improvement of quality control	2	Avoid the double spending of certifications	2
		Create a loyalty relationship with customers	4

Table 3.20. Evaluation of Almaviva solution

At this point it is possible to see in the map how solutions more involved in building a transparent supply chain such as Provenance or Foodchain have higher scores in external benefits, while solutions such as Maersk or Walmart, which are more interested in the improvement of the integration of actors and activities along the supply chain, have higher scores on internal benefits.

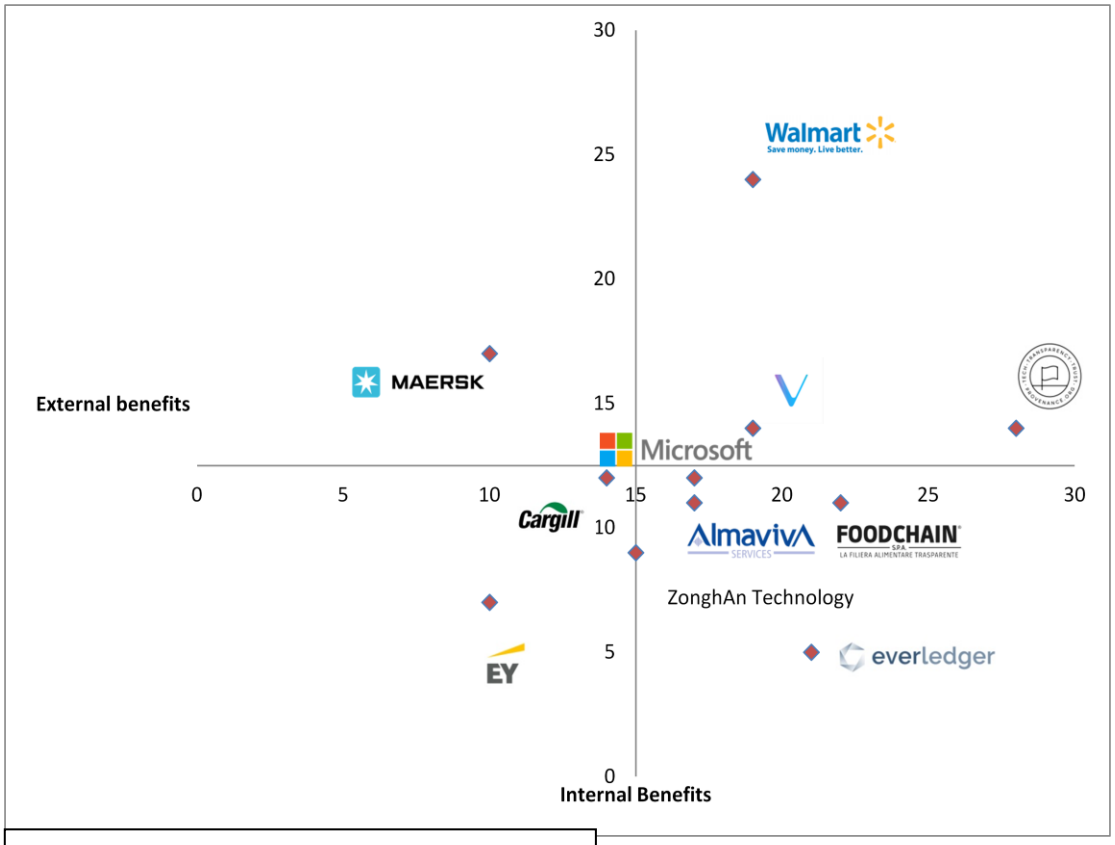

Fig. 3.20. Perception map of existent cases

Blockchain solutions	External benefits	Internal benefits
Everledger	21	5
Provenance	28	14
Cargill	14	12
ZonghAn Technology	15	9
Walmart	19	24
Vechain	19	14
Foodchain	22	11
Ey Italy	10	7
Maersk	10	17
Microsoft	17	12
Almaviva	17	11

Table 3.21. Scores of the existent cases

3.7 DEDUCTIVE AND INDUCTIVE REASONING: ANALYSIS OF GAPS

In the deductive analysis, it was proposed a lot of possible ideas of application of the blockchain in the supply chain management, taking into consideration only the theoretical knowledge of the characteristics of the blockchain technology, and of the practices currently adopted to support the supply chain management.

Therefore, it was necessary to investigate if there are already some applications of the blockchain in the supply chain management and which are their characteristics, to understand if the hypothesis of blockchain adoption are applicable. Thus, there were analysed several pilot projects, and these went exactly in that direction hypothesised in the deductive analysis. Indeed, in pilot projects, the blockchain technology was used to improve the traceability of items, to monitor the items' journey guaranteeing secure transactions and validity of information recorded, to enhance collaboration between companies and to improve activities' planning. In addition, in some projects, such as the Vechain project, or Foodchain, or Maersk, there were applied smart contracts to remove cost of intermediaries in contracting phase and to improve the quality control of the production process.

Theoretical benefits	Benefits from actual practices	Pilot projects related
Blockchain technology guarantees secure transactions	Blockchain technology protects data and assures validity of transactions thanks to the consensus algorithm	Everledger, Provenance, Walmart, Foodchain, Vechain, Maersk.
Remove intermediaries	The Blockchain adoption reduces cost of intermediaries	Provenance, Walmart, Maersk, Microsoft, Almaviva
Smart contracts assure the automatic execution of transactions, payments and settlemements	Smart contracts will digitize and automate the contracting phase	Maersk, Microsoft, Almaviva
Blockchain technology favour the collaborated planning	Blockchain technology allows companies of the same supply chain to share data and collaborate	Provenance, Cargill, Walmart, Maersk, Almaviva
Real time traceability and monitoring of items' journeys	Real time traceability	Provenance, ZonghAn Technology, Walmart, Vechain, Foodchain, Maersk, Microsoft, Almaviva
Blockchain technology and smart contracts contribuish to the quality control of items	Blockchain technology improves the quality control of the process	ZonghAn Technology, Walmart, Vechain, Foodchain, EY Italy, Maersk

Table 3.10. Comparison between theoretical and practical benefits of blockchain

Thus, it is possible to establish that the current level of technology allows the realisation of the proposals introduced in the deductive analysis.

Furthermore, the analysis of these pilot projects was useful also to understand which are the barriers and difficulties of the blockchain adoption in the supply chain. Now, there will be compared the theoretical barriers hypothesised at the end of the deductive analysis, with barriers that companies which begun blockchain projects faced.

Firstly, there are those hypothesised barriers that effectively resulted in the reality, that are: the limitation of available suppliers, the necessity to transfer the responsibility and decision power from men to machine, and the implementation costs. In the projects analysed, it rose how it is necessary the collaboration of every node of the chain to exploit the advantages of blockchain, and this important condition inevitably limits the application fields and the scalability of the solution. Indeed, it was already noticed in the deductive analysis how the limitation in the sourcing process, about suppliers that are available to adopt the blockchain technology, could affect both the choice and the power relationship between supplier and customer. However, observing the application cases, the scenario is also darker: a single, even not-value adding, supplier, as a transportation service provider, could stop the whole project. Thus, for this reason, it is possible to declare that sometimes companies, which want to adopt the blockchain technology in their supply chain management, will must take into account the possibility to invest in making in-house those activities which stop the beginning of the project.

Then, another theoretical barrier which was confirmed by the pilot projects concerns the lack of standard and legal rules, that moves all the responsibility on the technical code of the blockchain, implying in this way difficulties in respond quickly to negative events happened inside the code. Finally, the pilot projects confirmed the doubts companies have about the scalability of the solution and its impact in the cost structure.

