

Final Degree Project

DEGREE IN INDUSTRIAL ENGINEERING

Blockchain implementation into a seafood company

FINAL REPORT

Author: Fabio Facchini Amondarain
Directors: Ferran Vilà Picas and Emilio Rosico Muñoz
Edition: June 2019



Escola Tècnica Superior
d'Enginyeria Industrial de Barcelona



ABSTRACT

Today supply chains are facing the complexities of a globalized ecosystem where multitude of actors are involved. In general, companies do not know enough about the products they buy and sell as they lack from an end-to-end system for traceability.

Blockchain can be the game changer to equip companies with a seamless traceable system in order to cross borders of their own organisation and track products from the upstream to the downstream of the supply chain. When implemented effectively, it connects and enables efficiency, transparency and accountability among participating actors which tend to be disconnected and lacking from trusted relationships.

This project consist in the development of an end-to-end model particularised for the food industry with traceability as the cornerstone. It has been developed a business case over a seafood company with the intention to serve as a prototype model to be exported and implemented in other companies of the industry. The report starts analysing the maturity level of blockchain and examining platforms and networks where it can be implemented by breaking down strengths and weaknesses of each. It concludes with a feasibility study of the developed solution taking into account economic, technical and scheduling considerations.

INDEX

ABSTRACT	3
INDEX	5
1. GLOSSARY	7
2. PREFACE	8
2.1. Origin of the project.....	8
2.2. Motivation	8
3. INTRODUCTION	10
3.1. Objectives of the project.....	10
3.2. Scope of the project	11
3.3. Blockchain	11
4. SUPPLY CHAIN	12
4.1. Supply chain's architecture	12
4.2. Supply chain management (SCM).....	13
4.3. Supply chain challenges	13
4.4. Food supply chain challenges.....	16
4.5. How blockchain can support the food supply chain industry	22
5. INTRODUCTION TO BLOCKCHAIN	26
6. CASE STUDIES: FOOD COMPANIES AND PLATFORMS CURRENTLY USING BLOCKCHAIN	34
7. CASE STUDY: IMPLEMENTING BLOCKCHAIN IN MARESMAR	38
7.1. Maresmar: a seafood company	38
7.2. Maresmar current business model.....	38
7.3. Current supply chain of Maresmar.....	41
7.4. American lobster supply chain	48
7.5. Rethinking the American lobster supply chain	49
7.5.1. Critical drivers and potential use cases	49

7.6. Benchmarking.....	56
7.6.1. Decision on the type of blockchain network.....	56
7.6.2. Selecting the blockchain platform	63
7.6.3. Project implementation	74
7.6.4. Blockchain as a Service (BaaS)	79
7.7. Implementing Microsoft Azure Blockchain	83
7.8. Developing an end-to-end solution.....	91
7.8.1. Blockchain ecosystem	91
7.8.2. Smart tagging and smart devices (IoT)	95
7.8.3. Tokens and cryptocurrency (ETH).....	100
7.8.4. Smart contracts	101
7.8.5. Customer's access to information.....	102
7.8.6. Total Cost of Owership (TCO)	103
7.8.7. Project feasibility	110
7.9. Progressive adoption of the end-to-end solution.....	115
CONCLUSION	123
ACKNOWLEDGEMENTS	128
BIBLIOGRAPHY	129

1. Glossary

Supply chain: A supply chain is a network between a company and its suppliers to produce and distribute a specific product to the final buyer. This network includes different activities, people, entities, information, and resources. The supply chain also represents the steps it takes to get the product or service from its original state to the customer.

Disruptive technology: Disruptive technology significantly alters the way businesses or entire industries operate. It often forces companies to change the way they approach their business for fear of losing market share or becoming irrelevant.

Blockchain: Blockchain is a type of distributed ledger for maintaining a permanent and tamper-proof record of transactional data. A blockchain functions as a decentralized database that is managed by computers belonging to a peer-to-peer (P2P) network. Each of the computers in the distributed network maintains a copy of the ledger to prevent a single point of failure and all copies are updated and validated simultaneously.

Distributed ledger technology (DLT): Distributed Ledger Technology refers to the technological infrastructure and protocols that allows simultaneous access, validation and record updating in an immutable manner across a network spread across multiple entities or locations.

Hash: A hash is a function that converts an input of letters and numbers into an encrypted output of a fixed length. A hash is created using an algorithm, and is essential to blockchain management in cryptocurrency.

Consensus: Consensus mechanisms are protocols that make sure all nodes (devices on the blockchain that maintain it and sometimes process transactions) are synchronised with each other and agree on which transactions are legitimate and are added to the Blockchain.

Smart contracts: Smart contracts are self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code. The code and the agreements contained therein exist across a distributed, decentralized blockchain network.

Internet of things (IoT): The Internet of Things (IoT) refers to a network comprised of physical objects capable of gathering and sharing electronic information. The Internet of Things includes a wide variety of “smart” devices, from industrial machines that transmit data about the production process to sensors that track information about the human body.

2. Preface

2.1. Origin of the project

Nowadays supply chains have evolved to complex global supply chains networks where rapid advancements in technology play a vital role to integrate business, technology, people, and processes not only within the enterprise but also across extended enterprises.

Moreover, among the food industry it exist an increasing demand for traceability, from customer service purposes, to safety, regulatory and managerial reasons.

Involving different actors like farmers, warehouseers, shipping companies, distributors and retailers means involving different record-keeping methods: from robust databases to email chains to paper printouts. Consequently, information gets fractioned and it is more difficult to track products and assets back to their origin. Despite considerable investments in running enterprise resource planning (ERP) and supply chain management software, they are often out of sync and move data only one stop down the supply chain. Companies are willing to adopt Supply Chain Management (SCM) systems that provide them inter-enterprise cooperation and collaboration with suppliers, customers, and business partners.

The complexity and the need for greater transparency and traceability are the reasons behind the increasing interest in blockchain application within supply chains. Blockchain is a distributed ledger technology (DLT), meaning data becomes permanent and easily shared, giving supply chain players more comprehensive track-and-trace capabilities than ever before. Such system could reduce delays, increase transparency, and reduce human errors.

2.2. Motivation

My attraction for the blockchain technology arose from an interesting conversation with my broader Marco with who we were talking about different emerging technologies. He showed me the Gartner Hype Cycle where technologies like AI, machine learning, IoT platforms or digital twins among others are classified in a curve according to expectation and time. What make me focus into blockchain was the fact that it has passed first years of hype and theoretical approaches and is now driving to real adoption in today's world. Then I started reading articles and watching videos to know more about how blockchain works and in which areas can become a game changer. I saw a strong potential in the supply chain use

case combined with realistic and plausible possibilities to adopt it. Therefore, I thought where I could develop a business case and here is where a friend of mine, Jordi Cubells, open me up the possibility to study the seafood company Maresmar founded by his father. He posted no objection in analysing and discovering how his company works in order for me to develop this project.

