# POLITECNICO DI TORINO

## Facoltà di Ingegneria

Corso di Laurea in Ingegneria della Produzione Industriale e dell'Innovazione Tecnologica

## Tesi di Laurea

# Blockchain Implementation in Supply Chain Management.

# Case study on an E-Commerce Food Retailer.

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# 1. Abstract

The "Amazon effect" has revolutionized supply chain management and created new requirements for any industry in terms of efficiency, speed, traceability and customer satisfaction. Companies are struggling in all industries to keep up with these new challenges. The key capability is to be able to deliver the right information to the right people at the right time for decision-making purposes. New technologies are now available to further improve supply chain management in terms of data availability, from cloud ERPs to blockchain technology. This study will focus on how blockchain can be used in Supply Chain Management to address challenges that have not yet been solved, with specific focus on Inbound Supply Chain issues in retailers. A business case study is presented to analyze blockchain implementation in a food e-commerce retailer.

# 2. Goal and Research Questions

The purpose of this study is to highlight the changes and new challenges that E-commerce brought to Supply Chain Management, its consequences and the positive impact that new technologies, such as blockchain, can have for companies in the revolutionized retail business. The study was conducted thanks to a combination of personal experience from past internships in Supply Chain in P&G (Madrid) and Amazon (Munich), a deep literary review and recent news analysis, along with two personal interviews with Blockchain Researchers at TUM, **Andranik Tumasjan** (12th September 2017, TUM Building 5, Munich, Germany) and **Ulrich Gallersdörfer** (14th September 2017, TUM Informatik Building, Garching, Germany).

An initial understanding and analysis of the topic led to the formulation of research questions that were answered in this study, before presenting a business case to assess the implementation of blockchain technology in an e-commerce retailer.

Q1: What is the E-Commerce revolution? How did it impact supply chain management? What are the newly born challenges and which previous ones still remain?

Q2: How can technology support companies to further improve the efficiency of their supply chain and lead to a Digital Supply Chain or Network?

Q3: What is the role of Blockchain in this panorama?

## 3. The E-Commerce Revolution

It was already in the 1960s that businesses started using primitive networks to exchange business documents, such as order forms, invoices and shipping confirmations, across EDI (Electronic Data Interchange). The technology was inspired by the military ARPAnet, used to ensure that crucial communications were circulating in time. In 1979, the American National Standards Institute (ANSI), further improved this system introducing a universal standard regarding the format of the business documents, ASC X12. The greatest networking evolution arrived around 1982, when the military ARPAnet was transformed into TPI/IP (Transmission Control Protocol and Internet Protocol). Not long later, individual computer users could access email services and share documents over networks and the first browsers appeared when hypertext-based information was proposed by “WorldWideWeb”. In 1994, the first services for processing online credit card sales appeared thanks to companies like

Virtual and CyberCash. In 1995, Verisign entered the market and focused on encrypting and securing e-commerce servers. (1)

In this context, Jeff Bezos incorporated Amazon.com in 1994 and delivered the first book ever sold on Amazon.com in 1995. His motto was “Get Big Fast”, the slogan he printed on the first employees’ t-shirts. By December 1996, Amazon reached 180.000 customer accounts after only one year of operation, and by October 1997, the number boosted up to 1 million. In May 1997, less than 2 years after opening its “doors” to customers and not having made any profit yet, Amazon.com became a public company, quoted on the Nasdaq market. Revenues started jumping up year per year and Jeff Bezos was elected Person of the Year by the Time magazine in 1999. At first it was books, then, by 1999, it was also music and videos, consumer electronics, software, home improvement items, toys, games, and much more. When he founded the company, the strategy was to not carry any inventory. Things changed when the obsession for great customer experience led to the need of achieving more control over deliveries. So in 1997, Amazon.com began holding inventory in its own warehouses. In 2000, it started offering a service to smaller companies and individuals to support them in selling through Amazon.com and in 2006 the Fulfilment by Amazon program saw the light as a further improvement of the previous service. (2)

At the same time, in September 1995, Pierre Omidyar, created AuctionWeb, an online marketplace now known as eBay, in just one weekend. He sold a broken laser pointer for 14$, and started a popular marketplace, in which sellers listed all sorts of objects. In 1997, the name officially changed to eBay and the one-millionth item was sold. Its expansion across the world began in 1999, launching in UK, Australia and Germany. (3)

In 1999, on the other side of the world, Jack Ma founded Alibaba Group, with the initial intention of helping Chinese exporters, manufacturers and entrepreneurs to sell internationally. It is today more successful than eBay, Amazon and all the US retailers put together, selling in fiscal 2016, $485 billions of goods on its online marketplaces, which is 42% more than the $341.7 billions that US online retailers sold for in 2015. (4)

With eBay and Amazon now taking over all the western countries, Alibaba dominating the Chinese market and the surrounding areas and growing businesses like Jumia, part of the Rocket Internet group, in African countries, e-commerce is an established reality that has changed customers' perception of buying.

E-commerce is defined by Investopedia (5), as a type of business model, or segment of a larger business model, that enables a firm or individual to conduct business over an electronic network, typically the internet. Electronic commerce operates in all four of the major market segments: business to business, business to consumer, consumer to consumer and consumer to business. It can be thought of as a more advanced form of mail-order purchasing through a catalogue. Almost any product or service can be offered via e-commerce, from books and music to financial services and plane tickets. E-commerce has allowed firms to establish a market presence, or to enhance an existing market position, by providing a cheaper and more efficient distribution chain for their products or services.

As the E-commerce giants revolutionized the retail business, supply chain management suffered huge changes. First of all, the performance gap was no longer a secret: dot.com companies highlighted the potential performance level that all supply chains could reach, the bar was raised and keeps getting higher. New technologies to support supply chain management were developed and keep growing. Procurement, marketplace, planning and fulfillment software development accelerated and tech companies remain aggressive in this sense. Supply chain had always been the tough node of all businesses, the area of improvement with the highest potential but that required greater effort. The reluctance to invest and improve has no chances to persist: e-commerce provided new solutions to old problems and reduced all barriers, opening up to a cross-functional, cross-company and cross-country vision of the retail business and its supply chain. The rise of E-commerce did not change the structure and needs of supply chain management but rather the way these are approached. The i~~I~~nteraction between different actors of the supply chain has changed and will keep changing, as well as the way in which supply chain operates between companies and geographic boundaries. (6)

## 4. Impact on Supply Chain Management

A supply chain is considered to be an integrated network of organizations and/or individuals delivering products or services to its customers. This typically involves ~~several~~ different material (physical), cash (financial) and information flows, the efficiencies of which drive the overall quality of service to end customers and the associated costs (7). E-commerce has had an impact on all three of these flows. In terms of physical flows, information can be used to avoid physical movements that were needed in the past. Companies can now access more markets in an easier way, reducing physical flows. E-commerce solutions also changed the perception of product tracking and tracing, providing 24/7 and 365-day access to information regarding products and deliveries. Regarding financial flows, faster payment and settlement solutions affect all stages of the supply chain. (6)

Historically, Supply Chain has always been based on the "four Vs": volatility, volume, velocity and visibility and professionals had the goal of optimizing results in terms of total cost, service quality and support for innovation. These priorities aren't likely to change, but with the new challenges of today's fast-paced world, new digital technologies should increase the level of performance. (8)

The roots of Supply Chain Management are often attributed to Peter Drucker and his article from 1962 in which he discussed the areas of business that could be improved to achieve major efficiency gains and cost saving. Along the following two decades, supply chain was still viewed as a series of disparate functions. Once these began to be integrated, key themes emerged and became the main challenges for the following years. There was a shift from a push to a pull supply chain, mainly demand-driven as customers were gaining more power. Secondly, information systems to gain better control of the supply chain were enhanced. Cost saving strategies were analyzed and unnecessary inventory was found to be a major source of cost that had to be eliminated. Maximum effectiveness could be achieved only through integration and total cost optimization: ongoing relationships with trading partners had to be established. The main challenge however was related to market demand. Agile supply chains need be highly responsive to market demand and the improvements in information technology are key to capturing "real-time" data to improve forecasting and create a virtual supply chain between trading partners. (9)

Hence, the last couple of decades have witnessed a revolution in the integration of supply chains, which was possible thanks to synchronization of the activities and operational flexibilities. New information technologies and increasing market uncertainty and competition made these changes necessary. Starting in the 1990s with emerging ERP systems, the dot-com-bust in 2002, as long as globalization challenges and 2008's financial crisis, this change was accelerated. (10)

The goal of supply chains in these times was to reduce transaction costs and improve the quality of information exchange amongst partners. E-commerce was able to reinforce these efforts: not only did it support synchronization and integration efforts, but it also changed the way supply chains are designed, operated and maintained (11). With the rise of e-commerce, new supply chain models have emerged: fully e-commerce based such as Amazon.com or dual-channel such as Walmart, that kept the traditional retail channel active and added online buying options to the business.

E-commerce is here to stay and will keep increasing its importance once established standards for data transfer across the supply chain are realized. (9)

Supply chains, to face this revolutionary change, are transforming from a staid sequence to a dynamic, interconnected system, called DSN – digital supply network or DSC – digital supply chain. These are meant integrate information from many different sources, to enable integrated views of the supply network. (8)

DSN is, in fact, characterized by the strategic and operative exchange of information between suppliers (financial, production, design, research, etc.) to enhance communication between actors in the chain (12). In modern DSNs, integrated supply chain information models are essential: information integration and service automation have~~s~~ been identified as an important business driver (13). The information flows, if automated, eliminate the need for manual entry and provide trustworthy information with reduced chances of human error.

The benefits of DSN are also to reduce product and service costs, reducing supply chain lead times and increasing the flexibility in supply chain design (14).

New technologies that can support “digital” supply chain management include Internet of Things, Big Data Analytics, Cloud Computing and newer revolutionary systems such as Blockchain. Efficiency and effectiveness of supply chain management strictly depend on IT technology and its efforts in making real-time data available and integrated, to improve both the operational level and the decision--making process. (15)

## 5. Elevating Supply Chain to meet Tomorrow’s Challenges

The rise of digital business changes traditional business models and, mostly, **how** we conduct business. In a world now operating 24/7, the pace of business accelerated. This changed how businesses communicate, transact and interact with customers, suppliers and partners. A study conducted by the Institute of Supply Management in 2017 (15), shows that 65% of the value of company’s products or services is derived from suppliers. Suppliers and supply chain impact everything: from quality, delivery and costs, to customer service and satisfaction and profitability.