Theoretical barriers	Practical barriers	Pilot projects related
Limit the available suppliers	Blockchain adoption requires full participation from every company of supply chain	Walmart, Maersk
Transfer of responsibility and decision power from men to machine	Lack of existing standards and legal rules	ZonghAn Technology, Microsoft, Maersk, Walmart
High implementation costs	Doubts about the impact in the cost structure of a company	Cargill

Table 3.11. Theoretical barriers present in the pilot projects

Moreover, there are some barriers that were not identified during the deductive analysis, such as:

- Difficulty in tracking components of complex products;
- Possibility of reiteration of the same components in the blockchain;
- The choice of IoT devices affected by the nature of the item;
- The easiness to imitate QR codes or NFC tags
- The necessity of the honesty of all nodes.

The first two barriers could be grouped together and tell us that with the actual level of technology, the adoption of the blockchain could hide difficulties and inaccuracies whether applied to track complex products. Indeed, when it was asked to ZonghAn Technology representatives why they choose to apply the blockchain in tracking chickens, they answered that the choice was based on two reason: the first is that usually consumers buy an entire chicken and not a part, making easy to track the product, and the second reason is due to the simple life of these animals. Actually, they can neither fly, nor swim, so they are perfect to the proper functioning of the tag fixed in the anklet.

Then, the other two barriers can also be grouped together because these depend on IoT devices and not on the blockchain technology, and for this reason, there were not identified in the deductive analysis.

While, for what concern the need of honesty by participants of the network, this comes from the fact that the blockchain technology and its algorithms assure the safety of transactions between member of the network and unalterable data, but, these do not substitute the activity of evaluation of suppliers. Indeed, information about nodes filled into the blockchain are not controlled, as instance: if the company A declares in the blockchain that it does not exploit the child work, the blockchain, obviously, cannot physically control the validity of the affirmation; so, companies must continue to apply the traditional evaluation of suppliers activities near the adoption of the blockchain.

Finally, there are those theoretical barriers that did not appear in the pilot projects such as:

- Risk of frauds and thefts;
- Time asymmetries between virtual and physical transactions;
- The risk to focus on old partners loosing in this way open innovation opportunities.

These barriers are not present in the pilot projects analysed, but, it does not mean that they are not effective barriers; actually, reasons of the absence of these barriers in the pilot projects are different and necessitate a one to one analysis.

First of all, the risk of frauds and thefts, although the safety of the blockchain algorithm is high, must be always taken into account because the blockchain technology is not yet a consolidated technology and some failures in the system can happen, such as in “The DAO” case.

Then, for what concern the time asymmetry, there were few doubts also in the deductive analysis about the impact of this barrier, because not validated transactions are anyway visible on the ledger; in fact, companies do not see any difficulties related to time asymmetry.

The last barrier was not present in the pilot projects simply because it is related to the concept of reiteration of these projects and activities, but it remains absolutely a real barrier to the blockchain adoption, also related to the limitation of suppliers that are available to adopt the blockchain technology.

The impact of Blockchain on ROA

In this section there will be analysed how the benefits brought by the blockchain could affect the ROA of a company. First of all, here it is showed a traditional way to estimate the ROA of a company, which indicate the ability of a company to create value starting from the short-term investments sustained.

$$ROA = \frac{Revenues - Costs}{Current\ Assets - Fixed\ Assets}$$

Thus, the adoption of the blockchain can positively affect ROA in four ways:

- *Impact on costs through the reduction of logistic costs;*
- *Increase revenues through the improvement of the customer service;*
- *Reducing the current assets through a reduction of inventories and the cash-to-cash cycle;*
- *Reducing the need of investments in fixed assets;*

Blockchain impact on logistic costs

The adoption of the Blockchain in the supply chain management improves the efficiency and the quality of the logistic process.

First of all, as was explained both in the deductive and inductive analysis, the blockchain favours information sharing between participants of the network and limits opportunistic behaviours of companies, allowing the creation of trust between nodes of the supply chain. Information sharing is the first step for collaboration between customer and supplier, however, even if companies are not partners, the blockchain improves the integration of all the nodes, and in a business world in which the competitive advantage come no more from a company vs company competition, but from a supply chain vs supply chain competition, the integration of all the nodes of a supply chain is fundamental to achieve performances higher than competitors. The shared distributed ledger of the blockchain favours automatically the integration of all the nodes of the supply chain and therefore reduces the time and money companies have to spent in integrating suppliers or customers in the supply chain activities.

Moreover, the improvement of the planning activity, allowed by the information sharing through the blockchain, optimises the management of logistic activities such as: transportation, handling materials, storage of materials and packaging. In the meanwhile, the capability of the blockchain to avoid document duplication and the importance of smart contracts to speed up the contracting phase reduce the cost of all those administrative procedures and bureaucratic activities, that characterise the logistics and transportation management.

Finally, an important contribution to the reduction of the logistic costs is due to the improvement of the reverse logistics, so, the exploitation of the advantages offered by Blockchain in the recalling and withdrawal procedures.

Blockchain impact on revenues

Because customers wants to know more about products they buy, one of the benefits of the blockchain is exactly to offer customers information about the journey of products in the shelves, therefore companies could ask for the transparency of their supply chain a premium price to customers, that, according to a survey conducted by EY would pay a premium price for products with a transparent supply chain.

In addition, the blockchain adoption and a transparent supply chain improve the customer service offered by the company. Indeed, Walmart, in its pilot projects, highlighted how the blockchain can improve the management of the shelf life of perishable products, helping retailers in the replenishment planning of goods, to provide customers more fresh products, avoiding the waste of unsold products and potential stockouts.

Furthermore in the B2B market, the blockchain allows customers to have information on the state of their orders (Maersk case) and, in addition, if their relations are regulated by a smart contract, after the control on order compliance, the release of penalties or rewards by each of the two parties involved is guaranteed by the technical code, avoiding in this way the loss of costs and efforts in lawsuit disputes.

Blockchain impact in current assets

The blockchain is able to reduce current assets in two ways: reducing the inventory holding costs and controlling the "cash-to-cash" cycle. The improvement of the replenishment planning granted by the blockchain technology affects the sizing and deploying of stocks, and allow companies to avoid overstocks; this result in a reduction of inventory-related costs for companies of the network.

On the other side, smart contracts could reduce the impact of the "cash-to-cash" cycle on the companies' capability to invest cash, avoiding payments delays thanks to the automatic issuing of virtual coins in the company's wallet.

Blockchain impact in fixed assets

Altough lower, the impact of the blockchain in reducing fixed assets can be seen in the effects of a better supply chain planning, which comprehend also the reduction of some fixed costs such as the cost of labour, or, in the long-term, savings coming from the better use of warehouse capacity allowing by the reduction of inventories.

4. APPLICATION CASE

Now, it is the moment to exploit the conclusions coming from the analysis of theory and existent cases, to propose the application of the blockchain technology to another company operating in a different industry. However, it is necessary to choose carefully the target company to exploit at maximum the blockchain advantages, limiting difficulties of implementation. Thus, the main benefits of the adoption of blockchain in tracking items along the supply chain are:

- Fight frauds and black markets;
- Real-time traceability;
- Protect data stored in the ledger;
- Make the supply chain processes more efficient;
- Prove the ethical and environmental behaviour of companies;
- Improve the replenishment planning activity;
- Create a loyalty relationship with customers.

However, among these advantages, it is possible to identify one which originates all the others, and it is the possibility of the blockchain to create a unique digital and unalterable identity of products, that can be tracked real-time during their journey along the supply chain. Indeed, the real time traceability allows from one side to prove the origin and practices behind the realisation of an item, and from the other side, it allows to collect more and more data to improve the internal process performances and the planning activity of each node of the supply chain. Thanks to the blockchain algorithm, data stored in the blockchain are safe and no one can enter in the system and alter these; in this way, companies which take care about the sustainability of their supply chain can proudly show it to customers through the blockchain, and create with them a loyalty relationship. Loyal customers contribute in increasing revenues and in improving financial performances of companies, that now can achieve premium prices thanks to the information stored on the blockchain, accessible to clients. Finally, the adoption of the blockchain will result in a competitive advantage for sustainable and transparent companies.

