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Blockchain Technlogy: applications, implementations and barriers in Supply Chain

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Introduction

Cryptocurrencies were formally born in 2009, when Satoshi Nakamoto's whitepaper came out. Initially the topic was object of many debates among experts in the field. Subsequently, Bitcoin also divided public opinion between those who supported it and those who instead questioned its usefulness.

Bitcoin and all the cryptocurrencies that were born later are based on one technology, blockchain technology. In the simplest of terms, the blockchain can be described as a register composed of blocks, to which, however, it is only possible to add data and not delete or modify them.

Hence the term chain, the data are then consolidated into blocks which are added one after the other to the register, so as to form a chain. It is the fact that you cannot modify or delete information from this database that makes it different from traditional databases.

Although the first application of the technology was precisely on the financial field and therefore with Bitcoin, its applications are not limited only to this industry.

In fact, blockchain technology is defined as a potential innovation that can disrupt other industries as well. It is a technology that can have great impacts mainly on sectors in which the management of data and information is important and contracts are widely used to manage commercial exchanges or regulate relationships.

Many, like (Mougayar, n.d.) define blockchain technology as the most important innovation since the invention of the Internet.

Nowadays, in fact, plans to implement the use of blockchain are not limited to the financial and payment sectors. It is expected that the technology, although in its infancy, will be implemented in other sectors such as healthcare, government, legal, fundraising, security, education and academia and many other industries. The main reason why industries are embracing blockchain technology is because of its unique features, such as real-time information sharing, cyber-security, transparency, reliability, traceability, and visibility.

This study attempts to understand the possible applications of technology in supply chains.

In Chapter 1 through an analysis of the literature is analysed the definition of Supply chain, an overview of Supply chain management and what are the business processes that are part of it. The chapter then closes with an analysis of what are the main pain points of supply chains nowadays.

Chapter 2 introduces the topic of blockchain technology, explaining its origins, properties and main applications. The chapter, therefore, ends by analysing how blockchain can help solve the supply chain's pain points discussed in chapter 2 and how it can also make supply chains more efficient.

Chapter 3 analyses the processes of adopting a new technology and its and barriers.

Then proceeding with the Chapter 4, is explained the research methodologies used to verify the applications and implementations of blockchain in real supply chains.
It therefore starts with a selection of start-ups that use blockchain technology in their value proposition to research which are the areas where blockchain mainly brings added value.
Finally, it was decided through the interview methodology to deepen what was discovered in the literature and verify the practical feedback in two real cases of companies that are implementing the technology in their supply chain. The aim of these case studies chapter is to deepen analyse the motivations that led companies to approach the technology and thus start the project of implementing the blockchain besides the difficulties encountered.

1. Supply Chain and Supply Chain Management

Nowadays the concept of Supply Chain is widely spread among companies. An efficient supply chain, in fact, allows companies to maintain or obtain a significant competitive advantage over their competitors, as it permits the optimization of available resources, to avoid wastes and to respond quickly to the fast-changing customer's needs.

Before going more into the detail of the relationship between blockchain and supply chain, a brief outline of the concept of Logistics, Supply Chain and Supply Chain Management follows in the next paragraphs.

The term logistics has ancient origins. In fact, the term originated in domains related to war and war strategy. According to (Jayne Kimberley on behalf of IoSCM, 2018) the term 'logistics' first appeared in 1810 with Wilhelm Müller's publication 'The elements of the Science of War'. This book contained the memorable operations of war from 1667, describing the various procedures from the point of view of artillery compositions, engineering, tactics, strategy and politics of war, among which it also devotes a chapter to logistics. The outcome of a war was very often determined by the skills and knowledge in the organisation of a troop's logistics. Logistics therefore played a very important role in the wars of human history.

Between the 1980s and 1990s, other definitions and interpretations emerged in the business world.

The first scholars to talk about Supply Chain were Oliver and Webber in their paper of 1982 titled "Supply Chain Management: Logistics catches up with strategy", by many referred (Cooper et al., 1997) to as the publication in which the term Supply Chain Management was first indicated. In this publication the term was used in reference to techniques for stock reduction in companies (Felea & Albăstroiu, 2013). In other words, they defined Supply Chain Management as an activity warehouse management and as a technique of reducing inventory in a company.

Again in (Cooper & Ellram, 1993), dating back to the beginning of the 1990s, Supply Chain Management is defined as an approach to reduce inventory. However, it is also mentioned that the more companies and functions are involved in this

process, the easier it is to achieve a result. The definition is always based on the view of inventory reduction, but it also includes a hint to the actors involved in this process, which are the company functions and other companies.
The concept of vertical integration between enterprises is also included. In fact, they see the concept of Supply Chain Management as "the underlying concept of complete vertical integration between companies" (Cooper & Ellram, 1993) and where each player operates independently of the others through its own business functions.

It can be seen from these initial definitions that the emphasis was primarily tactical, focused on cost optimization. The aim was to analyse which companies participating in the chain had particular cost advantages, such as lower labour costs or better access to capital. This analysis was necessary to better co-ordinate the channel as a single entity to gain a competitive advantage and profitability creation through lower inventories.
Subsequently the growing national and international competition between companies, shifted the focus to a more strategic supply chain vision, emphasizing the creation and delivery of value to the end customer.
In 1998 (Tyndall et al., n.d.) explained that half of all services even in service industries, are purchased from outside the company and, in other words, the majority of what a company is in terms of raw materials, components and services are obtained from outside sources. That is why vertical integration was becoming less and less credible, leading to inflexibility in terms of cost structure and adaptability in the marketplace.
Companies could no longer act in isolation, but interaction with other companies was essential. It has thus been realized that whenever a company has to deal with another that carries out the next phase of the supply chain, one has an interest in the success of the other. It has become common to say that “competition is no longer between companies, but between supply chains” (Kumar & Pugazhendhi, 2012).
Supply chain management is about relationship management. A supply chain is managed, link-by-link, relationship by relationship, and the organizations that manage these relationships best will win.

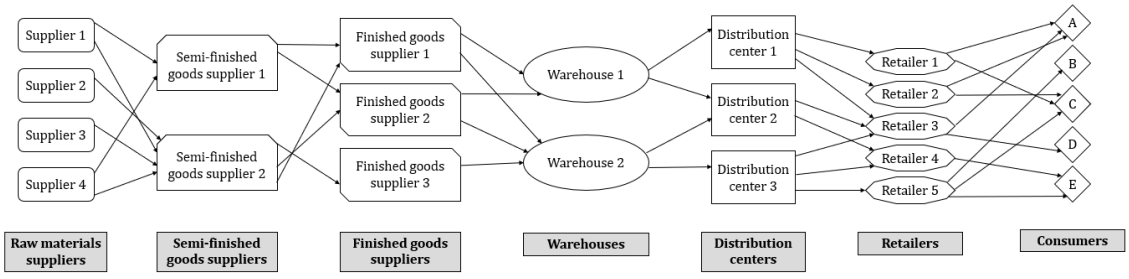
It is from here that the concept of complexity develops, completing the concept of supply chain as a dynamic and complex system of autonomous companies that interact with each other, contributing to the pursuit of a common goal: deliver value to the end consumer.

After years of focusing their attention on their internal resources, companies now aim to reduce overhead costs and increase efficiency and effectiveness of their whole network. The shift in focus from the individualistic to the global view of the supply chain involves suppliers and distributors, making control of the very complex overall system. In fact, according to an empirical study (Perona & Miragliotta, 2004) the way in which companies manage their operations system complexity has a direct impact on their performance turning it in a strategic issue.

According to (Chopra & Meindl, 2007) a supply chain consists of "all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves. Within each organization, such as a manufacturer, the supply chain includes all functions involved in receiving and filling a customer request. These functions include, but are not limited to, new product development, marketing, operations, distribution, finance, and customer service".

The supply chain is therefore defined as a network of parties involved directly and indirectly in satisfying customer demand, Figure 1.

Figure 1 Network of parties involved in a supply chain



Source: personal elaboration

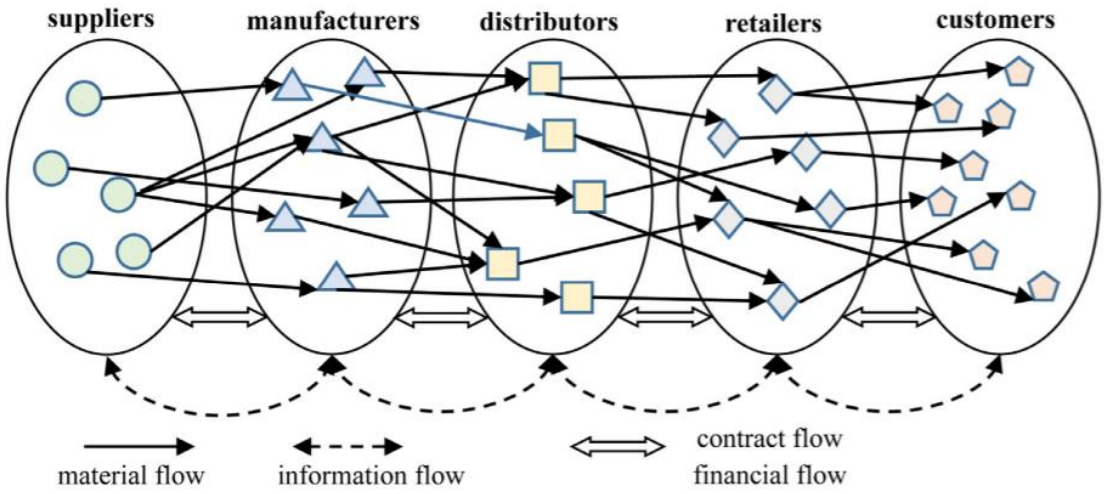
When we go to a shop to buy a pair of shoes, we are a consumer who, having the need to buy a pair of shoes, takes part in the supply chain of that product. In that case we are at the bottom of the process. Looking at the product, we probably do not consider the vastness of actors, flows and transfers that the product has been through.

For example, in a pair of shoes there can be up to forty components and each component can come from a different supplier, from anywhere in the world, who in turn could have many different suppliers of raw materials. In order to effectively build the shoes, all components need to arrive at the manufacturer's factory. There may be cases where geographically the shoes are not assembled in the same factory or even by the same manufacturer. In basic terms, one part of the construction of a shoe, such as the upper part of the shoe, i.e. the uppers, could be done only that by a manufacturer or plant specialised only in uppers constructions. This manufacturer or plant will receive components to build the uppers and proceed to perform several operations, such as checking the incoming components, cutting the fabrics, stitching the upper itself. In this case we are talking about a semi-finished product and semi-finished goods suppliers. Once the operations for which it is responsible have been completed, the upper is transferred to another factory or another producer who will transform the semi-finished product into a finished one. Also in this case, the manufacturer of the finished product will receive incoming components that he will need to finish the shoe. Once the construction process is finished, the shoes are boxed up and shipped to large sorting centres, which in turn sort the products to regional centres, for example, that in turn will supply the retailers.

Mentzer et al. (2001, p. 4) in their definition of supply chain, adds another perspective, going more into the details of the type of relationship or better the flows that take place between the various actors in the supply chain. In fact, according to them, a supply chain is composed of “a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer”.

Upstream and downstream flow is meant to be a continuous back-and-forth flow between the different actors from upstream to downstream and vice versa, Figure 2.

Figure 2 Structure of a complex supply chain network



Source: (J. Wang et al., 2021)

Mentzer outlines 3 types of flows:

- Flow of products and services, which can be in three different stages:
    1. Purchase
    2. Processing
    3. Distribution

Purchase refers to the flow of raw materials or semi-finished products that need to be transformed and therefore pass from the raw material suppliers, usually called Tier 3 suppliers, to Tier 2 suppliers, identified as the party that transforms the raw material. Then comes the transformation of the raw materials or semi-finished products, which are defined as inputs to processes that transform them through the work of man or machine, into a finished product. Afterward, in the distribution stage, the finished good, pass through eventual warehouses and then distribution centers in order to let the product be available in retailer's shop for customers.

In this context, it is worth noting that the flow as outlined so far, from the supply of raw materials to the transformation and distribution, is defined as a product or service flow, from upstream to downstream. For various reasons it can also be a backward flow. The product may then, from the final consumer go back upstream

as for example to be repaired, to be recycled, or just a return of goods. This backward flow in the supply chain is called “reverse chain” or “reverse logistic1”.

- ❖ Financial flow

The management of a supply chain generates financial inbound and outbound flows. The correct integration between these flows determines the company's cash flow position and consequently its profitability. It involves the management of payment flows between suppliers, between companies and final consumers, transporters of raw materials, semi-finished or finished products, etc.

- ❖ Information flow

The flow of information is a continuous, two-way flow that crosses the whole supply chain and involves all actors in the network. Examples of such flows, may include product data sheets, product information, quotation requests, component information, inventory data, delivery scheduling, contact and payment data, electronic data exchange, order flow of finished products and components, production work orders, data on industrialisation of a product, new product developments, etc.

Thus, the scope of Supply Chain Management can be defined as the number of firms, activities and functions involved in a supply chain (Cooper et al., 1997). As the concept of supply chain management has evolved, its scope has expanded from tactically manage logistics functions, e.g. cost optimization and inventory efficiency to a much more strategic focus.

(Mentzer et al., 2001) described the scope of supply chain management from both functional and organizational perspective.

Since process refers to the combination of a number of functions to achieve a specific output, all traditional business functions should be included in supply chain management. In order to achieve a successful supply chain, supply chain

[1] The Council of Logistics Management (CLM) clarify the definition of Reverse Logistics in the in the early nineties (Stock J.R., 1992): “…the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal.” Reverse logistics is linked to sustainable development issues and is gaining increasing attention from academics and companies. The re-use and potential re-manufacturing of products prevents the negative environmental effects of excessive consumerism. Governments have also placed limits and regulations on the subject. European legislation, for example, emphasises the importance of reusing and recycling products (Turrisi et al., 2013).

management has to integrate all internal business functions such as marketing research, sales, promotions, research and development, new product development, product industrialisation etc. In fact, supply chain management need to start to first connect each other the internal business functions and then pursue the organisational scope of supply chain management that is the proper integration of inter-company relationships with the company's business processes and functions. Without this inter-company coordination, supply chain management cannot reach its full potential.
Ultimately, the goal of supply chain management is to integrate functions within the company and to integrate inter-firm processes.

As, highlighted above, over the last few decades, there have been different definitions of supply chain. (el Mrabet W et al., 2017) carried out a study of the definitions of supply chain existing in the literature from 1992 to 2016, from which emerged four categories of definitions:

- "Supply chain **as a network of activities**", these activities are associated with the flow and transformation of goods and services, considering also the flow of information that crosses the process, from suppliers of raw materials and components though production activities, through the distribution chain up to the end users.
- "Supply chain **as a system**" that consider the interaction between different entities through the upstream and downstream flows.
- "Supply chain **as a set or network of entities**" including different actors such as suppliers, manufacturers, assemblers, distributors, logistics centres, customers and sometimes also competitors which are interconnected by different flows of information, products and moneys.
- "Supply chain **as a complex system/network**" of corporate relations since each node may be a member of many other supply chains.

Customer requests to buy products and services delivered quickly on time, without defects and at a low cost, have led companies to broaden their supply horizons with a view to global procurement. This globalization of supply requires companies to seek efficient coordination methods for the in and out flows of raw

materials, semi-finished and finished products and information. A driver for the efficient coordination of flows is a collaborative relationship with suppliers.
The focus of supply chain management then has become an “hot topic”, referring to the proper management of these relations between all actors that compose the network leads to the awareness that “the whole can be greater than the sum of its parts” (Christopher, 2011).

1.1 Difference between Supply chain e Logistic

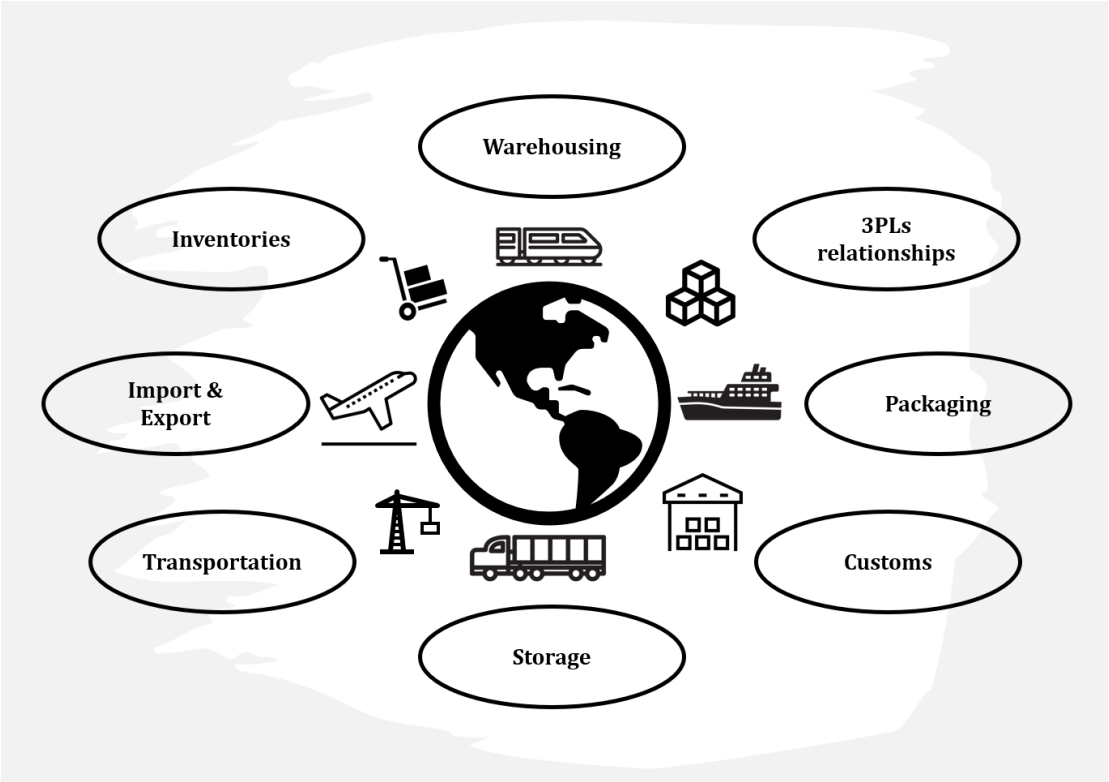
In many cases terms Logistic and Supply chain are used interchangeably, but they are not. Logistics and Supply Chain are closely related, but do not mean the same thing and are not terms that pertain to the same activity.

Logistics is a sub-component of supply chain management. (Cooper et al., 1997) reported a definition of Logistic given by the Council of Logistic Management in 1986 defining it as “the process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in process inventory, finished goods and related information flow from point of origin to point of consumption for the purpose of conforming to customer requirements”. Then in the glossary of the Council of Supply Chain Management Professional[2] is possible to find a revised definition of logistics management: “Logistics management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements” (Council of Supply Chain Management Professionals (CSCMP), n.d.). In this second definition, is therefore clearer the distinction between Logistic and Supply chain management, pointing the first as a part of supply chain management. Logistics management deals with the inbound and outbound transportation management through a network of transportation by road, rail, ship or air, efficient handling and storage of raw materials, semi-finished and finished products with the aim of meeting the needs of consumers Figure 3.

[2] It was founded in 1963 in America and its purpose is to provide networking, career development and exchange and learning opportunities in the community of people working in the supply chain. The expressed mission is: “*“To advance the supply chain profession by connecting, educating, and developing the world’s supply chain management professionals throughout their careers"* (Council of Supply Chain Management Professionals > Who We Are , n.d.).

Logistics management makes sure that the right thing is in the right place at the right time.

Figure 3 Logistic management activities



Source: personal elaboration

It is therefore essential to integrate, in addition to logistics, all other internal and external processes, to manage the entire Supply Chain. When, for example, a company considers bringing a new product to market, it must consider involving various business functions such as: marketing, research and development, production and logistics, and finance to raise the necessary capital. In addition to the support of the company's internal functions, it is also necessary to involve external agents in the process, such as first or second tier suppliers and end customers to test market reactions. It is clear, therefore, that to achieve success in the entire supply chain is necessary to integrate all the functions and actors involved, thus defined as Supply Chain Management.

The second part of Supply Chain definition by (Chopra & Meindl, 2007) clearly reported to the integration of company's business functions as: "…Within each organization, such as a manufacturer, the supply chain includes all functions involved in receiving and filling a customer request. These functions include, but

are not limited to, new product development, marketing, operations, distribution, finance, and customer service".

The first scope of supply chain management is the functional scope (Mentzer et al., 2001) with the core purpose of integrating intra business process allowing them to achieve at upstream and downstream levels, coordination and visibility.

1.2 Companies functions and business processes

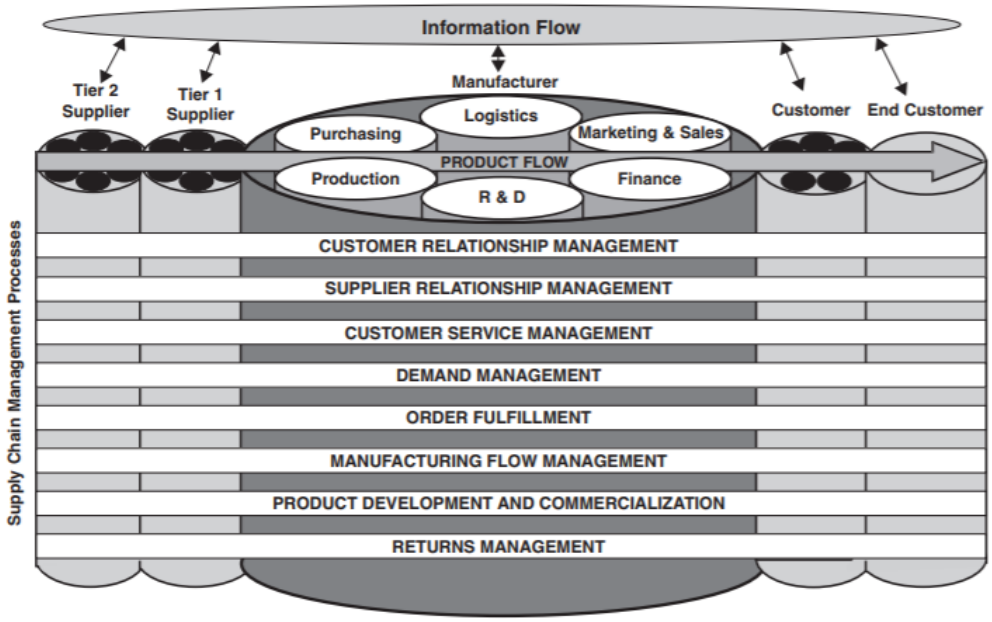
Supply Chain Management involves a set of processes that in turn involve other micro processes and micro activities. In the literature, there is now a consensus that the integration and collaboration of business functions add high value to the entire supply chain. (Croxton et al., 2001) reports on the business functions and processes identified by the Global Supply Chain Forum, analysing and describing them in more detail.

They identified eight key business processes that run the length of the supply chain and cut across the company's functional silos:

1. Customer relationship management
2. Customer service management
3. Demand management
4. Order processing
5. Production flow management
6. Supplier relationship management
7. Product development and commercialization
8. Returns management

Eight key business processes run the length of the supply chain and on firms' functional silos, see Figure 4 below:

Figure 4 Supply chain management: integrating and managing business processes across the supply chain



Source: adapted from (Cooper et al., 1997)

Functional silos are: Purchasing, Logistic, Marketing & Sales, Production, R&D and Finance. All the eight-supply chain business process are contained in each functional silos but an entire process is not contains in only one function. Below are briefly described each business process.

1.2.1 Customer relationship management

The customer relationship management (CRM) is a model used by companies to manage relationships with current or future customers. Obviously not all customers are equally important, it is therefore necessary to identify the target customers who actually bring a certain value to the company. CRM outlines the structure that must be followed to maintain and develop relationships with customers. Based on the corporate strategy, the CRM team identifies the key accounts that are strategic to the success of the organization. Then it establishes criteria to categorize customers to determine which customers will have tailorized Product and Service Agreement (PSA) and which will be grouped and provided a standards PSA.

1.2.2 Customer service management

The customer service team, is responsible for managing the PSA. This team is the company's interface with the customer. It provides information regarding the status of production, availability of products, order status and delivery dates. The team in charge for taking care of customer service management, has also to respond to internal and external events that could impact the company service level, it should try to foresee these events in advance and design a process to mitigate the impacts on customers. This implies for customer service team to closely cooperate with the other functions where events may occur.

1.2.3 Demand management

This team is charged to balance demand from customers with company's supply capabilities. They will decide which method to use to make demand forecast. This forecasting process involve different parties such as trade marketing, customer relationship management, customer service management, order fulfilment, manufacturing flow, product development and commercialization. All these processes are involved and contribute, each for the inputs of their own competence to the construction of the forecasts. With forecasts data in hand, they track and analyse data in order to adjust the process in a learning process perspective.

Furthermore, demand team develops the contingency plan to support and give instructions in case internal or external events disrupt the balance between supply and demand. This plan is written by the demand team but also following the instructions of CRM process, from manufacturing flow and supplier relationship management. Demand management should also lead the projects related to the measurement of performance and development of processes aimed at increasing flexibility and reducing variability, in demand, lead times and capacity.

1.2.4 Order processing

The main goal of this process is the reduction of the total delivered cost to customers. This implies the collaboration with manufacturing, logistic and marketing in order to design an effective distribution network. According to The supply chain management processes of Keely and Dale, 80% of the total cost of the

final product is affected by the design of the network. Evaluations on the network should consider which plants produce which products, where warehouses and suppliers are located and which in turn is the best transportation modes to use.

1.2.5 Production flow management

This process deals with making the products and all the related strategies for increasing flexibility and optimally serve target customers. Analysis of make or buy are also developed in this process in conjunction with supplier relationship management as it gives indications of which suppliers to look for and possibly provides guidance on the type of partnership to develop. In addition, in this process are established the acceptance criteria for materials passing through the production flow. With the involvement of supplier relationship management, product development and commercialization or returns management, production is responsible for product quality and to detect causes of quality problems. This results in inputs for the supplier relationship team to develop a supplier development program that takes into account the quality requirements needed for the manufacturing process. They translate the output of demand management into resources and production planning, also the priority of the operations is defined together with the demand management and supplier relationship management to set priorities for suppliers.

1.2.6 Supplier relationship management

As the company has clients, it also has suppliers. It is necessary to select a network of suppliers to create partnerships and reach an agreement that defines the terms of the relationship, enclosed in a PSA. The team defines criteria for selecting and categorizing suppliers, also considering the information that other processes can provide. As in customer relationship management, there can be more or less customized agreements depending on the supplier categories, but it is important to develop win-win relationships.

1.2.7 Product development and commercialization

Today, new product development is what makes companies truly competitive and allows them to maintain a position in the marketplace. To define a successful new

product development process, it is necessary to involve consumers to ensure that the product meets their needs as closely as possible and to minimize time to market. As the products life cycle shorten ever more is important to launch the new products before competitors. The process of new product development starts with an analysis of consumer needs. Marketing department analyses needs and wants of the consumers. Then starts the brainstorming of ideas to generate the new product begins. Certainly, the customer relationship team is involved, as they need to understand the impact on customers of bringing the new product to market. In this stage are also involved key supplier that provide advice and support.