With the rise of E-commerce, the relationship between logistics performance and customer loyalty is much closer: the logistics service is directly provided to the final customer, who has developed high expectations on the service level. The globalization of companies increased the complexity of the logistics model. It is now a key element to improve and integrate the information systems. The complexity of decision-making requires data share in real time. (15)

If in traditional supply chains, information travelled in a linear form and inefficiencies in one stage impacted the following stages in cascade, nowadays DSNs are capable of creating integrated networks that can overcome the action-reaction process using real-time data and enable~~ing~~ collaboration. The figure below (fig.1) shows the shift from the traditional supply chain to the digital supply network. (8)

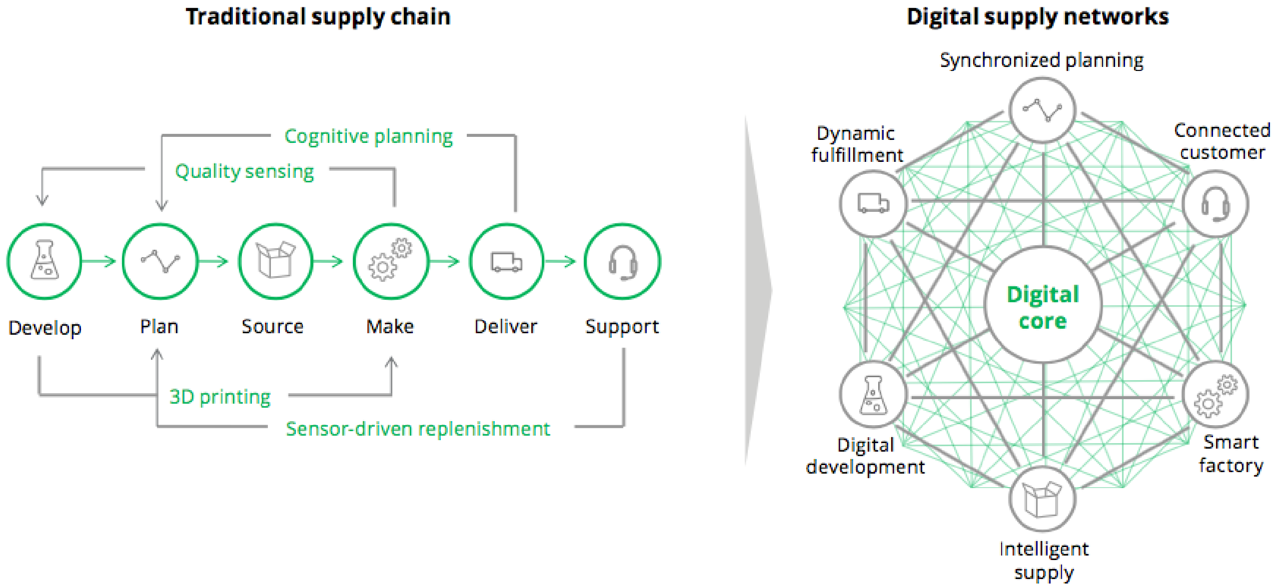


**Figure 1. The evolution of SC (Deloitte, 2016)**

In the presentation of its project Watson Supply Chain, IBM declares we are in a new era of supply chain. Supply chain leaders now have to ensure top quality, delivery and supply availability while reducing costs. Many potential disruptions must be taken into account, from the common events like weather, delivery delays and quality defects, to major events such as political issues, natural disasters or financial instability of suppliers. The customers' expectations are getting higher and higher, as well as social values that the brand has to represent. In this perspective, inbound supply chain needs to be just as focused on customer experience as the outbound side. Fostering great efficiency, innovation and customer satisfaction can be possible when all actors of the supply chain are able to collaborate. The main challenge that the collaborative supply chain model encountered is lack of visibility and transparency. Critical links in supply chain processes often lack of visibility. The root cause is often the inability to combine and make available to all the overwhelming amount of data companies are now collecting from different processes, sources and systems. Establishing greater visibility is the key to surviving the challenges of this new era. Not only would it be easier to predict and mitigate disruptions and risks, but it would also help companies to boost the value of the business. One shared view of supply chain data and intelligence across all actors, showing both internal and external sources of data, would be the key to increase visibility (16).

As already clarified, changing business and customer requirements are putting new and greater pressure on the business. New technologies are offering interesting ways of working around this challenge. The old ways of working will not be enough and even the "supply chain masters" will not be able to last long in their first place performance if digital transformation will not take place fast. The view of IDC (International Data Corporation) (17) is that the supply chain must become a "thinking" supply chain, intimately connected to all possible data sources, to enable fast analytics, cloud-based networks. In 2017, thanks to social media and IoT, supply chains had~~ve~~ 50 times more data available to them tha~~e~~n 5 years ago. Less than a quarter of it is being analyzed in near real time. Companies that are leading their business are moving extremely fast to improve their use of this data, slower ones may very soon become uncompetitive. (17)

The "Amazon effect" requires supply chains to be customer-~~-~~centric, with direct selling to individual consumers in real-time, to be dynamic, agile, accurate and maintain integrity. Supply chains are expected to be data-driven, always "on" and demand aware, while still maintaining their resilience towards external forces and risks. Revolutionary technology is helping in this disruption, as it is enabling new capabilities and new business models that are not yet possible otherwise. It is essential that supply chains acquire access to the available data, which is perhaps existing but unstructured, and hence inaccessible through basic algorithms and human language, or not yet visible to organizations. IDC's vision of a "thinking" supply chain involves enormous benefits: data not previously utilized, or utilizable, could be analyzed in real time and become part of the decision-making process, becoming more efficient and effective, avoiding internal and external disruptions and supporting new business models. IDC has defined the "thinking" supply chain thanks to five technology trends: "five Cs". (17)

1. Connected. The ability to access as much data as possible, integrating the data sources and automating all documents across both internal functions and supply chain partners. Connected also means being able to access unstructured data from social media, IoT and combining them to traditional datasets such as ERP.
2. Collaborative. As IDC estimated that over 50% of the value of manufactured products comes from suppliers, improving collaboration is crucial. Cloud-based networks can enable multi-enterprise collaboration and engagement.
3. Cyber-aware. Paying attention to cyber-intrusions and hacks is nowadays crucial. Hardening database security, while opening them to a wider network of users is the biggest challenge.
4. Cognitively enabled. An automated and self-learning supply chain could be the future of optimization and efficiency. Platforms could conduct decisions and next best

actions in an automated and timely way, understanding the business impact of data and events and prioritizing attention based on the potential impact.

5. Comprehensive. Analytics must be scaled with data and real time. Speed is the key to having better performance than humans.

Digital technologies in supply chain led to great rationalization in costs. The automation of procedures in, for instance, the purchase of supplies enabled a reduction in costs of approximately 12%. Web-based models are playing a critical role in companies, mostly in terms of generation of value. Not only is the benefit present in the improvement of physical flows, such as supply purchases, but the biggest gain is perhaps the improved flow of information and the tighter structure or relationships between supplier, manufacturers, distributors and customers. (18)

## 6. Technological options for Supply Chain

Technology offers companies the option of reducing internal management costs and increasing efficiency through the digitalization of networks. Technology focuses on where a transaction occurs and when goods, services or information are transferred across activities and systems. Data models need to be designed so that the information flow can be transferred electronically end-to-end to secure interoperability within systems.

Nowadays, the payment and exchange of supply chain documents involves third party, trusted intermediate companies. These services have significant limitations from a DSN perspective, as they are still often using a computer-paper-computer manual operation model. This aspect along with the involvement of more parties makes these transactions cost-ineffective and slow. Intermediaries, including banks, are often lacking fundamental functionalities: standards, timestamping of transactions, monitoring and tracking of information flows and secure end-to-end delivery of information. Many of these missing functionalities could be granted by cost-effective integration models: private cloud (ERP/Hub companies), public cloud (ERP/SME) and Blockchain public cloud.

**Global Trade Network and Cloud-based Technology**

A global trade network is a living ecosystem of supply chain partners all connected through one cloud-based technology platform. The focus of this model is on interactive collaboration among carriers, shippers, suppliers, 3PLs and customers. The connectivity that cloud-based technology can promote creates many benefits ~~that can~~ helping companies improve their supply chains and face the "Amazon effect" successfully.


**Figure 2. Global Trade Network (19)**

Thanks to could computing, the amount of data available will improve decision-making. By providing real-time data and removing the black holes and the guesswork on what is happening in the supply chain. The demand for big data analytics is among the main reasons for cloud subscriptions. Among the 5 key benefits of a Global Trade Network highlighted by Blue Jay Solutions are, in fact, improving the access to capacity data and performance to guide decisions in selecting a partner, giving an end-to-end supply chain visibility, and moving towards a macro-optimization that can search for cost-saving opportunities not only internally in the supply chain but through the whole network. (19)

IBM is an early pioneer in the cognitive computing space, thanks to its Watson technology. Watson Supply Chain has brought notable capabilities to the supply chain space. These platforms enable organizations to build supply chains that are more intelligent, demand sensitive and customer centric. Watson Supply Chain can predict, assess, mitigate disruptions and risks while establishing a business partner network that helps organizations to become more efficient and agile in meeting the demand of digital business. Interesting case studies can demonstrate how IBM solutions are on the way to making the "thinking" supply chain possible. (16)

IBM Supply Chain Insights (SCI) can optimize supply chain by predicting, assessing and mitigating disruptions and risks. Cognitive-enabled insights and recommendations are available thanks to learned best practices to drive collaboration. Smart alerts are provided in case of exceptions or disruptions. (16)

IBM Supply Chain Business Network (SCBN) is focused on establishing connections with suppliers and partners in order to automate, digitize and correlate B2B documents. Real-time information on the entire business transaction landscape can be searched and viewed. SCBN has blockchain capabilities that provide shared multiparty visibility around key business transactions. Blockchain technology will be the topic of the next chapter. (16)

**Advanced ERP Systems**

ERP systems (Enterprise Resource Planning) integrate all internal processes into a single system, sharing the same database. Finance, HR, manufacturing, supply chain, procurement and others united under the same technology to provide visibility, analytics and efficiency. ERP facilitates the flow of real-time information across departments. The planning applications are connected and share the database, to eliminate information silos and give everyone one single source of truth. The most advanced versions of ERP, proposed by SAP, are on clouds and scalable to any company size. (20)

# 7. Focus on Inbound Supply Chain

Most businesses have invested money and time in optimizing and improving the outbound process chain to the end customer, and the space for improvement is decreasing. Untapped potential can be found in inbound logistics: controlling all the workflows from procurement and goods receipt to the supply of production or distribution centers. There are five basic parts in inbound supply chain, as stated by AEB (21), that can be highly improved and show great potential for technological applications, shown in the graph below.

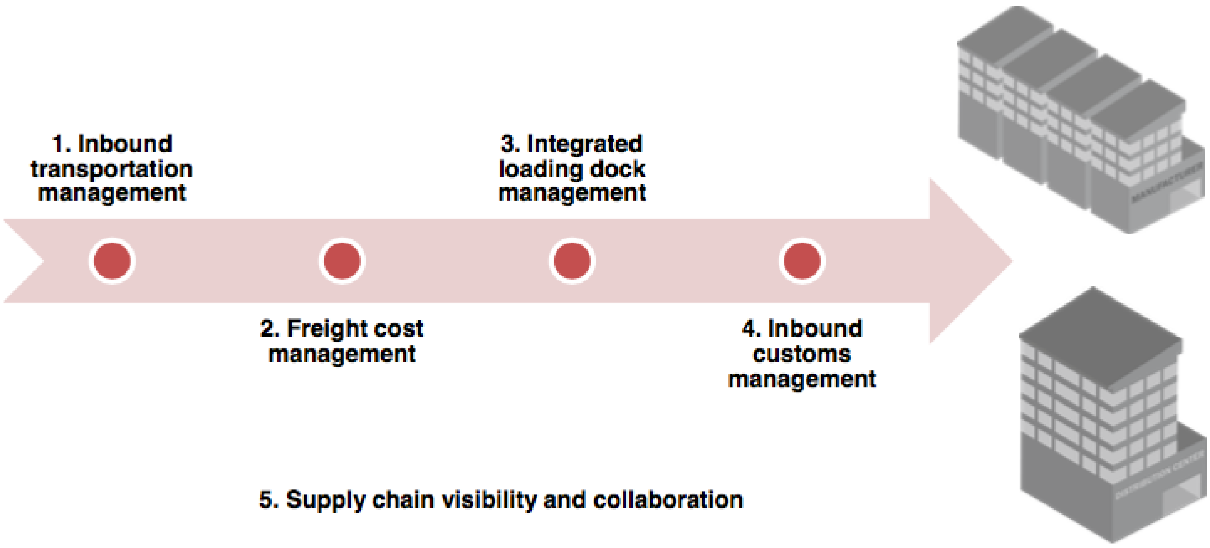


**Figure 3. Inbound Supply Chain - Areas of Improvement (21)**

Inbound transportation management involves transportation processes. Inbound shipping is one of the most important cost factors in the supply chain, reason for which many big actors in retail are looking at internalizing transports. This is strictly related to freight cost management, where the greatest potential lies in invoice auditing (checking carriers' invoices), establishing partnerships, measuring immediate impact, etc.

Loading dock processes are also a crucial area of improvement. Everyday inbound deliveries in the retail and consumer goods industry are causing unscheduled wait times and inefficiencies.

Globalization in trades did not erase customs from the picture: customs barriers are still often slowing down processes due to incorrect, delayed or missing import declarations. Automating this paperwork and declaring the goods while they are still in transit could highly improve the performance.