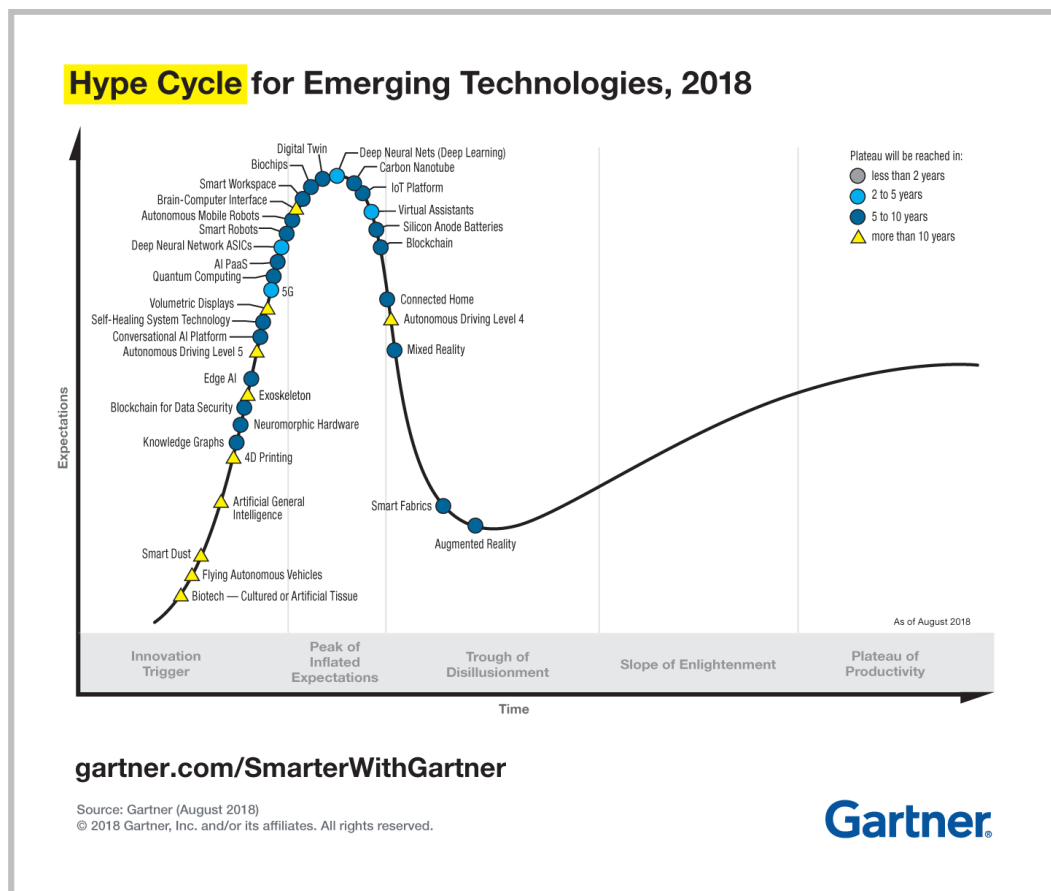


Figure 2.1 Gartner Hype Cycle for Emerging technologies. 2018

3. Introduction

3.1. Objectives of the project

The main objective to achieve in this project is the realization of a business case study of the application of blockchain technology into Maresmar, a seafood company located in Barcelona. Other minor goals are developing a model able to be adapted in other companies of the seafood industry and analyse how blockchain can become a disruptive technology in the supply chain management field. That is, in schematic form:

Main goals:

- Study the potential use cases of blockchain into Maresmar company and develop a viable model to be easily implemented and seamlessly working.

Secondary goals:

- Explore how far blockchain adoption has gone at the moment in the supply chain and food industry to learn from complexities of implementation in order to develop a particularized solution. It is mainly focussed in traceability and process automation purposes.
- Develop a prototype model solution to serve a starting point for food companies that are looking for an end-to-end blockchain integration into their current supply chains as the blockchain hype increasingly turns into reality.
- Gain Maresmar attraction to develop the created solution.

3.2. Scope of the project

The initial scope of the project was to develop an end-to-end system in the overall of Maresmar supply chains able to:

- Provide traceability capabilities to track products to their origin and furnish real-time shared information at any stage of the supply chain.
- Integrate smart tags and IoT devices.
- Develop an improved customer experience for Maresmar clients.

After facing different hurdles and limitations to implement all these features, the project changed to a narrowed scope. The coverage of the model is limited to one seafood product, the American lobster, but having in mind a wider adoption for the rest of Maresmar products.

3.3. Blockchain

Blockchain is one of the top ten strategic technologies identified by Gartner, research and advisory company, which will undoubtedly disrupt digital business. [1] It started as a digital currency infrastructure for Bitcoin, but its intrinsic features to publicly validate, record, and distribute transactions in immutable, encrypted ledgers provide a promising potential for infinite business use cases. One of this is in the supply chain value creation. Many processes can be optimized by eliminating slow manual processes in the lower supply tiers and by bringing trust across supply chain actors for the development of an efficient and reliable traceability system.

Although it holds long-term promise and hype about this technology has already overpassed, blockchain promise outstrips blockchain reality, and many of the associated technologies are immature for the next two to three years.

4. Supply chain

In order to examine the potential use cases of a blockchain implementation into different companies of the food industry, it is essential to define and understand what supply chain and its management consist of as well as weaknesses and challenges they are currently facing.

4.1. Supply chain's architecture

A supply chain is a network of facilities that procures raw materials, transforms them into intermediate subassemblies and final products and then delivers the products to customers through a distribution system.

In order to execute all the steps it takes to get the product or service from their original state to the customer, the supply chain involves producers, vendors, warehouses, transportation companies, distribution centres, and retailers.

The elements of a supply chain include all the functions that start with receiving an order to meeting the customer's request, where customer refers either end-user or intermediaries. These functions include product development, marketing, operations, distribution, finance, and customer service.

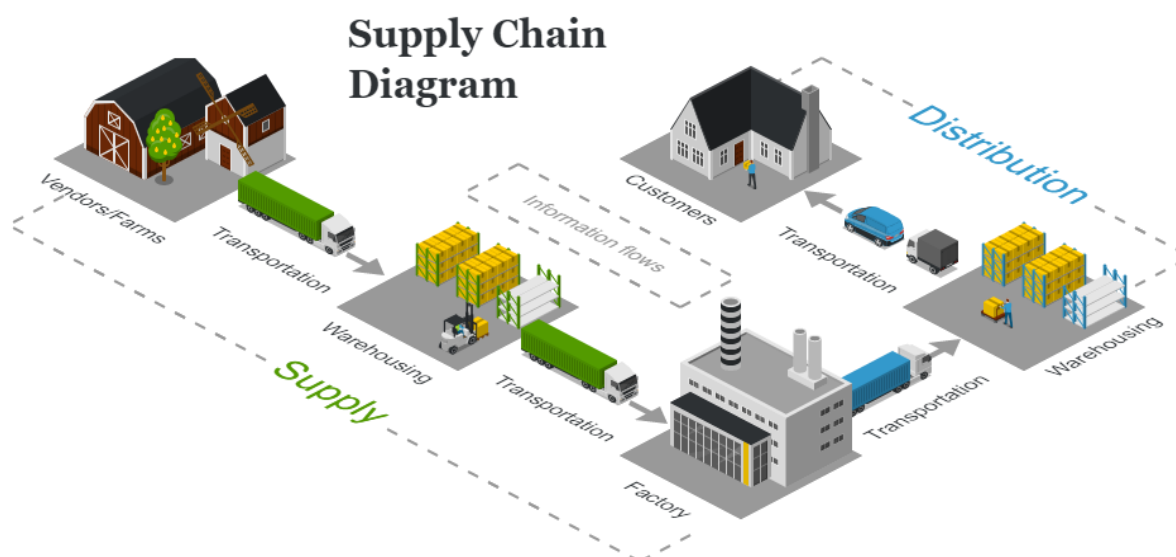


Figure 4.1 Example of a supply chain diagram

4.2. Supply chain management (SCM)

Supply Chain Management (SCM) is the active management and integration of all the entities in order to distribute the right product or service at the right quantity, at the right place and at the right time. By managing it properly, costs are minimized while adding value to products and satisfying customers' requirements in order to gain competitive advantage in the marketplace.