1.2.8 Returns management

The process of managing returns has not always received the attention it deserves. For decades, only flows from upstream to downstream in the supply chain were considered. In reality, these physical, informational, and financial flows may not only be unidirectional. In fact, if the consumer/end-customer no longer uses the product or encounters any problem in using it this does not mean that it has become totally worthless. These considerations are, however, changing also in the light of rigorous regulations for the protection of the environment that make the producer responsible along the entire life cycle of the product and, therefore, also along the return channel of the flows linked to the products themselves. The management of return processes implies the coordination between different business functions such as marketing, logistics, finance. The activity of return management is not limited to the supervision of the logistic flow of returns (reverse logistics), but it also seeks to highlight the most strategic aspects with a view to recovering efficiency, improving effectiveness and creating value.

1.3 Critical issues in supply chains

1.3.1 Physical flow issues

- **Lack of traceability & transparency**

Lack of traceability, mainly due to data silos. Data are not made accessible by all actors in the supply chain in the same way (Kshetri, 2021). Consumers strongly value the possibility of knowing the origin of products and thus the traceability and transparency of their supply chain. In the literature is found that there is a correlation between transparency and traceability optimization (Francisco & Swanson, 2018).

Traceability can be defined as the ability to track the values of an object along the chain at a certain time, rather than its position in time and space over a period of time. However, the relationship between traceability and transparency is not completely simple and straightforward. The difficulty of being able to trace the components of a product, and thus enabling the supply chain of that product to be traceable, is directly proportional to the complexity of the supply chain.

Complexity understood as the number of relationships, flows, products and actors involved in the entire supply chain.

Transparency is defined by (Awaysheh & Klassen, 2010) as able to capture the extent to which information is readily available to end-users and other firms in the supply chain. Transparency has become in the last decades a social issue, in fact, consumers are demanding to have visibility of the products' supply chains. For example, the consumer requires to buy meat coming only from certain geographical areas rather than the certainty that the animals have not been mistreated or that a shoe contains only sustainable components and that there has not been an excessive consumption of resources in the production of it rather than the components coming from recycled materials or fluorine free.

Companies are also required by national and international bodies such as FSC[3], Organic[4] or Fairtrade[5] to have certifications and standards to prove that they are

[3] The Forest Stewardship Council is an international non-profit NGO. The FSC has created an internationally recognised forest certification system. The certification aims at the proper forest management and traceability of forest products (Forest Stewardship Council website, n.d.).

[4] Organic certification is a certification process for producers of organic food and other organic agricultural products (European Commission Web Site, n.d.).

compliant with certain standards and allow consumers to know the life cycle of the product and that no child labour, unfair conditions for workers or environmentally unfriendly practices have been used in its production.

Supply chains today, are quite complex due to the large number of actors participating in them and many other variables. Because of this complexity, it is therefore difficult for the companies to set up systems that respond to consumers' demands for transparency and traceability. For example, a manufacturer of finished goods may have no information about the supplier of raw materials and on all his upstream supply chain. This lack of knowledge and trust between the actors means that it is necessary to rely on trusted third parties who can provide information about the counterparts and guarantee for them in order to be safe and able to do business with each other making the bureaucratic process, slow and time and money consuming.

- **Counterfeiting & Fraud**

As supply chains become more complex, it is difficult to check the origins and movements of products and thus to believe that they are original and have followed an ethical and fair path in their supply chain. Counterfeiting is an imitation of a product by means of an unauthorised replica of the original product. This unauthorised duplication of products often uses logos and trademarks that are similar to the original and of lower quality and very often the products are also toxic in the materials used. Cases of fraud are widespread in food supply chains (Unapace.it, n.d.). Fraud occurs when food products are sold and do not comply with food standards and regulations. Ingredients other than those stated on the labels are included in the food, or the production process does not comply with the standards. In food supply chains there are mainly two types of fraud, trade fraud and health fraud.

Trade or commercial fraud occurs when the product remains hygienically safe and unaltered from a health point of view, but nevertheless the consumer is deceived

[5] Fairtrade is an international organisation that works to improve conditions for agricultural producers in developing countries. The improvement of the conditions of developing communities is implemented by guaranteeing a fair wage and granting an additional cash premium to allow them to consolidate their farms and lead a respectful life (Fair Trade Web Site, n.d.).

because is requested to pay more for the product than it is worth. For example, the product is labelled as organic when it is not.

The second type of fraud, health fraud, is more dangerous. We are facing this type of fraud when the product's qualities have been affected and ingredients that are dangerous to health have perhaps been used. However, there are different types of health fraud depending on the alterations that the food has undergone. An example would be the sale of defrosted fish declared as fresh, or the sale of second quality meat passed off as first quality meat.

❖ Ripple effect

The ripple effect is the effect that take place when a big disruption happens. This effect has the high potential to undermines supply chain resilience (Dolgui & Ivanov, 2021). It occurs as a result of a series of events that disrupt the supply chain and rather than having a limited effect along all the supply chain or isolated to a part of it, it is thus characterised by having repercussions along the whole supply chain causing significant cascading impacts. These effects can affect the performance of all the supply chain, e.g. lower revenues, delays or shortfalls in deliveries, loss of market share, etc..

A very significant example is the impact that the COVID-19 pandemic has had on supply chains around the world. The virus exploded in China in winter 2019, leading to the closures of factories, port blockages and therefore missed shipments of raw materials, components, finished goods etc to the rest of the world. Companies and supply chains around the world suffered from a lack of components and immobilised stocks.

Another recent example, perhaps of lesser impact than the pandemic, is the case of the cargo ship that was stranded in the Suez Canal in March 2021. The Ever Given was carrying around 18,000 containers from Malaysia to the port of Rotterdam. During the crossing of the Suez Canal, it was hit by atmospheric agents (various hypotheses have been made) which caused the ship to curve and run aground on the Suez Canal, blocking the passage of some 400 other ships behind it. The ship was stuck in that position for several days and with it all the ships behind it. The economic impacts were estimated at a loss of $9.6 billion per day caused by delays of stranded ships and congested ships waiting to depart for

that route. Clearly this had worldwide consequences, delays in deliveries, goods thrown away, congestion in ports of arrival etc..(Wikipedia, 2021).

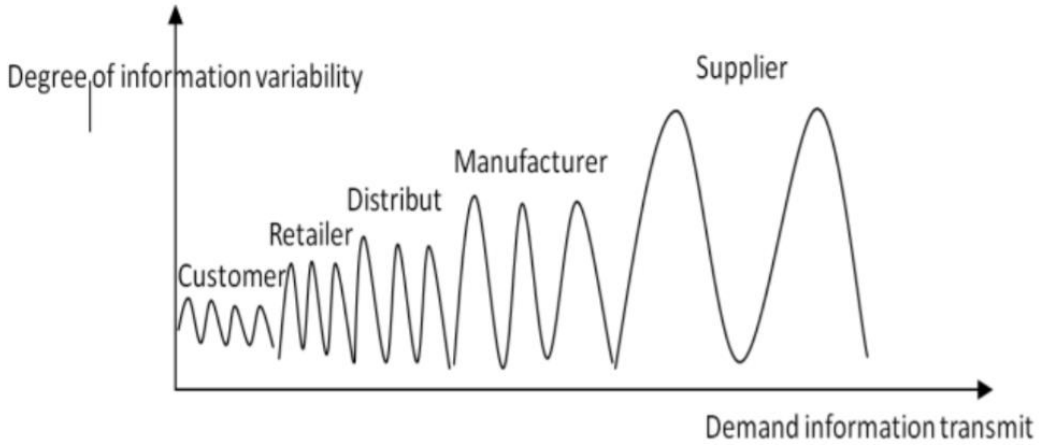
- **Bullwhip effect**

As seen, supply chains are increasingly composed of many different actors, each of whom plays a role in increasing the value of the product. Normally, the chain works in that component suppliers supply raw materials to other companies, which then carry out processes, transforming the raw materials into semi-finished products which are then transferred to other companies that assemble the semi-finished products into finished products. In turn, the finished products are delivered to sorting centres and then consolidated and transferred to retailers. In addition to the physical flow of products, there is also the flow of information that runs throughout the supply chain, from upstream to downstream and vice versa. Retailers are the owners of the sales flow and those who have the direct relationship with consumers. The demand that wholesalers see is what is passed on to them by retailers, not what comes from the consumer and so on up the supply chain. In the literature it is verified that as the flow of information moves up the chain, a certain amount of distortion occurs (Metters, 1997). In fact, in a typical consumer products supply chain, even if sales do not seem to vary much, there is considerable variability in retailers' orders to wholesalers. From wholesalers to suppliers of finished products and from these to suppliers of semi-finished products there is even more variability. In other words, the bullwhip effect, therefore, refers to the amplification of demand which has repercussions, sometimes disastrously, along the entire supply chain (Mecalux, 2020). This amplification of demand leads to an exponential acceleration of orders and stock demand as one move from downstream to upstream.

This is why it is called the bullwhip effect, the oscillation increases the further you move away from the origin, that is the customers to the mount, so the production plants Figure 5. In this case the “hand” is the end customers, while the end of the whip can be the production plants and logistics. This effect occurs because the various actors in the supply chain use, as an indicator of the level of demand, the data provided by those who precede them along the supply chain, instead of relying on the end customer.

In other words, the bullwhip effect is not only generated by demand distortions, but also by the (wrong) desire of individual actors (players' irrational decision making) to locally optimise their own loop, avoiding a better global optimisation of the supply chain. (Lee et al., 1997) suggests the following corrective actions to reduce the bullwhip effects: integrate new information exchange systems (such as understanding the dynamics of the system, using POS -point of sale- data, electronic exchange of information ..), define organizational relationships, improvements in production efficiency (because long lead times aggravate the bullwhip effect).

Figure 5 Schematic diagram of bullwhip effect



Source: (Dai et al., n.d.)

1.3.2 Information flow issues

❖ **Inability to share relevant information**

Some parties in the supply chain have no idea where a product is or what is its status. Delayed notification of events or the very absence of notification makes it impossible to implement risk mitigation action plans. Furthermore, systems such as RFID and position systems have indeed been implemented in supply chains to help identify products along the chain, but this information is not always properly disseminated or fully exploited to make the information available to the whole network of actors involved in the flows. As a result, some actors who hold most of the information have gained power from this unbalanced distribution of information, on the other hand who lack some information spends a lot of resources in terms of time and money to fill these gaps.

- **Data duplication and no synchronization between the actors**

Most of the times actors participating the supply chain, mainly the ones on the sideline of the cain, suffer blind spots. In addition, very often a control and performance mechanism on the supply of a product is not present or where it exists it is not well implemented, allowing for continuous improvement assessments.

There is a huge waste of energy and resources as information is often duplicated a lot of times in the databases of each actor in the supply chain. Actors in every network need to share information to make business transactions. Considering the example of a retailer who sells household appliances, he needs to keep the store stocked with products on display plus a stock of materials in stock, ready to replace the products sold in the aisles. The retailer then manages in its systems the warehouse stocks and the reorders of goods to the supplier of household appliances.

The manufacturer or retailer of household appliances in turn must record in its system its stock stocks and in turn manage orders to its supplier of semi-finished components or products. Here as you can see each actor in the chain has a data management in each their own database. When one actor asks for information from the other, perhaps related to the lease of a batch of goods rather than tracing the origin of a component, the information most of the time takes some time to be found. This involves triggering time-consuming and often error-prone manual processes.

- **Data protection & Security**

For the supply chain to work well, needs information to be properly distributed along the chain and available to all actors who have an interest in knowing it in order to achieve the highest possible added value. On the other hand, there is also a need to protect information from malicious attacks and to protect data from people who should not have access to it.

1.3.3 Financial flow issues

Allied Market Research in September 2021, published a report with the title: ""Trade Finance Market by Product Type (Commercial Letters of Credit (LCs), Standby Letters of Credit (LCs), Guarantees, and Others), Provider (Banks, Trade Finance Houses, and Others), Application (Domestic and International), and End User (Traders, Importers, and Exporters): Global Opportunity Analysis and Industry Forecast, 2021–2030." According to this report finance trade market reached $44.09 billion in 2020 and is estimated to reach $90.21 billion by 2030 (Chhabra Monica et al., 2021). In the coming years, there will be an increasing demand for trade finance services from emerging countries and new trade agreements will drive demand for these services. In all of this, it is assumed that the integration of blockchain can help trade finance to create new opportunities and support the growth of the industry (Yahoo!Finance, 2021).

Trade finance provides a range of services such as guarantees, letters of credit, document collection, supply chain financing and factoring. According to Allied Market Research's report in 2019, letters of credit was the predominant service, accounting for 39% of the total. In Figure 6, is shown the current state of the finance trade process.

Figure 6 Current state trade finance process

Current-state process description		
1 An importer and exporter agree to the sale of a product at a future date and time	5 The export bank provides the exporter with the financing details, which enables the exporter to initiate the shipment	9 Following inspection, the goods are delivered to the importer, which provides a receipt notification to the import bank
2 The financial agreement is captured within an invoice, which identifies the quantity of goods sold, price and delivery timeline	6 A trusted third-party organization inspects the goods for alignment with the invoice	10 Upon receiving notification, the import bank initiates the payment to the export bank through the correspondent bank
3 The importer provides a bank with a copy of the financial agreement for review	7 Local customs agents within the export country inspect the goods based on the country code	
4 The import bank reviews the financial agreement and provides financials on behalf of the importer to a correspondent bank, which has established a relationship with the export bank	8 The goods are transported by freight from *Country A* to *Country B* and local customs agents within the import country inspect the goods based on the country code	

Source: (*The Future of Financial Infrastructure An Ambitious Look at How Blockchain Can Reshape Financial Services An Industry Project of the Financial Services Community | Prepared in Collaboration with Deloitte Part of the Future of Financial Services Series* •, 2016)

The following weaknesses in the financial flow of supply chains can be identified:

- **Need for safety and security of trading activities**

The actors involved in a business transaction, most of the time do not know each other. There is therefore a lack of trust between the actors. In the absence of this, to complete commercial transactions it is necessary to involve third parties, trusted by both parties, such as banks, credit institutions, insurance companies etc.

- **Contracts manually created and paperwork**

International trade is one of the sectors with the highest rate of paperwork and with the lowest digitization. The transport of containers from one country to another in the world involves a long backlog of bureaucratic work and preparation of documents. For example, transporting goods from East Africa to Europe requires to prepare up to 36 original documents and 240 copies and confirmations and approvals from about 30 people and organizations who must interact in turn with other organizations up to 200 interactions. All this takes weeks if not months to complete. The total cost of processing trade-related paperwork is estimated to be between 15 and 50% of the cost of the goods themselves being transported (Hackius, 2017).

- **Invoice factoring**

Exporters pass sales invoices to a financial intermediary in order to obtain payment for the goods immediately and thus have liquidity instead of waiting for the goods to arrive at destination and for the importer's bank to issue payment. Factoring is in fact the practice whereby companies assign their present or future receivables to a factoring company in order to obtain immediate liquidity. The factoring company assumes the burden of collecting the amount of the receivables against payment of a commission. Factoring is very common in business relationships, as the payment terms imposed by some companies are difficult for others to accept. Considering that today's supply chains are

increasingly complex and involve many players located in geographic locations far apart, it is possible to imagine how the timing of transport, for example by ship, has an enormous impact on the exporter's time to collect the credit.

- **Augmented lead time**

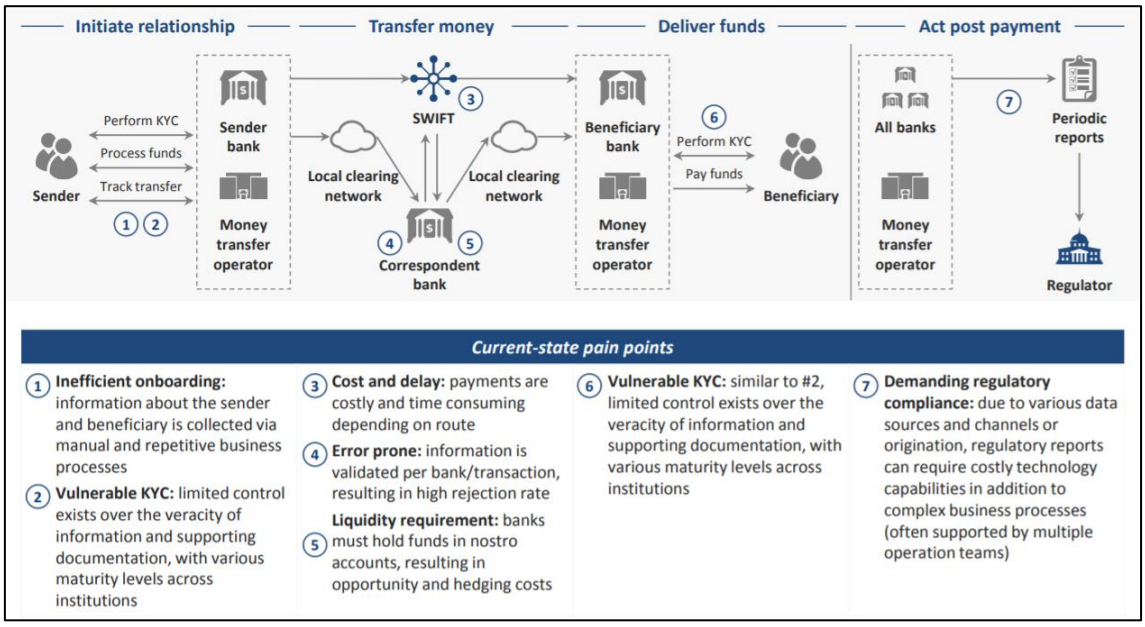
A product that has a complex supply chain, which includes a large number of actors, located in very distant geographical points who have to comply with very different standards and regulations, implies a high level of bureaucracy and therefore slowness in the process. Linked to the fact that most documents are paper based, there are risks such as incorrect data entry, loss of documents or document theft. All these risks lead to consequences such as a ship being held up in port while waiting for all the administrative formalities to be completed before it can be released. This leads to delays, increased lead times, rescheduling of flows after the blocking event, lack of products in the shops and therefore lost sales and increased costs due to the ship being held up in port.

- **Know Your Customer & Anti Money Laundering review activities**

When an exporter and an importer have a commercial relationship, they use financial intermediaries to protect them and carry out money transfers. Know Your Customer and Anti Money Laundering activities refer to the broader category of due diligence practices required in contractual relationships involving financial transactions Figure 7. These activities include obtaining financial and non-financial information on the contractual parties to avoid situations of risk or damage to economic activities.

A report on KYC -Know Your Customer- activity released in 2016 by Thomason Reuters (Mairs & D. Harrop, 2016) showed that financial companies spend up to $500 million per year globally on KYC activities. 89% of customers surveyed disclosed that they did not have a good onboarding experience and 13% even changed financial institutions in the end. What was clear from the report is that the cost and complexity of KYC activity has increased significantly and is having a negative impact on businesses. 30% of respondents reported that the onboarding process may have taken more than two months and 10% reported even more than four months on average.

Figure 7 KYC current state pain points



Source: (The Future of Financial Infrastructure An Ambitious Look at How Blockchain Can Reshape Financial Services An Industry Project of the Financial Services Community | Prepared in Collaboration with Deloitte Part of the Future of Financial Services Series •, 2016).

- **Delayed payment**

Multiple intermediaries must verify that funds have been delivered to the importer as agreed prior to the disbursement of funds to the exporting bank.

2. Blockchain: a technology overview

It was from the idea of Satoshi Nakamoto and his whitepaper (Nakamoto, 2008) published in 2008 that the first cryptocurrency, bitcoin, was born: "Bitcoin: A Peer-to-Peer Electronic Cash System". The objective of the white paper was to describe a new way to perform transactions, completely decentralized, based on a consensus mechanism able to eliminate intermediaries.

But what does cryptocurrency mean? Consob, defines cryptocurrencies as: “New technologies, favoured by the progress of cryptography - i.e. the application of methods that serve to make a message comprehensible/intelligible only to persons authorized to read it - and by the evolution of the Internet, are determining a radical change in the global economy, with particular reference to the financial sector, from the point of view of the modes of exchange of goods, services and any financial activity. Among the most significant applications of digital technology to the financial sector stands out the birth and spread of "cryptocurrencies" (or "virtual currencies"), the most known is bitcoin”. “..The term is composed of two words: crypto and currency. It is therefore a 'hidden' currency, in the sense that it is visible/usable only by knowing a specific code (the so-called 'access keys': public and private). The cryptocurrency does not exist in physical form (also for this reason it is defined 'virtual'), but it is generated and exchanged exclusively by electronic means. It is therefore not possible to find bitcoins in circulation as paper or metal format. Some concepts traditionally used for legal tender currencies, such as that of 'wallet', have also been adapted to the context of virtual currencies, where we speak of 'digital/electronic wallet' (or digital/electronic wallet or simply e-wallet).”

Cryptocurrency, can be exchanged in peer-to-peer mode (e.g. between two devices directly, without the need for intermediaries) to purchase goods and services (as if it were legal tender to all intents and purposes) where there is consensus between the participants in the relevant transaction.

Cryptocurrencies have peculiar characteristics that set them apart. The following are the constituent elements:

- a set of rules (called "protocol"), i.e. a computer codes that specifies the way in which participants can carry out transactions;

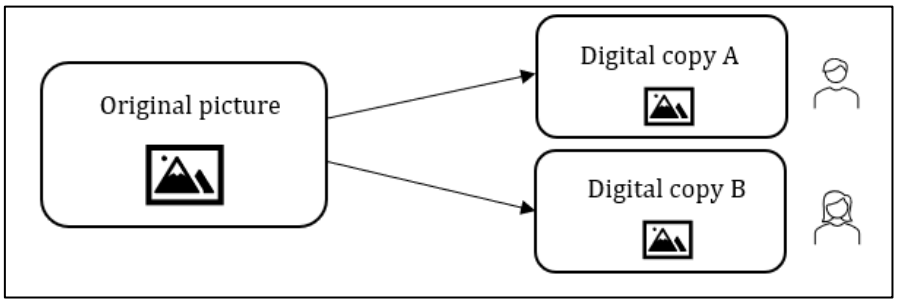
- a sort of "ledger" (distributed ledger or blockchain) that preserves the history of transactions in an unchangeable way ;

- “a decentralized network of participants who update, store and consult the distributed ledger of transactions, according to the rules of the protocol” (Consob. Commissione Nazionale per le Società e la Borsa, n.d.).

We can assume that behind Nakamoto’s project there was actually the desire to give life to a real revolution with the aim and the potential to disrupt the current method of money exchange.

Behind this revolution, there is a new technology, the blockchain. Through this technology, it was possible for the first time to create digital scarcity, avoiding the endless replicability of the same computer document. This is the first example of the Internet of value (Chiap G. et al., 2019).
We now use the Internet to exchange data and the mechanism by which data transfer is regulated, is called TCP/IP protocol[6]. However, this protocol transfer data ad a copy. In concrete terms, when we send an image via email, we are duplicating that same image. Once sent the email the result will be that there are two not distinguishable copies, see Figure 8.

Figure 8 Copies of a digital file



Source: personal elaboration

This is concept is also known as problem of double spending. In this situation there is more than one digital copy of something that should or would like to be unique.
It is not conceivable a scenario in which is possible to transfer money as a copy, since it would be possible to spend it several times. In a traditional system, double

[6] Transmission Control Protocol (TCP) and Internet Protocol (IP). When talking about TCP/IP protocol it is generally referred as the group of protocols that form the foundation of the Internet (Digital Guide Ionos, 2020).

spending is avoided thanks to a trusted authority, e.g., a bank, which has the role of holding the truth. The bank, therefore, is in charge to avoid double expenses by correctly updating the registers, noting an exit of money on one side and an entry on the other.

In a blockchain it is not possible to spend the money twice because the consensus of the network would not authorize it. The fist transaction would be authorized and the second refused.

The first application of blockchain was on currencies field (with Bitcoin), which laid the foundations for the creation of a new digital money system, parallel to the current one, making the world of payments more usable also by non-banked users.

The problems identified by Satoshi Nakamoto that led to the development of the paper are the society excessive dependence on referents called "trusted third parties" in addition to the weaknesses of the system highlighted by the erroneous and excessive use of the "model based on trust." Nakamoto says that transactions based on these two models have meant that financial institutions have kept management costs high, consequently putting them on the backs of users. The problem becomes much more concrete especially in small transactions. Cyber-fraud itself is now treated as an "accepted as inevitable percentage."

Payment uncertainties are lowered through the use of cash, but the problem remains on digital payments with people whose trustworthiness (confidence) is uncertain. That is why, according to Nakamoto, a transaction system based on cryptographic proof, rather than trust, was needed. The dangers of fraud themselves could have been greatly reduced through the use of a "transaction system that is computationally impractical to reverse".

Nakamoto proposed an electronic payment system based on cryptographic proof instead than on trust. This system allows the parties to negotiate directly with each other without the need for a trusted third party. Transactions that are computationally impractical to reverse would protect sellers from fraud, and customary escrow mechanisms could easily be implemented to protect buyers.

In recent years, blockchain has been the subject of much attention thanks to its ability to eliminate the central intermediary and therefore to substantially change the models on which the modern society is structured changing the concept of trust for how it is conceived today.

Nowadays we are used to trust bank to exchange money, to rely on notaries to certificate the ownership of a property and so on. At the end, today, when we do not trust the counterparts of our deals we need an intermediary, a trusted one, from both the parties to conclude the transaction. With blockchain, indeed, the trust of the user is all placed in the technology and in particular in the software/protocol that regulate its operation.
This makes the blockchain not simply a technological solution but, a new approach, a "shift from trusting people to trusting math" (Antonopoulos A., 2014) with developments that extend beyond implementation in finance with crypto.

In the book (Mougayar, 2016) blockchain is described as a layer that rely on top of Internet just like the World Wide Web.
The blockchain protocol can be seen as a new paradigm[7]: that is, the exchange of currency between subjects who do not know each other without the necessary presence of an authority, an intermediary. In blockchain, is the protocol that guarantees trust.
The benefit of the blockchain includes eliminating the need to rely on a trusted third party (e.g. banks, notaries ecc..) and implementing the execution of commands through a cryptographic code, that protect members against risks of fraud and a considerable reduction of management overheads.

Blockchain technology is also described as a disruptive innovation[8] as long as it is assumed that it could revolutionize the operation of several sectors, human activities and modify or even allow the creation of new business models.

[7] The topic was first introduced by Thomas Kuhn in his 1962 book "The structure of scientific revolutions". According to Kuhn, instead of progressing gradually towards the truth, science is subject to periodic revolutions that he calls "paradigm shifts". He defines paradigm as: "The set of formal theories, classical experiments and trusted methods of scientific experiments in which such theories are universally accepted".
[8] The concept of *disruptive innovation* is introduced for the first time in 1995 from Clayton Christensen, professor at Harvard Business School. Christensen, together with Joseph Bower wrote an article in the HBR magazine, defining a "*disruptive technology*" as a technology capable of revolutionizing a pre-existing business model by redefining the boundaries of the competitive arena and transforming the way consumers are used to use products and services (Bower Joseph L. & Christensen Clayton M., 1995). The concept is then further deepened in 1997 in the book "The Innovator's dilemma", (Christensen Clayton, 1997) where innovations are divided into two categories: sustaining and disruptive. The first are those defined by Schumpeter as "incremental innovations" from his writing "Theory of Economic Development" published in 1934, as continuous improvements of existing products. In this category of sustaining/incremental innovations, fall in turn another subdivision: evolutionary and revolutionary innovation. Evolutionary innovations involve all those changes in the product that are part of the normal

Bitcoin and blockchain are two separate things: blockchain is in fact the technology that allowed the development of bitcoin. Although bitcoin is the most popular project today, the technology behind it allows for countless applications, even beyond the concept of a digital currency. In other words, Blockchain is to bitcoin as Internet is to Google (Chiap G. et al., n.d.).