General supply chain visibility strictly depends on high-quality data. Integration is essential, especially in this node of the supply chain, where different actors are sharing information that is crucial for performance, without a uniform standard for exchanging information: integrating partners becomes complex. EDI (Electronic Data Interchange) allows different systems to transmit data one to the other, after agreeing on a common messaging standard. Imagining we are managing incoming goods in a warehouse, the combination of purchase orders, order confirmation, delivery date and quantities of a specific good is the information we need to optimally plan resources, capacities and processes. The more precisely you can estimate which transport volumes will arrive at your storage facility and when, the better you can plan and coordinate your downstream processes. (21)

## 8. The Bullwhip Effect

The bullwhip effect, also known as the Forrester effect, refers to the phenomenon of demand variability amplification as moving up in the supply chain: from the point of actual demand to the point of origin. In a typical supply chain, as we move up in the chain from retailers to wholesalers and to manufacturers, each stage in the chain distorts demand and the variability in demand keeping increasing. As the illustration shows, the effect occurs when the ~~costumer~~ consumer places an order (whip) and the fluctuations build upstream the supply chain, increasing the variability. This effect has quite a negative impact on~~f~~ supply chain efficiency. It leads to excessive safety stock, higher logistics costs, lost sales, and so on. The four major causes of the bullwhip effect were identified by Lee et al. (22) include demand forecasting updating, order batching, price fluctuation, rationing and shortage gaming. Impacts are inefficient inventory management, backlogged orders and poor service, unpredictable production schedules, lost revenues. Initiatives to deal with the bullwhip effect are mostly related to information sharing in order to help reduce the variability, improve forecasts, coordinate systems, react rapidly to changes in the SC, reduce lead times.


**Figure 4. Bullwhip Effect Example Graph**

## 9. Blockchain technology

As stated in the previous paragraphs, digital supply chain integration is becoming increasingly dynamic. Customer demand must be shared effectively, product and service deliveries must be tracked in real time provide visibility. End-to-end integration of product data is the main requirement for the supply chain industry. There have been intermediate companies operating to establish process and data integration, by providing interoperability through the mapping and integration of organizations and systems. Blockchain technology could be the next revolution to electronic data exchange over the internet between business partners. DSC (Digital Supply Chain) aims at integrating data, but still uses trusted third parties. Blockchain (BC) promises to minimize the unnecessary use of third party intermediaries. In this way, it would simplify B2B integration and enable micro level IoT integration (23).

This chapter will, first of all, describe what blockchain is and how it works. In a second section, the focus will be on investigating how such technology could support DSC integration.

**What is Blockchain?**

The blockchain, a decentralized and encrypted digital ledger, was acknowledged as one of the top 10 emerging technologies in the World Economic Forum in 2016. Blockchain is nothing more than a data structure. It can be viewed as a decentralized database in which information can be stored. This database is distributed across all participating nodes, which all agree on a certain set of rules, related to the allowed behavior in the network and to the structure of the information stored. Blockchain is designed so that all stored contents are immutable. This allows all nodes to have access to the ledger as an immutable source of data. (24)

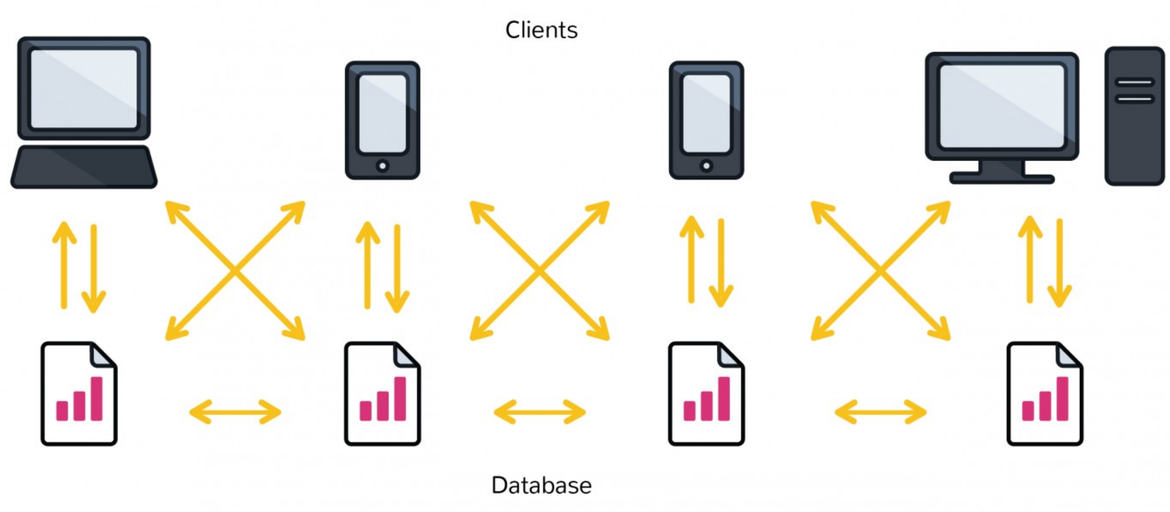


**Figure 5. Blockchain structure (Coindesk)**

The creator of bitcoin Nakamoto, created not only a digital currency but also a protocol of consensus, providing trust even without the central intermediary and working on a peer-to-peer network. The protocol is based on three basic pillars to provide this trust within the system: **decentralization**, **consensus** and **cryptography**. **Decentralization** means that the database is distributed with participants in the system: everyone has the possibility of accessing a full copy. Due to this decentralization, more versions of the database could exist: this is where the **consensus** comes in. Participants have to agree on the source of truth and this is possible thanks to computational power and the Proof of Work. Miners (specific nodes) are constantly working to solve mathematical problems using computational power and energy: once the problem is solved a new block can be added to the database. So within the blockchain system, the source of truth is the longest chain (25). The third pillar is, perhaps, the most important: **cryptography**. Cryptographic technologies are necessary for the digital signatures and data integrity. SHA-256 cryptography is applied within the bitcoin blockchain to generate hash values that, combined with the other 3 pillars, make the bitcoin protocol unique. SHA-256 ensures data integrity thanks to its one-way hash value creation: input data always derive a hash value, but the hash value cannot be reconverted in the original data input. This concept is at the base of digital signatures, for example. So what is a block? For every transaction, a unique hash is calculated. Numerous transactions are combined and aggregated under one unique hash value. The time stamp, the hash value of the previous block and a nonce, the mathematical problem of the Proof of Work concept, make a new block. (26)

Even if the name “blockchain” did not appear in the first articles by Nakamoto on Bitcoin, it is the name that was later given to this concept of distributed ledger technology for the financial sector. Most studied applications are, in fact, strictly related to financial and legal transactions, in which this technology represents a disruptive innovation (27). However, a blockchain can be used in different ways and the usage depends on the group supervising the network (24). Some features are useful and innovative also for other business areas. The following characteristics of blockchain are, in fact, the ones that could support Supply Chain applications.

One of the main features of blockchain technology is that it maintains an **open distributed ledger of transactions** that is copied to all the nodes of the network. If a transaction is changed, a new block is created and chained to the previous blocks. Ledger data between nodes of the blockchain network are matched at random intervals (on average every ten minutes). This is what makes this technology secure from hackers, as there is no bank information or identities of the parties and the data is public in real-time. From the practical perspective, a traditional business transaction involves two parts: a public ledger entry about the transaction and private messages between the parties involved about identities, security keys for transactions and location. The combination of these two parts makes it possible to avoid the intermediary third party and execute the transaction rapidly, at very low cost and in secure way. How does this practically happen? The seller (or initiating party) notifies the other party about the existence and exchangeability of DSC documents, using the public key infrastructure messaging. At the same time, the seller sends the buyer (other party) an element of PKI software to decrypt and encrypt the transaction identifier(s) that are attached to the documents exchanged. If the buyer (or receiving party) forgets this single key security message, the transaction will not be valid and must be repeated. In this case, a new blockchain entry and a new security message will be generated. The solution of the exchange depends on the **combination of public and private keys**. Additionally, in order to conduct the transactions and document exchange, the parties must agree on how that is done: this is where the smart contract comes in. (28), (29)

The **smart contract** was firstly defined in the 1990s by Zsabo as a "computerized transaction protocol that executes the terms of a contract. The general objectives of a smart contract design are to satisfy common contractual conditions, minimize exceptions and minimize the need for trusted intermediaries. Related economic goals include lowering fraud loss, arbitration and enforcement costs, and other transaction costs." (30). Smart contracts are extremely flexible and can be used to automate DSC transactions at a very detailed level.

There are three types of blockchain (31): decentralized, hybrid or permissioned or centralized. These differences are based on the users that set the rules related to accessing, reading or writing transactions. The decentralized blockchain is governed by everyone who participates. The hybrid is governed by a Consortium of users and the supervisors are preselected. The centralized blockchain is where only one entity sets the rules of the blockchain. Additionally, there is a distinction between public and private, where public means that anyone can access the network and read the information and private means that the access is restricted.

**The use of blockchain in Digital Supply Chain integration**

To address the limitations of traditional systems that have been deeply described above, we consider the use of blockchain technology, mostly focusing on the public ledger of transactions copied to all nodes of the blockchain network without transaction party identities, on the use of public key infrastructure PKI to decrypt and encrypt a transaction and to notify the counterparties about the existence of an executable transaction with unique single-time keys and on the concept of smart contract. (23)

Based on the needs of supply chain management and on the challenges of Digital Supply Chain integration, the suggested type of blockchain discussed in a personal interview with Dr. Ulrich Gallersdörfer (32) is the hybrid one. In fact, it would be a group of companies, usually called “Consortium” in this context, have access to the data and trusted to read and write, with a combination of public and private keys.

Blockchain technology is able to provide security and flexibility at lower costs than traditional transactions and more rapidly. However, a limit for use in supply chain management is that it does not provide standardization of electronic supply chain documents: international document standards should be used, relying on their future development to ensure fully automated transfer of documents between organizations (23).

DSC integration design should take into account the requirements of business stakeholders and related system functionalities. One of the few methods for designing and analyzing large business networks is the DBE framework[1] (33), which has been used by Tapscott (30) to integrate blockchain functionalities and activities into the architecture of a network.

Korpela, Hallikas and Dahlberg (23) interviewed blockchain technology experts and deeply analyzed literature to integrate blockchain functionalities within the DBE framework: transaction data, processing ledger or smart contract, storing blocks to peer-to-peer networks and managing blocks by mining experts.

[1] DBE, Design by Expectation, provides a collaborative scheme for genetic algorithms and domain-specific knowledge to carry out the engineering design optimization (33).

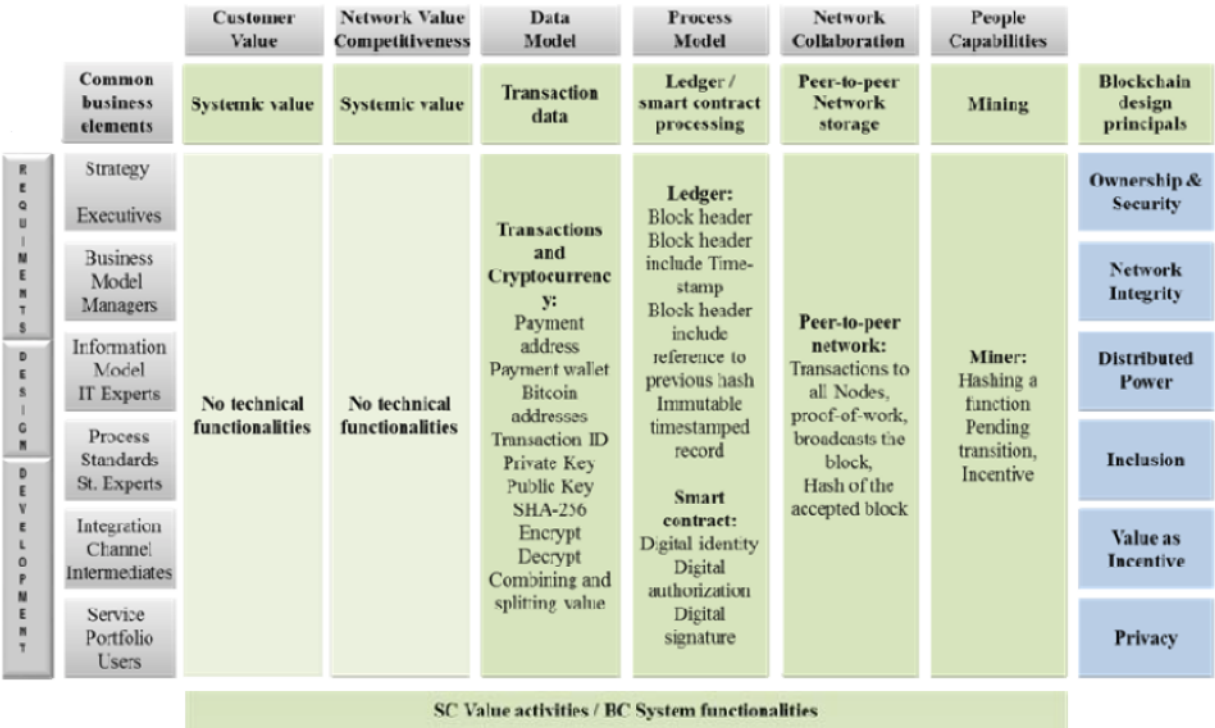


**Figure 6. DBE Framework and BC (23)**

Their study was conducted by first understanding the current stage of supply chain integration and the requirements to reach it. Using the QFD method, the supply chain functionalities ("whats") are combined with the "hows" of blockchain support in the integration. The results show that business experts consider that blockchain functionalities could support good integration thanks to the ledger and the smart contract, but less for transactions and hash. This can be explained by the fact that blockchain can support data integration but does not offer a data model to solve end-to-end integration, which needs to be standardized. So overall, BC could be integrated for its system security and privacy and for the contracting. The most interesting functionalities which make BC the most promising technology are the timestamping of transactions, the data encryption that enables secure data transfer and the digital signatures for smart contracting.