The terms supply chain management and logistics are often confused. Logistics refers specifically to the part of the supply chain that deals with the planning and control of the movement and storage of goods and services from their point of origin to their final destination. Logistics management begins with the raw materials and ends with the delivery of the final product. Supply chain management, for its part, deals with three major flows: material, information and financial. Material flow tend to be unidirectional as physical products move from supplier to customer. Information flow consist on transmitting purchase orders, delivery status, invoices, customer complaints in a bidirectional way between supplier and customer. The financial flow involves the movement of money from the customer to the supplier.

Proper implementation of supply chain management can result in benefits like increased sales and revenues, decreased frauds and overhead costs, or quality improvement. Moreover, this will also lead to accelerating production and distribution with an overall improvement in efficiency.

The interconnectivity of different elements in the supply chain gradually becomes more inefficient when a business grows. In order to resolve these inefficiencies and save a company's money, different technologies like AI and Machine learning are being applied to SCM. Amongst these, blockchain is exploring new ways to change the overall game.

4.3. Supply chain challenges

Contemporary supply chains come with unprecedented complexity as multiple parties must cooperate to move goods around the globe. To deal with sophisticated supply chains, almost every company runs computerized enterprise resource planning (ERP) and supply chain management software together with a large variety of connected devices and equipment, enabling product tracking within computerized systems. However, all this digital infrastructure provides limited visibility into where all their products are at any given moment as there are still existing gaps once they cross organizational boundaries. By the hand of technology, supply chains have developed to supply chain networks and companies start to realize that to succeed in this digital economy, integration of technology, people and

processes must go beyond their own enterprise and extend across other enterprises.

Retailers and manufacturers place trust in their upstream suppliers, distributors, and transportation providers. The quality of their end-customer experiences depends on other organizations' ability to transfer the right assets, to the right place, at the right time, in the right manner. Traditional methods such as manual inspections, audits and record reconciliation become expensive, time-consuming, and susceptible to faults, therefore inducing extra costs on all parties.

Nowadays dynamic supply chains demand a better solution able to integrate all these parties to optimize processes in order to reduce costs, wasted materials and production errors.

Moreover, supply chain disruptions like natural disasters, transportation failures or geopolitical instability may affect the cost, timing or risk of a supply chain at any given time and having the tools to minimize their impact should be a priority for companies.



Figure 4.2 How blockchain will transform the modern supply chain, Microsoft [2]

Globalization

Trying to cope a globalized marketplace requires having a powerful and trustful network able to coordinate and collaborate with parties across borders regarding manufacturing, storage, and logistics. Many companies are outsourcing their manufacturing operation to countries with lower labour costs, lower taxes and lower costs of transport for raw materials. This cross-border movement entails an increase in complexity of the supply chain while delivery times still have to meet customers' requirements even if manufacturing processes are held abroad. According to enterprise managers, it is essential to have strategic and reliable suppliers that ensure global quality and real time control of the processes.

Besides, on a globalized world, an adapted and integrated supply chain must be implemented allowing data access and communication between parties. In some countries, manufacturers are still working with email and fax for communicating yet any kind of EDI (Electronic Data Interchange) system is considerably more effective. At that point, is where the company desiring to move abroad should ask itself if they are able to develop their

supply chain technology on the new country and accurately manage limited communication forms and globalization challenges.

Fast-changing markets

Another major challenge for supply chain emerges as consumer behaviour change according to constantly changing new trends. Globalization and technology, by the hand with social media, continuously change customers' demands, forcing enterprises to adapt to them in order to stay attractive and competitive.

Products have shorter life cycles and supply chains must be flexible and able to be reused for future products. Each supply chain needs to be adapted and redesigned according to products changing features.

Another problem that arise with fast-changing markets is the requirement of an agile supply chain that can easily readjusts to a fluctuant demand as forecasting new products become harder.

High quality products

In addition to the influence on consumer behaviour, social media points out the value of having high quality products. Many customers base their purchases on reviews and comments on social media, which increases pressure over providers to create quality products. This quality then, can be addressed on various levels of the supply chain: from manufacturing and packaging to logistics and product handling. The truth is that an equilibrium must be found as increasing quality generally means increasing costs. If there is the chance of decreasing costs of a specific process benefiting from a new technology or rethinking the current process, then an increase in quality must be considered as it could result in an increase of sales.

Safety and compliance

Related with quality, enterprises have to deal with safety and compliance too. Satisfying certain levels of regulatory standards with documents such as permits and certifications can present some challenges for the SCM. A lot of paperwork is currently used to undertake products and enterprise safety and compliance. Emerging technologies could definitely cut this tendency and work on faster supply chains. IoT, smart packaging, and blockchain allow this change but at the same time require IT systems able to manage the amount of output data that is going to be created.

4.4. Food supply chain challenges

Complexity is also inherent in the food industry and companies do not always know enough about the products they are trading with. Some companies are realizing the value creation of traceability for efficiency, cost savings, and brand reputation. Technologies like blockchain can furnish companies with real-time traceability of products within global food supply chains. Better and more reliable data can help optimize business decisions and reach higher standards for production, efficiency, and sustainability.

On the other hand, it is undeniable that food is an essential product for human beings, which requires a precise synchronization of all the steps of the supply chain to accomplish due dates. Besides, the fact of working with perishable products increases the complexity of the supply chain compared to other industries.

In order to guarantee food quality, safety, and freshness within limited time, supply chains entail efficiency and optimization on every stage and on the use of resources like trucks, warehouse facilities, transportation routes and workers. It has been reported that two-third of the wasted food occurs as a result of an inefficient food supply chain management.

New technologies such as the Internet, IT or automation have considerably improved food processing, but there exist many challenges that food supply chain management is not capable to assuage yet.

Challenge 1: Coordination across multiple and often disconnected supply chain actors

Complexity in global supply chains involve many different actors (producers, transporters, processors, wholesalers, retailers and consumers) among which trust could not always be achieved. This lack of trust limits the level of collaboration. Different parties might be reluctant to share data or invest in a direct relationship with the other actors though it could result beneficial for all of them. Lack of trust is generally caused by a lack of communication. Having close communication between parties provides faster and better services at lower costs and that is the reason why business models that integrate coordination across these many actors are required.

Communication plays a vital role when things do not go as planned and supply chain disputes occur. When a member of the supply chain fails to deliver assets on-time and in-full, or if the quality of assets has been compromised en route, they will likely have to deal with fines. Dispute resolution involve clarifying responsibilities and without a close relationship and communication it can become even harder to determine and lead to major problems between parties.

Challenge 2: Arduous and costly data reconciliation processes

Nowadays supply chain are spread across multiple facilities and countries and the lack of an end-to-end integration hampers keeping track of inventory and manage the great amount of data and legal regulations. In consequence, vast volumes of duplicative data appear and huge efforts in the tracking and reconciliation of data for a single transaction is needed. Multiple copies of the same documentation (certifications, transport orders, bills of lading, etc.) into different actors leads to the risk of the data becoming out of sync and making it difficult to identify original versions and rely on its preciseness.

In many cases, these reconciliation processes are still manual and paper-based, and errors and data duplication imply high reconciliation costs. In the same way, working with hand written documentation implies transferring it to an ERP or supply chain management software, demanding for a person to constantly updating it with the amount of time it requires. Despite digitally recording documents, point-to-point messaging systems limit sharing capacity as they move data only one stop down the supply chain. Besides, in many supply chains each participant has their own and different from others parties label to identify products, which obstructs tracking and having reliable and synchronized information.