From the first Blockchain, the one related to Bitcoin, more and more specialized Blockchains started to emerge. The introduction of systems such as Smart Contracts have subsequently greatly expanded the use and the possible potential of the blockchain system in real life: this type of technology becomes more and more tangibly and usable by an ever wider portfolio of users. It ranges from private institutions such as banks or insurance companies, to ordinary people, thus making possible transactions (both monetary and information) of various kinds, between various entities and/or individuals and/or professionals and/or companies and so on: quickly, safely and lowering the costs and the risks of intermediation.

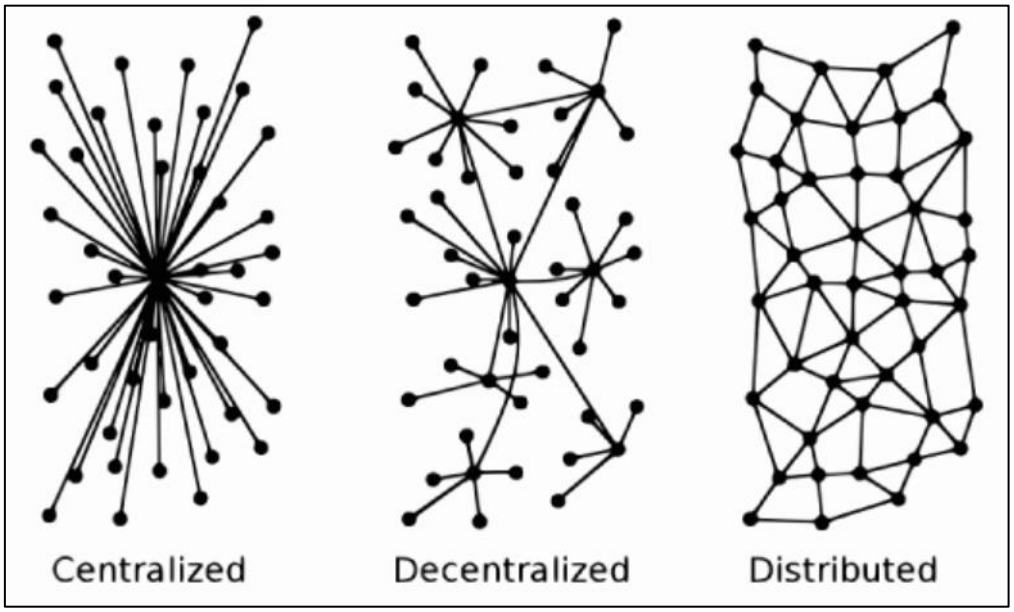
technological progress, such as the inclusion of the camera in the smartphone or access to the internet. In the second category, the revolutionary innovation or radical innovations are those related to the strengthening of core competencies for the future. They take existing technologies and look for new long-term applications on them, an example can be Apple.

2.1 Distributed Ledger Technologies

Ledger is a concept that has been widespread and integrated in business processes since ancient times. While the concept of ledger has not changed over time, the technology behind it has changed, moving from paper to digital archives. The main purpose of ledgers has always been to save and store information.

Based on the characteristics of the network and the role of each node, three network models can be identified as in the Figure 9 below: centralized, decentralized and distributed ledgers.

Figure 9 Centralized, decentralized and distributed networks' architecture



Source: (Bhardwaj et al., 2021)

Starting from the left, the *centralized ledger*, has the focus in the one-to-many relationship. Everything is managed by the centre, whose centre is identified as an authority, which has the power to define the truth of the system: the trust of the whole system is placed in the central authority. Some examples of centralized authorities could be a bank, Facebook or Google where the authority has the power to decide the rules of the systems deciding so what is correct and what not based on the unconditional trust of the users. This type of ledger structure brings problems at the level of information management, in fact the central authority, if deemed appropriate, could modify or delete information from the register. In any

case, even if the central authority acts in good faith, the system is exposed to hacker attacks, that could modify the data or even delete the register.

In the middle of the figure, is the *decentralized ledger*, which proposes the logic of "centralization at the local level" (Bellini Mauro, 2021). This second system replicates the logic of the centralized ledger, with the difference that there is not a single central authority. Authorities in the decentralized ledger are many. Many small satellites organized with the one-to-many relationship. Trust, even here, although closer to the nodes than in the centralized system, is placed in a central authority. Also in this case, is possible to identify the same problems of the centralized structure reported above, although to a different extent. In fact, in this case, since the authorities are different, each one carries out a sort of control over the other, thus being able to block malicious actions in the event. On the other hand, the probability of a hacker attack is also lower considering there are several parties that hold a copy of the ledger.

At the right end of the figure, there is the *distributed system or distributed ledger technologies* (from now on DLT). The nodes that are part of the system all participate in the same way and with the same power in the network. There is no central authority, but each node store, share and synchronize digital data. Decision making is guaranteed by the definition of consensus mechanisms, which allow the network to agree on the truth. According to (Mayer et al., 2021) the fact that distributed systems do not rely on intermediaries, enables secure, tamper proof digital transactions and the documentation of ownership. Distributed system allows the identical duplication of the ledger in each node, this does not guarantee that the data is entered correctly, but it does allow for the revelation of any manipulation of the data.

Distributed systems allow benefits not achievable with the centralized and decentralized system. First, each node provides to the network its own computational power, making the system faster. Secondly, the problem of hacking is overcome. In fact, in the two previous systems, malicious third parties could attack the system by appropriating or tampering with the data. With DLTs, attacks by malicious parties are almost impossible since they would have to attack every single node simultaneously in order to modify the data and then approve the

changes. It is therefore clear that this would require an enormous amount of computing power. Consequently, not recognizing the operation as reliable, they would not validate it.

Blockchain belongs to the family of distributed ledger technologies because it is a database that is developed on different nodes or different computing devices. Each blockchain is a distributed ledger, but not all distributed ledgers are blockchains. A blockchain, in fact, is a structure organized in blocks, the succession of blocks generates the chain. The structure "append only", allows only to add information and the modification or deletion of data previously added to a block is impossible.

2.2 Blockchain technology: definitions and operations

In the literature is possible to find many definitions of blockchain, however since the technology is still not that widespread, there is no consensus between academics on a standard definition. The definitions that can be found range from purely technical to those that emphasize the technologies behind the blockchain or its implications on business and society. In her book (Swan, 2015), proposed a definition of blockchain considering the technology into three categories:

- Blockchain 1.0 is to identify the currency application, meaning digital payment systems and cryptocurrencies;
- Blockchain 2.0 to describes contracts applications as the more sophisticated value transfers of stocks, loans and bonds through smart contracts;
- Blockchain 3.0 considering all other application in addition to finance, that are in government, arts, industries, health...

(Mougayar, 2016) after having analysed Satoshi's paper extracted three definitions of blockchain depending on whether one looks at the technology from the perspective of technical, business or legal point of view:

- from the technical point of view "the blockchain is a back-end database that maintains a distributed ledger that can be inspected openly";
- according to the business view "the blockchain is an exchange network for moving transactions, value, assets between peers, without the assistance of intermediaries".

- ❖ lastly, as per the legal perspective, "the blockchain validates transactions, replacing previously trusted entities".

Here, in this thesis, is preferred to not go into the details of the technicalities of the technology rather to analyse the definition of blockchain from the point of view of its implications on business and its properties and characteristics that enable the implementation of the technology in the supply chain.

According to (Wright & de Filippi, n.d.), blockchain can be understood as a: "distributed and shared database, based on encryption to ensure the authenticity of information that allowed for the first time, unrelated people to reach a consensus on the occurrence of a particular transaction or event without the need for a controlling authority". In this definition particular emphasis is placed on what a blockchain is, i.e., a distributed and shared ledger that allows two unrelated parties to reach consensus without having to engage a trusted third party, an intermediary.

But then if the ledger is distributed and shared, who owns it?

We can find this detail in the definition by (Morkunas et al., 2019) which states that the blockchain ledger is owned and shared among a network[9] of nodes (hence the explanation of distributed), these nodes are PCs or hardware in general which maintain and update it by verifying transactions before approving and adding them to the ledger.

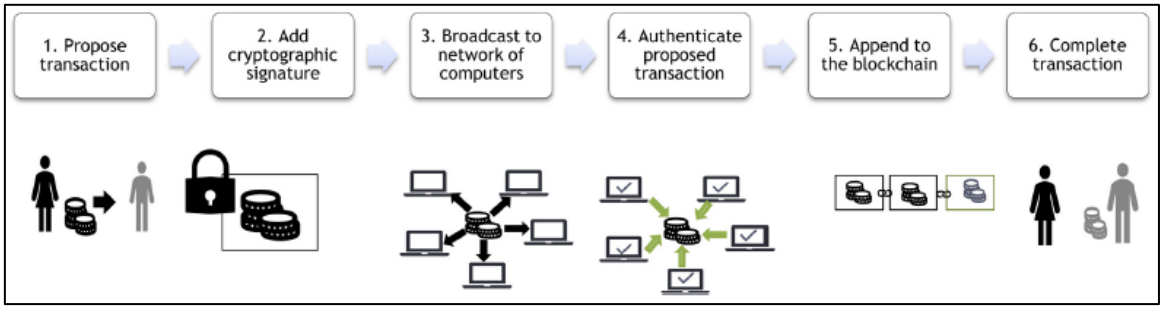
The process is structured in six steps, see Figure 10. Subject A wants to send a transaction to subject B. As shown in Step 1 in the figure, it is a transaction proposal that is filled as a candidate to be printed in the ledger. It contains basic information (see Figure 11 for block structure) such as sender, receiver, date and time, content, quantity and double asymmetric key cryptographic.

In Step 2 the transaction is signed with a unique cryptographic key which guarantees its authenticity and integrity and then it is broadcasted to the entire network in Step 3. Transactions are grouped into blocks. As long as a transaction is awaiting confirmation it remains unblocked. Then in Step 4 the transaction will be

[9] We can define a network as a group of interconnected machines that exchange information through communication channels, such as the Internet. channels, such as the Internet. A machine connected to a network is called a node (Chiap G. et al., 2019).

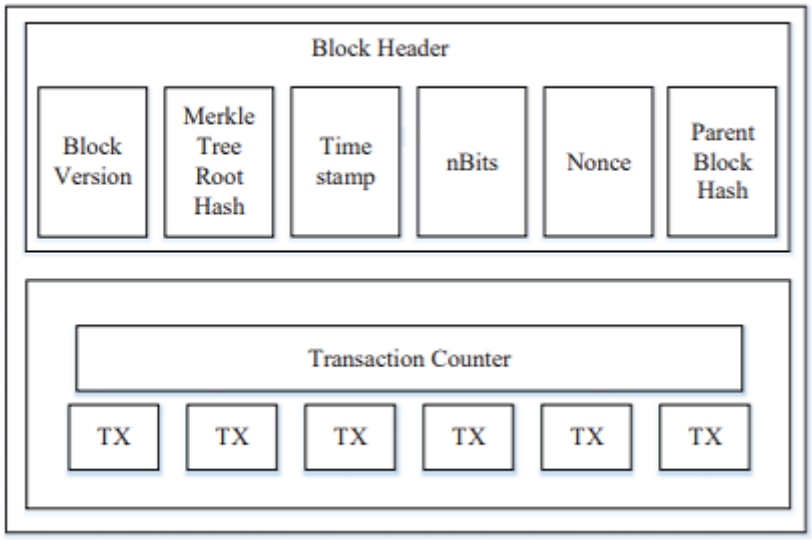
processed and authenticated. Once authenticated the transaction is added to the ledger, Step 5 which decrees the completion of the transfer from A to B step 6.

Figure 10 The six steps of asset exchange using Blockchain



Source: (Satya & Medida, n.d.)

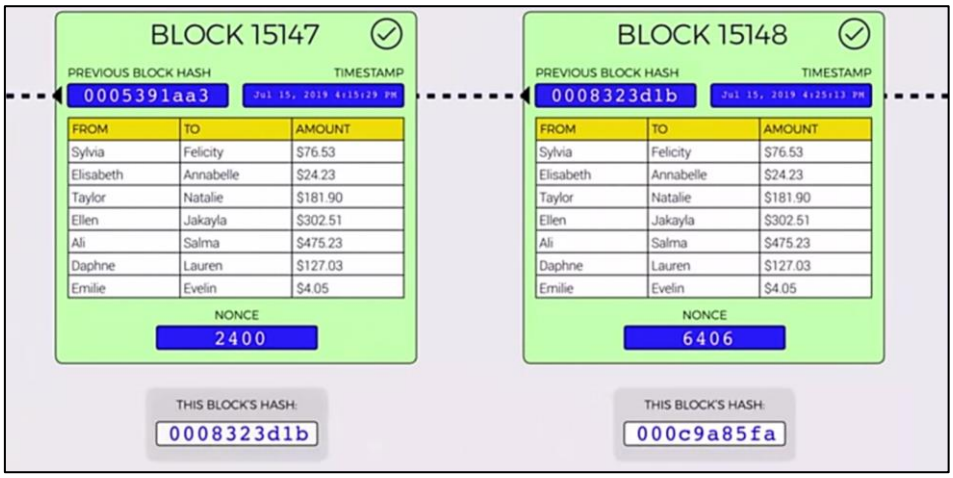
Figure 11 Block structure



Source: (Zheng et al., 2017)

Transactions, be they of money, properties, or contracts, are grouped together and once verified are included in a block. Blocks are added to the blockchain sequentially as in Figure 12. Hence, chain of blocks, block chain.

Figure 12 Blockchain structure



Source: (Consensys Academy, 2020)

Each block is incontrovertibly linked to the previous one by a cryptographic function (specifically the cryptographic hash function), which creates an indissoluble mathematical link between them. Hash cryptography is a mathematical function that transforms all incoming information (input) be they mp3 file, video, contracts in the block into a fixed-length string (output). This operation cannot be reversed and prevents the initial data being traced back to the input.

This mechanism is what allows the blockchain to be immutable or better, difficult to hide other nodes that a change has been made in the previous blocks. In fact, if a malicious node were to modify a data within a block, this would result in a hash value of the block completely different from what was previously, thus making all subsequent blocks invalid because of the hash link between each block. The malicious node could only complete its attempt to modify data and maintain consensus if it had such a high computational power that it could recalculate all the hashes of the subsequent blocks.

A hash function has the following characteristics (Italia4Blockchain, 2021):

1. Resistance to pre-image: it is impossible to find the text corresponding to a given hash value;

2. Resistance to the second pre-image: it is impossible, given a text that generates a hash, to find another text that generates the same hash value;

3. Collision resistance: it is impossible to find a pair of texts that give the same hash value.

As we see in the example below Table 1, even a small change in the input generates completely another hash. It is therefore easy to detect changes, if the hashes are not the same, then you know that the file has been modified in some way. Comparing hashes is more convenient than comparing entire files.

Table 1 Example output of a hash function

Input	**Hash function**	**Output**
blockchain	SHA-256	EF7797E13D3A75526946A3BCF00DAEC9FC9C9C4D51DDC7CC5DF888F74DD434D1
Blockchain	SHA-256	625DA44E4EAF58D61CF048D168AA6F5E492DEA166D8BB54EC06C30DE07DB57E1

Source: Coding.Tool SHA256 Hash Generator Online Tool - Coding.Tools

2.3 Consensus mechanism

In the section on blockchain definitions, it was mentioned that it is the nodes participating in the network that verify and validate the transaction and then enter it into the blockchain. The question arises, how do these nodes, which have nothing to do with each other, reach consensus?

The nodes that constitute the network have the task of reaching a decision on what happened in the blockchain, this process is called consensus.
A blockchain is based on (mathematical) rules, but it has no rulers. The participants of the network each has their own roles and responsibilities. The two main players in this process are full-nodes and miners. The consensus of a blockchain is the guarantor of the trust we place in this system.

The process of validating transactions, aggregate into blocks and adding them to the blockchain is called mining. The nodes that take part in the mining process are called miners. More generally, mining can be seen as the decentralized mechanism by which distributed consensus is reached and network security is ensured.

It is important to note that maintaining a full node is not the same as maintaining a full mining node. While miners have to invest in expensive hardware and software, anyone can maintain a full validating node. Furthermore, before attempting to mine a block, a miner must collect pending transactions that have previously been accepted as valid by full nodes. Then, the miner creates a candidate block (with a group of transactions) and tries to mine the block. If the miner succeeds in finding a valid solution for the block, it passes it on to the rest of the network and the full nodes verify its validity. Thus, the consensus rules are determined and guaranteed by the distributed network of validating nodes, not by the miners.
As pointed out, there are no rulers that govern the network decisions, but rather rules, i.e. algorithms that are used in the process of creating a block.

There are many consensus mechanisms and each blockchain can define what it wants to use. Below are briefly described two of the main ones: Proof of Work and Proof of Stake.
Proof of Work is a protocol used to achieve distributed consensus in which voting power is based on computational power. In concrete terms, Proof of Work is based

on the search for a number that is computationally difficult to find, but once found it becomes easy for all other nodes to verify its correctness. In a system using the PoW, a block is only valid if it contains a valid solution to the PoW.
Solving this problem involves a random process, with the miner having to proceed by trial and error testing all possible combinations until the right one is found. The first miner to solve the problem has the right to create the next block and earn the reward (cryptocurrency from the blockchain in question plus a fee from the applicant for placing the transaction on the blockchain). Once a new block is created, it is transmitted to the network, waiting for the other nodes to check its validity. If the block is valid, it is forwarded to the adjacent nodes, otherwise it is ignored.

Proof of Stake is a protocol used for achieving distributed consensus in which each token corresponds to a vote. Proof of Stake is the second analysed protocol used in the process to reach a distributed consensus. The purpose of Proof of Stake is the same as that of PoW, but the process to reach the final goal is different. Unlike Proof of Work, where miners are rewarded after having solved mathematical problems, Proof of Stake alternates between validators (they can be considered the equivalent of miners in PoW) chosen in advance based on the amount of cryptocurrency they own for the relevant blockchain, also referred to as a stake. Users that own tokens can “stake” their tokens (staking means temporarily blocking tokens until the staking process ends) to get in return the right to confirm transactions of a block (become a validator) and receive a reward.

Unlike Proof of Work where block is mined, with Proof of Stake block are forged.
Although in PoW systems, the security of transactions lies in the huge resources - economic and energy - needed to complete the validation of a block, in PoS systems it is the stake that discourages validators from validating fraudulent transactions. In fact, if the network detects a fraudulent transaction, the validator node will lose part of its stake, as well as the right to be selected as a validator in the future. The only way to bypass the network's controls and approve fraudulent transactions would be to own 51 per cent of the cryptocurrencies in circulation, which is almost unfeasible, as in such a context the costs incurred to obtain the absolute majority would not find a satisfying profit margin in the fees because the market, in

correspondence with such an attack, would attribute to the cryptocurrency purchased an economically much lower value than the purchase price.

It seems that Proof of Stake offers more advantages than the Proof of Work mechanism. Many blockchains are in fact changing their consensus mechanism from Proof of Work to Proof of Stake (e.g. Ethereum). We will not go into all of them in detail but the main ones as:

- Attacks are more expensive. Even the PoS is theoretically vulnerable to a 51% attack. An attacker, in this case, will not need 51% of the total hash rate but 51% of the total tokens. However, if an attacker tried to buy 51% of the tokens, the market would react with a rapid increase in the number of tokens and with a rapid increase in the price of the them. In addition, people with many tokens have less incentive to attack the blockchain, since an attack would have the counterproductive consequence of destroying the trust in that blockchain, and consequently the value of that token.
- More economical. Since there are no electricity and hardware costs for mining, all people can afford to participate in the network, reducing the current centralisation of PoW-based systems.
- Punishment. It is possible to create economic disincentives for malicious parties, e.g. by destroying their stake.
- Loyalty. Validators are encouraged to stay on the same blockchain. If they wanted to participate in the PoS on another blockchain, they would have to change the tokens in their possession. In the PoW, on the other hand, if the coin you are mining is no longer profitable, you can simply change blockchain.

2.4 Blockchain properties

As seen earlier, blockchain technology has not only impacted finance with cryptocurrencies, but also promises to have major impacts on other industries, such as healthcare, government, music, supply chains and so on. In this paragraph, we will analyse the characteristics and properties of blockchain that make it unique.

In the following Table 2 will be analysed the main blockchain properties:

Table 2 Blockchain properties

Property	Effect
Distributed Database Data are distributed among each node participant to the network. Every node maintains a copy of the ledger.	**Decentralization:** no need of intermediary **Resiliency:** difficult to attacks means no single point of failure
Peer-to-Peer Transmission Communications take place directly between nodes following a protocol called "gossip protocol"[10].	**No need of authority**

[10] In this protocol a node to spread information is connected to others randomly. Once connected this first node passes the information to the second, which in turn will pass the information to the nodes connected to it. This way of spreading information allow to spread them in the network in an efficiently manner. (bit2me, n.d.-b)

Privacy with Pseudonymity Users have a unique alphanumeric address that identify them, they can both reveal their identity providing proof of identity or remain anonymous.	**Transparency**
Immutability of Records Cryptographic link between data (blocks are cryptographically linked each other) serves as a final record of past transactions. Data modification from a malicious node is computationally hard and expensive.	**Tamper proof** **Trust**
Computational Logic Eliminates the need to rely on intermediary (such as banks) and to correspond them transaction fees.	**Smart contracts**: algorithm and rules can automatically trigger transactions
Consensus driven Each transaction is independently verified by each block following the rules defined by the blockchain and the consensus mechanism.	**No need of intermediary:** trust is based on the algorithm
Full transaction history Since the blockchain is an open file, any part can access it and verify history of records.	**Transparency:** it depends on the types of blockchain system, private is the least auditable
Timestamping This function is needed to record in the blockchain the date and time when a certain event occurs. E.g., the occurrence of a transaction or the change of ownership of an asset.	**Proof of an event has taken place in a particular data/time**

Source: personal elaboration

Source: personal elaboration

When it is said that one of the properties of blockchain is immutability, it is necessary to define the meaning. It may seem that immutability is guaranteed by the hashing link between the blocks, that is, the hash of the previous block is contained in the hash of the next block. Hashing does not prevent block editing. If a malicious node wanted to change the information of a block, it could. This would result in changing the hash of the block and consequently also changing the hash of the next block with immediate visibility to all nodes. What is difficult, is to convince the nodes that the tampered blockchain is the correct one, in effect nodes would not validate that malicious transaction. The blockchain can be considered immutable only if the consensus protocol is able to guarantee immutability.

The blockchain, thanks to its inherent computational power, permits the development of smart contract, considered by (Mougayar, 2016) as "to program our world on the head of blockchains, and potentially replace some of the functions currently executed by expensive or slow, legacy intermediaries".

2.5 Smart Contracts

The concept of Smart Contract was proposed in 1994 by Nick Szabo, defining Smart Contract as: "a computerized transaction protocol that executes the terms of a contract". The purpose of smart contracts in Szabo's opinion should have been that of "satisfy common contractual conditions" for example payment terms, liens, ecc all digged in the hardware and software we deal with. Besides other economic purposes such as lowering fraud loss, arbitration and enforcement costs, and other transaction costs.

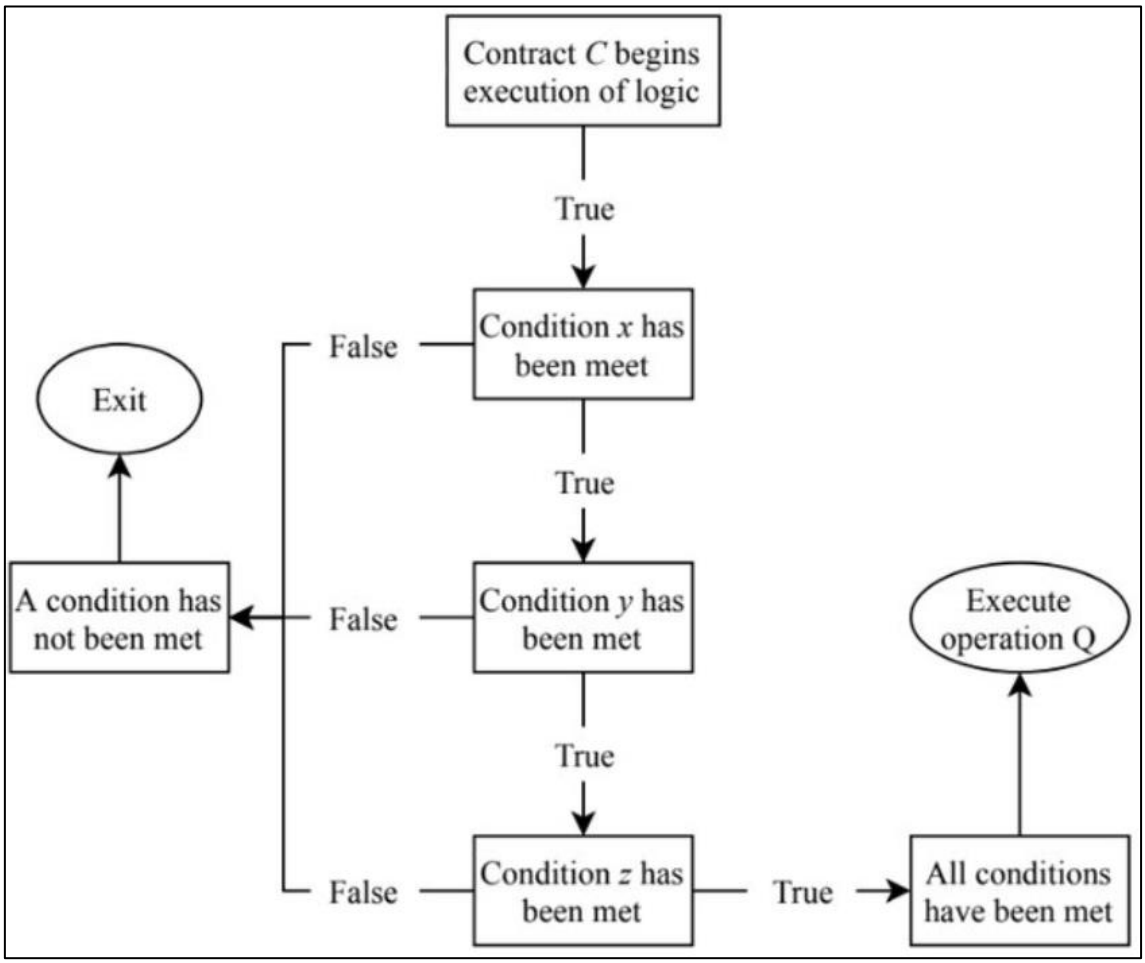
The first smart contract application invented by Nick Szabo was the vending machine. His idea was that a machine was able to receive money from the user and only when this action has occurred release the selected drink or object.

At that time that Szabo introduced the concept of Smart Contract there was no platforms able to run them. In fact, even though there was the idea, there wasn't the suitable technology available - were still the very beginning of Internet diffusion. - It only took off with the emergence of Bitcoin blockchain technology in 2009. The breakthrough in the application of smart contracts was achieved in

2015, when Vitalik Buterin published the Ethereum whitepaper, whose platform subsequently became the main reference for the development and execution of smart contracts on the blockchain.