Therefore, in the choice of the company it is important to take in mind a basic prerequisite: the interest of the company in achieving competitive advantage through the transparency of its own supply chain, and the interest in constituting a sustainable supply chain.

After that, it is necessary also to consider the barriers that rose during the analysis of the pilot projects, to avoid problems that could occur during the experiment. Thus, firstly, it is better to avoid companies which realise products through complex assembly phases, because this could make difficult the traceability of components in the blockchain ledger. Then, it is important to analyse the company supply chain: to make quicker the process it is preferable to try the adoption of the blockchain in those supply chains characterised by long-term relationships between buyer and supplier, that can favour an agreement about the adoption of the technology. Moreover, for the same reason, it is better to avoid supply chains characterised by adversarial buyer-supplier relationships that, on the contrary, could obstruct the project.

4.1 THE CHOCOLATE INDUSTRY

Firstly it is exhibited the sector in which there will be proposed the application of the blockchain technology: the chocolate industry. None of the previous projects took into account the chocolate industry, but actually, this industry is similar in something with the coffee industry, analysed in the project pursued by Foodchain with the "Caffè San Domenico" company, because the chocolate supply chain, like the one of coffee, is characterised by a quite easy production process, which modifies the cocoa beans, the main chocolate raw material that grow in the same areas of the coffee beans. Furthermore, the chocolate industry peculiarities will be presented shortly in this paragraph.

The chocolate arises a lot of different products: chocolate bars, snacks, chocolate eggs, praline etc... but, the main raw material in the production process is cocoa. Cocoa beans are farmed mainly in two areas of the world: Africa and South America, with the exception of the Indonesia, which is the third country for the quantity of cocoa produced. In particular in 2016 the 53% of the cocoa beans were produced in Côte D'Avoire and Ghana, while about the 8% were produced in Venezuela, Perù, Colombia and Equador, but, here it is farmed the most valuable cocoa, which owns a particular flavour.

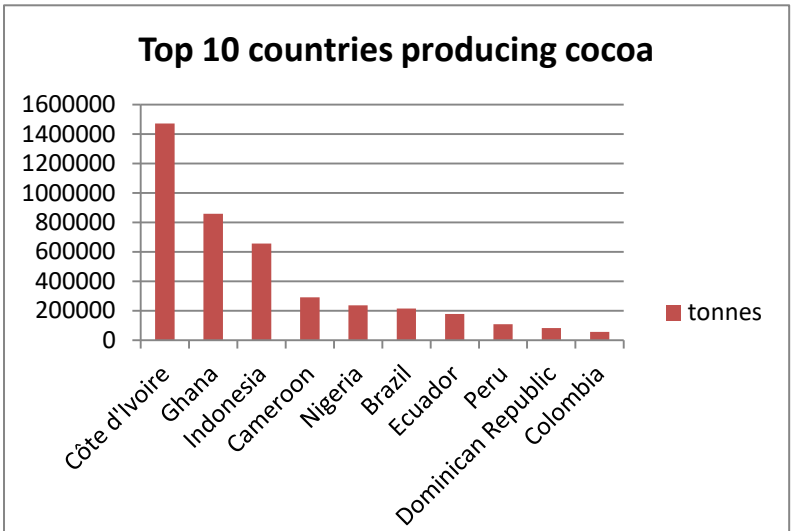

Fig. 4.1. Countries producing cocoa in 2016 (Data taken by FAO)

Cocoa is a delicate and sensitive crop which is grown mainly by small farmers who often do not know anything about the further processes "their" cocoa beans will be undergone. Cocoa farmers sell what is considered a commodity, indeed returns for local producers are very low, and sometimes for this reason cocoa farmers decide to abandon cocoa plantation and to dedicate themselves to a more profitable business, like soya; otherwise, sometimes the abandon of cocoa plantation is caused by civil wars, as in the 2011-2012 in Côte D'Ivoire. Moreover, the cocoa farming implies the need of high attention, farmers have to put in defending cocoa plants from diseases, and of waiting five years before obtaining the peak production by a cocoa tree. The difficulty in obtaining profits for small farmers lead them in some cases to exploit the child labour: in 2013 the NGO "Save The children" estimated 330 000 children which work in cocoa plantations only in Côte D'Ivoire.

Despite it is a commodity, the cocoa price became very volatile in last years, signal of uncertainty in a market that, after a constant growth, saw a decline of 5% of demand from 2013 to 2015, and then a following growth since 2016, which resulted in the achievement of 4 billion tonnes of production and a total spent of 123 billion $. Currently the cocoa price accounts for 2531 $[5] per tonne, but some journalists suspect that under this price fluctuation there is an unfair game played by the International Cocoa Organisation and other speculators. Indeed, in 2013 the ICCO (International Cocoa Organisation) launched the alarm of an important deficit of cocoa in 2020, this information immediately affected the cocoa market price which rose of 30%; then, in 2017 Euromonitor declared as too pessimistic the forecasts of ICCO and that none cocoa crisis will occur in 2020, so the cocoa price fell again. Thus, some sceptic journalists suspects that the price fluctuation of cocoa is used to affect the attractiveness of the business and to push small farmers embracing again or leaving the cocoa farming.

Although the cocoa crisis won't happen, the average increase of 2% annually of the cocoa demand, caused by the increasing interest of the emerging countries such as China and India in chocolate products, meant years in which the consumption of cocoa overcame the demand; in fact, traditional farming methods of small cocoa farmers saw difficulties in fulfilling demand. Moreover, the climate change in cocoa's environment damages cocoa production and favour the spread of diseases among trees.

After the harvest, Cocoa beans are moved to countries in which are placed chocolate factories. Through data by FAO on the main importers of cocoa beans of the year 2013, it is possible to establish where are the main producers of chocolate. It results that the Europe is the main region in which is produced chocolate, with several countries present in the list, while for what concerns extra-European countries, there are Malaysia and Singapore in Asia, and USA in America, which occupies the second place in the ranking.

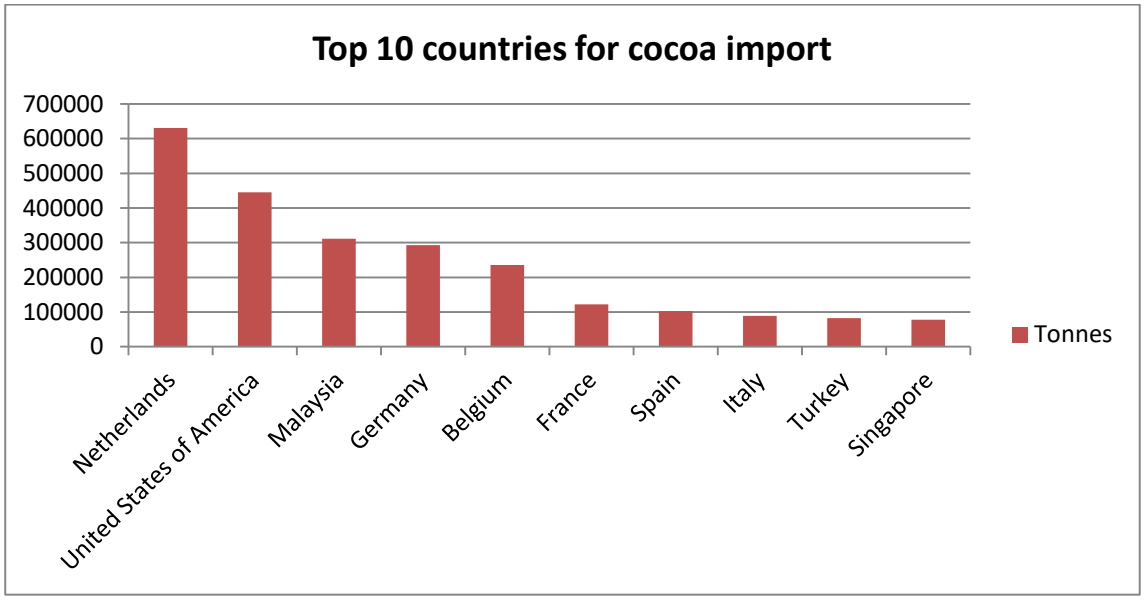

Fig. 4.2. Main countries importing cocoa in 2013 (Data taken by FAO)