Challenge 3: Lack of trust and transparency among stakeholders

The lack of shared information and the lack of communication between parties directly affects trust and transparency of a company. Being able to show a detailed vision of your business is a powerful way to build trust around you, which translates into strengthening brand integrity and increasing customer loyalty.

Moreover, food supply chains are constantly threatened when counterfeit and adulterated food and drink cases appear on the news. An example of this is the horsemeat scandal that came out in 2013 in Britain and Ireland where beef burgers mixed with undeclared horsemeat were sold. [3] Consequence of this major scandal that rapidly spread around Europe resulted in the loss of supply contracts with major supermarkets chains for some the beef suppliers and a general decrease in the sales of red meat. Cases like that show how important is to have a trustful system and network of suppliers as well as the need of a strong regulation to force food companies to show all the blind spots of their supply chains.

Challenge 4: Lack of product traceability and visibility

According to EU law, traceability is the ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all stages of production, processing and distribution. [4]

Challenges like the lack of trust and transparency go hand in hand with product traceability.

Providing the traceability of a product can help to tackle them as it clarifies any doubt of good's origin as well as sets out the relevant responsibilities of each party.

A lack of traceability is commonly caused by using outdated systems or traditional paper tracking and manual inspections that introduce errors and delays into sharing information.

From the seafood industry perspective, the challenge of a lack of traceability resides in the fact seafood supply chains are highly fragmented with very little connection from the point of harvest to the point of consumption.

According to the United Nations Food & Agriculture Organization's Report: The State of World Fisheries and Aquaculture, 85% of the world's seafood proceeded comes from developing nations where much of that is harvested by independent smallholders selling their product to independent intermediaries, who at the same time, sell batches of seafood to independent processors, and so on. This massive lack of traceability is aggravated when final vendors are selling seafood to their customers whilst being completely unaware of the key data elements (who, what, when, where) of their products. It goes even further as many of these final sellers are promoting sustainability commitments with a complete data ignorance and capabilities to track back their goods to their provenance.

Being able to visualize and share this information enhances food safety, strengthens brand integrity and increases customer loyalty.

Due to the major impact of traceability in food supply chain, a deeper approach on this challenge is needed, focusing on three main areas: consumer's demand for traceability, processes optimization, and recalls and regulations.

Consumers' demand for traceability

Over the last few years, consciousness over food products origin have considerably increased whereas a massive drop appeared in food supply chain's trust. There are not few the surveys and studies backing that phenomenon like the one conducted in Europe in 2012 by the European Commission (figure 4.3). It showed that 71% of consumers consider origin, after quality and price, as an important factor when buying food. [5]

QD3. When buying food, how important are the following for you personally...?

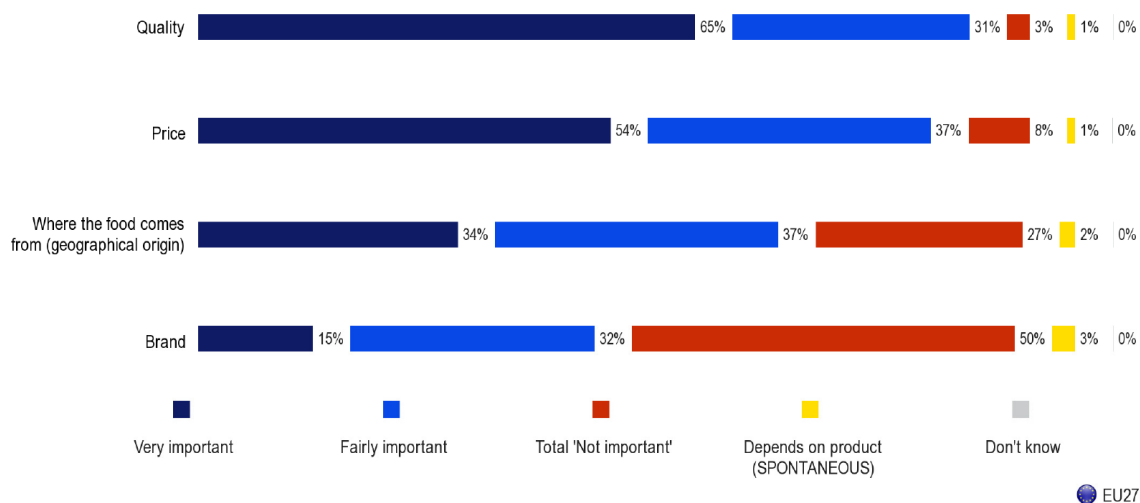


Figure 4.3 Europeans' attitudes towards food security, food quality and the countryside, 2012

Another survey from 2018 carried by the Label Insight and the Food Marketing Institute found that 75% of consumers are more likely to switch to a brand that provides in-depth product information beyond what's on the physical label. It is a significant increase compared to a similar study from 2016 when 39% agreed they would switch brands.

Directly focusing on seafood, Oceana organisation revealed that one in three of the 1215 seafood samples they took in the United States were mislabelled, demonstrating fraud and trust issues comes in the whole seafood industry. In accordance with this facts, a Marine Stewardship Council (MSC) survey showed that almost half (46%) of respondents agreed that they trust brands that use eco labels (a form of third party certification) more than those that don't.

With these findings, companies should consider focusing their efforts to make a better customer experience and satisfy this increasing demand for traceability with full sharing of information. Nowadays technologies allow gathering and showing all this information to consumers in a matter of seconds and implementing this kind of solutions in a company suppose a competitive advantage not to be missed as it leads to increased consumer's confidence.

On the other hand, because consumers cannot know in detail what processing steps and resources are used in the production of food, they seek for a guarantee of high quality and safe consumables. Having certified labels on products from third parties organizations is the best mechanism to proof in front of consumers that a food item has gone through various

inspections and that meets safety requirements. In addition, it provides certainty that food does not come from illegal activities, whether that's corruption where a farmer does not get paid what he is due or overfishing without a license, giving suppliers and customers the confidence that what they are buying is legal, safe and fairly traded.

Likewise, some consumers are looking for local products or they prefer to avoid foodstuff from certain areas in the world, and here is where traceability can help to make their shopping choices. In the same way, it encourages and promotes the consumption of domestically produced products and local commerce.

Processes optimization

In order to tackle all this consumers worries, enterprises should take traceability more seriously and adapt it into their current supply chains processes.

Beyond satisfying consumers, traceability also has a direct impact on the company's productivity as it provides a precise knowing of its product and processes in a complete manner which allows addressing the difficulties and weaknesses straight forwardly. This better understanding of the company leads to an undeniable improvement of the operational efficiency: inventory accuracy is more flexible to consumers demand; it reduces out-of-date product losses by allowing efficient operation of first-in-first-out systems; communication and relationship with suppliers is improved; errors rates, shrinkage and food waste decrease as product recalls can be tackled more efficiently.

Traceability also helps identify and minimize certain hidden costs and misunderstandings like, for example, attributing the problem to the wrong supplier.

Recalls and regulations

Product Recalls are defined as the action to remove food from the market at any stage of the food chain, including that possessed by consumers. Detection of a food safety problem can arise as result of a regulatory sampling and testing or due to a food poisoning outbreak. In any event, responsibility relies on food business operator to follow up the problem, and trace-back in the supply chain to identify its cause and origin. Once identified the source of the problem, it also needs to trace forward to warn all the operators to recall the unsafe product.