Two parties be they two people, it means peer-to-peer (P2P), person-to-organization (P2O) or person-to-machine (P2M) can make agreements and define their rules. The rules defined between the parties are written into the contract in a programming language, so they are unambiguous. Once the events defined in the rules occur, the contract automatically performs any specific actions, such as transfer of money or ownership of an asset. The logic function (see Figure 13) underlying smart contracts is "if this happens than do that". The transaction is then duplicated and validated on the blockchain.

Figure 13 Smart Contract's logic function



Source: (Gilcrest & Carvalho, 2018)

The value added of Smart Contract is that by providing a programmatic interface with blockchain allow the possibility of disintermediating, as well as the reduction of costs for finding and processing information. This opens the possibility of disintermediating the entire legal system and creating a new form of virtual agreements.

Smart contract utility is defined as “being able to perform useful functions to create, maintain or augment the value of digital assets” (Sultan et al., 2018).

Smart contract applications are ideal for interacting with real-world assets, IoT, properties, financial instruments. They are not limited to applications only in coin transactions. In general, they can find application in anything that has a value and that over a period changes its status. According to (Dal Mas et al., 2020) “the efficiency improvement produced by smart contracts allows for developing different organizational forms and new business models”. In the same article has been analysed a case study of an European company which mission is to become a pioneer in offering completely decentralized insurance platforms based on blockchain technology. In this case, Smart Contracts are integrated into the business model to allow the automatic execution of some procedures without the need of an intermediary. Blockchain technology and the application of smart contracts has allowed the company to reduce some transactional costs thus being able to focus on providing a better service at lower prices.

In the health sector, for example, IoMT (Internet of Medical Things) applications are already widespread. They are tools that allow you to collect medical data to carry out analysis and monitoring. However, today these implementations are not fully exploited as the data collected does not offer medical staff a unique view of the patient's health. Through the implementation of Smart Contracts based on blockchain technology, it would be possible to detect anomalies in real time, providing a complete view of the state of health of an individual. Smart Contract also permits the automatic triggering of processes and/or specific actions such as if certain values are reached then sends a notification or book a visit or the automatic communication of information to any insurance linked to the patient.

2.6 Blockchain value proposition and its potential applications

A describes in the paragraph dedicated to blockchain properties, many are the blockchain's characteristics that together (e.g., increasing transparency and immutability of information) allow endless potential applications on businesses and not only on money transfers.

In his book, (Mougayar, 2016) identifies 6 main elements that blockchain touches and which best define where the blockchain brings value. He uses the word "ATOMIC" where each letter stands for:

- Assets
- Trust
- Ownership
- Money
- Identity
- Contracts

These elements constitute the core of blockchain business applications by facilitating the creation, management and transfer of digital assets through automated validation rules, cryptographically encrypted data, rights verification and ownership, transactions validation without requiring intermediaries.

Implementing blockchain platform implies that every of those six elements is programmable, and without brokerage third parties, blockchains can enable businesses to promote new services with lower transaction fees and faster execution. With these benefits, blockchain technology is poised to disrupt many business models that depend on (often expensive) brokers.

Before considering in which industry sectors blockchain technology may have significant impacts, is important to distinguish blockchain according to its type. To be more specific according to whom is allowed to participate in the blockchain and how the authority is managed, is possible to distinguish between: public, private, and hybrid blockchain structure.

Public also known as permissionless blockchains are the most well-known. They are based on the Internet. These types of blockchains are publicly accessible from the Internet. Some examples of public blockchains are Bitcoin, Ethereum, Zcash.

They make data accessible and software development open to the public so that anyone can examine, verify, develop, or improve it (bit2me, n.d.-a).

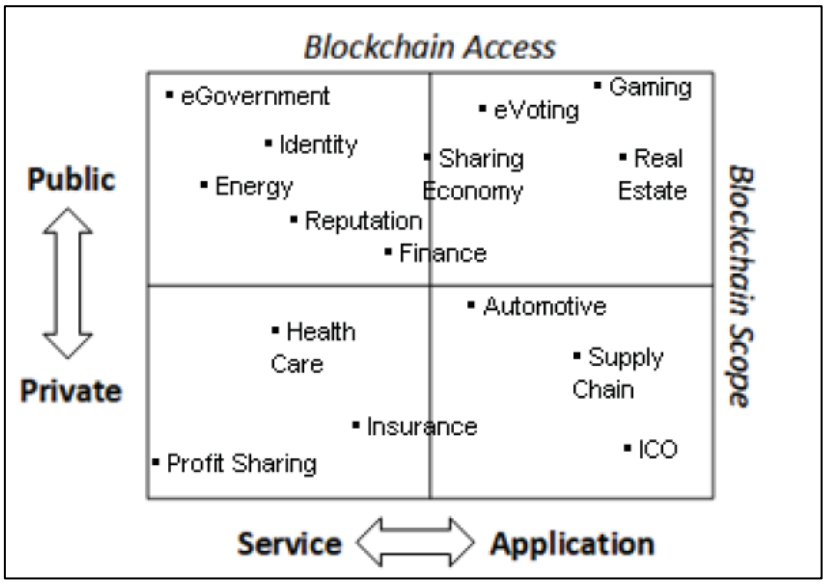
Private blockchains, unlike public ones, are less decentralised. However, they exchange control over access permissions. In fact, private blockchains have a level of access verification controlled by one or more authorities. The access control level allows deciding who can read and/or write data to the blockchain.

The third type of blockchain is called hybrid or consortium, they are a ramification of private blockchain. In fact, they differ from the completely private blockchains because in the hybrid model, authority is quite distributed among some participants of the network and not just concentrated in one authority. To give a real example a consortium of 30 institutions, each controlling a node in the network and with a consensus mechanism working as: a block is only valid if validated by at least 20 nodes. This is a model that may find some applications in industry, for example, or more generally in processes where collaboration between several entities is required. This would lead, for example, to an improvement in supply chain processes where a product to pass from producer to consumer requires the coordination of many different actors.

(Sultan et al., 2018) proposed a 2x2 matrix (Figure 14) after considering the potential applications of blockchain technology in different domains and the three types of blockchains: private, public and hybrid. The result of this matrix is to give an overview mapping of industry sectors against blockchain scope (public/private/hybrid) and blockchain access (blockchain-as-service or blockchain-as-application).

In this contest blockchain-as-service is intended as a transfer of data or applications, while blockchain-as-application is meant as a programme designed to perform a function, or a number of functions linked to benefits perceived by the end user.

Figure 14 Blockchain access vs scope matrix



Source: (Sultan et al., 2018)

The vertical axis is the result of the distribution against the scope, therefore if the authority model favoured by companies in the industry is the public blockchain (or permissionless), the industry sector will be placed in the upper part of the matrix. Alternatively, if the preponderant type of blockchain chosen among companies is private (or permissioned), the industrial sector will be in the lower part of the matrix.

The horizontal axis maps industries according to the scope by categorising them as blockchain-as-application if the main function of companies belonging to the industry sector is to transform data. In this case they will be placed in the right part of the matrix. Otherwise, if the main function is to transfer data, then they will fall under the blockchain-as-service category and will be placed in the left part of the matrix.

Considering two opposite industries: Supply Chain and eGovernment; supply chain is placed at the bottom right of the matrix because the most used blockchain type is private or hybrid. In this case of supply chain, entities that are authorised to validate transactions are defined among the participants in that specific value chain. On the other hand, eGovernment is positioned among public blockchains for those applications of the technology that require public verifiability of transactions. Among the access, supply chain is considered as a blockchain-as-application because it might consider the implementation of smart contracts that

are considered as a function that, when activated, generates a benefit for the end user. On the other hand, certain applications of blockchain in eGovernment can only involve the transfer of data from one subject to another, thus categorised as blockchain-as-service.

2.7 How can blockchain help to solve supply chain pain points

The supply chains of the last decades, as seen, are very complex both in terms of number of actors involved in the network and in terms of the very large amount of information that should run along the entire value chain. These are the characteristics of a network that is well suited to benefit from a technology like blockchain. Many studies in the literature have highlighted how the features of blockchain technology can benefit the supply chain environment.

The object of this chapter is to analyse the current level of application of blockchain technology in supply chains. Through an analysis of the literature, the main pain points of today's supply chains are identified. The issues are divided into those mainly related to the physical flow of products, to the information flow and to the financial flow. Then are exposed how blockchain technology implementations could help to solve the discussed pain points.

2.7.1 Benefits to the physical flow

The blockchain makes possible to increase trust in the journey a product crosses to be made. Consumers should be able to know where a product comes from, what it is made of, what processes were used to produce it, how many resources were used and what environmental impact the manufacturing process had. Manufacturers and retailers benefit from this increased traceability and provide consumers with greater awareness of the product they are buying.

In the supply chain of the agri-food industry, for example, RFID technology has been widely used for years. RFIDs collect various input data that are then recorded in the blockchain to be immutable and made available to the various actors in the supply chain or those with an interest in it. The consumer or data verifier is thus able to know which route the product has taken or where it is at any given time. Not only the actors in the supply chain or the final consumers have an interest in

knowing this data, but also the control and inspection bodies themselves, such as government control bodies or other international regulatory bodies. This system of collecting and maintaining information in an immutable way allows in case of incidents to take targeted decisions and measures to prevent the spread of the quality problem.

- **Increase traceability leads to product provenance**

Tracking products along their supply chain is made easier as the data is transparent and auditable. Making the life of products along their supply chain transparent should also discourage malicious actors from introducing counterfeit products or using processes or working methods that do not comply with standards and legislation. Tracking the status of products along the supply chain also allows for easy identification of bottlenecks or inefficiencies along the process thus allowing stakeholders to make decisions in advance to mitigate negative effects instead of being faced with the problem without any room for action. Blockchain can provide proof of ownership, proof of creation, proof of existence, all of which facilitate the administration and management of intellectual property rights.

Being able to trace a product also means, as in the case of food, being able to identify batches of food with quality problems and which could potentially be harmful to people's health. Walmart, for example, relied on IBM Food Trust, a blockchain solution developed by IBM that enables the supply chains of companies in the food sector to be transparent, trustworthy making them smarter, more efficient and sustainable (*Https://Www.Ibm.Com/Blockchain/Resources/Food-Trust/Why-Foodtrust/*, n.d.). According to (IBM Food Trust, 2020), the blockchain is expected to save $31 billion in food fraud by 2024.

IBM Food Trust is developed in 3 main modules designed to make supply chains less susceptible to fraud. With the Trace module, products in supply chains can be traced from upstream to downstream making the production path visible, therefore transparent and authentic. In the Insight module, through the implementation of IoT and augmented reality, it is possible to increase the visibility of the status and location of the products by identifying and mitigating any malicious fraudulent actions. In addition, with the Documents module, users

can share certifications, records and quality controls making the data collected during the product journey auditable by all participants.

- **Reduce fraud & counterfeiting**

According to (Köhler & Pizzol, 2020), the blockchain should prevent misconduct. Precisely because of the way the system is structured, the tracking and transparency with which transactions and events are recorded in the blockchain would make any attempt to tamper with the data ex post immediately visible. Smart contracts also prevent the occurrence of malicious behaviours because once the agreement has been defined and sealed in the smart contract it self-executes once the events defined in the contract happens.
2015 saw the birth of Everledger, the start-up that uses blockchain and smart contracts to protect the diamond market from counterfeiting and the black market. By involving the main certification authorities that analyse the physical properties of diamonds, such as brilliance, weight, shape, clarity, etc., Everledger is able to create a digital identity for each diamond subsequently written in blockchain. Today Everledger is based on the Hyperledger Fabric (*Https://Everledger.Io/*, n.d.).

- **Reduce uncertainty in the supply chain**

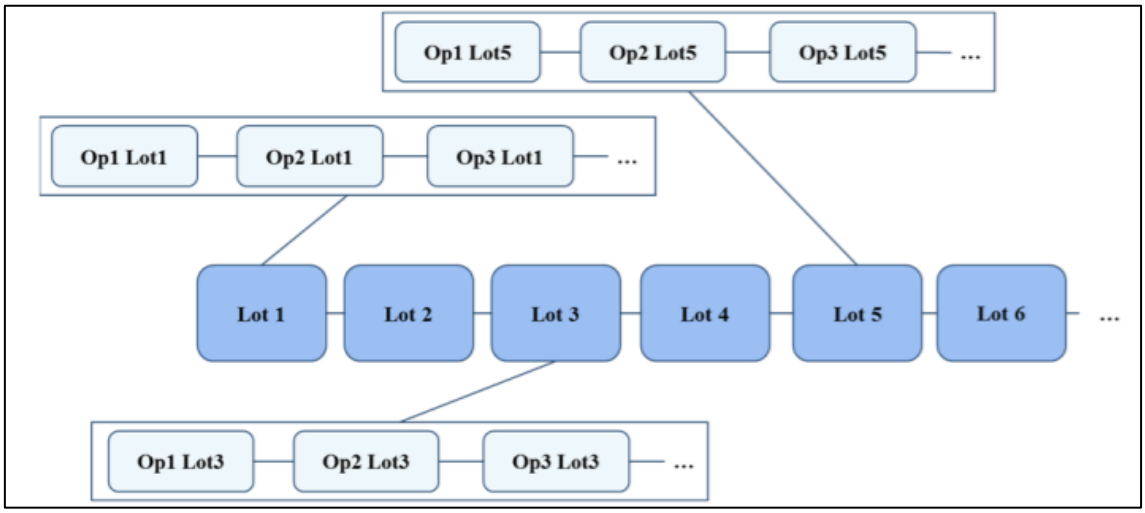
Uncertainty, generally widespread in supply chains, thanks to blockchain could be minimised by the fact that blockchain makes information and data usable throughout the value chain. Although there will always be underlying uncertainty, it is still minimised, as blockchain helps companies in two ways (Schmidt & Wagner, 2019):

1. First, it increases internal transparency, as warehouse management operations and production processes become fully accessible. By making operations more transparent, it makes decision-making smoother and better. It also increases efficiency, which frees up previously occupied resources that could potentially be dedicated to controlling uncertainty.
2. Secondly, transparency is also spread beyond the company borders and thus extended to other actors in the value chain. A better exchange of information between actors allows a more efficient flow of products from one actor to another, making the flow itself smoother and contributing to

improved supply performance in terms of lead time reduction and availability of products for the end customer. Data analytics capabilities and improved availability and transparency of information allow companies to increase their forecasting and planning performance, all to counteract the bullwhip effect. Smart contracts along with other emerging technologies such as biga data analytics, machine learning determine optimal production parameters with speed and accuracy.

The implementation of blockchain in the supply chain would also enable improvements in operations management. As an integral part of operations management, activities such as production planning, production control and quality control should benefit from the implementation of blockchain. In a study by (Herrgos et al., 2020) on the evaluation and development of the blockchain concept on production planning and control in the semiconductor industry, it was found that due to the confidential nature of manufacturing data, a public or permissionless network is not considered suitable for the use case. More specifically, it is hypothesised to manage in the blockchain all the transactions that occur in production related to each batch. In practice, individual blockchains would be created for each batch to track and record the transactions and statuses it undergoes during the manufacturing process. This would allow reliable pre-planning of subsequent operations, such as the assembly of certain components. Each blockchain would then be merged with the others to create a single blockchain Figure 15.

Figure 15 Structure of the blockchain concept in the production of semiconductors



Source: (Herrgos et al., 2020)

In the study, the blockchain solution was compared to the solution available in the case company that uses different software tools connected to a central database. 3 categories of criteria have been identified for carrying out the analysis: technical, organizational and economic criteria. It was found that the blockchain was not totally predominant in the category of technical criteria but outperformed on data security, completeness and fault tolerance (Herrgos et al., 2020). The other two categories, organizational and economic criteria have seen the blockchain be more performing compared to the systems currently used. It was also found that the choice of the type of architecture is of primary importance. Many applications and concepts of the blockchain, so far in the B2B field, can only be applied in a private network or in a consortium environment.

2.7.3 Benefits to the information flow

- **Increase trust in data**

The blockchain, as designed, guarantees the immutability of data. As seen in chapter 1 on the blockchain, the data is encrypted and placed in a pool of transactions that are at some point cryptographically added to a block. This block contains the hash of the previous block and is tied in the same way in the next block. The more blocks that are added, the more it is almost impossible to change any data in the previous blocks, as to do so would require recalculating all the hashes of the subsequent blocks. A high computational power would be required and all nodes in the network would have to accept the change. This clearly increases trust because the data is almost completely immutable, but in any case, at the moment of entry the data must be correct and true. Blockchain allows supply chain actors to share information in a trustworthy and transparent way as a result of increasing collaboration between them.

- **Widespread accessibility of information**

The architecture of the blockchain is based on a network of nodes that is distributed and decentralised to some or a great extent and this allows actors in the value chain to participate in the exchange of information in a way that is not

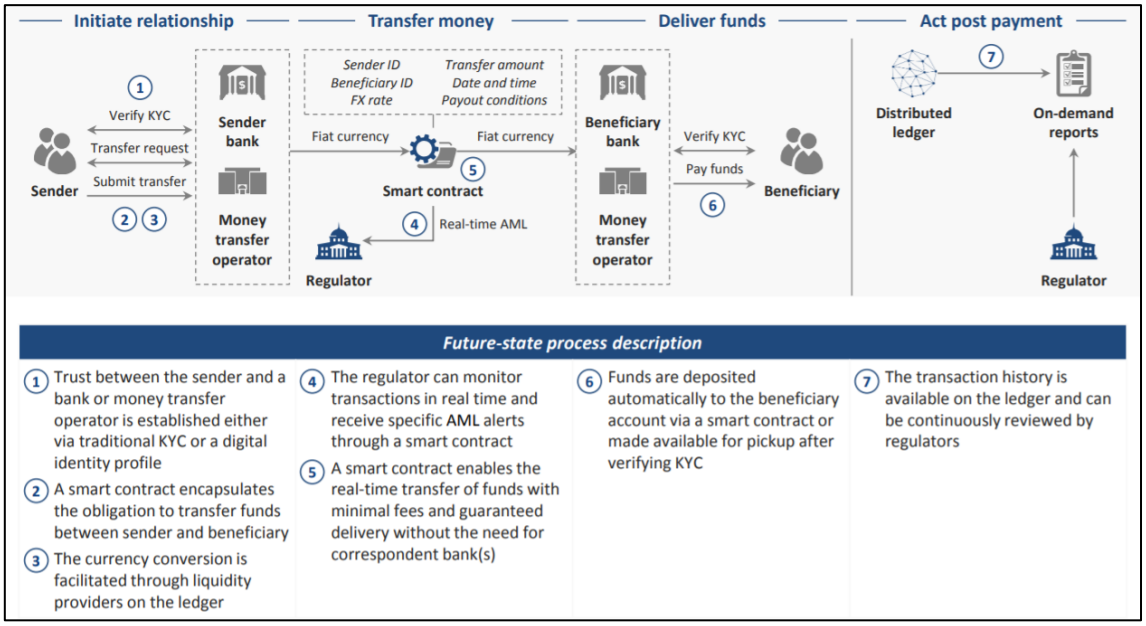
controlled by a single entity, which would then hold the power of information. This means that the actors belonging to a supply chain will no longer each own their own database. Since blockchain is a technology that enables the management of distributed and shared ledgers, each member of the network will hold a copy of the ledger, which will be the same for everyone. For example, when a member of the network needs to know the location of a batch of goods that should have been delivered, he can query the system. The path along the supply chain that the batch of goods takes is traced in the blockchain by building a detailed history of record. By having this shared and immutable register, companies can drastically reduce the time spent on finding information and resolving conflicts or disputes.

2.7.4 Benefits to the financial flow

❖ **Increases speed in KYC & AML processes**

The blockchain allows disintermediation, i.e. it eliminates intermediaries such as banks or financial entities and delegates KYC and AML activities to the system and thus to the algorithm. As blockchain is the single source of truth for digital identity. Users create their own identity over which they have full control. Once the identity is verified, users can allow access to their private information to any third party they want without losing control over their data. In Figure 16 is possible to see which could be the future due diligence processes.

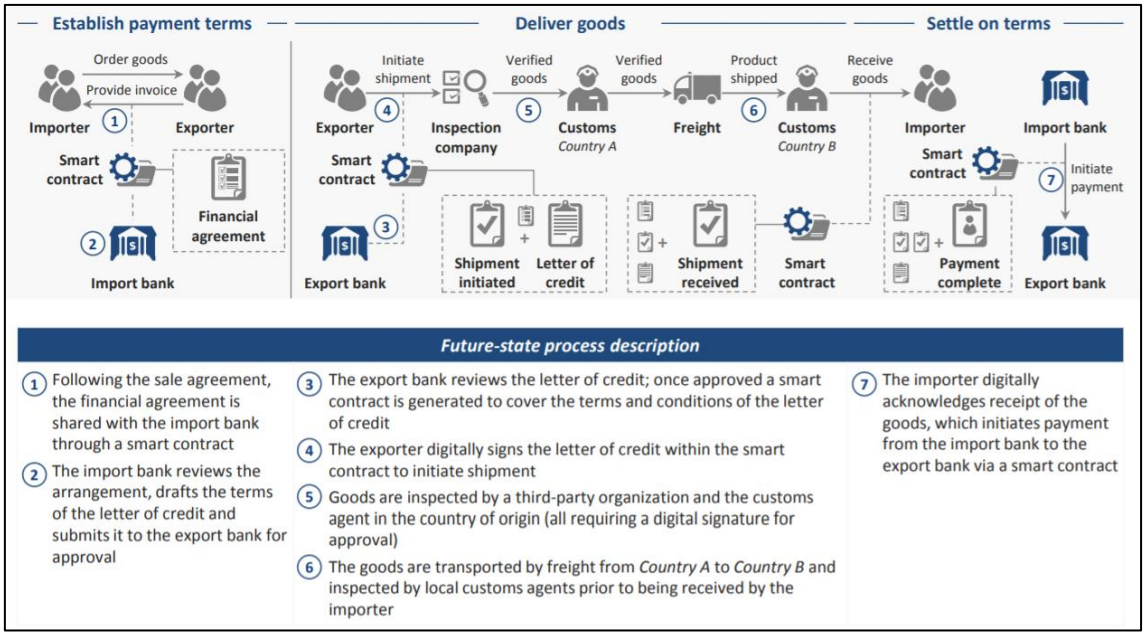
Figure 16 KYC Future-state process



Source: (The Future of Financial Infrastructure An Ambitious Look at How Blockchain Can Reshape Financial Services An Industry Project of the Financial Services Community | Prepared in Collaboration with Deloitte Part of the Future of Financial Services Series •, 2016).

As can be seen from the image showing the future due diligence process and how it can be implemented on the blockchain, a smoother and faster KYC and on-boarding process is immediately evident. Through smart contracts it is possible to define the rules of the agreement between the parties. It will then record events and release payments at the right time in real time without having to wait for the intermediaries to carry out all the necessary checks. In an international transaction, it can often take up to a week from the time of sending from bank A located in Europe to bank B located in Asia. The future process of global payments will also have the benefit of reducing costs as many of the activities that were previously handled by an intermediary can now be automated with digital identity and smart contracts, Figure 17.

Figure 17 Future trade finance process



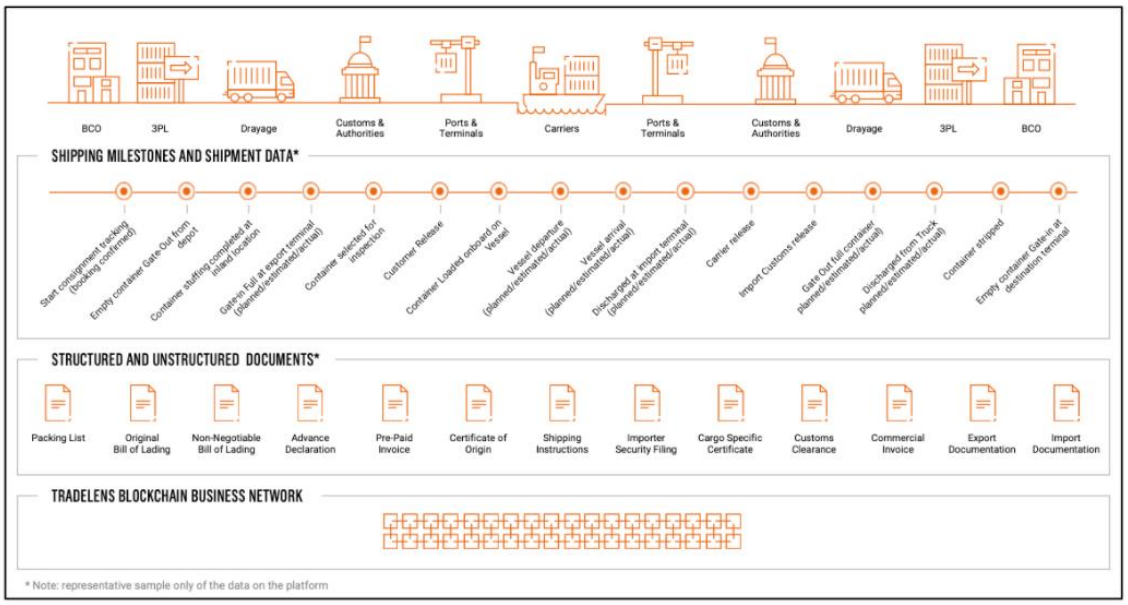
Source: (*The Future of Financial Infrastructure An Ambitious Look at How Blockchain Can Reshape Financial Services An Industry Project of the Financial Services Community | Prepared in Collaboration with Deloitte Part of the Future of Financial Services Series* •, 2016)

- **Mitigation of costs and paperwork related to trade operations**

Invoices and agreements terms can be distributed between the parties and recorded in a smart contract so every change in the status of the goods is recorded in the blockchain, and the smart contract releases the payments or trigger other events as defined in the contract thus reducing the time required to monitor the deliveries of the goods. The automation of the agreements registered in the smart contract eliminates the need to rely on banks and financial intermediaries thus reducing commission costs and paperwork.

In 2015 Maersk and IBM merged in a joint venture to find a solution to the inefficiencies related to international trade and digitalize the industry. A platform has been implemented that relies on blockchain technology to manage maritime transport. In merchant shipping, the use of the blockchain makes it possible to independently manage the hundreds of documents accompanying each individual transported item in a single window. What makes blockchain useful in this context is the fact that the documents are encrypted and can therefore be authenticated, guaranteeing privacy and security. The actors that can participate in the platform are logistics operators, freight forwarders, port operators, land and rail carriers and supervisory authorities. These actors, having access to the platform, are informed in real time about the condition of the goods, whether all the necessary documents have been uploaded, etc... Figure 18. The monitoring of the condition of the goods is possible thanks to the adoption of IoT sensors that allow parameters such as temperature, humidity and weight to be checked.