[5] https://www.bloomberg.com/quote/CC1:COM

Instead, to analyse which are the countries in which is consumed more chocolate, it is possible to refer to data about the chocolate import, taking into account that it is not included the consumption of local chocolate. The European countries, except for the USA that occupy the first position, dominate the list, and Italy is not one of the first 10 countries for quantity of chocolate imported, but, it is in the top 10 for the value of imported chocolate, data in accordance to the traditional preferences of Italian consumers for high quality products. In particular, Italy is the most important exporter of chocolate in China, with 665 Mln Euro of chocolate sold.

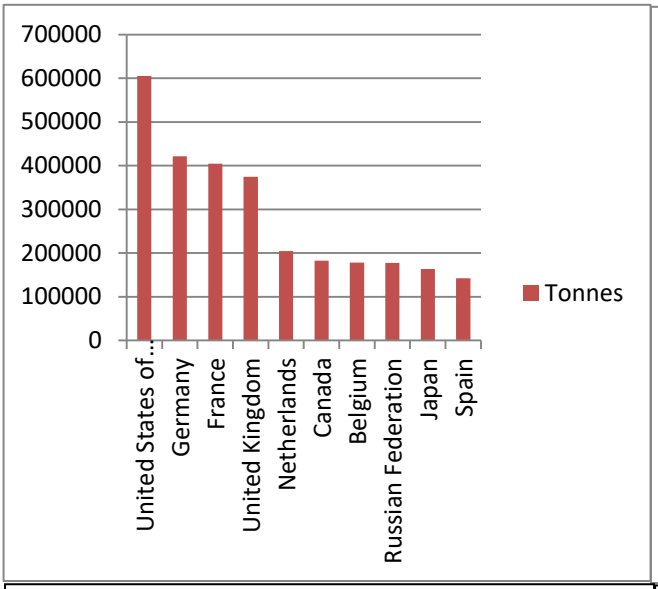

Fig. 4.3. Main countries importing chocolate in 2013, ranked for volume (Data taken by FAO)

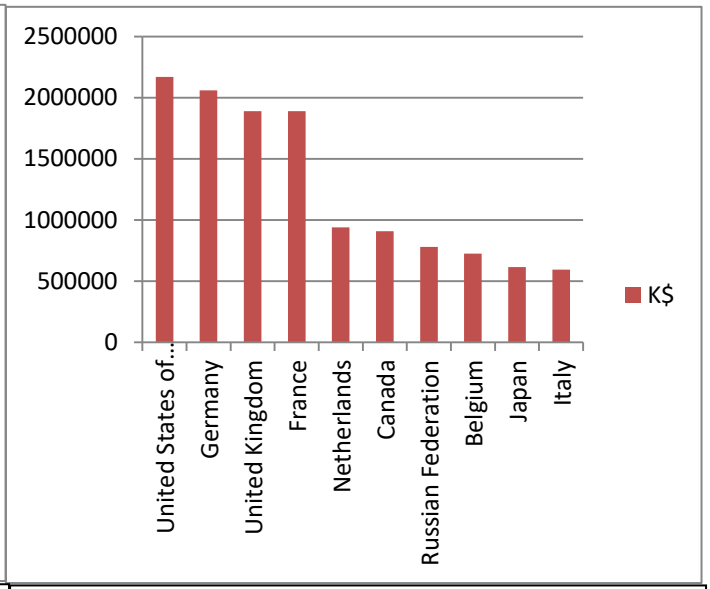

Fig. 4.4. Main countries importing chocolate in 2013, ranked for spent (Data taken by FAO)

In Italy, the chocolate market is dominated by big multi-nationals such as: Ferrero, Mars, Lindt & Sprüngli and Nestlè. Moreover, several Italian brands were grasped by multi-nationals, such as Perugina that was acquired by Nestlè, while the main Italian players are: Icam, Loacker-Ritter, Witor's, Venchi and Novi.

Multi-national groups	National companies acquired by Multi-national	Italian companies	
Ferrero	Perugina (Nestlè)	Icam	Loacker-Ritter
Mars	Caffarel (Lindt and Sprüngli)	Zaini	Witor's
Nestlè	Milka (Mondelez)	Venchi	Sorini
Lindt and Sprüngli		Novi	

Table 4.1. Summary of the main players in chocolate Italian market

Thus, the chocolate industry is characterised by a lot of international or local producers which make high the competition in the market. Products are characterised by a low price that have to repay variable and fixed costs sustained by the companies in the production process: the majority of the product cost can be considered fixed, because it is composed by investments and assets companies sustain to produce a large quantity of chocolate. Indeed, due to the low value of the product, companies have to compete on the sales volume, and high production volume requires high investments in big automated plants, that, for the particular characteristic of the industry, are also specific: this is the main barrier to new entrants in the market. For what concerns the chocolate production planning, although the chocolate demand suffers of seasonality, the production planning can be distributed along the entire year, storing in the warehouses excess production for periods of peak of the demand. The storage of the product is not very complex and expensive: indeed, chocolate is not a perishable product, the only requirement is to store it in an environment not too hot, with a temperature not higher than 18°C, and not too humid, with a humidity not higher than 50-55%.

The absence of switching costs makes important for companies the creation of a own identity to reach customers and be preferred over the other competitors. Creating a own identity for chocolate companies is possible thanks to the high product differentiation and innovation allowed by a lot of possible recipes, so, consumers can acquire chocolate bars with a relative price difference very high, usually related to the brand of the company and the customers' value perception. The chocolate taste and the feelings that a company is able to create in customers during the consumption are fundamental to achieve preferences of customers and maybe maintain them over the time. Thus, companies like Venchi or Lindt succeeded in be perceived by customers of high quality, and this perception results in the premium prices customers are available to pay to acquire these products. Moreover, to improve the brand image an effective marketing activity is fundamental: indeed, it is enough to enter in a supermarket to see a direct relation between the price of the chocolate and the place occupied in the shelves, or the dedicated space to promote the product.

Moreover, if chocolate companies can easily leverage on their bargaining power in contracting with poor cocoa farmers, in the negotiations with buyer, the brand value is important to find good agreements with clients.

The importance of the quality of chocolate in Italy is demonstrated by the fact that the "pure" chocolate recipe is protected by the law since the 30's to differentiate good products from ones which want to enter in the market without respecting the production standard, damaging in this way the quality and the image of the product. Also in Europe chocolate is protected by the directive 2000/36/CE, and in Italy by the law 178/2003, the main themes of the European directive are:

- Limit of 5% for the usage of vegetable fats in replacing the cocoa butter;
- Obligation to indicate in the products' label information about ingredients and expiration date;

- Obligation for those companies which use vegetable fats to declare it in the label;
- Allow companies which do not adopt vegetable fats to declare it in the label;
- In Italy's law 178/2003, there is also the possibility to denominate in the label as "pure chocolate" the chocolate produced only with cocoa butter.

A further complication could be for those companies which use the palm oil instead of the cocoa butter in producing chocolate due to the recent scandal of deforestation practices related to the extraction of palm oil in the tropical countries.