A well-constructed traceability system can help to minimize recall size as it is clearly visible when and where the unsafe food has been or is currently located and respond quickly to tackle it concretely by reducing the scope and not by retiring the whole shipment of the product. A precise knowledge of which batches or facilities have been affected provides an under-control situation that helps to keep customer trust.

Removing unsafe products from the supply chain before creating bigger damages is a way of protecting against legal issues as well as reducing extremely high costs associated with a recall process and the damage to the brand.

Traceability not only can result beneficial for a recall process but there are various regulations to comply with. The EU's General Food Law that entered into force in 2002 makes traceability compulsory for all food and feed businesses. It requires that all food and feed operators implement special traceability systems. They must be able to identify where their products have come from and where they are going and to rapidly provide this information to the competent authorities. Business operators have to document the names and addresses of the supplier and customer in each case, as well as the nature of the product and date of delivery.

	Overall responsibilities	Actions taken when a risk is identified
Food and feed businesses	<ul style="list-style-type: none"> Identify and document information on products "one step forward and one step back" in the food chain. 	<ul style="list-style-type: none"> Immediately withdraw the affected products from the market and, if necessary, recall them from consumers. Destroy any batch, lot or consignment of feed that does not satisfy food safety requirements. Inform the competent authorities of the risk and of the action it has taken.
Member State authorities	<ul style="list-style-type: none"> Monitor production, processing and distribution of food and feed products to ensure that operators have traceability systems in place. Fix and enforce appropriate penalties for operators that do not meet EU requirements on traceability. 	<ul style="list-style-type: none"> Ensure that operators are meeting their obligations. Take appropriate measures to secure food safety. Trace the risk backwards and forwards along the food chain. Notify the Rapid Alert System for Food and Feed (see box).
The EU	<ul style="list-style-type: none"> Establishes sector-specific legislation on traceability as appropriate. The Food and Veterinary Office of the European Commission carries out regular inspections to ensure that food and feed operators are meeting food safety standards – including the implementation of traceability systems. 	<ul style="list-style-type: none"> The European Commission alerts members of the Rapid Alert System for Food and Feed of the risk. Requests information from operators to enable traceability and coordinates action by national authorities. May impose import/export restrictions.

Figure 4.4 European Commission guidelines: Roles and responsibilities when a risk is identified

Particularizing for the fish industry, Regulation 01224/2009 provides fisheries control by requiring product information to be available throughout the supply chain. It includes lot number, name of fishing vessel or aquaculture unit, FAO species code, date of catch or period over which caught, quantity, date of supplier, commercial designation, scientific name, catch area and production method.

4.5. How blockchain can support the food supply chain industry

If you're buying some food or medicine, for example, you have this complex global supply chain...Ideally, you'd want to have some kind of common shared network that you could use to get all the information about where each individual thing came from so you could trace every part of the product back to where it came from. You could have a smartphone app that you could check everything about the product and see if it satisfies your needs. To do this kind of thing, you need to have a shared network and the Blockchain is a great way to do it. - Vitalik Buterin, Ethereum co-funder

Vitalik Buterin states a reality as more can be done to equip companies with real-time traceability of products within global food supply chains. Blockchain, a type of distributed ledger technology (DLT), has been increasingly gaining market attraction in supply chains. While blockchain alone does not solve traceability, it can be a game changer. When implemented effectively, it can connect and enable efficiency, transparency, and accountability among participating actors. Better and more reliable data can help optimize business decisions and reach higher standards for production, efficiency, and sustainability.

Blockchain, due to its intrinsic properties, offers substantial benefits as it creates value to different actors in the supply chain that can undertake the challenges discussed in the previous section. Moreover, bringing blockchain with other technologies can even broaden the field of action.

Value 1: Product traceability

Combining blockchain technology with IoT sensors, RFID tags, and other monitoring technology enables instantly capturing and sharing more data to each party in a supply chain. It ensures that products are being kept in agreed-upon conditions and empowers participants to identify and fix mistakes in real time.

The entire record of production techniques, product data and certificate documents can be shown in the blockchain to discerning end customers to prove the veracity of product claims. Consumers benefit from an increased confidence in products, permitting to discern between brands based on alignment with values. On the other hand, suppliers and retailers benefit from decreased risk of counterfeit products, condition fulfilment and increased brand loyalty from consumers due to ability to accurately attest asset provenance. Moreover, systems based on blockchain bring great traceability solutions for a fast-dangerous product when a recall situation is undergone. In a matter of seconds, it is possible to discover the source of contamination.

At the same time, blockchain interoperability can overcome the challenge it represents having different traceability systems to track products and meet compliance requirements. Each entity can maintain their own traceability system while being able to view the same data on a product's lifecycle through a constantly refreshed digital ledger. Blockchain technology enables data sharing without the need to change the traceability systems each entity has.

Value 2: Transparency and auditability

Uploading information and data about products enforces transparency and provides a real-time sharing platform for the different stakeholders of the supply chain. Depending on the settings and policies of the network, different layers can be applied to show specific information to specific actors regarding product processes, origin, delivery times, etc. of the product. Hence, transparency and visibility levels increase with its attached increase in trust due to major communication between partners.

Using blockchain to record asset provenance, environmental conditions, and transfers in real-time removes ambiguity and increases accountability. Transactions are sequentially documented in the blockchain and provide deeper auditability capabilities to verify a product's authenticity and trace it through its chain of custody. In consequence, disputes can be solved much faster as everything is recorded in the network.

On the other hand, transparent data collection and monitoring are auditability features that can help to reduce risk and allow suppliers to evaluate their performance and demonstrate it to potential clients. Consumers for its part benefit from a lower frequency of out-of-stock goods.