As big organizations often use ERP systems as a private cloud and their supplier are often SMEs just entering the cost-effective cloud services: blockchain technology offers a public cloud model that can help integrate smaller and larger companies, also enabling agile new start-ups to enter the market. If a data model could eventually be agreed upon and standardized both for B2B and M2M IoT transactions, the cloud integration through BC could lead to a disruptive DSC. (23)

**Blockchain Technology according to IBM**

IBM declared that 2017 is the year of Blockchain enterprise deployment. An analysis by IDC, Vendor Profile (34) explores the blockchain story of IBM, currently in a great position in this emerging market thanks to a well-formulated and a well-communicated blockchain strategy. IBM Bluemix Garage is the initiator of this strategy that started researching on the topic in 2014, very early for the blockchain space. They are now one of the leaders in the Hyperledger Project. [2]

IBM is focusing most of its attention on enterprise-ready solutions that can overcome the technological limitations in terms of privacy, confidentiality, performance and scalability. This is of great support when looking to meet enterprise requirements and support the creation of networks, whose members can have different accessing rights. (34)

The first application was part of the Global Financing program and affecting transaction disputes. Many of the projects announced for 2017 are within the financial service sector, however various deployments are also outside of it, such as the food-traceability system

[2] Hyperledger Project was launched by the Linux Foundation in 2015 with IBM and 29 other partners. The goal was to develop a framework for enterprise blockchain deployment. In the first 10 months, over 100 paying members including IT vendors and large financial services players joined. (34)

built for Walmart and transaction management among shippers, ocean carriers, freight forwarders, ports, customs, etc. in collaboration with Maersk.

Currently, IBM offers blockchain as a service (BaaS) built on top of Hyperledger deliverables in the IBM Bluemix cloud environment. In 2016, IBM blockchain projects were at their initial stages, but the expectation was to have growing source of revenue in 2017. IBM's goal to develop enterprise-ready blockchain solutions to overcome the existing limitations of technology in terms of privacy, confidentiality, auditability, performance and scalability. IBM is aiming at increasing the speed of blockchain operations: the initial platforms are designed to handle Bitcoin transactions at a speed of 7/10 transactions per second and take approximately 10 minutes to add a block to the chain, this is far from the enterprise-use requirements. Another goal is to develop permissioned networks: for enterprise use of blockchain technology, the existing model of free access for individual actors cannot be applied. IBM is working to develop a network membership management. (34)

An important example of IBM's use of Hyperledger Fabric blockchain is Supply Chain is the project on food provenance carried out with Walmart. The goal of the project is building an end-to-end food traceability system that provides a single view of the purchase order life cycle across the supply chain. This use case is an important blueprint for the industry of physical assets management. Blockchain is particularly suitable, in this case, for addressing pain points such as low efficiency, lack of automation or manual and error-prone workflows. (34)

## Example Use Cases

### *Example Case 1: Walmart*

IBM has partnered with a Consortium of food companies including Unilever, Nestlé, Walmart and Kroger to promote food safety. Walmart had already adopted blockchain previously and is now extending the technology to the whole consortium. The main goal is reducing costs and timings of recalling unsafe food batches. The initial investment to move all data to a blockchain and create new simpler standards to ease the tracking process is justified by the cost savings and the brand awareness that follows. In food supply chain, when it comes to safety, there are three main costs that retailers face: human loss of health and life (according to the WHO 420 thousand people die on average each year due to food poisoning (35)), the cost of recalling a tainted good, that depends on the producer and the volume of sales, and the overall losses in sales of the product, even from other producers. These last costs are estimated to be, only in the US, from \$4.4 billion to \$93.2 billion per year (36).

### *Example Case 2: NepCon*

NepCon is an international non-profit organization that has been working on sustainable land use and responsible trade of forest commodities for the past 20 years. Its case study was presented and used during a Blockchain Summer School in the University of Copenhagen in August 2017 (37) and solved thanks to the application of blockchain technology. The case study is related to the supply chain of timber, from the forest to the final consumer after transformation in many different products. It is a good example of how blockchain can be applied to solve traceability issues and maintain a solid data integration along all nodes in the supply chain. In the specific case of NepCon, the main challenge is to be able to track the timber along the supply chain, to verify that illegal trade is not sold under the FSC Certificate. The complexity of the supply chain causes initial producers and the certification authority to lose track of the total certified volume. The output of certified wood is, in fact, greater than the input, as shown below.

The solution proposed during the Summer School is a private Ethereum blockchain that can support the volume reconciliation. This is done by assigning a specific token as a digital representation of the physical asset "certified wood" ($1m^3$) on the blockchain. This is enabled by Smart Contracts and results in the ability to control that the initial volume of certified wood is maintained along the transformation. The figure below shows the flow of the tokens in such system. In the final node of the supply chain, it is possible to verify the ownership of the tokens, that were transferred to the following node of the supply chain as certified wood was being sold and transformed. The overall volume of tokens is constant and is owned only by those that used certified wood.

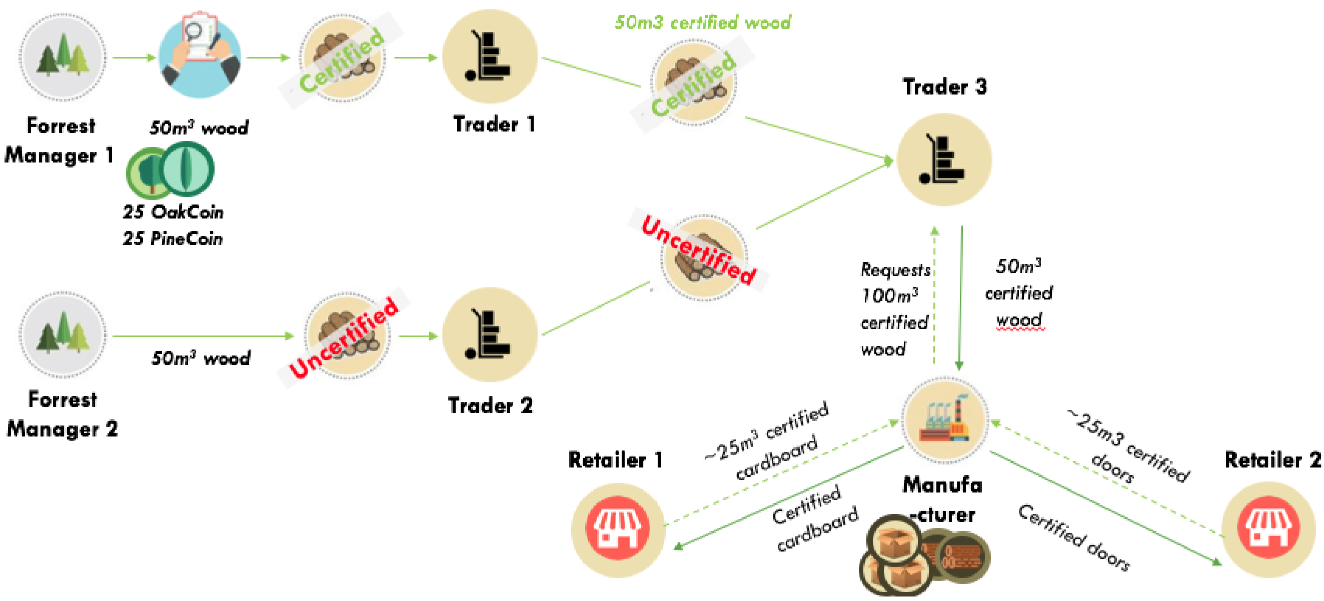


Figure 7. Token solution for NepCon

This case study leads to analyzing a critical element of applying Blockchain to SCM. When representing physical assets with digital copies, we encounter the dilemma of the “digital twin”. In the NepCon case, for instance, the overall volume can be controlled, but reality is more complex. If, for example, a truckload of certified wood is stolen and exchanged with a non-certified one, tokens cannot track this and uncertified wood will be treated as certified. This is a good example of the “digital twin” issue, which will be described in the next paragraph.

***Example Case 3: MediLedger Project***

The MediLedger Project (38), launched by The LinkLab and Chronicled, aims at developing a distributed ledger solution for the pharmaceutical industry. The goal is to manage records of ownership and transfer among all supply chain partners, including producers, wholesale distributors, hospitals and pharmacies, to track and trace prescription medicines. Genentech, Pfizer and others have defined the industry requirements to start a pilot program: a prototype system for registration and verification of medicines on the blockchain, while keeping business information private from other participants.

***Example Case 4: Provenance***

Provenance is a collaboration platform that connects producers, suppliers, retailers and end-customers in order to broker trust in the food supply chain. It gives each product a digital passport to authenticate key information, ending fake claims and counterfeits. (39)

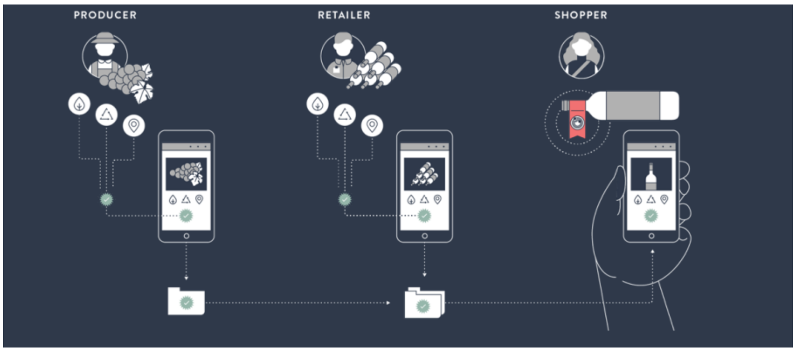


**Figure 8. Provenance**

Provenance’s project on tracking fish in Indonesia uses a mobile phone app that links identity, location, material attributes, certifications and audit information of a specific batch ID. This data is then stored immutably in the blockchain. Along with an input sent by SMS by the local fisherman related to a catch, local NGOs provide information on the conditions of the location in terms of compliance to standards. Raw material transformation is a contract that will be implemented in the blockchain to handle the transformation of a same batch of raw material to different final products. The blockchain system will use mass balancing to verify the amount of ingredients used in the transformation. Blockchain provides an audit layer on top of an existing ERP that allows data to be shared and mass balancing of certified product to be conducted along the supply chain.