Finally, recently, in Italy researchers identify five important trends in the tastes of consumers:

1. Preference for dark chocolate;
2. Affirmation of new types of chocolate such as vegan chocolate or organic chocolate, produced to satisfy requirements of some market niches;
3. Evolution of the traditional design: some companies like Ritter or Perugina started to produce chocolate bars with new designs which seems to positively affect sales;
4. Increasing interest for new recipes;
5. Increasing attention in the packaging designs that affect the customer's choice.

4.2 ICAM S.p.A.

Among the players operating in the Italian chocolate market, it is chosen ICAM, a family company founded by the Agostoni family in Lecco, after the Second World War, in 1946. The passion of the family has driven the company along two generation and has made possible to export the art of the Italian chocolate makers all over the world, because the company during its life was able to overcome the borders of Italy, to sell at the moment its products in 70 foreign countries, under the ICAM name, or through private label's contracts.

The main reason under the choice of ICAM stands exactly in the company profile, which makes it suitable for a rapid implementation of a blockchain based pilot project. Indeed, ICAM, since the beginning of its activity, has given fundamental importance in controlling and monitoring every phase of the production process to offer its customers a guarantee of premium quality.

Now, ICAM has confirmed its own foresight, understanding before others the customer need of transparent supply chain; in fact, in 2010, the company decided to revolutionise its whole idea of doing business following two objectives: effectiveness and traceability. Thus, the company started to look for the best available technology to allow an improvement of the production volume, the products' quality and of the monitoring of activities, investing 70 million Euros in one of the most innovative production plant in the whole country, able to operate continuously 24 hours a day, 6 days a week. The result is a new fully automated production site located in Orsenigo, a small village near Como, in which the company is able to realise more than 25 000 chocolate tons annually (doubling the production capacity of the previous plant), with a product range of over 300 finished products, that then become over 3000 including all the product variations, and semi-finished products such as cocoa butter, cocoa powder, cocoa paste, liquid chocolate, moulded chocolate and chocolate drops. Thanks to its new production plant, the company succeeded in increasing revenues in these years; in fact, in 2009 revenues were around 95 million Euros, while in 2016 they reached 155 million Euros.

In the building of the new production plant, one of the most important objective, as said, was the creation of a production process that could be tracked since the cocoa farming; thanks to the collaboration with Siemens, the company is now able not only to monitor instantaneously, through sensors placed inside the machines, process characteristics such as temperature, acidity, cycle times and pressures along the production process, but, it is able to relate these information with the respective production lot and to collect these in internal servers. Essentially, the company is able to track origins and characteristics of each item come out from the plant.

The production process

The chocolate production process starts far from Italy and the Industry 4.0, which characterises the production plant of Orsenigo, it starts in the cocoa plantations farmed with the tradition and experience of local families. Cocoa trees are delicate plants which need to be protected by both the sunlight and high temperature variations; so, farmers take care of these replicating the

conditions of natural tropical forests, rounding cocoa plants with tall trees that create the necessary shade to protect cocoa plants by the sunlight.

Each year, the cocoa tree produces cocoa pods, which grow directly on the trunk or on the main branches of the tree, and inside the pods there are the cocoa beans. A cocoa tree reached the period of peak production after 5 years, and in that moment, it is able to generate from 25 to 30 pods each year. Each cocoa pods contains from 30 to 40 cocoa seeds that could be of three different types:

- Criollo: It is a delicate and sensitive variety which allows the production of a very fine cocoa, and it accounts for the 2% of the worldwide production;
- Forastero: This type comes originally from the Amazon forest and it is characterised by violet seeds and green pods, it stands for the 80% of the total cocoa production;
- Trinitario: It is a hybrid of the two types described before, it came originally from the island of Trinidad, and it accounts for the 18% of the worldwide production.

The pods are harvested by the expert farmers' hands: this activity requires a lot of ability and experience because it could be very easy to damage seeds within the pods. Then, farmers are in charge to remove the seeds and the pulp by the pods and to piled up them in baskets covered by banana leaves that accelerated the fermentation of cocoa beans. Cocoa beans are piled up in heaps of no less than 100 kilos and no more than 2000 kilos to produce the right amount of heat to allow the correctness of the fermentation process. In addition, it is important to separate different varieties of beans during the fermentation process because they need different time to undergo fermentation: 3-5 days for the Forastero beans, while 2-3 days for Criollo beans.

After the fermentation, the cocoa seeds are undergone to the drying process which stops the fermentation, because if it carries out for too long, it could cause a too high level of acidity on the cocoa. The process of drying the beans can be carried out in a number of ways. In case of smallholders, the drying process is carried out by using simple mats which can be made from split bamboo or polythene sheets. In areas where the sun is abundant and the air is dry, the beans can simply be laid on top of these mats and dried in the natural sun preferably on a raised platform to avoid contamination at the ground level. The cocoa beans can be dried out on a concrete terrace too, which is one of the common methods used to dry beans in West Africa. While the beans are dried in the sun, the workers should pick out any foreign contaminants and clean out the pile by removing any unwanted and broken beans or other materials from the pile. The drying pile should also be protected from rain and should be raked at intervals.

After that, ICAM identifies each cocoa bag with a unique barcode, and sends them to the Orsenigo warehouse.

During the transportation across the ocean, cocoa bags are carried out through containers similar to those which transport coffee, that have to prevent the change of the humidity level, and these containers have to be placed far from heat sources to prevent a possible post fermentation.

Once arrived in the Orsenigo plant, cocoa beans are subjected to quality checks to control the state of the fermentation process and any other possible defect. After that, the cocoa are cleaned by foreign bodies and the good beans continue their journey while the others are thrown away. Then the good beans are pre-toasted, so these are irradiated with infrared rays, at 400 °C, for 100 seconds, to let the easy removing of the cocoa beans from its shells.

Then, cocoa beans are crushed into small pieces called grain, and, in the meanwhile, shells are thrown out. Then, the grain passes through the alkalinisation phase, a bath in the water, in which, depending on the cases, could be added the potassium carbonate, to reduce the natural acidity of the cocoa.

After the alkalinisation, there are three phases of the production process that are needed firstly to turning the cocoa grain into the cocoa paste, and then to separate the cocoa paste in its two components: the fat component called cocoa butter, and the remaining part called the cocoa press cake. The first of these three process is the roasting, in which the grain is toasted using hot air at a temperature between 100 and 120 °C, for 30 minutes: this phase is fundamental to develop the noblest aromas of the cocoa. After the roasting there is the milling, in which the grain is ground in a pin-mill to become the product known as cocoa liquor or cocoa paste. Then it is the moment to separate the cocoa butter from the cocoa press cake thanks to the third phase, the pressing, in which the cocoa paste is pressed through an hydraulic press.

After these three phases, the cocoa butter and the cocoa press cake pursue for a while alone their journey in the plant. The cocoa butter has to be filtered to remove impurities and deodorised, to remove a part of the volatile acids and give to the cocoa butter a pleasant taste. The deodorising phase is possible through a high-pressure jet of steam directed to the cocoa butter.

On the other hand, the cocoa press cake is crushed and ground finely to obtain the cocoa powder.

Now, the two main components of chocolate are ready to be mixed and to create all the different types of chocolate, adding other ingredients such as milk, sugar and hazelnut paste. Then, the chocolate paste is refining to obtain particles with a size of no more than 18 microns. Finally, there is the last and most important phase of the chocolate production: the conching process. The conching process, which may take hours, allows to:

- Create a perfect combination of the various components;
- Reduce the acid and astringent aromas;
- Extract any remaining humidity, reducing it to no more than 0.5-0.8 % at the end of the process.

In addition, at this stage, a small amount of soya lecithin 0.3% is added as a fluidifying agent and emulsifier, as well as a little vanilla to enhance the aroma.