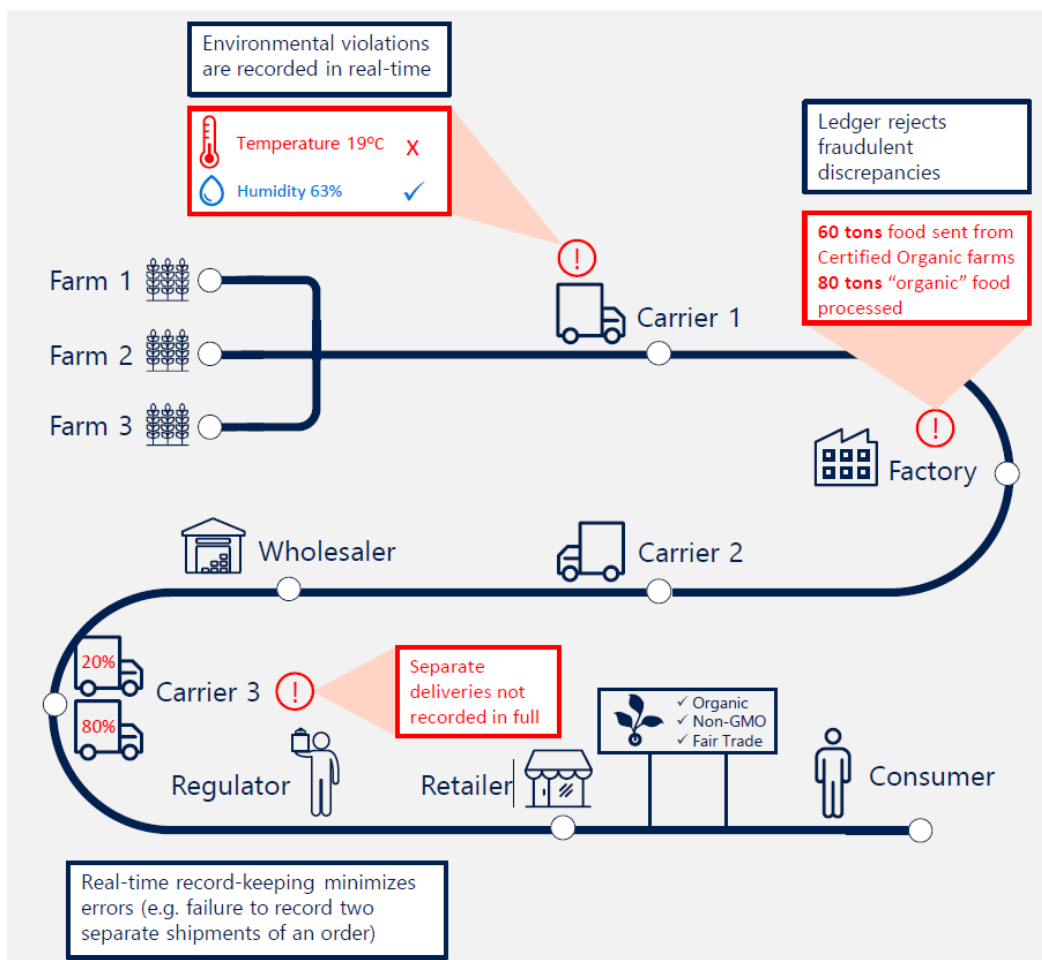


Figure 4.5 Blockchain in action - How blockchain will transform the modern supply chain, 2018, Microsoft [2]

Value 3: Streamlined operations and process automation

Blockchain brings the possibility to eliminate paper-based records and manual processes in the introduction of data. Key information is shared in a commonplace for all parties to access it without the need to ask for it individually to each other. Additionally, it allows involving less human interaction, and its associated errors, as it integrates data entry with automated smart devices. In the same vein, smart contracts play a vital role in a blockchain solution as they automatically process steps to execute the terms of an agreement between counterparties without the need for a human intermediary. When terms of an agreement are met, automatic actions are triggered.

In the overall, blockchain reduces the human error while automating and fastening processes in the whole supply chain.

Value 4: Security and trust

Trust will always rely on the correctly data entry from the person in the first step of the supply chain. However, once entered blockchain cryptographically secured it in a chronological way that facilitates identification after the initial data entry. In addition, data is distributed across the different actors as they own a synchronized exact replica of the ledger, which provides confidence on data that cannot be tampered or altered without the rest of actors noticing it. When data is going to be changed, every participant must agree according to established consensus mechanism.

Value 5: Eliminate the need for intermediaries

Working on a trustful environment such as the one provided by the blockchain opens up a world of direct trade between parties without the need of intermediaries to verify every action. Organizations can connect with each other directly in a secured way that accelerates product's movements or payments by reducing their dependency on single entities like banks or notaries.

Value 6: New channel of customer engagement

Data transparency can help smallholders farmers or producers and suppliers to adapt better to customers' demand to reduce risk of overproduction and waste and improve profitability while building a better delivery time for their store. In addition, providing some product information to the end-user can boost confidence and loyalty and create a stronger business relationship.

5. Introduction to Blockchain

This section breaks down the main technical features of blockchain in order to have a clear idea of this emerging technology. Definitions do not dive into technical details but try to simplify the complexity behind blockchain in a way it is understandable by non-blockchain experts.

Blockchain is an internet-based technology with the ability to publicly validate, record, and distribute transactions in immutable, encrypted ledgers. The technology was first introduced in 2009 by Satoshi Nakamoto to support transactions in Bitcoin, a virtual cryptocurrency that maintains its value without support from any centralized authority or financial entity. Rather, the coin is held collectively and securely by a decentralized P2P network of actors that make up an auditable and verifiable network.

Beyond Bitcoin, blockchain is a new type of data system that maintains and records data in a way that allows multiple stakeholders to confidently share access to the same data and information. In essence, is a type of distributed ledger technology (DLT), meaning it is a data ledger that is shared by multiple entities operating on thousands, if not millions, of computers linked to distributed networks in all parts of the world.

The term "Blockchain" is derived from the "blocks" of validated and immutable transactions and how they link together in chronological order to form a chain. Hence the term "Blockchain."

Distributed Ledger Technology (DLT)

In essence, blockchain technology provides the platform for creating and distributing the ledger, or record, of every transaction to thousands, if not millions, of computers linked to networks in all parts of the world.

Traditional ledgers are owned by one entity (such as a business, organization or group) and controlled by a designated administrator (for example, an accountant). This administrator can implement changes to the ledger without requiring consensus from all of the ledger's stakeholders. In contrast, blockchain is a shared, decentralised, distributed ledger among a network of stakeholders that cannot be updated by any administrator. Instead, it can only be updated with the agreement of network participants (Consensus) and all changes to the distributed ledger are auditable. A similar process can be used to trace other types of asset transfer, to commit new data to a blockchain, and to update data in it.

Dealing with a shared data system is only possible with strong cryptographic techniques that

make certain that copies are identical, transactions are not duplicated (double-spending), and specific permissions are enforced to access stored data. Here, public and private keys are used to ensure confidentiality and privacy. In simple terms, a public key can be compared to the address of a physical mailbox, which is publicly known by senders. A private key is similar to the key or password required to unlock the mailbox; it is safeguarded at all times by the owner and must not be shared with third parties.

Having a public register of transactions with the public addresses in it brings transparency and auditability levels that have never existed before and that forces companies to be accountable and honest for their actions. Nonetheless, this only applies for open ledgers like Bitcoin, where every single historical transaction is recorded and can be viewed by anyone without special permission. For enterprise use, private ledgers are more suitable as data can only be read and manipulated by users with the required access control.

As it is built on multiple systems belonging to multiple entities, responsibility of storing, maintaining and validating information present on the blockchain is shared by the different participants. However, none of the relying parties is connected to all others directly, but instead at least indirectly.

In the overall, working with a blockchain network provides peer to peer (P2P) participation, meaning everyone is treated equally and under the same conditions.

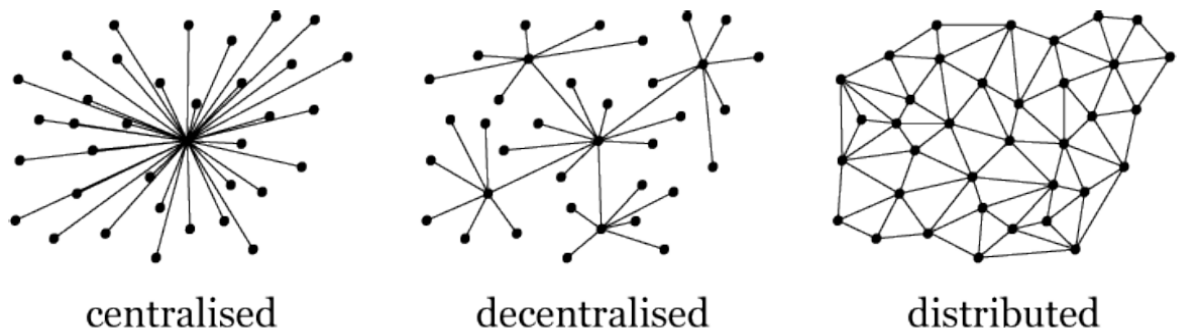


Figure 5.1 Centralised vs decentralised vs distributed network

Block structure: Immutability

This technology operates by recording and storing every transaction across the network in a cryptographically linked block structure that is replicated across network participants.