## 10. Limitations to data integration: "digital twin"

The "digital twin" model (40) is based on the idea that a digital informational construct about a physical system could be created as an entity on its own. This digital information would be a "twin" of the information that was embedded within the physical system itself and be linked with that physical system through the entire lifecycle of the system. This concept was presented in a formation course of Product Lifecycle Management through figure 9, that shows the data flow that links the real space and the virtual space and sub-spaces.

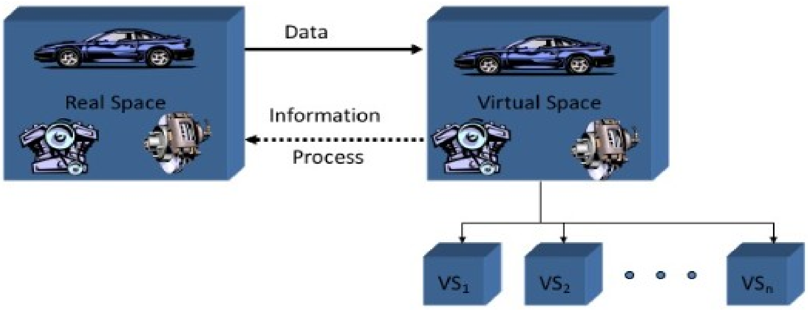


**Figure 9. Digital Twin Model**

The model is based on the idea that these are two separate systems: the physical has always existed and the new virtual system contains all the information about it.

As Professor Gallersdörfer (32) commented during our conversation, the relationship between the real space and the virtual space has limitations. These are mainly due to the fact that many possible events that can affect the physical space, cannot be reflected in the virtual one. Generally, if we think about blockchain as a virtual space that reproduces physical space, we can encounter issues such as identified batches that are substituted in a truck, or full trucks truckloads that are exchanged. An example of this was described in the Nep-Con case study. There are limitations to virtual spaces and data in this sense and any application of blockchain technology will be affected but some form of inaccuracy due to it.

# 11. Case Study

Based on the theoretical background explained up to now, the second part of this study is a business case proposition. This case study is meant to assess the best options of the blockchain technology in Supply Chain Management, with specific focus on Inbound Supply Chain.

As already mentioned in the previous chapters, the current ERP systems have limitations in terms of creating a global and connected supply chain network. The goal of applying blockchain technologies to SCM is to combine ERP systems of all actors in the supply chain, to improve visibility and real-time data access as well as guaranteeing traceability and compliance to standards. The main challenges that BC technology can help to face are:

- Promoting transparency, trusting the information, in terms of creating one single version of the truth, available to all
- Reducing the blind spots in transportation (Bill of Lading (BOL) is nowadays still manual and sent once shipment is received)
- Accessing the suppliers' inventory: visibility on workflow between firms
- Synchronizing demand planning and forecasting along the SC to reduce/avoid Bullwhip Effect
- Real-time data availability

- Improving traceability and compliance to standards
- Supporting Invoice Management

More specifically, the issues this case study must appoint are optimizing and increasing visibility in inbound flows by applying blockchain technology for e-commerce retailers. The focus will be on using blockchain to "connect" suppliers and retailers.

The case study will be structured into different parts: description of the business case and main challenges, analysis of different blockchain options with pros and cons for use, proposal plan for blockchain adoption, pilot project for the Italian market and deep dive on a product line to assess costs and implementation issues.

**"Fresko" Case Description**

Our e-commerce food retailer "Fresko" is located in Europe and buys from suppliers worldwide, both large multinational companies and medium or smaller ones. There are 10 warehouses and 3 distribution centers across Europe, located in different areas to ensure fast delivery in any location. Suppliers can either deliver at a cross-docking center or directly at selected warehouses, they are in charge of the first product order delivery. A specific carrier is contracted by our retailer to ensure deliveries from the cross-docking center to the warehouses and from warehouse to warehouse for inventory balancing and out-of-stock emergencies.

**Figure 10. Fresko locations in Europe**

The **key players** are:

- the e-commerce retailer, specifically the supply chain management team and the warehouse managers,
- suppliers, in terms of suppliers' supply chain teams for outbound and transportation,
- carriers
- producers and manufacturers (if different from the supplier that delivers the finished product)
- certifiers and auditors (where applicable, these agents are the inspectors of standards that assign certifications, e.g. Fairtrade or Bio-labels)

The graph below shows the simplified structure of the part of supply chain we are focusing on, to highlight the nodes involved and the flows of data and physical goods.

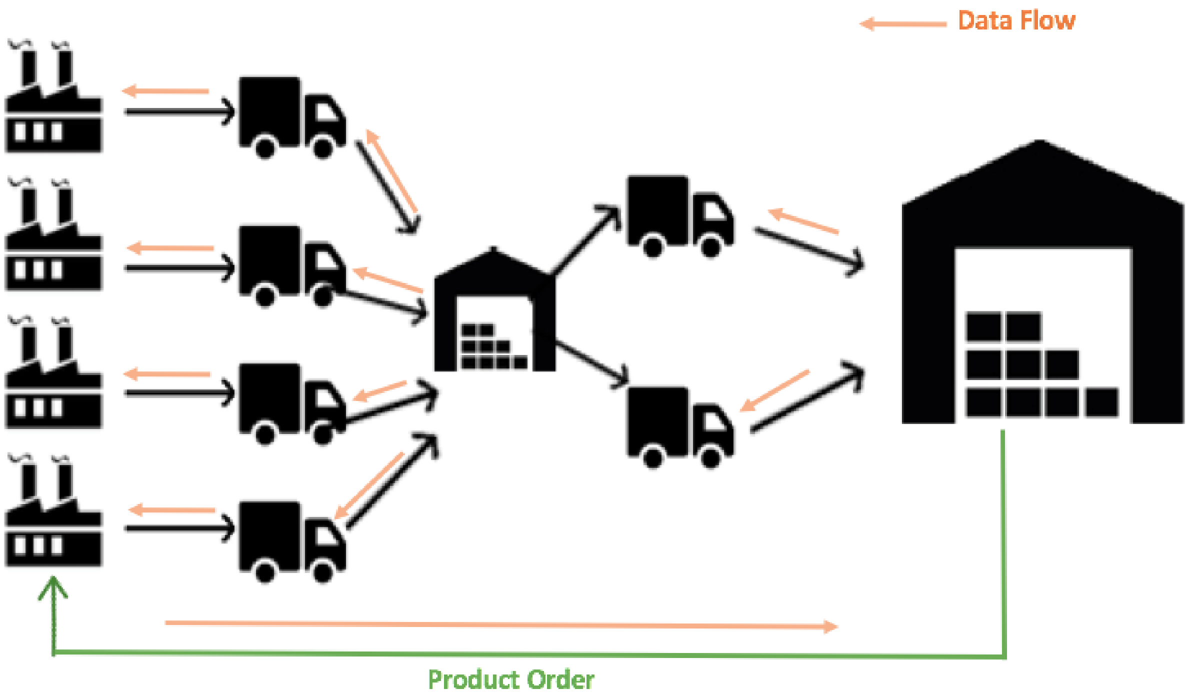


**Figure 11. Inbound Supply Chain Process**

As described in a document by UPS (41), no matter the size and geographical distribution of the supply network, inbound operations begin with the Product Order confirmation. In this case study, we assume an e-commerce retailer that predicts customer demand and forecasts volume to ensure product availability and avoid stock shortages, and orders accordingly from its suppliers. The POs can be regular or urgent based on the in-stock situation and on forecast accuracy. Once the supplier confirms the PO, in terms of quantities and delivery date, either supplier-owned transportation or third party carriers are in charge of picking up the truck load. Based on the PO request and the agreements between supplier and retailer, a destination warehouse or distribution center is selected for the delivery. If the supplier is a medium to large sized company and uses EDI systems, an Advanced Shipment Notice (ASN)[3] is then created,

[3] ASN is an EDI message that is sent to involved nodes of the supply chain, regarding detailed information of delivered goods, in terms of quantity, packaging information, etc. In 2010, ASN was expected to help save

which is an EDI document containing details on the delivery (order information, product description, physical characteristics, type of packaging, markings, carrier information, and configuration of goods within the transportation equipment). Thanks to the ASN, the receiving warehouse should have visibility on the incoming goods as soon as the delivery is planned. Our retailer's warehouses are quite small and only have from 2 to 5 dock doors for truck unloading, so the carriers have to request a time slot for delivery. Once the booking is confirmed, the carrier can plan its delivery to the distribution center or warehouse.

When the truck arrives at the warehouse, inbound physical operations take place: unloading, scanning shipment barcodes, signature of the Bill of Lading and shipping documents, placing the load on the inbound dock. The inbound dock is where pallets will be temporarily stored, trying to maintain FIFO and value streams in physical queues, then moved to the receiving area, where operators will receive (scan) the SKUs and send it to the stowing area. Our inbound operations end when the operators scan the delivered product and we consider it received. Based on the technology the supplier uses, our receiving station will be able to receive by scanning the ASN at a pallet level, since the pallet barcode contains SKU level details, or the pallet will have to be unpacked and each SKU will have to be scanned individually.

Based on the description of the inbound process, we can highlight the key issues that we need to appoint in order to improve and optimize operations. Proceeding in order of operations:

---

around 40% in receiving costs (53). ASN accuracy depends on the level of details (truck/shipment level or pallet, carton, unit level) as well as the SKU mix or single-product delivery, size and EDI development of the vendor, among other factors.

- PO quantity confirmation may not be accurate: the supplier can confirm an amount, but due to unexpected out-of-stock, they might send a different quantity at the time of loading
- Not all suppliers use EDI systems and can provide accurate ASN
- Traffic situation, customs operations, unexpected weather conditions can delay delivery operations and cause missed timeslot appointment and all consequent issues
- Details on incoming deliveries are crucial for capacity planning, labor planning, process management and future adjustments in terms of appointments when needed
- Wrong or inaccurate information of incoming goods can slow down receiving area, due to unpacking and no identification of the goods. Specificities on product type will be part of the scenario analysis.
- KPIs are affected by incoming goods: forecast accuracy and inbound lead time
- Bullwhip effect affects demand along the SC

**Blockchain Options for Supply Chain Implementation**

All these challenges can be appointed with the features that Blockchain technology offers. Using blockchain protocols in supply chain would mean creating a flow of information like summarized in the graph below. The ultimate goal is to connect blockchain to current ERP systems, to guarantee interoperability. Projects are already active on this point, such as Finlync's SAP integration for invoice management (42) and Microsoft's Bletchley (43).

According to the guidelines proposed by IBM (44), the driving principles in adopting blockchain in an enterprise are: business blueprint, technology blueprint and integration.

What blockchain promises is to create a network of value based on trust; this will be guaranteed by the following features:

- Consensus: "parties to a shared fact know that the fact they see is the same as the fact that other stakeholders see" (45)
- Validity: algorithms are setup to designate which updates in the system are valid
- Uniqueness: there is only one version of the fact, there can be two valid updates but if they conflict, only one will be globally agreed on in the network
- Immutability and Authentication: data cannot be changed and every action is secured with a key – there is no administrator account that has more power

From the technological blueprint perspective, TPS (transactions per second), integration and compliance requirements are fundamental when assigning a budget to a blockchain project and mitigating risks.

Among the variety of Blockchain technologies that are already in place and applied in different areas of business, the following are three of the best known ones. Each blockchain has different technical characteristics, hence different application options and benefits. In this case study, we will compare the characteristics of Hyperledger Fabric, Ethereum and Corda blockchain alternatives in order to assess which one would be more beneficial to supply chain management applications.

***Hyperledger Fabric***

The project, already introduced in the previous chapters, has been driven by concrete use cases and provides a modular and extendable architecture that can be employed in various industries. Already adopted in SCM by Walmart and IBM, it is a very flexible blockchain that can be applied to different situations. Hyperledger Fabric provides a modular architecture that allows a variety of implementations on cryptography, identity and consensus algorithms that can be adapted to the needs of the Consortium. This structure makes the system scalable across the business network and industries.

Consensus: operating in a permissioned mode, Fabric provides a more fine-grained access control. Performance gains are achieved thanks to less participants in the consensus transaction. Participants are differentiated based on their role of clients, peers, or suppliers. Different consensus algorithm can be applied based on the needs of the business requirements.