Finally, the chocolate is tempered : it is first cooled to 26/28°C and then heated to 29/32°C. This is essential for the cocoa butter to solidify in the stable crystalline form, which makes it suitable for moulding and gives it a glossy appearance and a crisp snap, as well as ensuring excellent shelf life.

Then, the tempered chocolate is poured into moulds of a variety of shapes and then it solidifies in large cooling tunnels. At the end, the solid chocolate is removed from the moulds and it is enwrapped and packaged.

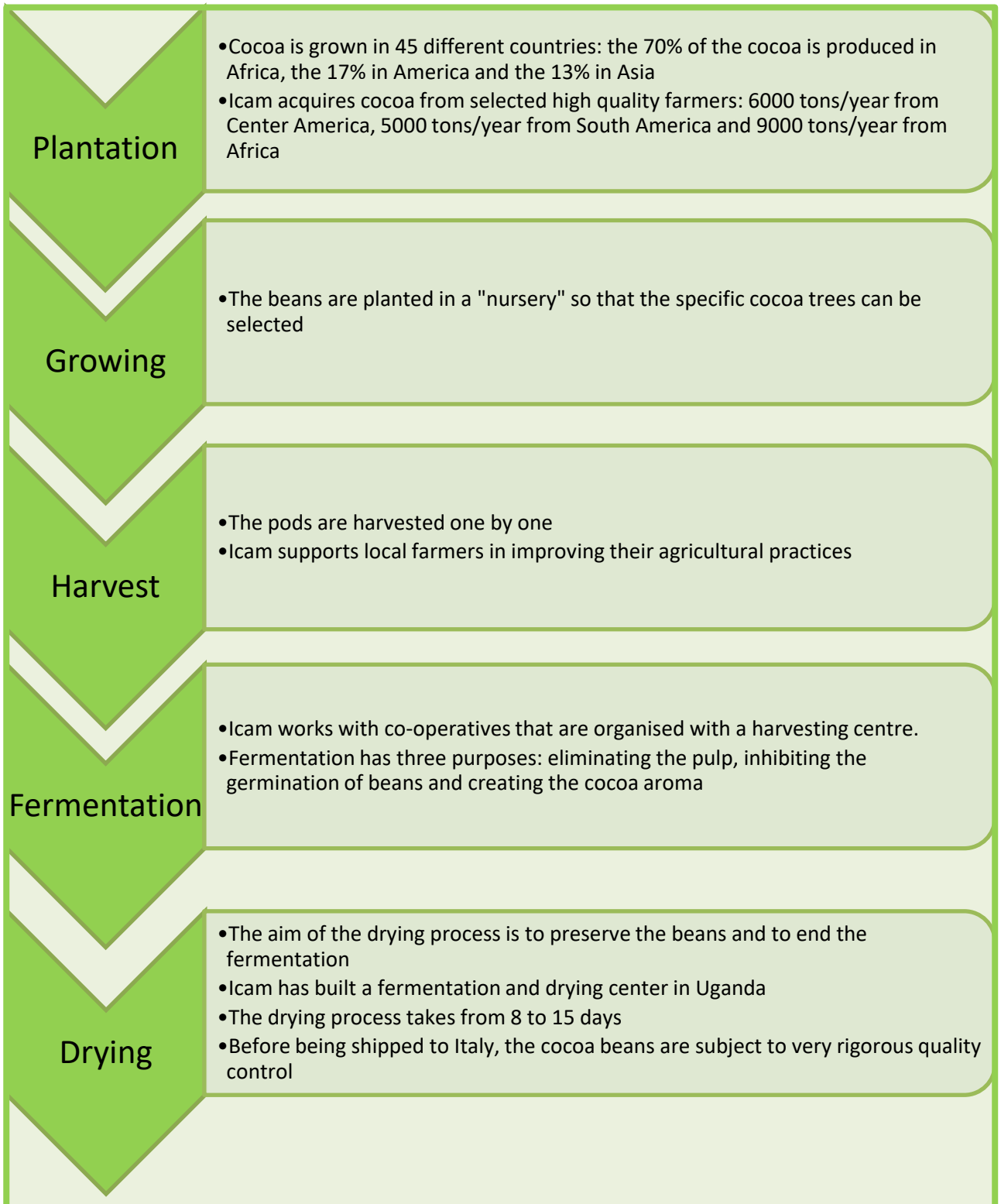

Fig. 4.5. The journey of cocoa: from plantation to the production plant

Fig. 4.6. The journey of cocoa: from cocoa beans to chocolate bars

Procurement

ICAM has established a long-term relationship with the local cocoa farmers in tropical countries, and it made financial and technological investments during these years to improve the working conditions of cocoa farmers, and consequently, to improve the quality of cocoa.

First of all, farmers with whom ICAM have relationships as cocoa suppliers are all owners of their lands, and ICAM aims at maintaining the plantations' ownership to farmers, that can in this way feel as a peer speakers of the company. In addition, ICAM takes care of some projects to improve education and infrastructures in the farming communities. Then, an important theme of the ICAM negotiation is to pay fairly farmers for their cocoa, also limiting the role of intermediaries that too often speculate on the product, damaging the cocoa farmers. This ethical management creates mutual objectives and a sharing of risks between ICAM and farmers, which in this way have to work together to pursue a sustainable and consistent grow. Now there will be presented the most important partnerships established by ICAM with the cocoa local farmers.

In the Dominican Republic, ICAM has established a relationship with four different local cooperatives: Aprocaci, Conacado, Coproagro and Reizek. In particular, the collaboration with the Conacado and Reizek cooperatives leads to an improvement of the cocoa quality, which is able to receive a lot of organic certifications. Thus, Conacado is becoming the major producer of the organic cocoa of the world, and ICAM purchases 6000 tonnes of organic cocoa every year from the Dominican Republic.

In Ecuador, ICAM collaborates with the cooperatives Maquita Cushunchic como Hermanos (MCCH) and Gruppo Salinas, that support small cocoa farmers for 20 years, with 22 harvesting centres; the cocoa produced by the two cooperatives accounts for the 12% of the total production in the country. In Ecuador, the collaboration between ICAM and local cooperatives guarantees technical assistance to farmers, therefore, they can increase volume and improve quality of cocoa. From Ecuador, ICAM acquires 1000 tonnes of cocoa every year, paying fair prices to farmers; however, cocoa of higher quality gives in any case the possibility to farmers to sell it at higher prices, and this contributes to an economic development of the area comprehended by the provinces of Bolivar, Manabi, Esmeraldas, Los Rios, El Oro and Guayas, impacting in the quality of life of 400 000 people.

In Perù, ICAM has established a direct partnership with: APROCAM, ACOPAGRO Cacao Huallaga and Vrae Cocoa Growers Association. The partnership aims at improving the quality of cocoa and through an increase of the value of the cocoa, improving also the life conditions of cooperatives' members. Perù is one of the most important cocoa supplier for ICAM, because from this country the company acquires the precious cocoa Criollo. The exceptional nature of the cocoa Criollo stands on the particular eco-system in which it grows and in the different practices used by local farmers in the cultivation of cocoa; therefore, ICAM and APROCAM work towards the recognition of the exceptionality of the Bagua cocoa with a own brand name, which would recognise the unique flavour and characteristics of Bagua cocoa. In addition, ICAM focuses the attention to the environmental sustainability, to guarantee the conservation of the existing eco-system, and social

and economic sustainability, to contribute to the wellbeing of the cooperative members; in fact, the Italian company gave up the idea to request the fair trade certification for the Bagua cocoa, therefore, it can use those money to increase the price paid to cocoa farmers. Thus, ICAM invests in Perù creating a nursery in which are selected the cocoa plants more resistant, more productive and with a more pleasant flavour: these plants give origin to the Bagua cocoa, with whom the company decided to create a new product line, under the brand Vanini. Vanini is the brand born in 2014 which comprehends different recipes of premium chocolate produced with the Bagua cocoa.