Each block has a hash, which is the output of an algorithm that turns the contents of the block into a random mix of letters and numbers. Putting it simply, hashing means taking an

input string of any length and giving out an output of a fixed length. This becomes critical when dealing with a huge amount of data and transactions. Basically, instead of remembering the input data which could be huge, just remembering the hash is enough to keep track of the transaction.

By mathematically validating that the hashes match the expected values, users can trust that the data has not been tampered with. Anytime someone tries to change the data inside the blockchain, it becomes instantly evident that a tampering-attempt has been made. Plus, with all the blocks linked to each other by having the hash of the previous block, if tampering does occur, it changes the entire structure of the chain, which is an impossibility.

On the other hand, blocks are added sequentially, providing a historical record of data and transactions. Timestamping is the functionality that permanently registers on the blockchain the time that a particular action took place. This helps to prove or verify at a later date that an event actually happened, which is useful when seeking the truth.

Since the blockchain consists of blocks referencing to the previous one, it is necessary to have the genesis block, which is the first block of the network. It is the only block within the blockchain that does not reference to a previous one, because no previous exist. Two nodes in the same network will only pair with each other as long as they have the same genesis block, otherwise they will reject each other.

Transactions, for their part, have associated fees in order to maintain the network and, depending on the consensus, reward the creators and validators of new blocks.

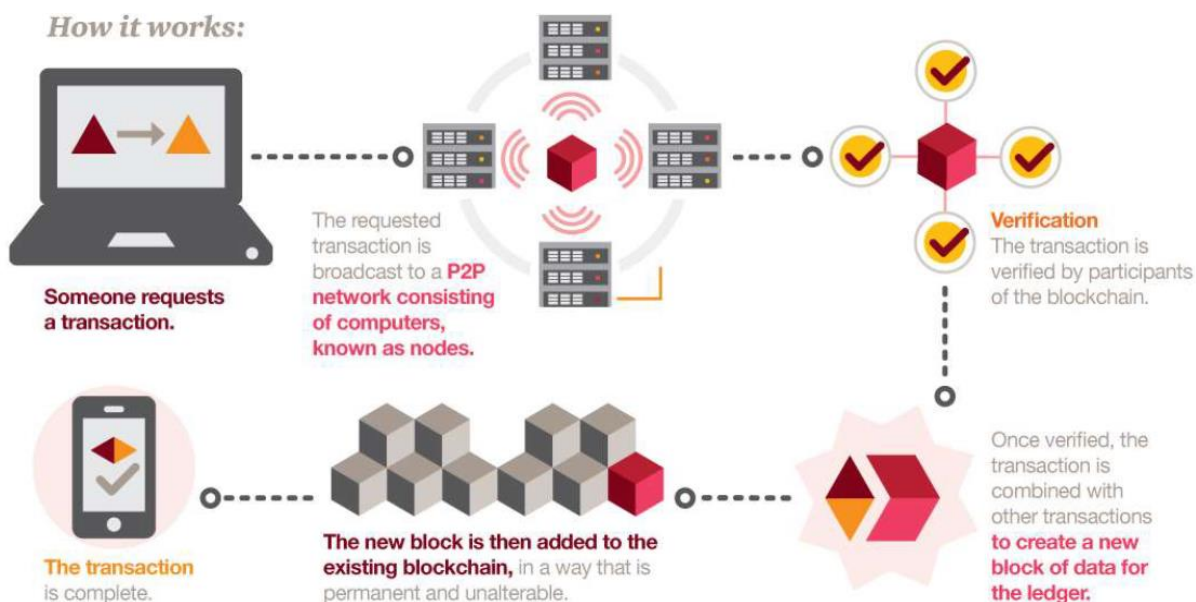


Figure 5.2 A look at Blockchain technology - Infographic, PwC

Consensus

Unlike centralized organizations, in a blockchain, decisions are not taken by a leader but by a group that needs to get to an agreement via consensus.

In short, consensus mechanisms are protocols that make sure all nodes (devices on the blockchain that maintain it and sometimes process transactions) are synchronised with each other and agree on which transactions are legitimate and are added to the blockchain. These consensus mechanisms are crucial for a blockchain in order to function correctly. Everyone within a blockchain can submit things to be added, so it is necessary that all transactions are constantly checked and that the blockchain is constantly audited by all nodes. Without a good consensus mechanisms, blockchains are at risk of various attacks.

Since the participating nodes act on their own and the distributed system has no hierarchical structure where a leading node instructs the rest, and the behaviour of the node can vary from being honest, the distributed systems face with the Byzantine Generals problem (for more information see *Annex 1*).

Consensus brings the solution to this problem as it is able to coordinate actions at the same time when a component of the distributed system is malicious or fails.

Most blockchains have a lot of things in common and function in similar ways, but one of the ways in which blockchains can be unique is the way consensus is reached. There exist different protocols but the followings are the most popular ones.

Proof of Work (PoW)

Satoshi Nakamoto, Bitcoin's creator, was the first able to bypass the Byzantine Generals Problem by inventing the Proof of Work protocol, which a part from the Bitcoin network it has been adopted by many cryptocurrencies.

The Proof of Work process is known as mining and the nodes are known as miners. Miners solve complex mathematical puzzles which require a lot computational power. The first one to solve the puzzle gets to create a block and receives a reward for creating a block.

These mathematical puzzles are asymmetric, meaning it takes a lot of time to find the answer, yet it's easy to verify if an answer is correct.

In addition, the only way to solve these puzzles is to 'guess' the answer. It is not possible to solve the puzzles quicker using any other method than trial and error. Hence, the more computational power is used, the faster the solution is found. In turn, it can get very costly.

Lastly, the difficulty of these puzzles changes depending on how fast blocks are mined. To

maintain a consistent supply of new coins, blocks have to be created within a certain time frame. If blocks are created too fast, the puzzles get harder, and if they are created too slow, the puzzles get easier.

This process ensures that in order to be able to create a block, one will need a lot of computational to solve the puzzle first.

Despite PoW is the consensus mechanism is the most reliable and secure, it also entails major consumption of resources which will make it unsustainable in the future. Moreover, the fact of relying on a distributed network of nodes for validation limits performance in terms of transactions per second (TPS).

Bitcoin Energy Consumption Index Chart

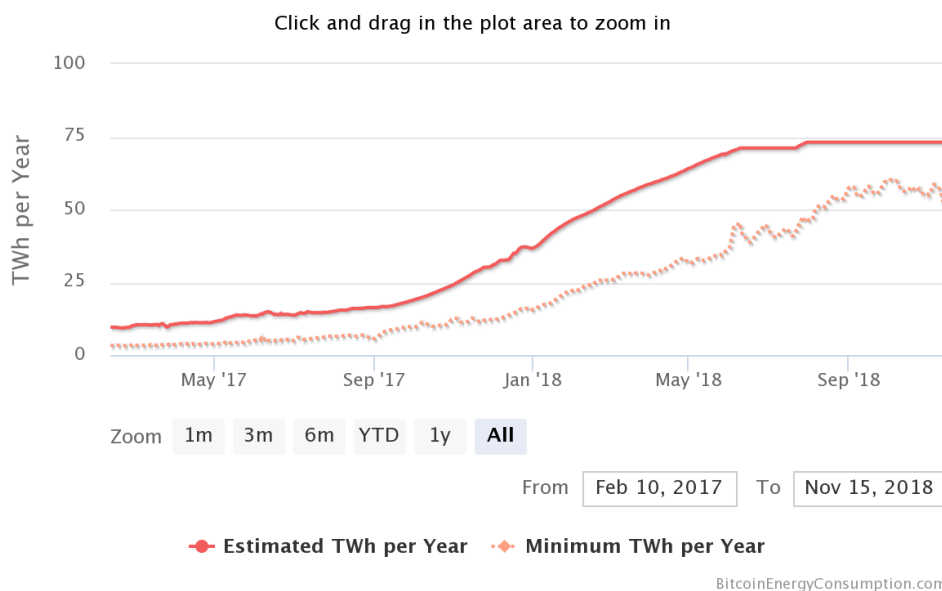


Figure 5.3 Bitcoin energy consumption

Proof of Stake (PoS)

The PoS algorithm is similar to the PoW system but the participants in the consensus building process is restricted to parties who have been identified to be having a legitimate stake in the blockchain. Proof of Stake makes use of the premise that those who own most coins in a network have a vested interest in keeping the network maintained and the value of its coins high.