The current performance goal is to achieve 100,000 transactions per second in a standard production environment of about 15 validating nodes running in close proximity (46).

Hyperledger Project recently gained SAP as a partner (47), whose goal is to integrate blockchain into its existing variety of products.

***Ethereum***

**Ethereum** is an open-source, public, blockchain-based distributed computing platform featuring smart contract (scripting) functionality (48). All smart contracts are stored publicly on every node of the blockchain. The downside is that performance issues arise in that every node is calculating all the smart contracts in real time, resulting in lower speeds. As of January 2016, the Ethereum protocol could process 25 transactions per second (48).

Consensus: all participants have to reach consensus, irrespectively of whether they have taken part in the transaction or not based on the proof-of-work scheme. This has a negative impact on the speed of transactions, caused by the need of all participants to access all entries recorded and it can be critical in case of higher degree of privacy.

**R3 Corda**

Mainly meant for the financial services industry, a Corda network is permissioned and communication between nodes is point-to-point, so without global broadcast of data. Corda rejects the idea that all data should be available to all participants, even if encrypted. The focus is on agreements and on interoperability. There is a doorman that grants access to the network.

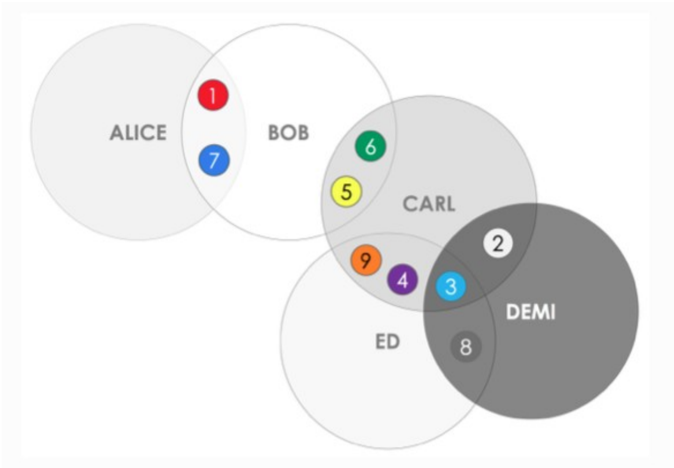


**Figure 12. Example of Network sharing**

The graph shows an example of fact sharing in the Corda network, and in hybrid blockchain in general. Although three participants are aware of fact 3, Alice and Bob are not.

In Corda, smart contracts are allowed to have legal prose added to the code, this is due to the original development for the financial services industry, that requires legal legitimacy.

Corda follows the general BC concepts in a specific way:

- Consensus: occurs only between parties to deals, not all participants

- Validity: validation logic is written by users, who needs to be in agreement on validity on a contract-by-contract basis
- Uniqueness: implementations can be requested on Corda to customize according to the business needs

Source: (49) (45)

**Proposal Plan for Blockchain Adoption in "Fresko"**

The adoption of Blockchain technology in "Fresko" aims at, first of all, solving SC issues to increase efficiency and reduce costs. Additionally, visibility on SC can benefit the entire business. General requirements for this purpose are:

- Creating a network of producers, suppliers, distributors, certifiers and final retailer
- Tracking batches all along the supply chain: from the initial ingredient to the final product – creating a digital history
- Respect of regulations in terms of expiration date, certifications, etc.
- Tracking respect of product-specific requirements all along the SC

The proposal is to adopt an Hyperledger Fabric distributed ledger. Corda would also be a good choice but its original purpose of application in the financial industry does not allow us to use SC used cases from other projects. Additionally, the suggestion is to apply to the IBM Blockchain Platform, already available as an Enterprise Membership program. The platform is built on the latest code and ensures enterprise-level security, data integrity, scalability and performance. The membership cost guarantees technical support and a cloud-based option that is enterprise-ready in terms of managing a secure business network across multiple organizations.

IBM also offers a Blockchain accelerator program that guides the managers in the last

## Pricing Plans

Monthly prices shown are for country or region: Italy

| | PLAN | FEATURES | PRICING |
|---|---|---|---|
| ✓ | Enterprise Membership Plan | **This plan entitles a member of a blockchain network to:**<br>- Access to the network's transaction ordering service<br>- A highly available Certificate Authority<br>- A network Peer, running in a highly secure environment, isolated from other members' environments (additional peers can be purchased for high availability)<br>- Coming Soon: Cryptographic Keys stored in a Hardware Security Module (HSM); certified to FIPS 140-2 Level 4; the highest in the industry. | €965.00 EUR/Membership Fee<br>€752.00 EUR/Small Peer |

The IBM Blockchain Platform is the only fully integrated blockchain platform designed to accelerate the development, governing, and operation of a multi-institution business network. Enterprise plan meets production requirements including security and performance for regulated industries.

**Figure 13. Pricing Plan for IBM Blockchain Platform in Italy (75)**

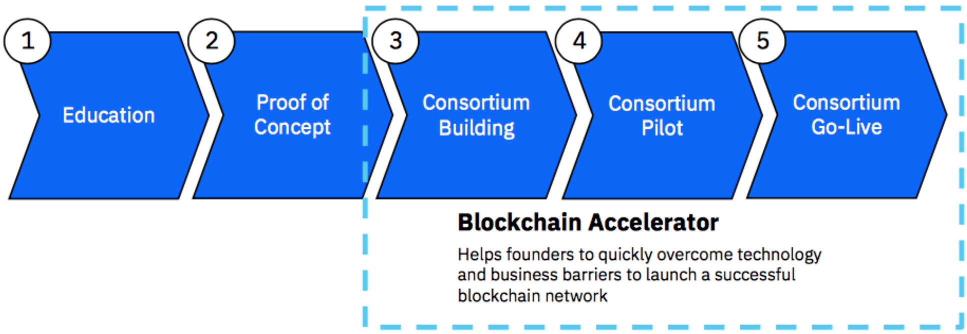


**Figure 14. IBM Blockchain Accelerator**

three and most complex steps of the implementation. (50)

Hyperledger Fabric allows to write algorithms for validity of transactions on a contract-by-contract basis. These algorithms would help in terms of creating a distributed ledger across the SC, while protecting suppliers' privacy and reducing validation time. Consensus would be agreed on by the actors in a deal, instead of involving other nodes: this would also simplify the validation process and reduce unnecessary spread of business critical information. Members are provided governance tooling with which they can administer and manage the critical business rules for their network.

A high security infrastructure is guaranteed, especially in the IBM Blockchain Platform Enterprise version, through LinuxOne Emperor that ensures code and data encryption at all times.

The model is made of various materials and components from initial production through manufacture and assembly to the final customer. Four key properties concerning materials must be updated: the nature (what it is), the quality (how it is), the quantity (how much there is of it) and the ownership (whose it is at any moment). Key attributes are linked from pre-existing datasets or newly ascribed along the way.

Network membership to IBM Blockchain Platform in the format Enterprise (already available, while more convenient ones will be available in 2018), will provide the following tools for **setup**.

1. Hyperledger Composer: allows the use of common programming languages in a framework that enables developers to model business networks, expose the business logic and create applications that consume the blockchain data.
2. Democratic management tools need to be setup to collectively manage the rules and policies of the business network, as well as adding new members and the establishment of new smart contracts → Activation Tool

3. Establish consensus and membership policy and enable update of the policies that govern the network → Policy Editor

**Technical requirements**:

1. Permissioned endorsements allow a distributed trust among participants of a known business network. Regulatory requirements (HIPAA and GDPR) dictate which level of detailed information should be shared in the network.
2. Vendors and their suppliers must adopt the blockchain and track from initial ingredient, in terms of batch ID, all transformations along the chain. Retailer can access the inventory of all its suppliers, suppliers can check in-stock status in the retailer's warehouses related to their past product orders.
3. Setup overall volume controls, to verify that no untracked ingredients are inserted in the SC along the processes. Algorithms can be implemented in each step to guide the upload of correct information and reduce human error.
4. Each product order (PO) confirmation is a unique transaction, containing details on the batch ID of the products sent, expiration date, health regulations, packaging details, etc. Each PO transaction is shared with the carrier in charge of taking the products from the supplier to our warehouse. A transportation transaction (digital token) linked to the product order is then attached (next block), to track the truck that moves the batch and verify the match of product specific requirements (in the PO's technical information) with the physical process.
5. Consensus structure based on participants in a transaction: supplier, carrier, certifier, retailer – the retailer is always present in the consensus flow to confirm

validity; certifiers will have to register their identity in order to act as an authority that can inspect all transactions involving the certification.

**SWOT Analysis**

This SWOT Analysis highlights the **Strengths** that “Fresko” would benefit from thanks to the adoption of such technology, strictly related to the Inbound processes and the **Weaknesses** that can still affect it. **Opportunities** are then listed, in terms of additional benefits that could come from the adoption, other than the inbound-specific issues, as well as the **Challenges/Threats** that remain unsolved.

- Increase in visibility on inbound processes and inventory status: capacity/labor planning
- Tracking from order confirmation to final stowing process
- No need for EDI
- No costs for expensive software implementation
- Interoperability with existing ERP
- Reducing costs and time on chargeback disputes

- Inaccurate information cannot always be avoided: wrong number of SKUs, units, size, etc.
- “Digital Twin” issue
- All participating nodes must implement BC and agree upon information to be shared

- Distributed information but not subject to hacking
- Certification and chain-of-custody tracking and control
- Forecast and production planning optimization thanks to in-stock visibility from supplier’s point of view
- Invoice management improvement
- Increased customer trust

- Data standards need to be agreed upon by all participants and respected
- Participants must agree to share to the network trustworthy data

**Figure 15. SWOT Analysis**

From this analysis, it is visible that the benefits are not only for our retailer, but for all participating nodes.

The **strengths** listed demonstrate how the adoption of blockchain could simplify the inbound processes, save costs and increase efficiency. The main sources of savings are the increased visibility and consequent improvement of capacity and labor planning as well as the savings in terms of **compliance and chargebacks**. According to a study carried out by LexisNexis (51), in 2016 only in the US, e-commerce merchants should recover 4.8$ billions from chargeback frauds. On average, 2 hours are spent on chargebacks' paperwork, demonstrating who is charge of issues that can lead to the impossibility of selling the product: expired, too close to expiration, wrong packaging, wrong transportation conditions, late delivery at the retailer's warehouse, etc. If a live tracking of the products is available, each participant would have access to the single version of the truth and chargebacks would be assigned to the responsible party, with no need for longer investigations and exchange of unnecessary paperwork.

Once the system is implemented, at a larger scale, other benefits ("**opportunities")** would result from the use of such technology.

Regarding **digital security**, centralized systems have been often subject to hacking attacks in the recent years. Blockchain makes hacking virtually impossible. Authentication is provided in the form of an unforgeable digital signature. In addition to the security that blockchain provides, a "Consortium" of participating actors is set up, as well as algorithms to control access between involved actors of each deal and avoid competitors to see price details in product orders in which they are not involved.

In terms of **certification control and chain-of-custody**, the implementation of blockchain would include registered certifications according to the following process.

1. Producers that request the certification are inspected by the auditors and obtain the recognition of a certified production program
2. Once the program is authenticated, producers can create the digital equivalent (token) of a batch of goods with the additional parameter of "certification"
3. Initial producers of raw material establish a production capacity of the good, that will serve as a volume control of the overall "certified" ingredient
4. Manufacturers have the additional constraint of tracking the usage of input goods, in order to subtract the volume from the overall capacity and globally control the correct flow of certified material from producer to manufacturer (control of the "digital twin" issue)

In terms of **forecast improvement,** important opportunities could come from having visibility of the whole network of suppliers. Anticipating situations of out-of-stock, reducing the bullwhip effect, and optimizing planning processes could result from the adoption of such technology. The impact that centralized and real-time information can have on reducing bullwhip effect in supply chains has been demonstrated through various studies, that mostly focus on measuring the standard deviation in demand. The most visible decrease in demand standard deviation occurs for the manufacturer, while the distributor is affected by BE reductions but to a minor extent. Higher inventory levels to increase protection against BE could be reduced, resulting in decreased total logistics costs and increased margins and profitability. The manufacturer would benefit from the highest savings, since its position upstream in the supply chain would mean higher BE: thanks to greater visibility of the whole SC, this issue would be reduced. (52)

A potential "**weakness**" is related to the inaccuracy of data. There is a remaining chance that the accuracy of the transmitted data is not fully guaranteed. Even if paperwork and human inputs are reduced, there is always space for error in any procedure. These errors could still impact elements such as SKU number, units per order, size, etc.