In Uganda, ICAM made one of its most important project, the creation of a company, ICAM Chocolate Uganda Ltd, to develop different projects in support to the local farmers. The Uganda scenario is different respect to the countries seen above, in fact, here farmers are not organised in cooperatives, but they farm and harvest cocoa on their own and then, they put the cocoa seeds on the roof of their houses or on tarps on the ground to complete the fermentation and drying process. This uncontrolled and shallow treatment of cocoa caused first of all the lost of cocoa due to the adverse weather conditions, or due to thefts, and then, also the lost of value of the cocoa which completed the fermentation and drying processes. Low quality of cocoa results in low prices, which force small farmers to work hard and more and also to make their children work to help them. ICAM Chocolate Uganda built an harvesting centre equipped with modern processing methods to support local farmers through trainings on modern farming techniques to teach them how improve the quality of their cocoa. Moreover, ICAM built a fermentation and drying centre to which farmers can bring their cocoa seeds without fermenting them in their house, therefore, from one side ICAM could exploit a cocoa with higher quality thanks to the right attention reserved to it during the fermentation and the drying process, and from the other side, farmers can reduce their work. As consequence of the improvement of the cocoa quality, the cocoa price of Uganda rose up, therefore, farmers can improve their economic situation, reducing the hours of work, leaving children to go to school, because there is no need of their help in plantations.

Technology development

Technology in ICAM is seen as the way to achieve the best standard quality for products. The innovativeness of the Orsenigo plant is an example on how much it is considered central the technology in the chocolate production process. As it was introduced before, the objectives in the built of the new plant were mainly two: effectiveness and complete traceability. The result is a fully automated plant, able to guarantee the complete traceability of the process from the raw materials to the final product. Indeed, the plant is provided of several sensors that control continuously the characteristics of the process to intervene whereby there would be some failures. Moreover, the plant autonomously operates observing the strict regulations on the food safety and hygiene, with an attention in the cleaning of machines and testing the production process' features. Now, different areas and technical departments of the production site will be presented, with their main characteristics:

- **Warehouse:** The trip of cocoa beans in the Orsenigo plant starts from the careful stocking of the cocoa sacks in the warehouse, which allows ICAM the complete traceability of the

batches of cocoa. Cocoa beans are moved from here to the following production phases (sterilisation and roasting), through a pneumatic transport system.

- **Roasting plant:** After the sterilisation, cocoa enters in the roasting plant which has a capacity of 4 tonnes/hour. Moreover, it is provided with a postcombustor, which guarantees the total elimination of any odour emissions and of the release of remaining volatile aromas into the atmosphere.
- **Presses and pulverisation:** In this stage it is separated the cocoa butter from the cocoa powder. This is provided of 36 tanks, with the capacity of 10 tonnes, for the storing of liquid chocolate, 2 tanks, with the capacity of 25 tonnes, for the storing of cocoa butter and 6 tanks, with the capacity of 25 tonnes, to load the tankers.
- **Production facility:** It allows ICAM to process until 50 000 tonnes of cocoa every year, and it is composed by 2 refining lines, 4 mixers and 8 conching machines. Moreover, separate, dedicated production lines are used for the production of different types of products: organic, conventional, white chocolate, milk chocolate and dark chocolate, because ICAM pays a lot of attention on cross contamination. The production facility is managed by 200 operators working in three shifts, and it is able to achieve production levels equal to: 16 000 tonnes/year of semi finished products, 26 000 tonnes/year of chocolate produced and 10 000 tonnes/year of chocolate bars realised.
- **Trigeneration plant:** The electricity used during the production process is provided by a Trigeneration plant of 2,4 MW, therefore the company is able to save 50% of the energy costs. Moreover, the plant is able to reduce the need of methane used in the production process, reducing the environmental impact.
- **Quality control and R&D laboratories:** Both the raw materials and the finished products are subjected to quality control. Organoleptic testing is carried out on all the semi-finished products and products bounded for end consumers, to assure the maximum level of quality and safety.

Quality control

ICAM creates a pool of 40 chocolate experts to taste the quality of cocoa grains, semi-finished and finished products. Moreover, quality inspections are taken both before the production and during the production process. Before the production process, following quality controls take place:

- A quality control on each batch of cocoa, taking a representative sample from each sack;
- A “Cut test” on each batch of cocoa, to assure the good level of fermentation and the absence of defects;
- A sensory evaluation of the cocoa paste.

While, during the production process the following quality controls take place:

- Constant physical and chemical analysis conducted on products to monitor quality throughout the production process;

- Computerised monitoring system to guarantee control over the whole process and complete traceability;
- Sensory analysis of all batches.

The focus of ICAM in quality products provided it a lot of certifications, which demonstrate the continuous commitment of the company toward the environment and people who live there. Thus, in the last few years, ICAM has gained the reputation of one of the world's largest producer of organic chocolate, and, now, it is listed in the Fair Trade registry.

Strenght	**Weaknesses**
• Capability to sold products in 70 foreign countries • Focus on the constant monitoring of the production process • Attention to quality management • Transparent supply chain • High innovative production plant, example of I 4.0 • Capability to increase revenues • Long-term relationships with suppliers • Attention paid to ethic and environmental responsibility • Research activity in originating new cocoa types • Complete traceability of the batches of cocoa • One of the main producer in the world of organic chocolate	• Low brand value • Few investments in marketing campaings to communicate costumers values of the company • Low capability to retain loyal customers • Low promotion of the product • Difficulty in achieving premium prices
Opportunities	**Threats**
• Increasing demand • High chocolate demand in Europe and interest for high quality chocolate in Italy • Easy production planning and storage of the product • High product differentiation • Easy introduction of new products • Presence of customer loyalty • Sales affected by marketing activities and promotion • High bargaining power in negotiation upstream and downstream • Unique characteristics of product protected by law	• Cocoa grows only in few areas of the world • Cocoa is a delicate and sensitive crops • Harvest affected by political issues of the country of origin of cocoa • Presence of Child labour • Volatility of cocoa price • Suspects of speculations on cocoa price

Fig. 4.7. SWOT analysis of ICAM and Italian chocolate industry

Inside the company

Now, it is the moment to enter in ICAM and ask directly to managers working there which is the level of knowledge they have on the blockchain, and blockchain solutions to support the supply chain management, and if they have ever thought about the adoption of this type of solution to improve the tracking of chocolate.

As introduced before, the activity of the purchasing department is fundamental in creating value for the entire company, because the choice of suppliers and raw materials contributes for most to realise a good product and so to achieve targets of the company. Now, tracking of cocoa batches is made through the cocoa bag identification via barcode, and, during the production process, the journey of cocoa is tracked by the collection of all data measured by sensors, which are collected on a central server provided by Siemens; therefore, all data concerning the characteristics of realised products are stored centrally in the server. Finally, each chocolate product is identified by a barcode which uniquely identify it and its story within the production plant.

Below it is possible to find questions made to ICAM also concerning strategies adopted in relationships with customers and suppliers, and then, a survey to understand the priorities of the company in tracking products. At the end, results of survey allow to position ICAM in a perception map, which identifies the main benefits brought by the existent blockchain solutions that are presented in the inductive analysis. After that, there will be asked to the company which is, according to them, the best product to track through the blockchain technology in an hypothetic pilot project.