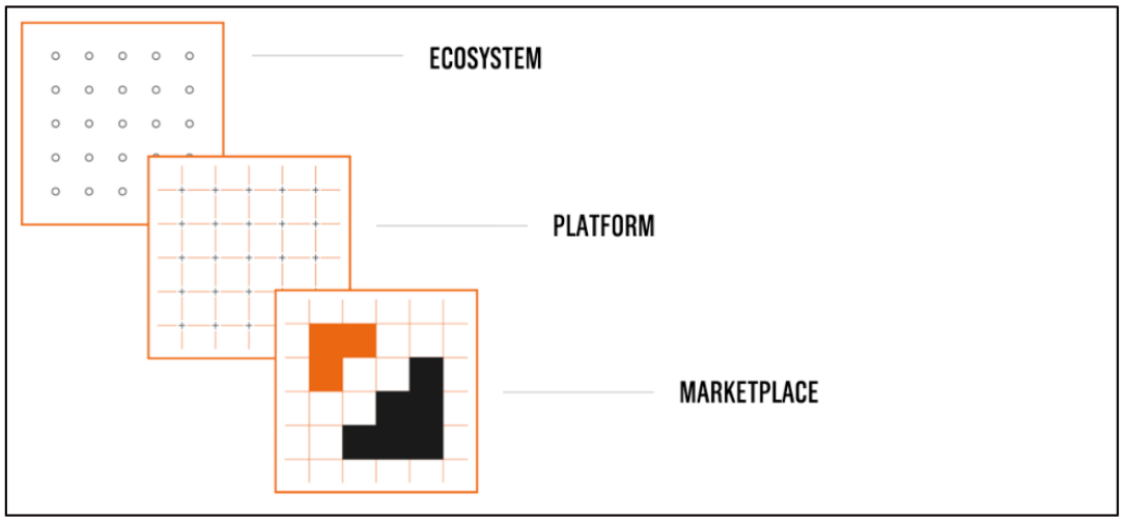
Figure 18 TradeLens overview of data and document organization



Source: (IBM Corporation and GTD Solution Inc. 2018, n.d.)

TradeLens is based on 3 pillars Figure 19. The ecosystem of participants in the platform, a set of applications and services running on the platform accessible through an open API and a marketplace that allows participants or third parties to publish services on the platform. TradeLens is built on an IBM service called Hyperledger Fabric, a permissioned blockchain where participants in the ecosystem are known in the network with encrypted identities (IBM Corporation and GTD Solution Inc. 2018, n.d.).

Figure 19 TradeLens solution landscape



Source: (IBM Corporation and GTD Solution Inc. 2018, n.d.)

❖ Enabling new business models: micropayments

The reduction of operational costs and the possibility of carrying out transactions in real time in a peer-to-peer way without the need to trust an intermediary, allows the development of new opportunities such as international micro transactions that in the current system are not possible because of the cost of commissions would probably be higher than the amount to be transferred. Secondly, the fact of being able to transact without an intermediary and therefore being able to carry out transactions in a peer-to-peer way allows access to these services to a part of the market that before was not served. This referred mainly to developing countries, or emerging countries in which the population and companies do not have access to credit, they are the so called unbanked.

3. Technology adoption process & challenges

Although as it turns out blockchain is promising to mitigate some supply chain pain points, on the other hand there are some barriers and challenges that determine the success or failure of blockchain implementations in companies' organisation. The literature review revealed several determinants that positively or negatively impact the adoption of blockchain technology in the supply chain.

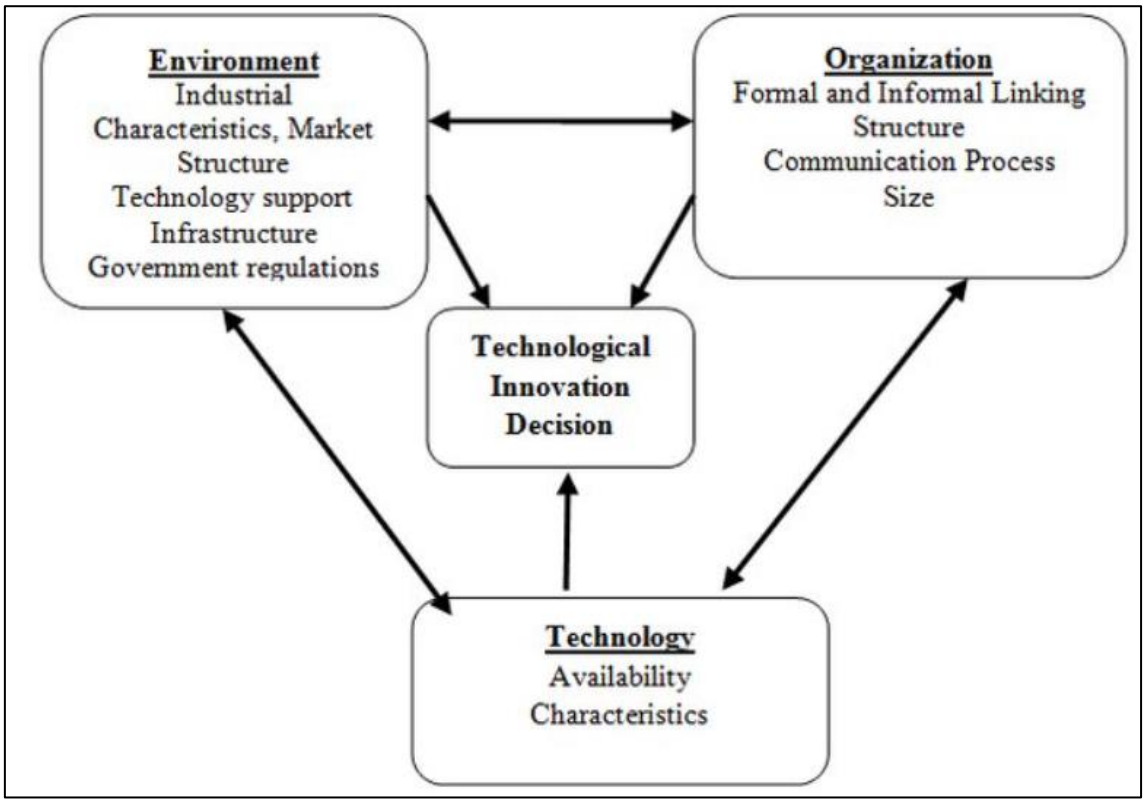
In the following paragraphs determinants are listed and analysed in detail and is defined whether the expected impact is negative or positive on blockchain adoption in supply chain.

The process of diffusion of an innovation was first addressed by Rogers, in his book (Rogers, 2003). In the preface of the book, he defines innovation as: "an idea, practice or object that is perceived as new by an individual or other adopting unit". Innovation represents for a person or a company a new alternative or set of alternatives or means that enable a new way of solving problems. Moreover, according to Rogers the probability that a new idea is superior to existing alternatives is not known at the beginning. What individuals or companies do, is to seek more information about an innovation. Information about an innovation often comes from peers, people or entities known to the individual or person. The diffusion of an innovation is thus essentially the social process of information exchange in everyone's network.

To organise the drivers that push or challenges the adoption of blockchain in the supply chain is decided to use the TOE framework. TOE stands for technology-organisation-environment framework.

This framework, shown in Figure 20, was released in 1990 by Louis G. Tornatzky and Mitchell Fleischer in the book "The Processes of Technological Innovation" (Tornatzky & Fleischer, 1990). This framework tries to map which are the drivers that make an organisation ready to adopt a technology or not. In particular, in their model, Tornatzky and Fleischer indicate three contexts that influence the adoption of an innovation: the technological context, the organisational context and the environmental context.

Figure 20 TOE framework



Source: (Tornatzky & Fleischer, 1990)

3.1 Technological context

The technological context is understood here as the context relating to the characteristics of innovation and some drivers are considered in the analysis: relative advantage, complexity, compatibility and security concerns.

3.1.1 Relative advantage

This concept is based on the individual's or company's perception of whether an innovation is better than the alternatives already available. In fact, Rogers defined Relative Advantage "as the degree to which an innovation is perceived as better than the idea it surpassed". Clearly, the acceptance rate of a new technology is directly proportional to the benefits it promises to deliver. It is also expected that the greater the perceived advantage, the greater the competitive advantage for the organisation (Y. M. Wang et al., 2010). The following theory is therefore proposed:

A.1 Relative Advantage has a positive effect on blockchain adoption on supply chain

3.1.2 Complexity

Complexity is perceived as the difficulty of implementing or using a new technology. It can take a long time and consume resources for an individual or organisation to learn the basics of the technology and how it works, thus complexity and difficulty is perceived. The perceived complexity is therefore considered as an aspect that negatively impacts the implementation of blockchain on the supply chain.

A.2 Complexity has a negative effect on blockchain adoption on supply chain

3.1.3 Compatibility

Compatibility is understood as the ability of new technology to respond consistently to the needs and current situation of an individual or company. Compatibility is often also referred to as "integrable" with the systems already in use and that a radical change in the practices used up to that moment is not necessary. With reference to compatibility, resistance to change also comes into play. It is difficult to leave what you know, even if at the moment it does not fully meet the needs, for what you do not know (although the benefits perceived by technology can still be high).

A.3 Compatibility has a positive effect on blockchain adoption on supply chain

3.1.4 Security concerns

The topic of security is very much on the agenda in recent times. In fact, all data of suppliers, customers, production, components, transactions and processes in general are contained in the IT systems of companies. A compromise of security systems could lead to huge negative impacts such as loss of credibility, litigation, loss of turnover, etc. Security is a fundamental and primary requirement for web services. Another point of view and point of attention related to security issues, could be the fact that the blockchain is not designed to be a database that captures and governs data. So far, in the cases found in the literature, one of the most widespread possibilities is the collection of data through RFID technology. However, the authenticity or originality of the data is not fully guaranteed many

times. This part of the process, in fact, the transfer of data from the real world to the blockchain, is one of the most critical points in terms of security.

A.4 Security concerns have a negative effect on blockchain adoption on supply chain

3.2 Organisational context

3.2.1 Top management support

The vision of top management is very important and determines the decision whether to adopt a new technology. To effectively implement a new technology, it is necessary that the top management is ready to sacrifice time, effort, allocate budget to the project and implement a business environment prepared and open to change (H Teo et al., 1997). The characteristics and viewpoints of top management determine the choice and all processes. If top management does not support the adoption of the technology in the company, it is difficult to have project champions who can take the project forward. Also, because at the beginning of the implementation of a technology the investments are high and therefore it is necessary that there are specific funds allocated to the project.

B.1 Top management support has a positive effect on blockchain adoption in supply chain

3.2.2 Organisational readiness

The organisational context of the company refers to the company's own characteristics and resources. It also includes connections between employees, communication processes within the company. The organisational context of the company has a strong impact on the success of adopting an innovation or not.

Organizational readiness in this context is defined as the availability of the resources necessary for the adoption of the new technology. The resources referred to are both financial and human resources. Companies with higher organizational and information-sharing readiness will be more likely to adopt a new technology.

B.2 Organizational readiness has a positive effect on blockchain adoption in supply chain

3.2.3 Adequate technical capability

Technical capabilities or technological readiness refers to the company's information technology infrastructure and IT professionals (Y. M. Wang et al., 2010). The IT infrastructure refers to the technologies and systems already in place in the company and it is necessary to understand whether these existing platforms can enable the development of the new technology. IT professionals refer to the human resources in the company who have the necessary competences and skills to understand the new technology and enable its development.

In the case of using blockchain technology in business systems and considering this technology as a still relatively new one, it is not sure that the companies have either the appropriate infrastructure or the resources that already have the skills and expertise to fully follow the implementation of a blockchain project. Therefore, companies that want to implement blockchain technology within their organisation need to map their current IT systems and understand if any changes or implementations are needed. On the other hand, they must also be aware of the need to develop knowledge and skills within the organisation to follow the implementation process. In any case, it is expected that a company with more technological skills is more likely to implement blockchain technology within the supply chain.

B.3 The availability of adequate technical capabilities has a positive effect on blockchain adoption in supply chain

3.3 Environmental context

Environmental drivers are those changes in the business environment that positively or negatively impact the adoption of a new technology (H Teo et al., 1997). The environmental context includes the structure of the industry in which the company operates, the pressure of external actors such as customers, society or competitors and the regulatory environment.

3.3.1 External pressure

Companies under external pressure from competitors, from certification bodies, customers ecc... usually adopt new technologies in their organisation more frequently (Sternberg et al., 2021a).

In this case, external pressure is regarded as the pressure exerted by customers, regulatory bodies etc to enhance for example transparency or traceability of the supply chains. In this regard the external pressure is considered to have a positive effect on blockchain adoption in supply chain, i.e., it drives the company to implement the new technology.

C.1 External pressure has a positive effect on blockchain adoption in supply chain

3.3.2 Partners' readiness

In the case of the application of blockchain technology in the supply chain, the value that a company alone has in adopting the technology is very limited. The implementation of blockchain technology suffers from what is called the network effect. According to (Katz & Shapiro, 1994), many products have little or no value on their own but can achieve a very high value when combined with other products. An example could be the number of people registered in a social network, the higher the number of people registered in that specific social network, the higher the value generated by the social network for its users, because the more users involved means heterogeneity of content, different points of view etc.. In other words, the value of a user is increased and positively enhanced when another user joins the network, thus enlarging it. These types of events are defined as network effects or network externalities.

As highlighted, the benefits deriving from the implementation of the blockchain as an increase in transparency in the supply chain, secure storage of information thus increasing trust and operational improvements, all derive from the fact that different actors contribute to fill the information database. In terms of network effect, therefore, the decision of an actor to participate and use technology, impacts on the added value that all other actors in the supply chain can perceive (Sternberg et al., 2021b). If there is not a number of actors such as to make these advantages

still perceived, then the advantage that by blockchain technology is not delivered at all.

C.2 Partners' readiness has a positive effect on blockchain adoption on supply chain

3.3.3 Governments and regulatory framework

Governments or the regulatory environment in general may have a positive or negative impact on the new technology. They can either make the adoption and implementation of the technology smooth or fail to keep pace and create the right environment for the technology to develop. In general, the activities involved in supply chains suffer from a lack of standardisation and certainty. This is because it is the duty of governments and regulators to create an environment that allows blockchain technology to spread and that there are no barriers to implementation due to lack of legislation or lack of clarity on the acceptance of standards.

C.3 Poor government actions and an insufficient regulatory framework negatively affect blockchain adoption in supply chain

4. Research methodology

Blockchain technology is still at the beginning of its development. It is still in its infancy, at least considering the uses of the technology in the business environment and more specifically in supply chains.
To understand what benefits blockchain can bring to companies, a study was first carried out on a selection of whitepapers found in a rating platform for ICOs created and aimed at experienced investors. The platform provided information on projects that have undertaken an ICO in recent years to raise funds. The search was filtered by sector and then focused on start-ups offering supply chain solutions. The analysis of whitepapers is carried out in Chapter 5. At the end of the paragraph of each start-up is presented a table which summarises which are the main focuses of the start-up, which property of the technology allows the pursuit of the focus and what is the final effect on the supply chain. Concluding the Chapter 5 with general conclusions regarding which are the blockchain benefits that the start-ups analysed leverage.

It was therefore decided, in this context, to continue the research work with the analysis of two case studies in Chapter 6. According to (Myers, 2013), case study research is particularly useful when the literature and study of a discipline or topic is still in its infancy and when not much is known. The role of the researcher in this case is to find out "how" and "why" a certain business decision was made, and how and why a business process works in that way. The purpose of the research case study is to describe a certain topic using evidence from real cases of business situations, involving real people and processes.

The method that has been adopted to gather information is the interview. In the present thesis it is considered that the interview gives a broader insight into the point of view of the companies and the environment in which they operate.
According to (Myers, 2013) the interview is the most common and probably the most important method to gather information in case study research. Moreover, the interview is defined as "an excellent window into an organisation that can help you find out what people are thinking. It is also particularly useful to find out people's motivations, their rationale and why they did certain things". For an

interview to be considered relevant and reliable, it is necessary to involve interviewers who know company's environment very well and who can represent the company as a whole. Considering this, however, it is not mandatory to involve the CEO of the company, thinking of him as the greatest expert in the business' dynamics but the choice of the interlocutor must fall on the figure who can best represent the company but on the other hand, he/she needs to be very familiar with the topic and the company's project, object of the interview.

In the two case studies analysed in the following paragraphs, it was decided to involve two figures who deeply know the company and who are sponsors within the organization of the blockchain implementation project on the supply chain.
In the case of Scamosceria Astico the person interviewed is Giuseppe Bettanin, Sales Manager. In the case study of Caffè Barbera, the person interviewed is Elio Barbera, Managing Director of the company. The data reported in the case studies are primary data, collected through the interviews conducted and secondary data, relating to the company and market in general in which they operate, mainly they were found from interviews published on blogs or websites or found on the company website.

The interviews carried out can be categorized as a semi-structured interview, which is therefore located in the middle between the structured and unstructured interview. The semi-structured interview, in fact, includes pre-formulated questions, but there is no strict adherence to them because it leaves the interviewee also free to space if deemed necessary. The motivation for this choice is twofold, mainly due to time limits, it was necessary to set a list and a set of topics to be addressed, second, it still leaves a certain margin to space in order not to stifle any questions that may emerge during the interview due to the novelty of the issue.
After a short telephone interview, that had the purpose to introduce this research work, the respondents were asked to answer to a questionnaire that involves some research questions. In fact, the respondents returned the completed questionnaire by e-mail, which then served as an outline during the interview and the topics were discussed point by point. This questionnaire, reported in Table 3, has been developed after adapting the TOE framework methodology to this specific case

study. It allows to analyse the implementation of an innovation in a business context and to study what impacts the technological, organisational, and environmental context have on the implementation process.

Table 3 Categories of TOE framework – Variables identifies and related questions

Category	Variables	Related questions
A Technological context	A1 Relative advantage	A1.1 My company expects blockchain technology allows us to do things or work in a way that was not possible before
		A1.2 My company expects blockchain technology to improve our supply chain physical flow
		A1.3 My company expects blockchain technology to improve our supply chain physical flow
		A1.4 My company expects blockchain technology to improve our supply chain financial flow
	A2 Complexity	A2.1 My company consider blockchain technology difficult or complex to use
		A2.2 My company consider implementation process of blockchain technology difficult or complex
	A3 Compatibility	A3.1 The changes that blockchain could potentially introduce are compatible with my corporate values and beliefs
		A3.2 Blockchain technology is compatible with existing IT

		infrastructure
		A3.3 Blockchain technology is compatible with existing company's practices
	A4 Security concerns	A4.1 My company believes that blockchain may have negative security implications
B Organisational context	B1 Top management support	B1.1 My top management is ready to invest a part of the budget in the blockchain implementation project
		B1.1 My top management views the blockchain implementation project as strategic and capable of giving a competitive advantage
		B1.3 My top management has analysed and is willing to take risks connected to the adoption of blockchain in the company organisation
	B2 Organisational readiness	B2.1 I believe that in my company there is an adequate and continuous information flow through all business units
		B2.2 My company is able to devote financial resources to blockchain implementation project
	B3 Adequate	B3.1 My company has adequate IT infrastructure to support blockchain

	technical capability	implementation
		B3.2 My company has already implemented or will implement blockchain training sessions for its human resources
		B3.3 My company already has or will get from outside, specialised resources with high-level blockchain-technology related skills
C Environmental context	C1 External pressure	C1.1 My company experienced pressure to implement blockchain technology
		C1.2 My company believes it may be at a competitive disadvantage if it does not implement blockchain technology
	C2 Partners' readiness	C2.1 My company believes that most of its partners are willing to implement blockchain technology in their own structure
		C2.2 My company believes that in 5 years most of its partners have implemented the use of blockchain technology in their company
	C3 Governments and regulatory framework	C3.1 My company believes that exist, or are expected to be regulated blockchain uses cases in the company's environment

		C3.2 My company perceives that the existing regulatory framework makes the blockchain implementation process smooth
		C3.3 My company believes that the government encourages the implementation and use of blockchain technology in companies

Source: personal elaboration of implementation variables of blockchain technology and its related resource questions

5. Qualitative analysis on supply chain blockchain based start ups

Axens

Axens supports companies to access loans without exorbitant interest rates (*Axens: Transforming Global Trade Distributed Supply Chain Finance & Trade Services*, n.d.). It presents itself as a platform for distributed supply chain finance and distributed trade services. It is a digital marketplace that provides liquidity and efficiency to import-export supply chains. Axens facilitates import/export financing operations thanks to the tracking and control of events, so it is therefore possible to automate supply chain finance interventions and free up working capital and liquidity blocked in the processes. It allows users to assess the risk of supply chain finance operations, through KYC – know your customer- and anti-money laundering implementations. This data collection relates to individuals and companies that are periodically verified and authenticated by various trusted subjects. The report is made incorruptible and non-rejectionable through the blockchain. Axens has introduced AXS, a crypto token that circulates among stakeholders, as a means of exchange of finance business and trade services. Using a decentralized ledger technology, Axens gives to SMEs easy access to short-term financing by converting their account receivable into marketable assets. The blockchain allows digital time stamping of every process in the supply chain so that there is proof that goods have being transported and received. The different actors who have interests in the supply chain have real-time visibility of which part of the contract has been executed so that payments can also be executed. The digitization of international trade documents takes place through optical character recognition to produce searchable and practically infallible documents recorded in the blockchain. Users can register on the platform and express their willingness to lend money or respond to suggestions received by email. In the first case they create a profile with their "preferences", in the second case they simply accept the opportunity fact sheet. On the other hand, when someone need to borrow money, can easily register and express their needs to borrow money under certain conditions specified in the profile. The entire process recorded in the blockchain allows the money to be lent by multiple lenders, which also reduces the risk of insolvency.

Their primary target is small and medium-sized enterprises in emerging countries, which suffer most from the financial gap.

Table 4 Axens' whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Facilitation of import/export operations	Tracking of events on the blockchain trough optical character recognition	Automation of supply chain events
Disintermediation – no unnecessary intermediaries – and security	Cryptography and consensus algorithm	Increased trust
KYC & AML implementations	Blockchain	Security and speed
Token	AXS	No need of bank intermediation
Tokenization of loan	DLT	Asset liquidity and minimization of lender risks
Marketization of loans	Smart contract	Flexibility and increase services
Simplification and streamlined payment process	Smart contract and events timestamped in the blockchain	Faster execution of payments

Cargocoin

Cargocoin is a platform whose main goal is to decentralize global trade and transport (*CargoCoin Whitepaper: Revolutionising the Global Trade and Transport by Decentralisation*, n.d.). It aims to facilitate and optimize the interaction between traders, freight transporters, booking agents as well as all other parties involved in the international trade and transport of goods and cargo. The platform will be available free of charge to users, who will be able to benefit from smart contracts, however, creating the demand for Cargocoin tokens, which will gradually increase its value with the growth of demand.

CargoCoin is designed to use platforms, both as a transfer method and secure storage through smart contracts, both as a payment method for services, freight and cargo. The CargoCoin concept completely unlocks the potential of cryptocurrencies and the blockchain, not only as a payment method and as a deposit of money, but also as an interactive method to send, receive, approve, reject and sign documents.

Moreover, with the implementation of smart contracts Cargo Coin can track every stage in the supply chain, from the order of the shipment to the final delivery in the agreed place, thus making the entire process fully transparent and visible in real-time. In addition, they allow to reduce fraud by releasing payments only when the pre-set conditions are met. Blockchain itself increase trust between parties, archive information and secure them.

The sender sets the conditions of the cargo in the smart bill of lading, then consignee and the shipper check them and eventually agree. Every party of the contract see identical information. Nobody can make changes without consent e confirmation from others. The courier or his agent at the port of cargo (for ships), or at the loading address/port (for containers) issues the Smart B/L, according to the sender's instructions and confirming the recipient details. The Consignee/Importer becomes the owner of the cargo once the smart B/L has been issued and released by the courier. The Crypto B/L is immediately in the position of the recipient. At this stage the Receiver has options on how to manage and execute Crypto B/L. It can be validated to another consignee/receiver if the cargo has been sold in transit.

The Transporter releases the load in the port of unloading/destination to the Recipient/Importer for cryptographic verification of the Smart B/L. At all times, the Smart B/L is in the blockchain, protected and immediately accessible by all authorized components, at any stage, according to the conditions of the pre-set smart contract.

Table 5 CargoCoin's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Interactions among stakeholders	CargoCoin Platform	Engagement
Process efficiency	Smart contract	Traceability - Reducing fraud – Delays minimization
Smart Bill of Lading	Smart contract	Fraud reduction – Cost efficiency - Security
Money exchanges	CargoCoin tokens	Disintermediation

CargoConX

Its goal is to connect supply chains actors regardless of the underlying structures and IT systems, in a way that allow to easy transfer and store information in a completely safe and transparent way thanks to blockchain (Mccaffrey -Ceo, 2018). Through their API, web and mobile platform partners in the chains can interact and make deals that are safety stored in a smart contract. The availability of real time information allows the algorithm to perform calculation and eliminate dead mileage. In other words, the algorithm processes all the information stated in a tender and quickly investigate the potential availabilities in the market to perform the consignment. This allows the shipper to have the goods delivered and to a transporter that otherwise had to come back empty to eliminate dead mileage.
All the signatures and events that must occur for the contract to be considered verified are included in the smart contract and are encrypted in such a way that only actors with an interest in that particular contract can have access to the information.

Table 6 CargoConX's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Efficiency and costs saving	Algorithms/Blockchain based payments	Improved productivity
Interactions between participants	Platform marketplace	Connectivity
API connection between mobile actors' app and blockchain	Smart contracts and blockchain layer	Transparency thanks to the possibility to upload cargo related documents on the blockchain

CargoX

It aims to replace the main paper documents with its fast, safe and reliable digital twin through smart contracts (*CargoX Whitepaper: Business Overview and Technology Bluepaper Reshaping the Future of Global Trade with World's First Blockchain-Based Bill of Lading*, n.d.). CargoX platform allows a new way to transfer or receive documents through a single point of entry and repository that allows you to know at any moment who is the owner of the document and at what point is in the process. Although all transfers of ownership of the Bill of Lading are recorded in the

blockchain, users' identities are "obfuscated" by their blockchain address, allowing only the parties which have the private key to see their identity.

At the beginning, the carrier generates a bill of lading registered in the blockchain, after the exporter has paid the shipping costs, the carrier transfers the ownership of the smart bill of lading to the exporter through the dApp. Then, after the importer has paid the exporter for the goods, he can claim the ownership of the document and thus allow the claim for the goods at the port of arrival.

The smart B/L can be created quickly and spread around the globe instantly, tracking its progress, only the parties involved can have access to the documents, this is because it is encrypted and registered in a decentralized database, visible only to certain subjects who have the private key to access. In addition to allowing instant and digital dissemination among the parties involved, it also allows for a reduction in paper consumption, which translates into cost savings; the average cost to ship 3 times the bill of lading is about $ 100.

Table 7 CargoX's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
From traditional B/L to digital B/L	Smart contracts	More security – less paper
Security	Encryption and decentralization	Transparency and security
Middleman elimination	Decentralized ledger	Faster and cheaper than the traditional process

Chronicled

Chronicled was founded with the goal of streamlining the process of how pharmaceutical drugs move from manufacturers to serving patients (*Chronicled Whitepaper: The Method & Impact of Eliminating Chargeback Errors through Blockchain*, n.d.). Chronicled launched with its Mediledger project two products: Product verification and Contracts and chargeback solution.

The product verification solution relies on open standard blockchain directory and encrypted peer-to-peer messaging. This system allows pharma industry players to verify authenticity of prescription medicines. The nodes are distributed and operated by industry participants and technology providers who serve the industry. This is possible due to unique cryptographic constructs which is the basis for the network and solve data privacy issues. With the contracts and chargebacks solution they aim to resolve disputes and chargebacks process in the

pharmaceutical supply chain. In the US pharmaceutical supply chain manufacturers negotiate the contracts' price directly with drugs' dispensers or Group Purchasing Organizations. Then these contracts are shared with distributors, so they know which contract prices to offer which customers. At the end distributors submit a chargeback to the manufacturers to receive the difference between the price they have sold drugs to the dispensers and the price they bought drugs from the manufacturers. A percentage of these chargebacks failed and are sent back, these costs billions of dollars every year to the pharmaceutical industry. Resolving these disputes require manual intervention creating unnecessary costs for the parties. The major causes of the chargeback errors are the delayed updates and misaligned data, customer identity misalignment and unforced chargeback rules. The modification ex post of customers, products and pricing produce errors because the sales have happened based on out-of-date contract information and require manual effort for companies in order to interpret and process data. Even though businesses nowadays are using EDI to run the process, gaps in how companies do business together still exist.