The **"digital twin" issue** is related to the creation of a secure link between physical goods and their digital counterparts. Serial numbers, bar codes, RFID or other forms of tags can be used to uniquely generate a digital counterpart of a physical good. Physical tags are linked to the blockchain identifiers using a secure hash. Overall volume control algorithms are also an additional method to further improve the validity of digital representation of physical goods. However, the accuracy of the digital twin will always be subject to risks.

Transitioning to blockchain would benefit all actors, reason for which the costs should be split accordingly. The retailer should promote the adoption, in an initial phase, by selecting a group of suppliers as a pilot project. The pilot project should involve one unique transportation carrier, that is willing to adopt the technology with the future perspective of controlling all the routes for our retailer, to simplify the process. The goal of the pilot project is to adopt the system on a smaller scale, to demonstrate the increase in visibility in inbound processes and the insight on forecasting future product orders, as well as reducing chargebacks and paperwork costs to confirm the return on investment. Additionally, the suppliers will be able to see how having visibility on the retailer's warehouse availability of past ordered products can support their production planning and avoid out-of-stocks at the time of next orders.

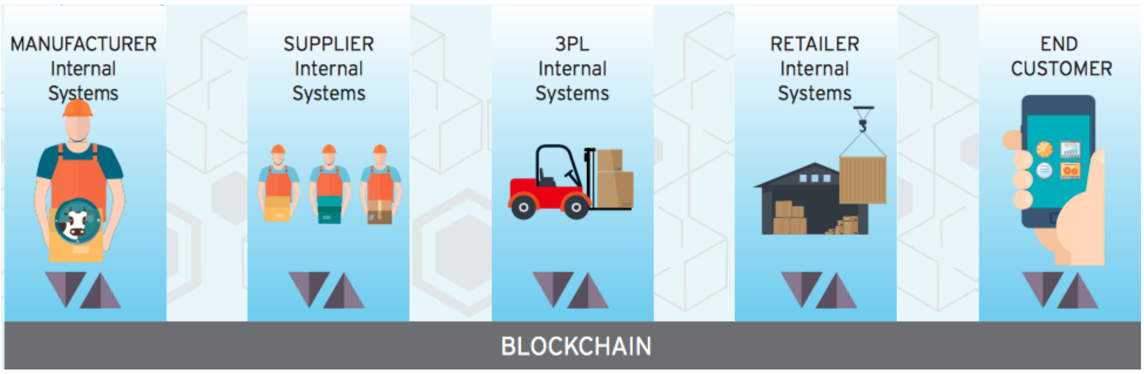


**Figure 16. Blockchain integration in SC**

## Pilot project: "Fresko" Italy

### *As-is-scenario*

Supposing our e-commerce retailer is a food retailer and the pilot market for blockchain adoption is the Italian one, the first requirement is to analyze the **as-is scenario.**

To have insight on the market, food and grocery shopping online in Italy increased by 30% in 2016, for a total value of 575 million euros. Even if this value only represents 3% of overall e-commerce sales B2C in Italy, it is a growing sector. Food is 90% of this total, while 10% is health and care products. (53)

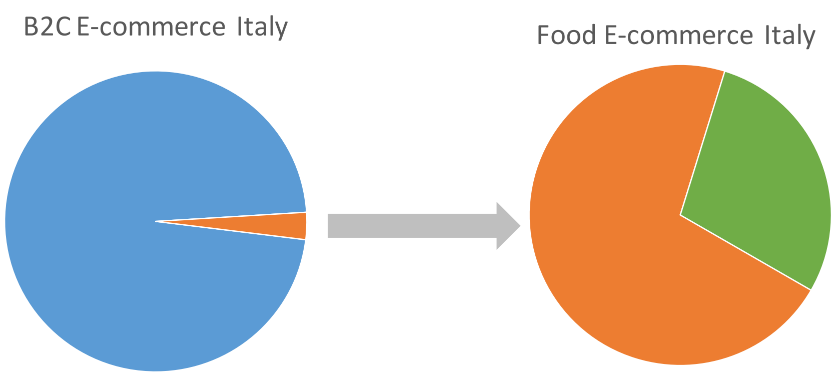


**Figure 17. Food E-Commerce in Italy and Fresko**

Supposing our retailer deals with 40% of this segment its sales are approximately of 230 million (EUR) in yearly sales.

Estimating we have 2 warehouses, one in northern and one in central Italy, these are 6 dock-door warehouses and average time for unloading is now 60 minutes (30 are due to unloading delays and delivery paperwork, 5 on average due to chargeback disputes), operators required per inbound deliveries are 4 per delivery, average daily deliveries are 25 trucks (15 are full truck loads and 10 contain on average 20 euro pallets).

Once the truckload is unloaded, the average lead time for the pallet to be "received" (unpacked if necessary, products scanned and sent to stow) is 36 hours. Pallets are placed in lines, based on product lines and FIFO is based on date and time of unloading. The average time needed to "receive" a pallet is 20 minutes. This is mostly due to the inaccuracy of the information in the pallet-level barcodes and ASNs. This operation is the bottleneck of the inbound process and currently leads to scarce visibility on the "not-yet-received" units. Slow inbound lead time is the root cause for increased safety stock levels and higher inventory costs.[4]

| **Operation** | **Resources** |
|---|---|
| Unloading time | 60 min/truck |
| Operators in Inbound area | 4 operators |
| "Receiving" operations | 20 min/pallet |

**Figure 18. As-is Operations and Resources**

In food supply chains, general challenges additionally involve:

- health certifications and quality labels (DOP, IGP, etc.)

[4] These numbers are an estimate based on assumptions and personal experience.

- expiration date and sell-by date
- food safety (contamination risk, origin, etc.)

The awareness on the **origin of ingredients** used in the final products consumers buy is increasing: 8 out of 10 UK shoppers want to know where their food comes from (54). After the horsemeat scandal in 2013, shoppers are more and more interested in knowing where their food is coming from and retailers are now naming the region of provenance, but often try to name also the specific farm or supplier. A provenance project on fish suppliers "Track your can", by John West (canned tuna in the UK, part of the Thai Union group) added €19 million to the brand's sales (55). According to the group's financial statements, sales from 2012, year of the launch to 2014, sales increase was of approximately €383 million (56) over the whole group. We can estimate that the provenance project contributed to this increase by approximately 5%.

There are also issues related to contamination of ingredients or finished products that can affect the consumer' health safety. Food recall events in Q3 of 2017 were 866 according to the Stericycle European Recall and Notification Index (57). This is a crucial point for producers and retailers, in terms of fast actions that must be planned to prevent further contamination with recalls. From the retailers' or manufacturers' perspective, **food recalls** cost on average $10 million in direct costs alone, according to a study carried out by the Food Marketing Institute and the Grocery Manufacturers Association (GMA). 5% of companies even incurred in over $100m in direct and indirect costs. (58)

A formula has been created to calculate an approximated impact in terms of costs of food recall (59):


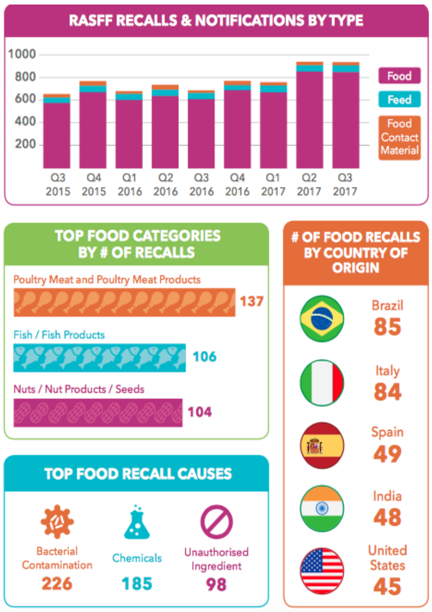


**Figure 19. Food and Beverage Recalls (57)**

As shown in figure 19, the main cause for food recalls is bacterial contamination which may have many causes: unsanitary food handling and pest infestations along the SC are the main ones.

The fight against **counterfeit products** and ingredients is also a huge topic in the food industry. Around 5% of goods imported in the EU every year, according to OECD and the EU's Intellectual Property Office, are counterfeit. Globally, this amounts to $16 billion. In the food industry, olive oil and wine are the main products affected by this issue.

For our specific case study, in the Italian market, the value of the counterfeit goods sales is around €4 billion (60). In an overall sales estimate in the food industry of €132 billion a year (61), reducing or eliminating counterfeit food could increase at least 3% the revenue from sales.

Last but not least is the **food waste** issue that affects our world. 1/3 of global food production is wasted every year. In Italy, according to studies summarized by the Barilla Center for Food and Nutrition (62), food waste is measured around 160kg per person per year. 12 % of this waste can be appointed to the distribution phase of the supply chain, especially for fresh products (cold chain).

***To-be Scenario***

The **to-be scenario** involves using Blockchain to create a distributed ledger that combines data all along the supply chain and tracks each batch of product from the manufacturer to the final consumer. This application would improve the food supply chain in terms of efficiency and speed, supporting warehouse storage, optimizing FIFO management and ensuring respect of regulations. In an advanced phase, it could also solve global issues such as poisoned food lots that need to be tracked and pulled out of the market, resulting in huge cost reduction for both the retailer and the producer, as well as the fight against counterfeit goods. In order to define the details and the impact of the **to-be scenario,** the following points summarize the benefits.

- Improved inbound efficiency (labor planning and capacity planning): optimizing schedule for delivery operations can save up to 875 man-working minutes per day in terms of capacity and 2 operators could be moved to a different area.[5] This means that potentially, the number of trucks delivered per day could increase by over 50%. Accuracy in data could reduce receiving time up to just the time needed for physical unpacking, saving 10 minutes per pallet, resulting as well in reduced safety stock.

In terms of costs, this would result in approximately 46.950 working hours saved per year, which can be measured to a potential saving of €939.000[6].

| Operation | Resources |
|---|---|
| Unloading time | 25 min/truck |
| Operators in Inbound area | 2 operators |
| "Receiving" operations | 10 min/pallet |

**Figure 20. To-be Operations and Resources**

- Reduced expired items (exceeded sell-by date or use-by date) or waste caused by unsafe stow conditions: using the data available of food waste in the distribution phase of the supply chain, we can assume this could lead to a 4% decrease of food waste and resulting 9 million increase in sales, if the whole volume is sold.

Ingredient tracking to ensure compliance to health regulations: this ensures fast response in case of food recall – the undeletable ledger will provide information on the ingredients, the processed products, the storage facility and the transportation details for each batch of initial ingredient. If the contamination occurs, for example, in some warehouses or trucks, it will be possible to follow the batches of product and safely remove from the market only the affected ones. This will save large amounts of money for retailers

[5] These numbers are an estimate based on assumptions and personal experience.
[6] Calculations based on estimate of 360 working days per year and a cost per hour of 20€.

and producers. Using the data on direct costs described earlier, the notification costs (that include campaigns to find where the contaminated ingredients are located) could be reduced or eliminated, saving $400k on each recall. Considering the amount of food recalls in Europe each year and the variety of products sold in an e-commerce retailer, which increases the chances of being affected, the impact could be huge. Supposing our retailer is affected by 10 food recalls on average per year, 4 million euros would be saved.

Additionally, the benefits of implementing BC could result in an increase in sales, mainly driven by the following.

- Counterfeit reduction: increased profit for the "well-behaving" suppliers and retailers and reduction of potential health issues for consumers. Result is increase in sales by 3%.
- Boost customer trust thanks to the ingredient tracking from producer to "shelf" could increase sales by 5%.[7]

The charts show the maximum potential increase in sales if all parameters were verified, after full implementation on all product lines and suppliers and the total cost savings split into its components.

[7] Estimated value based on example case of John West tuna tracking project.