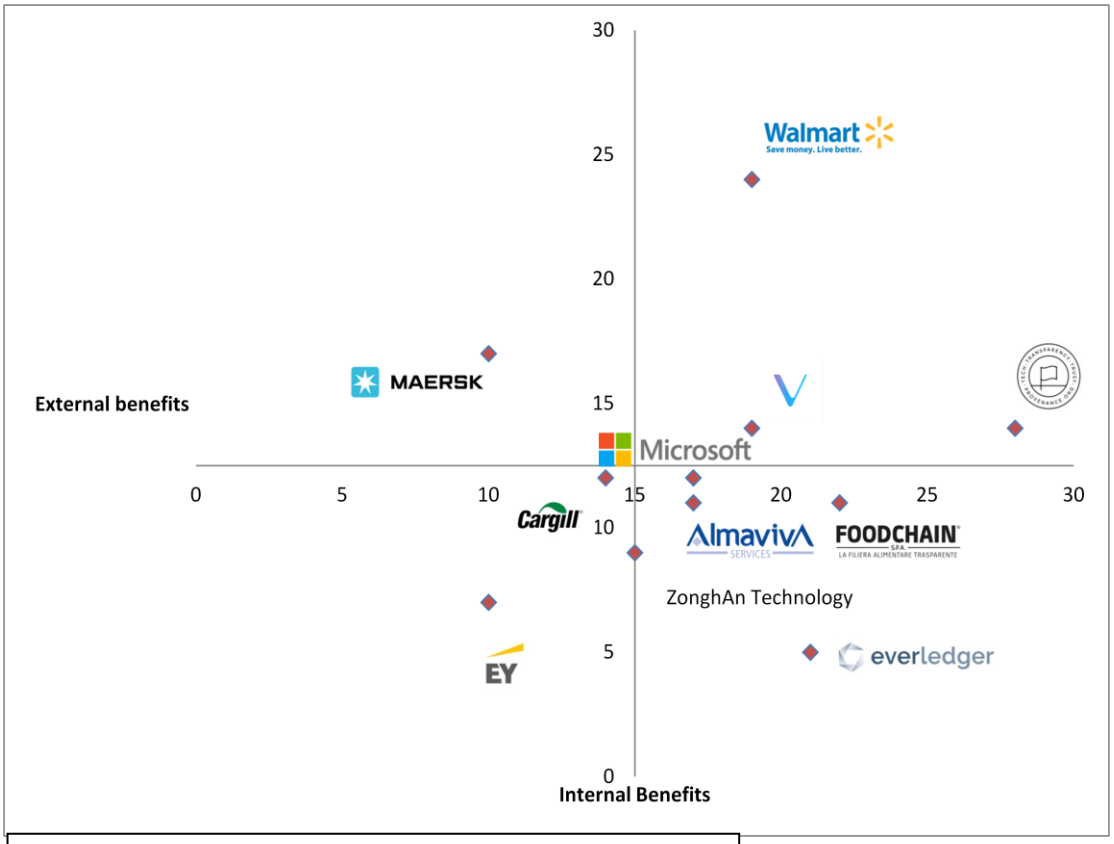

Fig. 4.8. Perception map of existent cases

Interview with ICAM

1. *Why is important for ICAM the entire traceability of cocoa batches?*
2. *Which is the system adopted by ICAM to track goods along the supply chain?*
3. *Do you use collaborative forecasting and replenishment methods with customers or suppliers?*
4. *How is managed the transportation activity?*
5. *Have you ever needed a higher safety level concerning the information about origins and characteristics of products?*
6. *In which moment happens the identification of the cocoa bag with the respective barcode?*
7. *Have you ever thought to replace barcode with other smart labels?*
8. *Have you ever thought to adopt a distributed system to track goods?*
9. *Have you ever heard about Blockchain?*
10. *Have you ever heard about Blockchain applications in supply chain management?*
11. *Have you ever thought to adopt a blockchain based solution to track goods along the supply chain? If yes, a permissioned or a permissionless one?*
12. *Have you ever thought to use smart contracts within your supply chain?*
13. *In which product would you invest to start a pilot project for the improvement of supply chain management and tracking?*

Positioning survey

1. *How much is important for ICAM limiting the document's duplication along the supply chain?*

1	2	3	4	5

2. *How much is important for ICAM to speed up the recalling and withdrawal procedures?*

1	2	3	4	5

3. *How much is important for ICAM the improvement of the replenishment and production planning?*

1	2	3	4	5

4. *How much is important for ICAM the reduction of costs of intermediaries?*

1	2	3	4	5

5. *How much is important for ICAM improve the quality control along the production process?*

1	2	3	4	5

6. *How much frauds and illegal market affects the chocolate industry? How muchi is it important to defend the company by these crimes?*

1	2	3	4	5

7. *How much is important for ICAM protect information on the life of products stored in the server?*

1	2	3	4	5

8. *How much is important for ICAM to communicate to consumers the ethic and environmental responsibility pursued by the company in its daily activities?*

1	2	3	4	5

9. *How much is important for ICAM limiting the companies' collusions?*

1	2	3	4	5

10. *How much is important for ICAM the limitation of double-spending certifications?*

1	2	3	4	5

11. *How much is important for ICAM the creation of a loyal relationships with its customers?*

1	2	3	4	5

CONCLUSION

Unfortunately, after an initial interest of the company in joining the project and fix a meeting, they started to hesitate because they did not feel enough prepared on the topic, and so they neither answer questions nor the survey.

Obviously, without opinions and information provided by the company, it is difficult to identify a blockchain existent solution near to the needs of the company, which was the objective of the survey, and, moreover, it is difficult to identify a product to implement hypothetically a pilot project. Nevertheless, from the information owned it is possible to propose a product of Vanini brand for an hypothetical pilot project, because it is the product line in which the company is investing more, and with whom the company wants to compete in the premium segment. Thus the company could gain a competitive advantage thanks to adoption of the blockchain and a QR code through which customers would access information on the ICAM supply chain. In addition, it is possible also to hypothesise a solution similar to the "Caffè San Domenico" project by Foodchain, because cocoa and coffee supply chain have some similarities.

Finally, it is the moment to sum up the results of the research. After the analysis of the characteristics of the blockchain technology and the pilot projects concerning the application of this technology in the supply chain management, it is possible to have an insight of the potential of the blockchain: in the future, it could make products talk to customers about their origins without any possibility of data falsification. Thus, supply chains will become transparent at customer's eyes, but also transparent to legal authorities that could control easily the legality of operations pursued by companies. In addition, the blockchain will bring a lot of benefits also to companies, thanks to a real time tracking system that will allow companies to have continuously information about the state of products, therefore they could improve all the activities of their supply chain management, from the signing of contracts with customers/suppliers, to the planning activities, to the quality control and the reverse logistics.

Nevertheless a constancy in these months of research, that was confirmed in the application case too, was the actual insufficient level of knowledge of the technology, and the difficulty in quantifying the impact it could have in the business environment. Indeed, the interest on blockchain is something recent and projects on this field are still few and at the embryonic stage. Thus, the blockchain will revolutionise the supply chain management in the next future?

After this research it is possible to declare that yes, the blockchain could revolutionise not only the supply chain management but probably the whole way to do business, but, only in the long term, because, at this moment, the level of knowledge of the blockchain and the interest of companies is still too low.

LIMITS AND FUTURE RESEARCHES

This research wants to present in a clear way the peculiarities and advantages offered by the blockchain technology if adopted to support the supply chain management, in addition, it wants to be a systematic collection of all the main existent projects in this field, with their characteristics.

Unfortunately, the novelty of the theme studied did not allow at this moment a quantitative analysis of benefits and costs of blockchain solutions, comparing KIPs of companies before and after the blockchain application. Therefore, one of the future improvement of this work will be absolutely the confirmation of the benefits and effects of the blockchain listed during the deductive and inductive analysis, made by a quantitative evaluation of data.

In addition, this work aims at being the starting point for future researches in the field, and at giving basic information for anyone who is interested in the topic, and who is interested in try alternative ways to adopt the blockchain technology to support supply chain management in other industrial sectors. During this research it was proposed the adoption of the blockchain technology in the chocolate industry, but future researches could be undertaken to find new companies in new industries where trying to implement pilot projects in tracking goods with the blockchain.

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