With the Contracts and Chargebacks solution now trading partners are all connected in a trusted network build on the blockchain that ensure everyone is aligned with the most up-to date customers or contract information providing accurate chargeback every time. The network is decentralized, so the parties do not have to rely on intermediaries, they are directly peer-to-peer connected.

Table 8 Chronicled's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Contract communication	Smart contract	Reduce time/money spent on resolving errors, increase price accuracy
Claim adjudication	Data timestamped and registered in the blockchain	Errors are found directly at the source through automatic rules, so they are immediately fixed.
Roster management	Blockchain digital ledgers	Unique source of truth, real-time visibility of contracts updates, no missing/incorrect data
Product Verification	Cryptographic construct	Solve data privacy challenges

E-Halal

"Halal" is the certification that guarantee to Muslim believers that a food product is compliant to religious precepts (*What Is Halal? Status of the Global Halal Food Sector EHALAL ERP/SCM MANAGEMENT SYSTEM*, n.d.). A product that is Halal certified ensure that all the principles has been respected at all stages of the supply chain process and therefore it can be consumed without taking any risk of committing a sin. Food discipline is in fact a pillar in the Muslim religion and consequently is very important for devotees being compliant with this. In the current Halal market, there are some issues that prevent consumers to really trust the supply chain of these products such as:

- the absence of internationally recognised standards;
- lack of transparency in certification mechanisms;
- risk of raw materials contamination (mix of non-compliant ingredients with halal food);
- difficult organization and communication of different regulatory bodies.

eHalal aims to provide to Halal certification authorities and small/medium companies an instrument for managing the supply chain management of Halal products.

Table 9 E-Halal's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Trust on the halal supply chain	Process and events registered in the blockchain	Unique source of truth, database accuracy, preventing improper changes
Halal food marketplace	Marketplace based on a blockchain layer	Transparency and certified products availability

Immla

Immla developed their solution (*Immla*, n.d.) after having analysed current logistics problems such as:

- no online complete transportation services (due to risks in the intersection of the transfer of the cargo from one actor to another);
- no professional IT solution for logistic that could become a standard;
- few cargo owners in transportation service exchanges;
- problems of trust (opportunistic behaviours);
- financial insolvency risks;
- risks of hidden damages;
- currency risks;
- lack of a common information environment (efficiency loss);

Immla aims to solve all the above issues with the "Buy-Ship-Pay" model which helps to manage relations between all the actors involved in the supply chain management, relying in internationally accepted standards (retail industry and multimodal standards) and legal models harmonised with the different legislations, including mechanisms for encoding electronic documents.

Users such as carrier, cargo owner, customs, insurance and other are called "*entities*" that need to obtain permissions from Immla that verify incoming user information and forward them to the Oracle which is a legal entity that checks and signs the users' data. Data hash and signatures are published to the blockchain; then entities can initiate new auctions and interact with other actors in the system. Blockchain is used to improve the efficiency of all the steps related to cargo delivery such as shipment requests and confirmations, tracking events on the process, automatic calculation of the price, terms of delivery ecc, payment execution, users' evaluation and data analysis to develop routes advice.

Table 10 Immla's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Reducing intermediaries	Smart contracts	Increased trust between actors that can cooperate without trusted intermediaries
Authentication and identity	Private and public keys	Reliability and trust

verification		
High speed information exchange	Integration between the network and IoT devices used in delivery	Improved quality of transport product

LaneAxis

LaneAxis harness the power of the blockchain to directly connect the shipper and the carrier, eliminating costly freight agents by creating an information bridge between them (LaneAxis, n.d.). The transported goods are monitored in real time, together with all critical events and transport documents, from the proof of pickup to the proof of delivery they are stored in the immutable register of the blockchains.

Once the shipper defines the requests with all the details such as the pick-up point, destination and carriage load, a smart contract is generated and spread to all nodes. Then LaneAxis forward to the shipper a list of carriers half automatically generated from an algorithm, half manually accepted by the carriers interested in the request. From this list, the shippers choose the most suitable one. If only one carrier accepts the proposal, the shipment will be automatically assigned to the carrier. Once a contract is set, the shipper is responsible for the creation of a new channel which means a new genesis block where the different actors have to be involved. It may happen that the shipper needs more than one carrier for the same shipment and that a carrier transports the goods of more than one shipper, in these cases Hyperledger allows each subject to be part of different channels. Those who do not belong to that channel will not be able to access that information. Furthermore, Laneaxis is by default a node of this channel because it is in charge to calculate the reputation internal score. The algorithm is able to provide the best suitable carriers to the shipper request because all the activities are tracked, and virtuous behaviours result in good reputation. For example, trip's cancellation after shipper's confirmation, delays in pickups/deliveries/payments, incorrect information in the profile generate bad reputation for the carriers/drivers. The advantage of the events registered in the channel is the real time visibility for each stakeholder involved in the process, this also allow to release automatic payments once one event take place.

Freight forwarders and carriers are configured as individual nodes. When an order is accepted by a carrier, the shipper is responsible for creating a channel, which contains the entire configuration of the deal/order (configtx). There are also some guests on the channel, such as insurance, drivers, etc. The drivers can be an optional node. They can act as a real node thus having the ability to act as a proxy of the carrier and accept trips from the shipper. If the carrier decides not to enable the driver as a node, they have access via the REST API interface with the carrier node to be able to provide information relating to the journey.

Table 11 LaneAxis's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Engagement and network	Hyperledger platform	More job opportunities for carriers and more productivity
Disintermediation	Platform and smart contract	Carriers/shippers direct relationship
Reward system	Reward internal score	Increase quality of services
Events and data automatically registered in the blockchain ledger	Smart contract and IoT	Release automatic payments

LogisticsX

LogisticX wants to disrupt last mile delivery by introducing the concept of freelancers delivering parcels (runners) between the collection points and end recipients (*LogisticsX*, n.d.). If Third Party Logistic fail to complete a delivery, they will be allowed to deliver to the nearest Parker Point that could be a supermarket, stationary shop ecc, rather than come back with the goods in the 3PL warehouse. When the recipient is at home and wish to have his/her parcel, a runner will be notified and will do the last leg of the job. The advantage is given by the fact that the whole process is tracked and recorded in the blockchain which guarantees the actors total transparency in the processes, as well as an increase in quality because of the time required for the delivery of a package is reduced. Moreover, the introduction of these freelancers/runners, also contribute to the creation of work opportunities.

By adding the freelancers, the network of stakeholders increases and with this the risk of missed parcels because of the multitude of hands involved. LogisticsX can

guarantee to stakeholders, transparency and traceability thanks to the decentralized system that allow for timestamping and real-time location tracking. Users can check the dApp to see the position of their parcels because the dApp will write to and read from the blockchain through secure RPC/IPC/API calls.

Table 12 LogisticsX's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Introduction of freelancers as "last leg" delivery	LogisticsX network based on a blockchain layer	Improved quality and efficiency
Supply chain visibility	Blockchain immutability of registered events, timestamped events and real time location tracking	Transparency

Open Port

It allows domestic distribution in emerging countries in Asia to have a direct and transparent relationship between freight forwarders and carriers. Is a marketplace for the supply of transports, where the carriers publish the rates and collaborate directly with the shippers for the tender (Lim Johanne & Relly Noman, n.d.). They are also assigned independent ratings on the performances based on the data collected in the platform, this allows a higher quality service for freight forwarders and potentially expand the volumes of work to deserving carriers. The purpose of Open Port model is to eliminate dependency on intermediaries and using blockchain to transmit orders, letters of credit, bills of lading and delivery receipts. This push efficiency, transparency and cost saving using an immutable and verifiable distributed register to record shipping documents, events and smart contracts to activate payments. The platform issues its own token utilities to facilitate the exchange of funds between the parties without delay, only when a delivery has been made. They are convertible into fiat currencies. The freight forwarder opens a tender in the marketplace or through the integration of its TMS, it perfects an agreement with the transported with a smart contract generated by OPN tokens, the transported assigns the task to a driver through open port dispatcher. All movements/events related to the shipment (collection, events along the route and delivery) are tracked in the blockchain. On delivery in particular a proof of delivery is issued by the driver, which is authenticated by the retailer, so the carrier can issue an invoice to the freight forwarder. Payments are activated after the pre-set

event in the smart contract takes place. Using digital payments to complete the smart contract, it allows a more efficient use of working capital and more competitive transport rates.

Table 13 Open Port's whitepaper qualitative analysis

Focus	Thanks to	Effect
Rating system	Immutable and verifiable distributed system	Shipping records, documents, events are tracked and visible to all the network
Exchange of money	OPN token	No need of banks intermediation and more competitive transport rates
Automation of events	Smart contract	Smooth the process and exchanges

Origin Trail

Origin Trail is an ecosystem that aims to interconnect global supply chains enabling collaborative and trusted data exchange (Rakic et al., 2017). This open-source project is currently focused on the development of the pilot program in Europe and China. Origin Trail allows a seamless and interoperable exchange of information between multi-organization supply chains. It allows the authentication of products, visibility of the "journey" of the product, efficiency in the recall of batches, freshness for perishable goods, chains of custody with responsibility, support for CSR activities, compliance assurance for the food chain principle "one step back, one step forward". When the Origin Trail protocol receives information from the various stakeholders, it develops a "consensus check" that verifies there is no difference in the information declared. The check on the truthfulness of the information is developed in several steps: each stakeholder must be approved by the one before and by the one after, creating a chain of responsibilities; moreover, a dynamic match is implemented between the various batches of verified information. Other cross-checks can be collected by sensors or external organizations can sell their confirmation.

The information that is entered into the system is encrypted; this is how the integrity of the information is guaranteed. If there is a need to verify that the data has not been tampered with, simply make a comparison with the hash registered

in the blockchain and the new one generated by the same data in the ODN (Origin Trail decentralized network). Origin Trail is based on a graph database, this is because this technical solution allows you to connect different information datasets while maintaining the flexibility of having different connection options between them, in particular it has 3 main advantages (interoperable - it is extensible and modifiable - high performance - fast cross connections - high availability - thanks to distribution). Once the information is entered, it cannot be changed, but more information can only be added to the graph. Each time information is added, a new encrypted hash is generated and stored in the blockchain. This allows you to have a version database that can be later checked and compared. The protocol can distinguish two different types of nodes which are respectively allowed different interactions with the network: data creators and data holders. The former is responsible for injecting data into the network and replicating it in several data holder nodes. For each n data creator node that is involved in a supply chain, there is at least one n + 1 data holder that holds the data replica. All nodes hold a copy of the data graph in their databases this means that in total the minimum replication factor is 2n + 1 where n is the number of nodes involved. In this way the system ensures that the data creator is always inferior to the data holders to minimize the possibility of collusion.

Table 14 Origin Trail's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Seamless and interoperable exchange of verified information	Consensus check	Increased trust and flexibility
Integrity of information	Encryption	Increased security
Creation of a chain of responsibilities	Verifications are made by each actor and also by sensor	Data verification

Partchain

The automotive supply chain network involves multiple participants such as original equipment manufacturers, suppliers and logistic service providers which exchange information, data and money (Miehle et al., 2019). Due to the inherent complexity and data protection specific of this highly competitive original equipment market, the whole supply chain results in a lack of transparency and responsiveness. Each participant has its own database and company-specific data model which turn out to release inconsistent information regarding the history of a component. This results in no common master data, missing standards and compatibility issues that in case of recalls of defective parts require a lot of human intervention.

The focus of PartChain is to provide a decentralized traceability application able to create and share the unique digital twin of a specific component by using blockchain technology. Participants use the mobile app to scan a part and automatically the location and a timestamp is registered in the blockchain to record the history of a part. They developed two smart contracts, the first for the Creation of an order the second for the Delivery of an order. In case of need, original equipment manufacturer or supplier can both create an order and set its conditions such as the quantity required and delivery specs. If the selected supplier accepts the order, scans the QR code in the mobile app and create a delivery contract. Then the logistic operator scans the parts and if they met the predetermined conditions, the ownership moves from the supplier to the logistic operator.

Once arrived in the agreed delivery place, to accept the order the original equipment manufacturer scans the products' QR codes and if the conditions match the order contract, the delivery is accepted and the ownership pass to the OEM, otherwise an error will appear.

Table 15 Partchain's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Creation and sharing of the digital twin of a physical component	Blockchain & PartChain Mobile App	Transparency and responsiveness through the supply chain - Record of parts' history

Security and authenticity	Smart contracts	Record of change of ownership

Provenance

It allows physical products to have a digital twin to prove authenticity and origin, creating a digital 'journey' behind each product (*Provenance Whitepaper*, n.d.). This brings great benefits to society and the environment as it prevents the sale of counterfeit products and double spending.

Information provided to the blockchain is only accepted if it is authenticated through a cryptographic mechanism that allows for proof of identity. Thanks to the blockchain, they can develop a model of the various materials and components from procurement, through production, to final consumption. At any given time, it is possible to know the nature of the various materials and components i.e., what they are, the quality i.e., how they were made, the quantity in which they are available and the owner. This allows the creation of an unbroken chain of custody/ownership, which can be inspected from the beginning at any time.

Producers can have their plants and processes inspected to obtain and use certifications, which will be recorded on the blockchain and authenticated by the certification body, allowing the producer to create the equivalent digital twin to the good acting as an avatar based on the blockchain. The final product is controllable as there is a constraint that an input good must be used for every output good created, just as in the physical world.

To give an example, a certain amount of organic cotton is recorded, then used by production to make the output, and after it is consumed, it can no longer be used. Due to its verifiability, the blockchain provides the same unassailable guarantee as the physical world since the creation of an output good can only take place if an input good has been used.

The link between the physical asset and its digital twin is provided by technologies such as serial numbers, barcodes, digital tags, RFID and NFC, genetic tags, etc., which are linked to the blockchain via a cryptographic hash.

By having the entire life cycle of a product available, the positive effects on the circular economy can be expanded. This system enables a single source of connected, secure and incorruptible information to enable more informed

purchasing decisions along the supply chain and to the end consumer. It is also thanks to this system that the premium cost of fair labour and sustainable livestock farming is recognised.

Table 16 Provenance's whitepaper qualitative analysis

Focus	Thanks to	Effect
Allow informed purchase decision to the customers	Availability and transparency of the entire	Trust on the product journey
Link between physical asset and its digital twin	RFID, NFC, genetic tags, barcodes..	Help to register in the blockchain the events that assets experience

Quasa

Quasa smart platform objective is to create a global marketplace for trade & transport services supported by smart contract and crypto payments (. . *QUASA 1.1. Idea of the Project*, n.d.).

The main focus of Quasa is the substitution of centralized services with blockchain and smart contract in order to put them in a direct relation ensuring transparency, security and cost reductions. Due to the fragmentation of the transportation industry, information flow is not transparent involving problems of trust between stakeholders and consequently increase of costs. With Quasa is possible to register all the actions involved in a deal and with the agreement of all the parties the smart contract automatically perform actions according to the agreements, so problems of trust and transparency are excluded.

Table 17 Quasa's whitepaper qualitative analysis

Focus	Thanks to	Effect
Resolving problems of trusts and transparency	Events registered in smart contracts	The agreed contracts will automatically perform
Elimination of intermediaries	Smart contract and blockchain based platform	Actors in the marketplace can easily interact in a peer-to-peer relationship

Shipchain

ShipChain aims to resolve different problems such as the bad tracking, lack of transparency, uncertainty, middleman markup and misaligned incentives (*ShipChain Whitepaper*, n.d.). The platform that makes use of blockchain and smart contracts aim to improve the tracking and transparency of the supply chain. The signals transmitted by barcodes and RFID integration are registered in the track and trace platform which lays on the blockchain. The encryption of the geographic waypoints turns out to release transparency to all the selected stakeholder involved in the process.

The decentralized brokerage marketplace of ShipChain allow the connection of shippers and carriers. The best solution in terms of optimization of costs and speed will appear to a shipper that need to move goods from one place to another. Furthermore, shippers can place order indicating beginning address, point of arrival, carriers selected, details regarding the shipments ecc. All these information generate a smart contract that will be executed if all waypoints' validations are affirmed.

Table 18 Shipchain's whitepaper qualitative analysis

Focus	**Thanks to**	**Effect**
Waypoint encryption	Blockchain ledger – track & trace platform – barcodes or rfid integration	Transparency
Elimination of middleman (brokers)	ShipChain Marketplace	Carriers can directly communicate with shippers
Tracking and transparency increase	Signals and data are transmitted by barcodes and sensors to the smart contract	Automation of events such as payments
Asset security	Events documentation on the blockchain	Full visibility and fraud and theft reduction

SyncFab

SyncFab aims to connect purchasers, developers, and manufacturers in trusted, more secure and verifiable manufacturing environment (*SyncFab Whitepaper: Decentralized Manufacturing Creating the World's First Peer-to-Peer Manufacturing Supply Chain and Incentivized Token System Adapted for Public and Private Blockchains*, n.d.). Comparison of order histories, production capacities and previous product designs, will link the purchasers needs to the manufacturers without the need of third-party interventions. Through smart contracts in the SyncFab platform, the requirements and the conditions of the purchases are registered and a match with the most suitable solution is ready-made.

The match between purchaser and supplier is the result of a bid process. Purchaser creates a Request for Quotation including all the characteristics and technical details the offer should contain and a tolerance amount of how much they are willing to go over budget. Supplier will have visibility only on the purchaser's budget but not on the tolerance. Besides the RFQ purchasers will add a reward in MFG token for the manufacturer that offer their bid within 24 hours. Manufacturers check the RFQ and make their bids. Bids that exceed the tolerance defined by the purchase will be automatically excluded by SyncFab. By the way to the manufacturers whose offer exceed the tolerance is given the chance to modify the offer during the bidding process. At the end purchasers receive three offer that are considered in line with the RFQ by the algorithm and they can select the winner.

Manufacturers can offer an amount of MFG token on top of their offer that can be seen as a discount for the purchaser.

Smart machines generate live data on the smart manufacturing blockchain that are available for purchasers and manufacturers allowing the tracking and status updated of the parts. In the traditional ERP a lot of manual work is still necessary that is why it results in poor reliability on the last version of the truth. Blockchain gives the possibility to all the participants to be sure on the latest version of the truth because every transaction is validated by the network. Furthermore, the registration of conditions and agreements on smart contracts, allows to automate repetitive processes.

Table 19 SyncFab's whitepaper qualitative analysis

Focus	Thanks to	Effect
Disintermediation and construct of peer-to-peer relationship	SyncFab platform built on blockchain	Peer to peer relationships in a more secure and transparent environment
Isolating recalls in the supply chain	Blockchain layer	Verifiable certainty
Process automation	Smart contracts	Time saving and precision on doing some activities
Real time information on parts production	Machine data feed	Transparency and streamlined information process
Discount proposal	MFG token	Pushes virtuous behaviours guaranteeing a reward in MFG token

The analysis of the whitepapers shows that the start-ups using blockchain can be mainly divided into three categories, those that mainly address the logistics part of the supply chain (9 start-ups out of 16), those that cover the area related to production (6 start-ups out of 16) and one that offers services mainly related to the financial flow of the supply chain.

Thanks to blockchain, all start-ups allow users to benefit from peer-to-peer relationships without the need of relying in intermediaries. In an environment where almost in every case the actors do not know each other and there is a lack of trust between them, the peer-to-peer relationship is enabled and made secure by the fact that all transactions and the entire supply chain, are visible and transparent to all actors in an immutable way, or rather any new status can only be added to the history of events, not overwriting events before; the change is therefore visible to all and to be added to the blockchain there must be the consent of the network.

Secondly, the blockchain serves as a repository of documents. In commercial trade operations, many documents are exchanged between players, but today they are all still mostly on paper, which can potentially lead to the loss of documents and the blockage of goods in port, for example, or to bureaucratic delays in the release of payments between customers and suppliers. The blockchain therefore allows a single repository of documents that is secure, shared and visible to all

stakeholders. Another important point that the start-ups analysed have in common is the function of the blockchain as an event tracker. With the help of GPS, sensors and RFID, it is possible to trace and control the status of goods along their journey. This data feeds the smart contracts that regulate the relationship between the contracting parties, so it is possible to automatically release events such as payments that can only take place when, for example, the goods arrive at the port, checks are carried out and customs clearance takes place.

Start-ups that address their services to the logistical flow of goods mainly propose themselves as a marketplace for matching supply and demand of logistics services based on a blockchain layer. Trading relationships are enhanced through algorithms that allow for efficient transport and service efficiency. The exchange platform allows the service buyer and the service provider to agree on the terms of the deal and to settle it through a smart contract, which keeps track of all the events that take place in the transfer of goods. This allows two unknown actors who do not trust each other to trust the blockchain layer and the contract so to make an agreement without the need to rely on third parties.

The fact that actors' behaviours are visible on the blockchain also allows platforms as OpenPort to give ratings for virtuous behaviour, which gives visibility to those who provide the best services and thus can potentially increase their customer base. Others, such as LaneAxis and SycFab, offer rewards in the currency of the start-up to reward partners who verify documentation rather than performance discounts given with the platform's currency. Only one case, Axens, the supply chain finance provider, was found to be able to tokenize loans and make them tradable in the network thanks to the decentralized structure of the blockchain, thus making liquid an asset that is not liquid by nature and minimizing the risk for lenders as it is divided into smaller parts.

In the case of start-ups that provide blockchain solution for the procurement of components and production, benefits are founded in the use of smart contracts. The physical asset is matched with its digital twin, recorded on the blockchain which, thanks to the connection between stock calculation algorithms and the connection to smart contracts, is able to issue supply orders. This addresses the fact that in most cases there is an asymmetry of information between the manufacturer and its suppliers of semi-finished products or components and allow

to automate processes that today are done mainly manually with a huge effort in terms of resources (both financial and human). Furthermore, the fact that a physical asset is matched by its digital twin makes it possible to verify products and manage recalls of defective or unhealthy products, thus guaranteeing the end consumer safety and transparency in the product's supply chain.

Table 20 Blockchain functions detected in the start-ups analysis

		Blockchain function										
		Trust between participants without central authority	Transactional e operational costs reduction	Tokenization of financial assets	Events tracking	Repository of documents	Product verification	Speed up the payments process	Process optimization	Reward to virtuous behaviours	Ratings provision	Marketplace for services exchange
Supply chain Finance	Axens	X	X	X	X	X			X			
Logistic Area	Cargocoin	X	X		X	X		X	X			X
	CargoConX	X	X		X	X		X	X			X
	CargoX	X	X		X	X		X	X			X
	Immla	X	X		X	X		X	X			X
	LaneAxis	X	X		X	X		X	X	X		X
	LogisticsX	X	X		X	X		X	X			X
	Open Port	X	X		X	X		X	X		X	X
	Quasa	X	X		X	X		X	X			X
	Shipchain	X	X		X	X		X	X			X
Production area	SyncFab	X	X		X	X	X		X	X		
	Chronicled	X	X		X	X	X		X			
	E-Halal	X	X		X	X	X		X			
	Origin Trail	X	X		X	X	X		X			
	Partchain	X	X		X	X	X		X			
	Provenance	X	X		X	X	X		X			

6. Business case of blockchain applications pilot projects

6.1 Case study 1: Scamosceria Astico

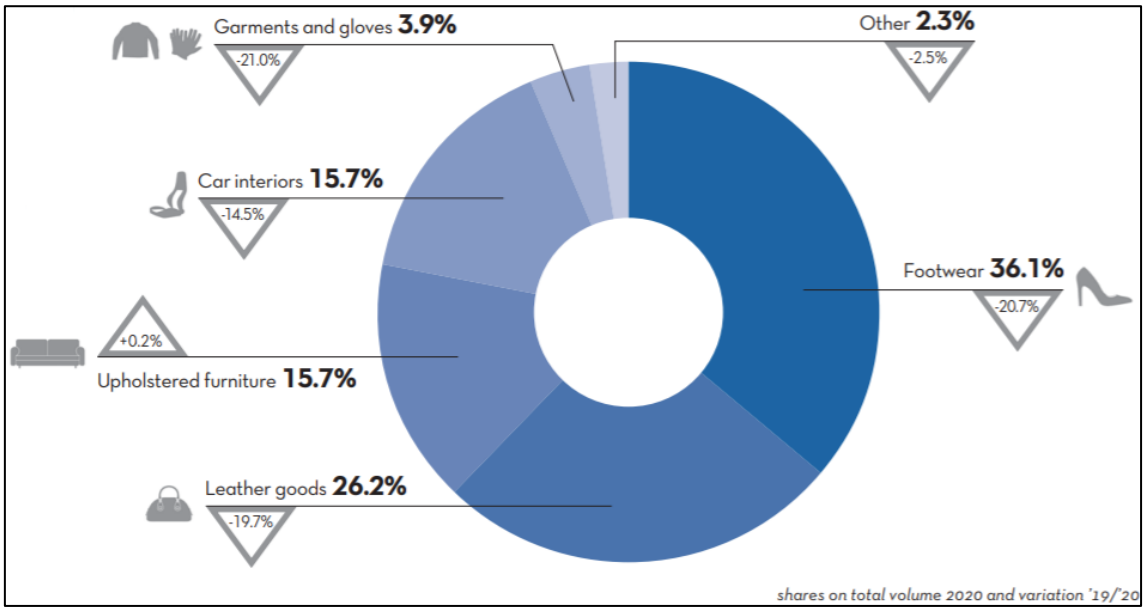
Case study 1 related to Scamosceria Astico is organised as follows: in paragraph 6.1.1 there is an overview of the Italian tanning industry, to continue with paragraph 6.1.2 in which the processes related to the leather industry are analysed at macro level, it is necessary to understand its peculiarities and difficulties as well as to identify the actors involved in the supply chain. In section 6.1.3 a brief overview of the Astico company and in section 6.1.4 we enter into the heart of the blockchain project that the company is implementing.

6.1.1 The Italian Tanning Industry

From the UNIC[11] report, emerges that in 2020 the Italian tanning industry involved 1,165 companies with 17,274 employees and the total value of production was 3.5 billion euros, of which 2.5 billion euros were for exports. The tanning industry serves several manufacturing industries, in first place there is footwear, which is the destination of 36.1% of total tanning production, followed by leather goods with 26.2% and car interiors and furniture both at 15.7%, see the Figure 21 below.

[11] UNIC, Unione Nazionale Industria Conciaria (National Union of the Tanning Industry) is the world's most important association for companies operating in the tanning industry. It was founded in 1946 to protect and promote the interests of the industry. Its aim is also to promote innovation and to enhance the social and environmental role of the industry.

Figure 21 Production by destination use



Source: (UNIC Concerie Italiane, 2021)

The Italian tanning industry, as well as being considered a world leader in terms of value and level of internationalisation, is also recognised for its high levels of technological and qualitative advancement. The Italian tanning industry is also an excellent example of a district model.

In particular, in Italy is possible to identify three districts: the Veneto district, the Tuscan district and the Campania district. The Veneto district, to which the company in the case study belongs, is the most important in Italy in terms of production and number of employees. The companies belonging to the Veneto district are both medium-small companies and large industrial groups. In terms of production, the Veneto leather production is mainly focused on bovine hides and skins mainly destined to customers in the automotive, furniture, footwear and leather goods sectors. The Tuscan district, on the other hand, is home to the largest number of companies and is characterised by a high level of craftsmanship and production flexibility. The production of this district is in fact destined for the haute couture sector as the leathers processed are from small to medium-sized bovines. Finally, the Campania district, with a production value equal to 6% of the national total, is specialised in the tanning of small skins, sheep and goat skins for clothing, footwear, and leather goods (UNIC Concerie Italiane, n.d.).