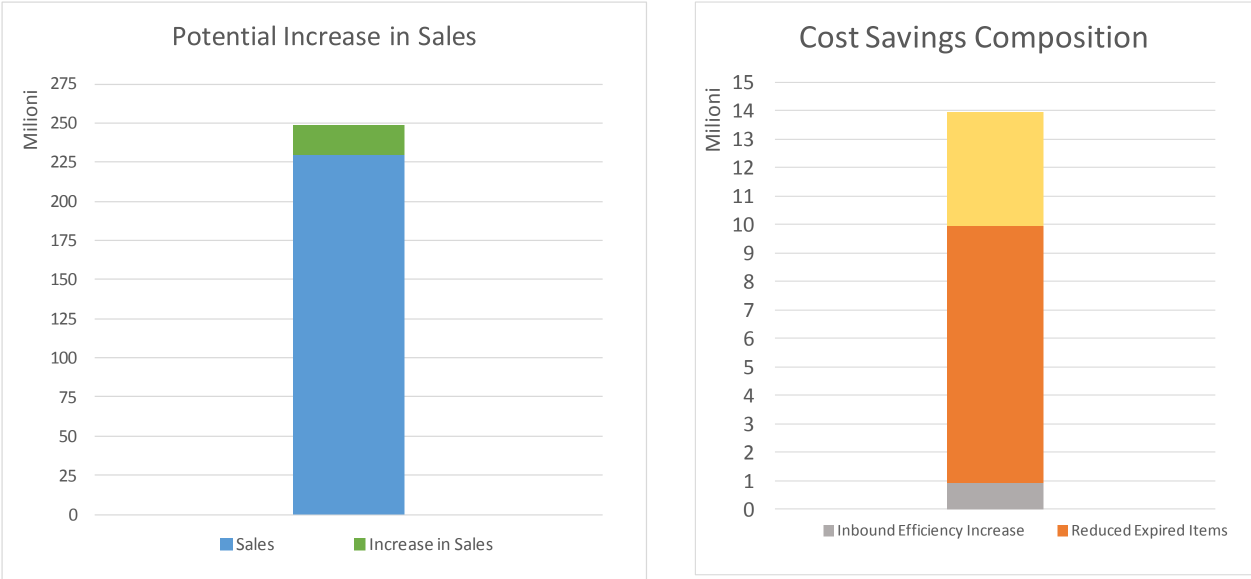


**Figure 21. Potential Increase in Sales and Cost Savings**

***Deep dive on single product line***

To analyze the cost structure of the implementation, we propose a pilot project exclusively on eggs in the Italian market.

An initial introduction on the eggs market segment is needed to understand the issues and the elements that make it a significant pilot project.

| **Fresko egg sales** | **Units** |
|---|---|
| ***Total units*** | 24.315.920 |
| *Direct consumption* | 13.373.756 |
| *Elaborated Products* | 10.942.164 |
| Cooperative X | 9.650.000 |
| Cooperative Y | 4.860.000 |
| Producer 1 | 2.730.000 |
| Producer 2 | 2.590.000 |
| Producer 3 | 1.375.000 |
| Producer 4 | 1.297.000 |
| Producer 5 | 954.000 |
| Producer 6 | 857.000 |
| Producer 7 | 2.920 |
| **Sales (€)** | **11.414.179** |

**Figure 22. Eggs in Fresko Supply Chain (units per year)**

In Italy, egg consumption is of 218 eggs per person per year, out of which 55% is consumed at its natural state and the rest is used in elaborated products such as pasta, cakes, cookies, etc. The total production is of 850 million tons of eggs per year for total revenues around € 6.65 million. The largest Italian producers produce approximately 90 tons of eggs per day. Specific producers are in charge of producing eggs for their transformation into elaborated products such as pasta and cookies. According to recent data on the Italian market, the egg supply network for our retailer can be simplified by the following graph.

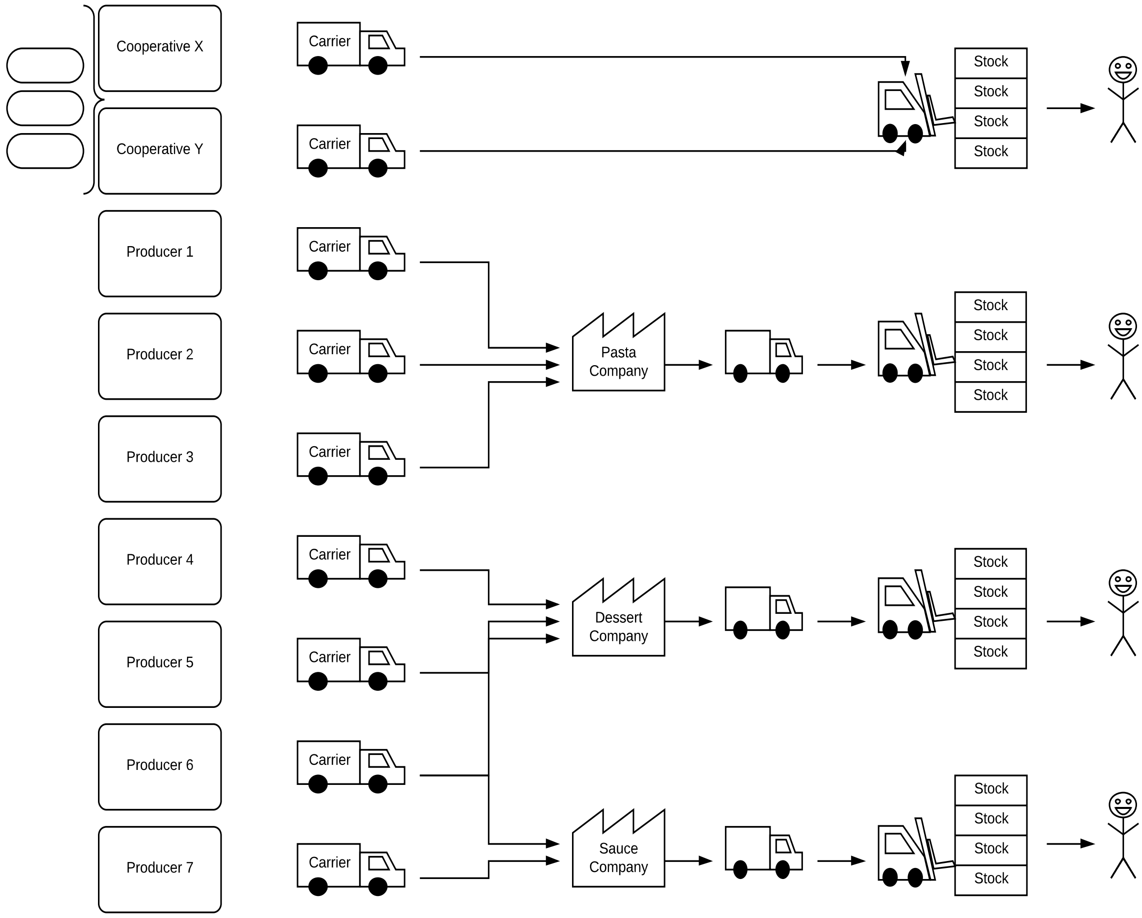


**Figure 23. Simplified Supply Network for Fresko's egg market.**

In order to fully understand the supply network and its issues, some assumptions must be specified:

- Cooperatives collect eggs from smaller farmers and are in charge of packaging for further distribution. This is a common custom in the Italian agriculture market. It is usually hard to keep track of what comes from where. Farmers must provide eggs that are already tagged with the EU code, stating farming method, country of origin, farm ID, best before date. Cooperatives are in charge of creating unified batches and storing the information in digital format.

- Transformation nodes, where batches of eggs turn into sauces, cookies, pasta, etc. are also crucial in terms of information loss. To increase complexity and realism, we assume that producers are not exclusive suppliers of one transformation companies (e.g. producers 4 to 7 deliver eggs both to dessert companies and to sauce companies).
- The graph is simplified, but Fresko offers 3 different pasta brands, 5 dessert brands and 2 sauce brands. This means that BC implementation must involve all of them.

***Cost Analysis***

The following cost analysis is meant to assess the potential of Blockchain adoption in terms of cost savings and potential increase in sales and to verify if the costs can be fully managed by the retailer. Assuming the adoption of IBM Blockchain Platform, we will exclusively need an internal IT support team made of 5 people (3 technical experts and 2 project managers). Yearly total costs of approximately 360.000 euro are fully covered by the cost savings. Additionally, there will be an increase in sales thanks to counterfeit reduction and boost in brand image and customer affection for certified products. The graph highlights the potential increase in sales driven by these elements. Note that the assumptions supporting this analysis are related to specific circumstances (e.g. 3 food recalls in the egg market per year, all non-wasted food is sold, customer trust results in 5 % increase in sales).

| Implementation Costs | | Cost Savings | |
|---|---|---|---|
| ***Internal IT team*** | ***126.000*** | Reduced cost in food recalls | 1.200.000 |
| IT expert in BC (avg per month) | 2.100 | Inbound efficiency | 46.600 |
| ***IBM Blockchain Platform*** | ***243.180*** | Reduced wasted food | 456.567 |
| Monthly subscription per member | 965 | | |
| Members (Fresko + suppliers/carrier) | 21 | | |
| **Year total** | **369.180** | **Year total** | **1.703.167** |

**Figure 24. Implementation Costs and Cost Savings in Fresko Eggs pilot project**

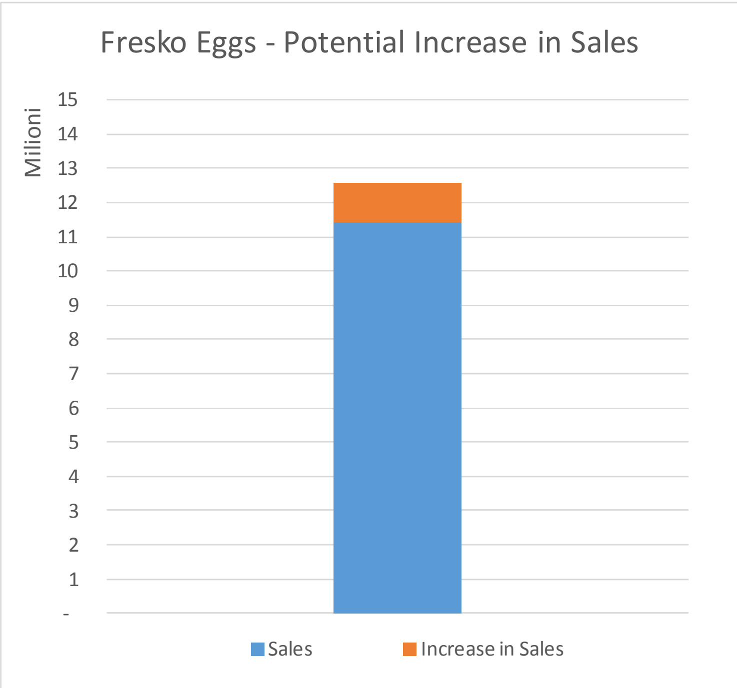


**Figure 25. Potential Increase in Sales in Fresko**

## 12. Conclusion

In conclusion, the case study shows that the cost of implementing blockchain is highly sustainable when compared to the benefits resulting from its adoption. The pilot project proposed for Fresko is an example of the challenges that be faced with blockchain when adopted across a Supply Chain. Blockchain can be a huge investment, mostly in terms of including all suppliers and transportation services in order to implement the technology and make correct use of its potential. As commented in the introduction of the case study, some weaknesses and threats will remain a struggle, since human operations will be reduced, but not eliminated thoroughly and there will be space for human error, limited but still present. The "digital twin" issue will confirm how virtual versions of physical flows could involve inaccuracies and affect the efficiency of blockchain adoption.

Overall, the challenges that are still to be solved in Supply Chain Management can be successfully appointed with blockchain implementation. The "integrated-digital supply network" that all experts confirm must be the goal for any industry at this point in time could be built thanks to blockchain technology. E-commerce, especially, must satisfy speed requirements, precision, real-time tracking at continuously increasing standards. Blockchain could be a successful and interesting technology to apply to a field it wasn't meant for, but where it finds great applications.

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