4.1.2 The production process of tanning skins

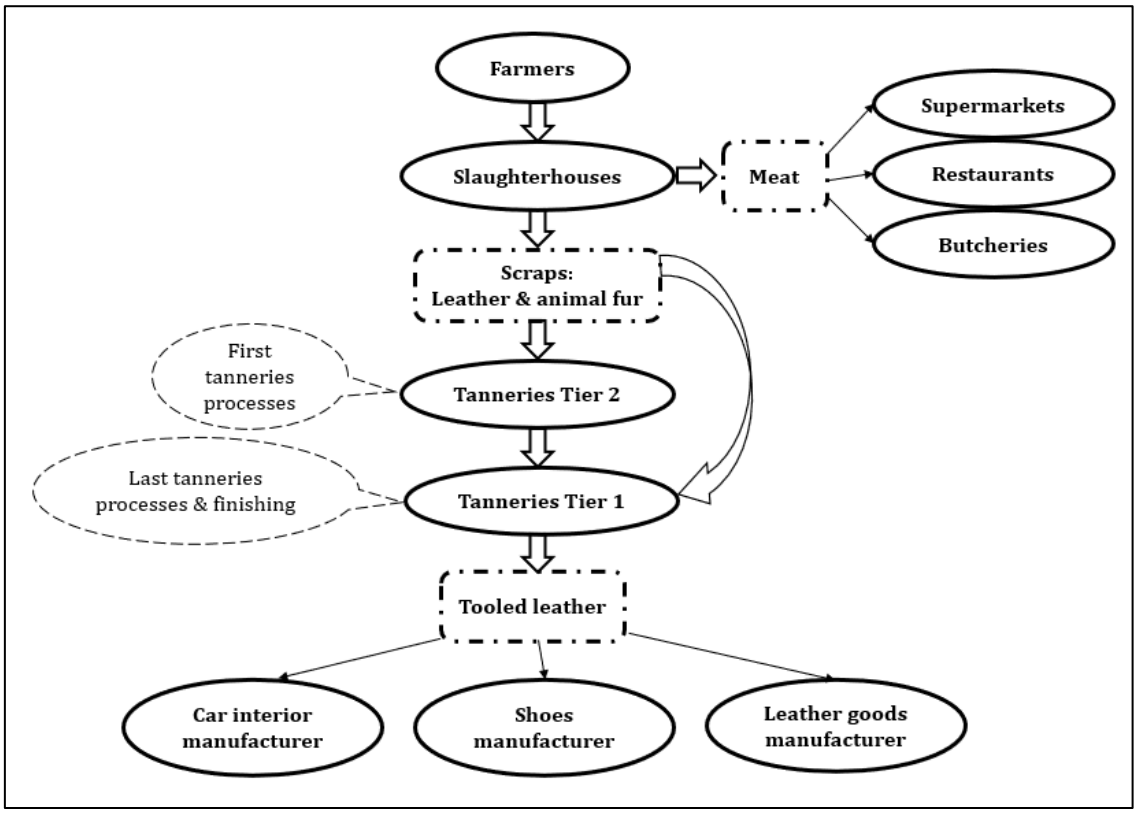
The raw material of the tanning industry, i.e., raw skins, is the result of the waste from the slaughter of animals. The main animal type processed is adult cattle, which accounts for 75% of total production, followed by sheep, goats and calves.

Imports from 119 countries of the raw material are of considerable importance, as they cover 90% of the industry's needs. Most of the imported volumes, 52%, refer to raw hides, while 47% are semi-finished hides, also called "wet blue", and the remaining small part, 1%, is covered by another semi-finished product called "crust" leather.

The main operations affecting the skin before tanning are slaughter, skinning and conservation. These first operations can take place at the place of the slaughterhouse if it is equipped or at the place of tyre 1 tannery. If the animal skin is not immediately subjected to the first tanning, usually the so-called chrome tanning, from which wet blue is obtained, it is necessary to subject the skin to so-called “salting” treatment to prevent putrefaction. Salt is introduced to prevents deterioration of the product during the transportation to the tanneries.

Subsequently, the leathers are transported to tanneries tyre 2 that carry out different leather processes before it results to be a product that can be sold to other industries such as the footwear, furniture, automotive industry, etc. See Figure 22 for the leather industry supply chain. The processes to which the leather is subjected mainly involve mechanical processes, which therefore use large machinery and at the same time various chemicals that treat the leather preventing rot without altering its softness and flexibility.

Figure 22 Supply chain of the leather industry



Source: personal elaboration

After this introduction of the tanning industry and the related processes, in the following chapters is analysed Scamoscieria Astico company and blockchain project implementation through the interview to Giuseppe Bettanin, Sales manager of Scamosceria Astico.

4.1.3 Scamosceria Astico: an overview of the company

Scamosceria Astico is a tannery specialized in the treatment of bovine hides and is located in Thiene (Vicenza). The company has been active in the sector since 1951 and is a family business, now at its fourth generation. The hides are treated from the raw to become a finished product. Scamosceria Astico with its finished products mainly serves the footwear, leather goods and automotive industries. It is a company with a strong international vocation that operates over 40 foreign countries with an innovative mindset and in step with the times.

From the table below is possible to see the trend of the company's turnover on three years. Scamosceria Astico, supported a turnover growth of 4.8% from the year 2018 to the year 2019. The trend has reversed with the advent of covid that

has lowered the turnover generated to 7 million euros with a drop of 13%. The number of employees, on the other hand, has remained fairly stable, indeed in 2020 they welcomed a new entry into the company compared to the previous two years.

Table 21 Scamosceria Astico Turnover and Number of employees 2018/2019/2020

	2018	*2019*	*2020*
Turnover	7,800,829 €	8,177,444 €	7,086,573 €
No. of Employees	23	23	24

Source: (*AIDA: Analisi Informatizzata Delle Aziende Italiane*, n.d.)

The innovative mindset of Astico, recently push them to begin a process of change in production management in a lean perspective. The lean transformation project was driven by several factors. Mainly a change in the market was observed, or rather a change in customer demand. A more personalized product is therefore required, product orders are more heterogeneous and of lower quantity. This changes in demand reflect in a more fragmented production. The goal of the project was to obtain a real-time warehouse of semi-finished products, which allowed for greater control and traceability of the products in house. The new configuration has allowed to lower the warehouse stocks making the stock more focused on the needs of production. As a result of the project implementation, a reduction in costs was observed, besides a decrease in production lead time reduction which has therefore permitted a better service and customer satisfaction.

Scamosceria Astico is now continuing its path towards innovation and the continuous involvement of technology in the company. This is how the company is approaching a blockchain implementation project.

4.1.4 Scamosceria Astico and its blockchain pilot project

What has pushed Scamosceria Astico to approach the world of blockchain are multiple factors, including the hot topic of skin traceability. “Acquiring precise and complete data on the traceability of leathers allows us to fully satisfy customer requests” reported Giuseppe Bettanin. According to recent studies, in fact, 60% of consumers require the origin of the skin (Redazione Xtannery, 2018).
The push of the customers is certainly of primary importance. Astico's customers as seen are car interior manufacturers, shoe manufacturers rather than furniture manufacturers. We are therefore talking about a B2B trade model. Clearly, the various manufacturers are pressing to receive from Astico traceable leather to put in their products, because they are in turn driven by the demands of traceability, visibility and originality of the end consumers. The brands belonging to the industries served by Scamosceria Astico play a fundamental role in determining the guarantees and topics in which the company must aim and be responsive. Transparency is therefore required in all the activities that are carried out in the leather production processes.
To respond to these requests for transparency and traceability of the supply chain, tanning companies therefore decide to undergo certifications and audits. It is the company themselves that decide to make their supply chains and the supply of their products more transparent.

Scamosceria Astico since 2018, has in fact decided, also driven by the request of a customer, to be audited by LWG. LWG stands for Leather Working Group[12] and is a non-profit organization responsible for the certifications of leather manufacturing companies. LWG has reached more than 1300 members, such as associations related to the leather industry, tanneries, suppliers of leather raw materials, furniture, footwear and leather goods manufacturers, brands and retailers that sell to end consumers products made of leather, suppliers of chemicals, machinery etc.
LWG has protocols that are updated every certain period introducing increasingly demanding and stringent criteria. The last protocol in force, Protocol 7 came into

[12] LWG was founded in 2005 by well-known brands such as Adidas, Clarks, Ikea, Nike Timberlad and leather manufacturers from all over the world. The goal of the organization is to create standards on the leather industry and safeguard the image of brands, manufacturers, suppliers etc. by protecting them by showing that the companies and productions that are put in place are audited according to standards that grant sustainability, ethics and safety (Leather Working Group, n.d.).

effect in August 2021 and one of the new pillars of fundamental importance is related to traceability. This new protocol will investigate the traceability of incoming materials and the traceability of outgoing materials. By incoming materials, we mean all those flows of physical products such as the raw leather that comes from the slaughterhouse and the document information flow connected to the goods. In particular, the audit verifies whether traceability information can be found. Together with them, is verified the legality of the products marketed (for example for exotic products), materials' origin and controls are made to ensure that the products do not come from areas at risk of deforestation or that the animals have not been mistreated. This protocol also verifies the flow of purchase of materials to ensure that even the most upstream suppliers are certified and that they produce responsibly. The level of traceability is also checked on the outgoing flows of finished good products.

Considering all this issues, Scamosceria Astico needs to set up and prepare its company's infrastructure to be ready to respond to ever higher requests for transparency and increasingly high traceability along the entire supply chain of their products. It is necessary in this context to distinguish between internal traceability, inside Astico plants and supply chain traceability related to most upstream actors. Internal traceability involves a series of internal procedures that allow to trace the batch number to which a piece of leather sold to the customer belongs, it is possible to trace that a certain chemical agent has been applied to that batch and that the material has been purchased from a certain supplier of raw material and transported with a specific number of DDT.

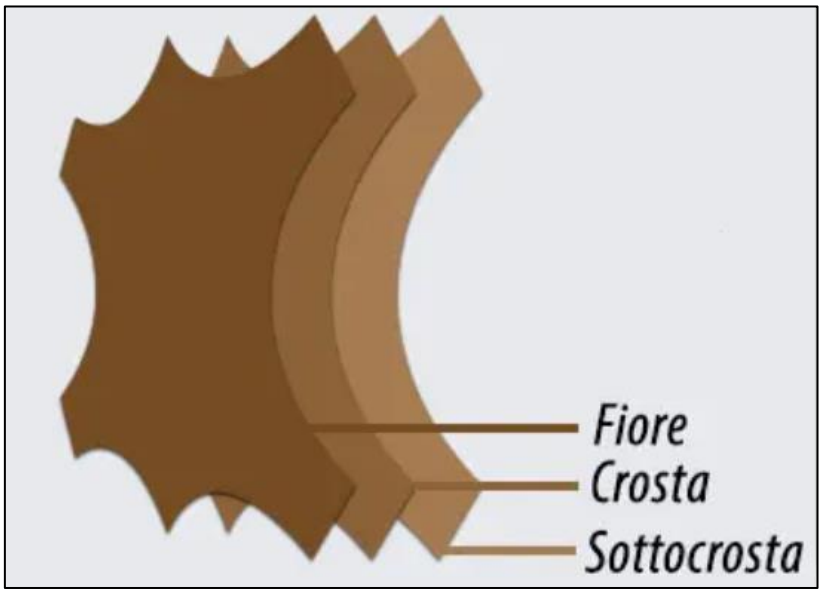
Supply chain traceability, on the other hand, is a process that goes beyond the boundaries of the company. The supply chain, or even the network of actors that belong to a certain supply chain is not composed of a single participant, but as seen in the leather production process, it is the result of different operations carried out by a number of different actors. This type of traceability is also required by the new LWG protocol. The traceability of the supply chain or the traceability up to the top of the product supply chain, allows to find information on the origin and transformations of the leathers. So, for example there is evidence that farms are certified farms, which comply with animal breeding standards, how are carried

over the slaughter processes and subsequently chemicals applied to hides during the process of transformation into finished product.

Scamosceria Astico, now, considers blockchain technology as the technology that the most suits the request for transparency. Moreover, is expected that blockchain will help to consolidate an already existing feeling of trust, guarantee and reliability expressed by the customers. It is therefore expected to be able to validate in a transparent and non-repudiable way the supply chain of the finished leather product. In addition to the benefits on the image and the guarantee of origin, it is also expected to automate and digitize some processes or activities that are still purely manual.

The current situation is that Astico can track the skin in batches. From the invoice they make to their customers they can connect what is the DDT that transported the raw material to them. What Astico cannot reconstruct is what kind of chemical product has been inserted into a leather process and what is actually the path that the skin has made. To understand this step, we need to take a step back. The animal's skin turns out to be a unique piece when in Tier 1 tanneries it is freed from excess animal fur and other waste. The skin is composed by different layers, see Figure 23 and the different layers imply different values in the market. The most superficial part is the most valuable because it is softer to the touch, as you descend towards the lower layers the more the preciousness drops.

Figure 23 The different layers of animal skin



Source: (Wikipelle, 2015)

The leather then after having undergone the first processing activities, is cut and three main types of leather are obtained: the flower, the crust and the under crust, each then inside the tannery can be subjected to different machinery and treatments. This means that the skin of the same animal initially arrives in Tier 1 tanneries as a batch, then this batch is sorted, because after cutting you get mainly three other types of leathers which will then be assembled into other batches and sorted to Tier 2 tanneries to be processed. It is therefore evident that the various processes to which the leather is subjected, and the many actors involved in the processing make it difficult to maintain the traceability of the leather product from the beginning of the supply chain to the end.

Considering all these difficulties, Astico is now mainly starting to map its internal processes. The IT infrastructure and the various production processes are not adequate to manage information and obtain traceability even of internal processes. That's why it was decided to start from inside the company, so to prepare the infrastructure and also the corporate culture that can be ready to implement a new innovation such as blockchain technology. It is therefore scheduled for April of this year the kick-off meeting related to the implementation of a new software that allows you to record the events that happen in production. It is planned to equip each machine in production with screens in which the operator can interact and then record that on a certain batch of material certain processes are being done with certain chemical products.

In parallel, Giuseppe Bettanin from Scamosceria Astico, is going to get more into the details of which should be the platform that will act as a layer for loading the events that take place in production in the blockchain. With this purpose he has contacted Trackgood under advice of a friends of him, Elio Barbera from Caffè Barbera that is analysed in the next case study. Trackgood will help Scamosceria Astico providing software advice and technical help to implement blockchain projects in supply chains. The architecture that they are planning to implement is a public one. The platform that Trackgood will develop and that will act as a layer to the blockchain will also be ready to receive the data and documents that the other actors in the supply chain, before Astico will in turn have to enter. This according to Giuseppe is a problem, in fact he believes that it is difficult to ask his suppliers to make their processes, their data and certifications transparent. He believes that

farmers and Tier 1 tanneries have no incentives to do so. In any case, he thinks that one day this will be the norm and more strongly their customers, therefore the shoe manufacturers etc. require having the leather product traced, in some way even the suppliers at the beginning of the supply chain must adapt to not lose customers.

Before the interview with Giuseppe Bettanin from Scamosceria Astico from which the case study emerged, the participant was asked to answer a questionnaire (reported below in Table 22) sent by email, which then served as an outline for further investigation during the interview.

Table 22 Questionnaire Scamosceria Astico

		Questions	**Answer: YES/NO**
A Technological context	A1 Relative advantage	A1.1 My company expects blockchain technology allows us to do things or work in a way that was not possible before	Yes
		A1.2 My company expects blockchain technology to improve our supply chain physical flow	Yes
		A1.3 My company expects blockchain technology to improve our supply chain physical flow	Yes
		A1.4 My company expects blockchain technology to improve our supply chain financial flow	No
	A2 Complexity	A2.1 My company consider blockchain technology difficult or complex to use	Yes
		A2.2 My company consider implementation process of blockchain technology difficult or complex	Yes
	A3 Compatibility	A3.1 The changes that blockchain could potentially introduce are compatible with my corporate values and beliefs	Yes
		A3.2 Blockchain technology is compatible with	No

		existing IT infrastructure	
		A3.3 Blockchain technology is compatible with existing company's practices	No
	A4 Security concerns	A4.1 My company believes that blockchain may have negative security implications	No
B Organisational context	B1 Top management support	B1.1 My top management is ready to invest a part of the budget in the blockchain implementation project	Yes
		B1.2 My top management views the blockchain implementation project as strategic and capable of giving a competitive advantage	Yes
		B1.3 My top management has analysed and is willing to take risks connected to the adoption of blockchain in the company organisation	Yes
	B2 Organisational readiness	B2.1 I believe that in my company there is an adequate and continuous information flow through all business units	Yes
		B2.2 My company is able to devote financial resources to blockchain implementation project	Yes
	B3 Adequate technical capability	B3.1 My company has adequate IT infrastructure to support blockchain implementation	No
		B3.2 My company has already implemented or will implement blockchain training sessions for its human resources	Yes
		B3.3 My company already has or will get from outside, specialised resources with high-level blockchain-technology related skills	Yes
C Environmental context	C1 External pressure	C1.1 My company experienced pressure to implement blockchain technology	No
		C1.2 My company believes it may be at a competitive disadvantage if it does not implement blockchain technology	Yes

	C2 Partners' readiness	C2.1 My company believes that most of its partners are willing to implement blockchain technology in their own structure	No
		C2.2 My company believes that in 5 years most of its partners have implemented the use of blockchain technology in their company	Yes
	C3 Governments and regulatory framework	C3.1 My company believes that exist, or are expected to be regulated blockchain uses cases in the company's environment	Yes
		C3.2 My company perceives that the existing regulatory framework makes the blockchain implementation process smooth	Yes
		C3.3 My company believes that the government encourages the implementation and use of blockchain technology in companies	No

To the affirmation "A1.4 My company expects blockchain technology to improve our supply chain financial flow" Giuseppe replied negatively. Indeed, he does not expect any improvement in the cash flow, at least not yet. In this questionnaire the financial flow is understood as the part of the supply chain that includes payments with suppliers, international trade, exchange of commercial documents etc. and Astico sees this development as a version two of the blockchain implementation project. Benefits that can also be received in the financial flow such as disintermediation or the possibility to use smart contracts to speed up the flow are acknowledged, but it is not mentioned so far as a priority that deserves attention. Regarding the complexity part of the questionnaire, there is a degree of complexity perceived. It is reflected in the positive replies to the statements: "A2.1 My company consider blockchain technology difficult or complex to use" and "A2.2 My company consider implementation process of blockchain technology difficult or complex". These positive responses to the perceived complexity of the technology and its implementation reflect the early state the project is still in. On the other hand, however, a relative advantage given by the technology is considered, since the statements A1.1, A1.2 and A1.3 were answered positively.

The embryonic state of the project is also demonstrated by Giuseppe's answers (A3.2) in which it is evident that the new technology is not compatible with the IT infrastructure currently present in the company, nor is there compatibility with the practices currently in place (A3.3). As seen in the previous paragraph, it is precisely from here that Astico is starting the project. They are preparing the company to correctly implement the new technology. In fact, as it can be seen in the answers B3.2 and B3.3, Astico intends to create the right environment by doing trainings and training sessions to employees. They will pursue this aim by implement the existing practices and by creating new ones that are compliant with the new technology. In addition, they are aware that it is necessary to find external knowledge and skills related to the new technology because they are not available in house (B3.3).

The fact that Astico is developing solutions to make the organisation compatible with the technology both at infrastructure and human resources level is supported by the fact that the drivers at top management support level (B1.1, B1.2, B1.3) are positive. The top management has allocated a budget for the project and perceives blockchain technology to give a competitive advantage over other companies.

Astico, as already pointed out in the interview, has been receiving pressure since some years now to give visibility, transparency and traceability to the supply chain. The pressure they receive comes from their customers and therefore from furniture manufacturers, car interior manufacturers and shoe or clothing manufacturers. These companies put pressure on Astico because they, in turn, receive pressure from the end user, i.e. the person who, for example, goes to the shop to buy a pair of shoes or a bag and wants to be sure that the product they are buying does not come from farms that have exploited or mistreated animals, or wants to be sure that no harmful chemicals have been used in the tanning process. In any case, Astico responded negatively to statement C1.1, pointing that that they are receiving pressure from outside to sell products with traceability and transparency of the supply chain, but not pressure to adopt the blockchain in specific. Blockchain is the technology that Astico see as the only one that can transparently and immutably trace the path of a product's supply chain. In fact, the non-adoption of technology is perceived as a source of competitive disadvantage (C1.2).

On the other hand, Giuseppe does not feel the environment in his supply chain ready to implement the technology. In fact, he believes that his partners, mainly in the processes before him along the supply chain, are not ready to adopt this technology (C2.1), at least in the near future. By the way, he considers a horizon of five years adequate to already have first implementations at supply chain level. First, it is necessary to get rid of the objective difficulty and find the way to make the physical asset digitizable. In fact, as seen before, the leather undergoes many processes along the supply chain and is also cut a lot of times, so it is necessary to transfer the information that it has gathered so far to the new pieces of leather resulting from the cut.

Furthermore, the government is not seen to be publicising and encouraging the use of blockchain technology (C3.3).

In conclusion, although Astico is sceptical about the readiness of other supply chain players to adopt the technology and is looking for a way to effectively track the leather product, it is confident that the efforts being made at the moment will pay off as by the time the technology will be a standard Astico will already be ready in the market to sell its leathers tracked immutably and transparently through the blockchain.

6.2 Case study 2: Caffè Barbera

Before describing Caffè Barbera case study, is appropriate to outline the Italian coffee market in paragraph 6.2.1. Then is presented the coffee production process and its actors involved in paragraph 6.2.2. To continue with an overview of Caffè Barbera company in paragraph 6.2.3, a little of its history is presented and what are its main company's purposes and vision. In paragraph 6.2.4 we will go into the details of the blockchain project that the company already started to implement.

6.2.1 The Coffee Industry

The origins of coffee can be traced back to Turkey, after which it spread to Europe in 1640 thanks to the opening of a small shop in Venice. This was the first coffee shop on the continent. The method used at the time was the Turkish one and consisted of boiling water in a container, then removing it from the heat and adding ground coffee with sugar and spices as desired. Two centuries later, in 1884, the focus shifted to Turin, with the famous espresso coffee. Angelo Mariondo invented the instant coffee machine. Espresso was thus obtained by roasting and grinding the seeds of Arabica and Robusta, two varieties of coffee. The coffee was obtained by percolating hot water under high pressure.

Coffee is one of the most consumed beverages in the world with over 3 billion cups a day, which leads to generating approximately 200 billion dollars a year. In the last 60 years the market has increased by almost 200%, growth that has been generated mainly by producing countries and emerging countries. This important growth is mainly due to three principal reasons: the first is the demographic growth in the world, which has brought from 5.7 to 7.8 billion people from the first two thousand years to today. The second concerns income, the increase in per capita income leads to greater economic availability to buy goods and services. The third and final motivation can be attributed to cultural transformation. The cause of the lack of coffee consumption in many countries was due to the consumption of tea as the main drink, a clear example is Japan which until 1950 did not consume coffee and today has become one of the largest countries in the world for importing green coffee.

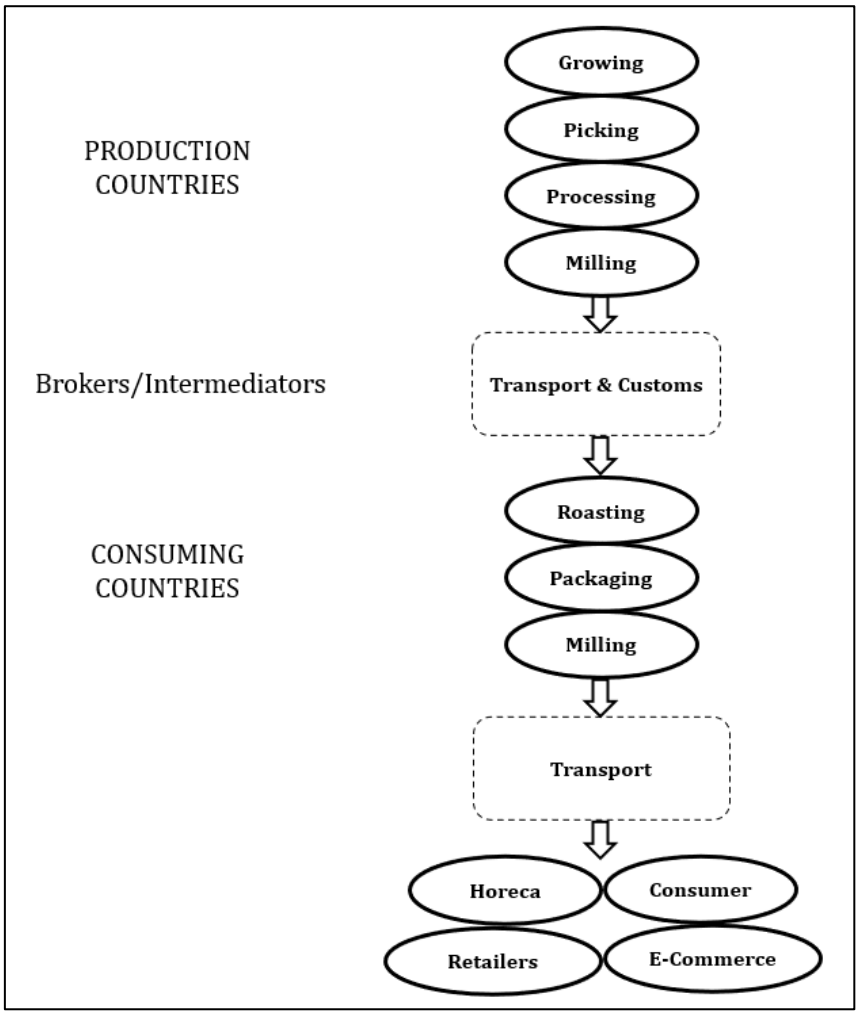
6.2.2 The coffee production process

Today, the largest coffee producer is Brazil. Coffee is a seed obtained from the fruit of plants of the genus Coffea. The main varieties of the coffea plant are coffea Arabica, coffea Canephora, also known as Robusta, and coffea Liberica. The oldest cultivation system is known as shade-grown coffee, which is mainly found in India and Central America. This method consists of planting the coffee plants in the shade of other types of plants, thus protecting them from direct sunlight. Another method called 'intensive' is widespread in Brazil and consists of extensive plantations of coffee only. The harvesting of coffee beans can be done in different ways. According to the industrialisation degree of the countries the harvesting can be done using specialised machines or by hand in less advanced countries. If harvesting is done by hand, we can distinguish between two techniques: "picking", in which only the ripe fruit is picked one by one, and "stripping", in which the fruit is torn off regardless of its degree of ripeness and then separated.

After harvesting the fruit of the coffee plant, some processes take place and different procedures can be followed: the 'washed coffee' process in which the fruit is mechanically stripped and left to ferment in tanks using water, after which the seeds are dried and extracted from the membrane. The second process, 'natural coffee', involves sun-drying the fruit, which, once completely dry, is processed with special machines to extract the seeds. These two processes produce the coffee beans, which are analysed and classified according to their defects, shape, etc. The raw coffee beans are then placed in the famous jute sacks and transferred to the roasting plants, which subject the coffee beans to the action of heat to change their colour, weight and aromatic richness.

Roasters play a major role in determining the unique qualities of a coffee. In fact, the temperature, quantity of aromas, time etc. are unique characteristics defined in the blends of each roaster. After blending, the coffee is then ready to be packaged in different ways: beans, ground, capsules, see the Figure 24 to see the entire coffee supply chain.

Figure 24 Coffee supply chain



Source: personal elaboration

6.2.3 Caffè Barbera: an overview of the company

Caffè Barbera that now has is headquarter in Naples, was founded was founded in 1870 by Domenico Barbera. He started the business with a small roaster in Messina and his skills in roasting coffee soon gave him the nickname of "Magician of coffee". The brand logo in fact, represents a magician that is carry a cup of coffee. Caffè Barbera turns to be the oldest roaster in Italy. The company is now in its sixth generation and combines the tradition of coffee know-how handed over through the generations by the founder with the innovation that the new generations is bringing. Over the years, Caffè Barbera has expanded its range of offer to include several product lines, starting from certified coffee to the supply of coffee machines, merchandising and more. The company also offers guided tours of the factory and training courses to spread the culture and knowledge of coffee. The

company has a proactive attitude towards sustainable development issues, environmental pollution prevention and aim at the continuous improvement of company performance always with a view to prevention and protection of the environment.

The heartfelt environmental theme is combined with social commitment. For Caffè Barbera, implementing sustainable business means combining environmental protection with the principles of ethics and social responsibility, thus aiming at the growth of all the players involved in the value chain and not just the company itself.

The company expanded its business over 65 countries in the world and cover 4 main distribution channels, the first is Horeca[13] which cover the 70% of the turnover, retail business with a chain of coffee shops, supermarkets and e-commerce. Caffè Barbera's business is a fast-growing business, which considering 2021 is closing with 13 million euros of turnover, a +13% compared to 2019 pre-covid and a sharp rise of +37% compared to 2020 when turnover was 9,5 million euros.

Table 23 Caffè Barbera Turnover 2019/2020/2021

	2019	*2020*	*2021*
Turnover	11,500,000 €	9,500,000 €	13,000,000 €

Source: data emerged during the interview with Elio Barbera

[13] Horeca stands for 'Hotellerie-Restaurant-Café' and defines a specific business sector including hotel, restaurant, catering and bar companies. It includes all activities related to consumption away from home, also known as "Away From Home", AFH, are therefore included in this business sector .

6.2.4 Caffè Barbera and its blockchain implementation project

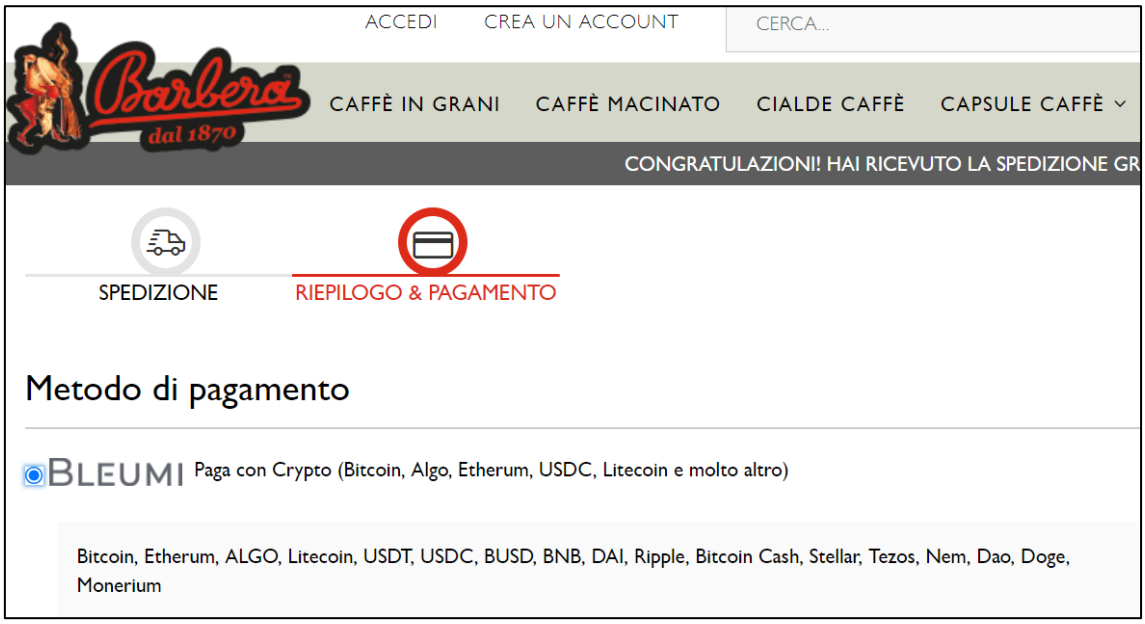
The pandemic caused by COVID-19 has also hit Caffè Barbera very hard, which with 70% of its turnover represented by the Horeca channel has clearly suffered from shop closures. However, the company's strong presence in several foreign countries made it possible to mitigate the overall loss of turnover. During the pandemic, in the year 2020, the company was able to take a rest and rethink its value proposition. They discussed about how to increase sales in channels that were already doing well and projected to grow, such as e-commerce. "The idea of accepting online payments in cryptocurrencies was born, allowing the company to capture new, previously unreached customer niches and thus officially becoming the first European coffee company to accept payments in cryptocurrencies" is reported from Elio Barbera, Managing Director of Caffè Barbera.

The company with this idea in mind, started to look for contacts and information on the possibilities of collaborating with some company that would allow the implementation of the blockchain. At the beginning it was not easy because they contacted several software houses which unfortunately only offered solutions built from scratch and at very high prices (hundreds of thousands of euros just for the software without all the maintenance etc.). At one point, however, they got in touch with Algorand[14] with whom they entered into a partnership and developed a plug-in with the support of Bleumi[15] to enable cryptocurrency payments on their e-commerce sites. In fact, as shown in the picture below when a customer proceeds to make a payment in the online shopping cart, you can select in which cryptocurrency you want to make the payment.

[14] Algorand with its Algo token is a blockchain developed by Silvio Micali, a professor at MIT. This blockchain is based on the pure proof-of-stake consensus method, which means that each token is worth as much as the others and its owner has the same probability as the others of being chosen to add a block. The generation time of a block is very short, in fact a block can be generated every 4.5 seconds. Two-thirds of the tokens agree on the block to be added to the chain and once consensus is reached with a two-thirds majority, the new block to be added will be unique, avoiding the risk of duplication. Decentralisation is guaranteed by the fact that an algorithm causally selects the group of validators. This system allows a scalable and also sustainable speed since the energy consumption for the various operations is really minimal, much lower and more efficient than proof-of-work based blockchains (Cimminella Marco, 2021).

[15] Bleumi is a crypto and traditional payments orchestration platform (*Bleumi*, n.d.).

Figure 25 Caffè Barbers's payments method with cryptocurrencies



Source: (*Caffè Barbera Online Shop*, n.d.)

Algorand was chosen mainly for two reasons: first, for the speed and transaction process that for an e-commerce is crucial and then for the cost of the transaction extremely low (few cents) compared to other blockchain.

This initial move of allowing the payments in cryptocurrencies, opened the door to the project of implementing blockchain technology in Caffè Barbera's supply chain. The company's entire supply of raw materials is now recorded and tracked immutably in the blockchain.

In collaboration with Trackgood, that was already mentioned in Scamosceria Astico's Case Study, a project was started to trace the supply chain of Caffè Barbera. The project began with the focus on three products mainly single origin. The single origin was a discriminating factor in the choice because they were best suited to be the subject of a prototype since in a single origin supply the complexity is not so high. These first three products are Clean Up Cup blend, Blue Baron Java and Ethiopia Sidamo.

Actually, if a customer searches for one of these three products in the Caffè Barbera e-commerce site, the screen shown in Figure 26 appears.

Figure 26 Clean Up Cup blend page on Caffè Barbera's e-commerce

Source: (*Home Clean Cup Blend - 100% Arabica - Caffè Barbera*, n.d.)

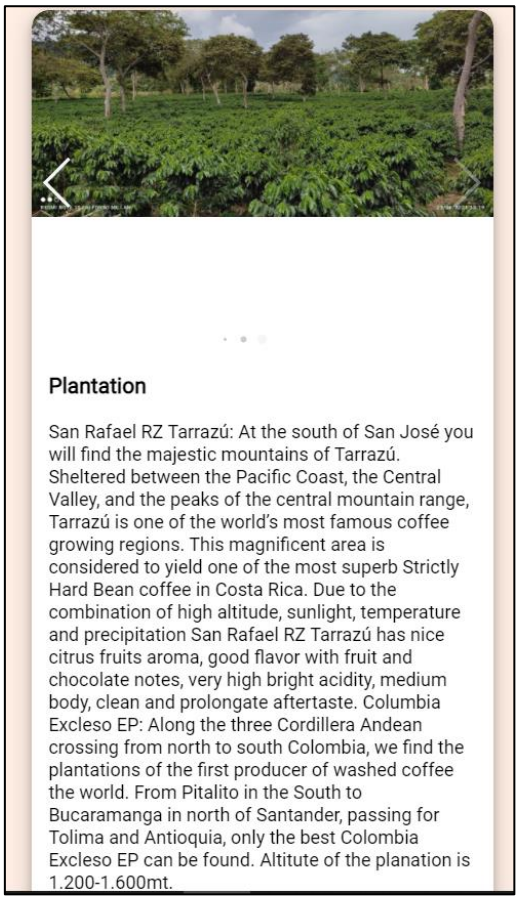
If you click on "Click here to find out more about this product", another page opens redirecting you in the landing page of Truckggod.io where you can find all the details related to the product, Figure 27. The information in the web page is related to the mixture description, the google map image of where the plantations are located, the process to which the coffee beans have been subjected and the documents related to all steps in the supply chain. What is interesting is that this information and related documents are encrypted and loaded with a hash into the blockchain in an irreversible and immutable way.

Figure 27 Trackgood.io Clean Cup Blend products details traced on the blockchain

Source: (*Your Product Has a Story - Clean Cup Blend - 100% Arabica*, n.d.)

After the description of the product, you have visibility of the processes and actors that are involved in that supply chain. So, the page starts with the information that introduces where the coffee bean comes from, i.e. from which plantation comes from, Figure 28.

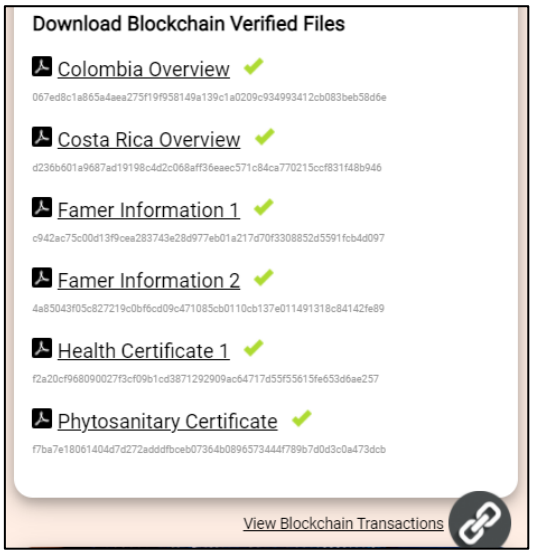
Figure 28 Plantation where Clean Up Blend comes from



Source: (*Your Product Has a Story - Clean Cup Blend - 100% Arabica*, n.d.)

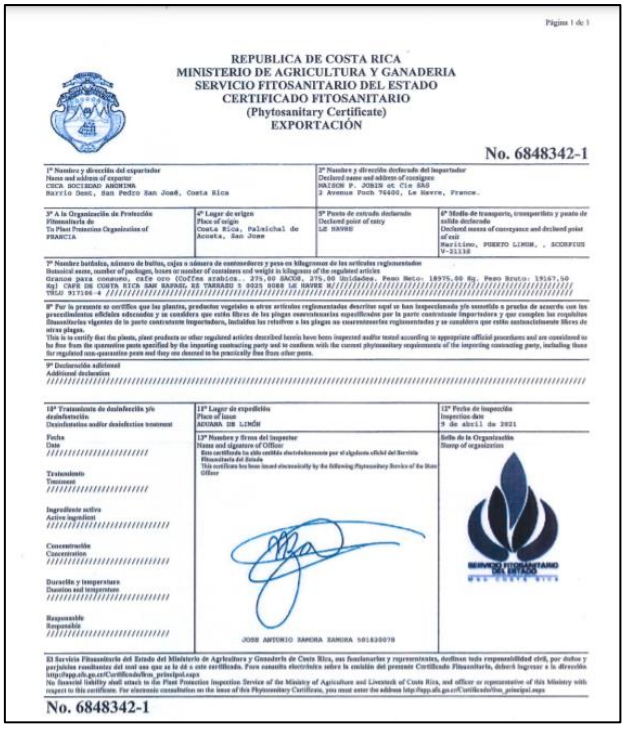
Then scrolling the page down a customer can have visibility of which documents are related to that part of the process, Figure 29, such as an overview of the country, farmer's related information, health and sanitary controls and checks ecc.. and even checking them, in the Figure 30 an example of document reporting the Phytosanitary Certificate.

Figure 29 Clean Up Blend related documents registered on the blockchain



Source: (*Your Product Has a Story - Clean Cup Blend - 100% Arabica*, n.d.)

Figure 30 Phytosanitary Certficate of Clean Up Blend


REPUBLICA DE COSTA RICA
MINISTERIO DE AGRICULTURA Y GANADERIA
SERVICIO FITOSANITARIO DEL ESTADO
CERTIFICADO FITOSANITARIO
(Phytosanitary Certificate)
EXPORTACIÓN

No. 6848342-1

No. 6848342-1

Source: (*Phytosanitary Certificate of Clean Up Blend*, n.d.)

The information on the coffee's journey from the plantation to the doors of the roasting plant will be public and certified, with no possibility of counterfeiting thanks to the blockchain protocol adopted. Moreover, it will be validated through a

cryptographic hash that will confirm its authenticity. In the next months, all Caffè Barbera products will have their own QR Code in the packaging.

In the current state, it is Caffè Barbera that retrieves all the documents and uploads them in the blockchain, also paying the related upload fees. This solution currently implemented by Caffè Barbera therefore allows to start making the supply chain transparent, even if not totally in a decentralized way, because Caffè Barbera is the only subject to make information public also for other subjects.
This is the real challenge, that is to make sure that all the actors in the supply chain will upload autonomously and independently the documents of their competence in the blockchain. With this aim, Caffè Barbera is therefore working to equip the actors of the supply chain with an app jointly developed with Trackgood that allows each actor to take a photo or scan a document and directly upload the data in the blockchain. However, it is difficult to persuade and maintain this routine in the downstream actors of the chain as the benefit of doing these actions is not already perceived today.

Before the interview with Elio Barbera, Managing Director of Caffè Barbera, from which the case study emerged, the participant was asked to answer a questionnaire sent by email, which then served as an outline for further investigation during the interview.

Table 24 Questionnaire Caffè Barbera

		Questions	**Answer: YES/NO**
A Technological context	A1 Relative advantage	A1.1 My company expects blockchain technology allows us to do things or work in a way that was not possible before	Yes
		A1.2 My company expects blockchain technology to improve our supply chain physical flow	Yes
		A1.3 My company expects blockchain technology to improve our supply chain physical flow	Yes
		A1.4 My company expects blockchain technology to improve our supply chain financial flow	No
	A2 Complexity	A2.1 My company consider blockchain technology difficult or complex to use	No
		A2.2 My company consider implementation process of blockchain technology difficult or complex	No
	A3 Compatibility	A3.1 The changes that blockchain could potentially introduce are compatible with my corporate values and beliefs	Yes
		A3.2 Blockchain technology is compatible with existing IT infrastructure	Yes/No
		A3.3 Blockchain technology is compatible with existing company's practices	Yes
	A4 Security concerns	A4.1 My company believes that blockchain may have negative security implications	No
	B1	B1.1 My top management is ready to invest a part of the budget in the blockchain implementation project	Yes

B Organisational context	Top management support	B1.2 My top management views the blockchain implementation project as strategic and capable of giving a competitive advantage	Yes
		B1.3 My top management has analysed and is willing to take risks connected to the adoption of blockchain in the company organisation	Yes
	B2 Organisational readiness	B2.1 I believe that in my company there is an adequate and continuous information flow through all business units	Yes
		B2.2 My company is able to devote financial resources to blockchain implementation project	Yes
	B3 Adequate technical capability	B3.1 My company has adequate IT infrastructure to support blockchain implementation	Yes
		B3.2 My company has already implemented or will implement blockchain training sessions for its human resources	No
		B3.3 My company already has or will get from outside, specialised resources with high-level blockchain-technology related skills	Yes
C Environmental context	C1 External pressure	C1.1 My company experienced pressure to implement blockchain technology	Yes
		C1.2 My company believes it may be at a competitive disadvantage if it does not implement blockchain technology	Yes
	C2 Partners' readiness	C2.1 My company believes that most of its partners are willing to implement blockchain technology in their own structure	No
		C2.2 My company believes that in 5 years most of its partners have implemented the use of blockchain technology in their company	Yes
	C3 Governments and regulatory	C3.1 My company believes that exist, or are expected to be regulated blockchain uses cases in the company's environment	Yes

	framework	C3.2 My company perceives that the existing regulatory framework makes the blockchain implementation process smooth	Yes
		C3.3 My company believes that the government encourages the implementation and use of blockchain technology in companies	No

What emerges from the questionnaire is that the relative advantage is perceived positively, except for point A1.4 where the company does not perceive that there will be advantages at the level of financial flows, at least not in the immediate future and in B2C relations.

Caffè Barbera does not perceive the technology to be complex or difficult to use, nor does it perceive the implementation process to be complex (A2.1 and A2.2), because implementation on some products has already started. While technology is perceived as completely compatible with the corporate culture, it turns to be not completely compatible with the company's IT systems and infrastructure, A3.2 in fact, a study of the IT infrastructure and a review of it was implemented with the help of Trackgood. As the implementation of the cryptocurrency payment system on Caffè Barbera's e-commerce only required the supplement of a plug-in to the payment platform, internal software and IT systems needed to be subjected to some changes, some of them substantial, in order to better manage the traceability of the coffee supply chain with blockchain.

At the level of top management support and organisational readiness the company was positively positioned, in fact there were no obstacles or opposition to the implementation of the project, on the contrary, it was fully supported by allocating financial resources to it. Regarding point B3.2, Caffè Barbera has not implemented and does not intend to implement, at least in the near future, training sessions or workshops to spread the knowledge of the new technology to the human resources of the company. The employees of Caffè Barbera are just informed and aware of the implementation of the new project and it is seen by them with curiosity, however they do not have an active participation, because the whole project has been followed and will continue to be followed by Elio Barbera.

This is because, until now, no implementation of traceability of internal flows at Caffè Barbera has been carried out, but it is something that is being considered as a must to do in the near future. For now it has been decided to start to trace processes and data upstream in the chain and then continuing along it. On the other hand, however, the company has hired external experts (B3.3) in blockchain technology, such as the Algorand and Trackgood teams to receive support and technical indications.

The point related to the external pressure is also completely positive, in fact Elio Barbera reported that the company perceived a strong demand from the end customer to have visibility on the supply chain of its products (C1.1). Elio Barbera said: "Thanks to the implementation of a decentralized blockchain protocol able to validate our precious supply chain and demonstrate to our consumers the long journey of coffee, from the plantation to the cup, we have emphasized an aspect that is fundamental for us: to make known to everyone the positive impact that a shared policy between all the actors in the supply chain can have on society and the environment".

As regard to its relationship with competitors, the company now feels it has a strong point compared to other companies in the industry (C1.2). They therefore feel that they have a competitive advantage because of being a pioneer in the field in Europe to implement the technology. On the other hand, however, Caffè Barbera recognizes that new technologies are around the corner and therefore they think that it will not take too long for other companies in their field to adopt the technology, at which point the blockchain implementation in supply chain will be a standard.

The point that Elio Barbera also underlined the most during the interview is the perplexity regarding the readiness of his partners in the supply chain to implement the technology also in their internal structure (C1.2). Elio's current main purpose is to convince and push the actors before him in the supply chain to be autonomous to feed, with the documents and data of their competence, the flow of the supply chain in the blockchain. Related to this, it has already developed an app with Trackgood that will be made available to growers to facilitate them in this process of uploading data directly into the blockchain. Clearly Elio is aware that the actors at the beginning of the supply chain do not perceive benefits related to

the effort to make their data and the processes transparent and traceable That is why Caffè Barbera is working on an incentive mechanism to reward the actors of the supply chain to make an effort and publish making visible the documents and the coffee journey.

Still analysing the readiness of Caffè Barbera's partners to adopt the technology, according to Elio, another barrier that prevent the adoption is also the still very low level of knowledge and information on blockchain technology. In any case, there is confidence that within five years the knowledge will spread, and many companies will be able to perceive the benefits and consequently implement blockchain adoption projects (C2.2). Caffè Barbera also places enough trust in the government environment and the regulatory framework (C3). In fact, it is believed that in the near future the uses of blockchain technology in the company will also be recognized and protected from a regulatory and governmental point of view. The only drawback is that there is no perceived real active push by governments to innovate and digitize the business environment with technologies such as the blockchain (C3.3).

To conclude, in this Chapter 6, two case studies of two companies operating in different sectors were analysed. As can be seen, Scamosceria Astico and Caffè Barbera, respectively, are analysing and have already implemented a blockchain application project in their supply chain. Referring to the start-ups analysed in Chapter 5, is possible to place the case studies in the use cases related to the production and procurement of materials. To study the implementation project, they are both supported by Trackgood, a company that can be compared to the six analysed in the start-ups and categorised in the production area's use case.

The main benefit found both in the analysis of the start-ups and in the case studies is that blockchain allows to increase the transparency of the supply chain, thus making products more reliable in the eyes of the final consumers. Less prominent in the case studies, however, is the benefits given by the transparency of the supply chain to automate and regulate relationship between supply chain actors. Therefore, in the interviews carried out there was no mention of the possibility of automating some manual processes such as issuing automatic orders registered in

smart contracts or automatically issue payments once a pre-determined state occurs in the contract.

It emerges that the main reason for adopting the blockchain for Scamosceria Astico and Caffè Barbera is attributable to the need of the end customer to have visibility and transparency and not on the optimization or automation of internal processes, at least for now.

On the other hand, is possible to find some correspondences in the functions of the blockchain as allowing to track events, as document repository and product verifiability, found as benefits both in the whitepapers of the start-ups and in the case studies of the two companies. Caffè Barbera, however, benefits like SyncFab from the fact that it can somehow remunerate the actors of the network for virtuous behaviours, however this solution is currently still under study.

It is therefore clear that in the real case studies analysed, only the primary benefits of blockchain are perceived, such as to allow transparency and traceability of products. It is probably necessary to leave them the time to progress in their implementation projects and wait the technology start to spread in the other companies' supply chain in order to fully take advantage of all the benefits that can guarantee the implementation of blockchain projects.

7. Conclusions

From the analysis just concluded, it is possible to state that there are many pain points that plague supply chains nowadays that can be solved through the use of blockchain technology thanks to its properties.

The analysis of the whitepapers of some start-ups has made it possible to map what are the main benefits that arise from the use of blockchain as a basis for the provision of services. Some of the benefits that can be mentioned includes the possibility of eliminating the presence of intermediaries such as banks and authorities. This is made possible through the digitization of documents and their related publicity in an immutable ledger such as the blockchain. Also, thanks to the use of complementary technologies such as IoT, sensors, RFID, and barcodes it is possible to monitor the status of assets and the recording of events in the blockchain, from which smart contracts can automatically release subsequent events once statuses have been verified thus decreasing paperwork and lead time to carry out international trade. The main benefits found in the analysis of whitepapers refer to greater transparency of the supply chain, elimination of third parties that slowed down processes and reward mechanisms intended for those who perform virtuous behaviours.

The analysis of the case studies of two real companies, specifically Scamosceria Astico and Caffè Barbera, has allowed to touch what are the motivations that led two companies to start a blockchain implementation project in their companies, as well as understanding what are the difficulties they are experiencing and benefits they will have.

As can be deduced from the case studies, it is immediately clear that while Scamosceria Astico is still at the beginning of the project, Caffè Barbera is already at a more advanced state of the implementation of blockchain technology in its business model. Giuseppe Bettanin, from Scamosceria Astico, began to think about using blockchain to track his products as a possible solution to the requests for traceability and transparency made by his customers under the advice of Elio Barbera, who had already started working on his project of blockchain implementation.

This is a real and practical example of what (Rogers, 2003) said about the importance of the network in spreading an innovation. In fact, Giuseppe Bettanin does not yet fully know how to actually implement the technology and has found in Elio a support and a source of information to understand how to start the project as well as to which external companies ask support and partner with to implement the project, such as Trackgood, already known and tested by Caffè Barbera.

The two projects have in common that they both leverage blockchain technology primarily to track their own supply chain in the blockchain. The benefit that derives from it and shared by both companies is that the blockchain allows to track events and data in an immutable and visible way to all stakeholders who have an interest in knowing the data and processes of the supply chain, first of all their customers.

Caffè Barbera having allowed payments in cryptocurrencies, has also exploited the benefit given by blockchain technology to eliminate third parties such as banks. The benefits received are attributable to the achievement of niche of customers not previously reached, that is, the crypto and coffee addicted; in addition to the possible economic benefit deriving from the lower fees that are asked for allowing payments in cryptocurrencies in the e-commerce site compared to the traditional fees required by payment systems such as PayPal, Visa etc.

Caffè Barbera has been able to experience this benefit given by blockchain technology because in its business model there is the B2C sales channel. It is believed, in fact, that the individual consumer is more prone to experience payments with cryptocurrencies rather than companies, which are still skeptical about the implementation of these types of payments in B2B relationships.

What is interesting to note is that while Caffè Barbera has begun to trace the coffee supply chain starting from the upper side, thus from the growers and the first processes of the chain and later will look at its internal traceability, Scamosceria Astico is first starting to fix its internal side before looking at the processes before them.

In any case, the main difficulty reported by both respondents is that of being able to convince the other actors in the supply chain to make public their documents and the processes for which they are responsible. In fact, it is possible to deduce that the higher you go upstream of the supply chain, the less the request for

traceability is perceived by the end customer and the less the benefit that can be derived from satisfying this request for traceability and transparency is perceived.
This is therefore the main challenge of actors such as Astico and Caffè Barbera: to be able to convey the need of the end user up to the upstream of the supply chain. It is therefore necessary to democratize the supply chain by placing all participants at the same level, thus favouring the creation of a true ecosystem in which the roles of each actor are balanced and that the benefits are not perceived only by a privileged few. This process of democratization of the supply chain and widespread benefit could be guaranteed by a reward mechanism addressed to those actors who make the information related to their added value reliable and accessible to all the actors concerned.
After this analysis it is therefore possible to suggest to other companies interested in starting a blockchain implementation project within their business model, to first map the current state of their supply chain and their internal organization infrastructure and then understanding what are the benefits that can derive from an implementation of blockchain technology. It is also advisable to start the project by applying it to a couple of products or focus on only a part of the supply chain processes to implement the technology step by step so as not to risk investing large amounts of money and then not getting anything concrete. At the end of this thesis is possible to state that although in some industry it is been discussed about the implementation of the technology on the supply chain and there are also concrete cases of application, the perceived and known advantages that the technology is able to give are still very few and it is clear that it is necessary to wait a few more years before we can see precisely what are the greatest benefits of the application of blockchain in supply chains.

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