The PoS removes the hash function calculation with a simple digital signature that proves ownership of stake. A randomized process is used to determine who gets to produce the

next block. Users can stake their tokens (digital currency) to become a validator (someone who can produce blocks), which means they lock their tokens up for a certain time. After doing so they are eligible to produce blocks. The process that decides who gets to produce the next block usually considers the factor of the person who has the biggest stake has the highest chance to produce a block. An example of another factor that can be taken into account is how long the coins have been staked.

Validators are also rewarded for their work with rewards that can go from all or part of the transaction fees of associated to the transactions in the block they created or a fixed amount of coins. Consequently, it is much more resource-friendly as no mining is required.

Proof of Authority (PoA)

Proof of Authority (PoA) is a reputation-based consensus algorithm that introduces a practical and efficient solution for blockchain networks (especially the private ones). The term was proposed in 2017 by Ethereum co-founder and former CTO Gavin Wood.

The PoA consensus algorithm leverages the value of identities, which means that block validators are not staking coins but their own reputation instead. Therefore, PoA blockchains are secured by the validating nodes that are arbitrarily selected as trustworthy entities.

The Proof of Authority model relies on a limited number of block validators and this is what makes it a highly scalable system. Blocks and transactions are verified by pre-approved participants, who act as moderators of the system.

Major advantages come in achieving higher performance than in PoW or PoS mechanisms as PoA provides major scalability which, in contrast, gives the perception that it renounces to decentralization.

Smart property

Smart property is a native unit requirement for blockchain operations. To understand it is necessary to define its two predecessors, digital file and digital asset. A digital asset is a digitized version of a product that includes specific rights to use, and typically has a value attached to it. Without rights, it is not considered to be an asset and it is just a digital file. Example of digital asset include a song, an e-book, a photo or a logo. Smart property takes the concept of digital asset further and it links the asset to a blockchain in a way it can never be double-spent, double-owned or double-sent. In addition, ownership or rights are also linked to the digital asset, meaning property is controlled by the owner and only transferred or sell when the owner decides to do it. This feature contrast to digital assets, for example, a photo, where different actors can be the owners of the same photo.

A smart property does not have to be a digital-only product as it can imply a physical object or thing linked to the blockchain. Tokenization, the creation of tokens, is the mechanism to introduce property into the digital realm. In this context, two main groups of tokens can be found:

- **Native or Built-in Tokens:** they are intrinsic in blockchains networks such as the Bitcoin, the ETH (Ethereum coin), etc. and are used either as block validation incentives ('miner rewards') and transaction fees. This type of tokens is generally related to existing currencies, which can be exchanged for, and by existing within an encrypted system like the blockchain they are called cryptocurrencies.
- **Asset-backed tokens:** they are the digital equivalent to physical assets. They are more than a currency because they can be used in a broader range of applications.

Tokenized assets allow for goods to be traded as close to directly as possible, sometimes without an abstraction of money. Tokens can be used in a multitude of applications such as tickets to an event, tokens of ownership, software licenses, rewards program or even to create your own currency inside a blockchain network.

The major advantage of attaching value to digital assets in the heart of a trusted ecosystem like the blockchain, is the possibility to managing and transferring value without incurring clearing-related delays due to the existence of intermediaries.

Smart contracts

Smart contracts are a key underpinning of blockchain technology. The concept was first introduced by Nick Szabo in 1994, but it underwent a long gestation period of inactivity and disinterest, because there was no platform that could enforce smart contracts, until the creation of Bitcoin in 2009. Since 2015, smart contracts have been gaining popularity, especially since Ethereum, a Blockchain platform, made programming them a basic tent of their Blockchain's power.



Figure 5.4 Smart contracts
Blockchain in logistics, 2018, DHL

Trying to give a definition to a smart contract, we could say that is a secure and unstoppable program representing an agreement that is automatically executed and enforceable. [6]

In another definition, smart contracts are computer programs that can be consistently executed by a network of mutually distrusting nodes, without the arbitration of a trusted authority. [7]

It is important to highlight that smart contracts are not law but software code representing business logic that runs a blockchain and they are triggered by some external data that lets them modify some other data.

Main characteristics of smart contracts include:

- Written in a language that a computer can understand.
- Includes agreements between parties in the form of business logic.
- Automatically executed when conditions are met.
- Enforceable, all contractual terms are executed even if adversaries are present.
- Secure and unstoppable, thus designed for fault tolerance and execution in reasonable amount of time.
- Deterministic, thus the smart contract can be run in any node on the network and reach at the same result.

Within the security ecosystem of the blockchain, smart contracts provide autonomy, as intermediaries are no needed to confirm agreements between participating parties; speed and accuracy, due to automatic execution of actions and no need for manual document processing; and in the whole, considerable savings of money.

Joining smart contracts with tokens or cryptocurrencies opens up a world of possibilities, from automatic payments to transfer of ownership, which can be deployed in different areas such as trading financial services, supply chains, real estate and many others.

6. Case studies: food companies and platforms currently using blockchain

Nowadays blockchain hype has already been passed and developers and companies are starting to dive deeper into real world applications. One of this is in the supply chain environment where it can drive considerable value at different levels. However, blockchain adoption is still in its early stages as it can be reflected by a Capgemini research Institute survey where only 3% of surveyed organizations are deploying Blockchain at scale. A 10% have started a pilot in at least one site and the rest 87% are only in a proof-of-concept stage. [8]

This reality demonstrates blockchain in the supply chain application is still in an experimentation phase where next decade will be where blockchain adoption maturity will start to transform how companies work.

Despite being in its early stages of implementation, blockchain technology has captured different food companies' attraction and principally gained adoption from big firms of the industry. Even though, blockchain startups like Viant and Provedance show how retailers or smallholders can also take advantage of this emerging technology. The following are some interesting cases of companies and startups leading blockchain implementation mainly focussed in traceability and tracking goals.

IBM Food Trust: Walmart and Carrefour

Walmart thought that blockchain technology might be a good fit for the decentralized food supply ecosystem. To test this hypothesis, the company created a food traceability system together with IBM they ran two proof of concept projects to test the system. One project was about tracing mangos sold in Walmart's US stores and the other aimed to trace pork sold in its China stores.

For pork in China, it allowed uploading certificates of authenticity to the blockchain, bringing more trust to a system where that used to be a serious issue. And for mangoes in the US, the time needed to trace their provenance went from 7 days to... 2.2 seconds.

Walmart can now trace the origin of over 25 products from 5 different suppliers and plans to roll out the system to more products and categories in the near future.

After the satisfactory pilots with Walmart, IBM promoted the creation of IBM Food Trust, a wide network to connect growers, processors, distributors, and retailers through a permissioned, permanent and shared record of food system data to help creating a global

standard for food traceability in every step of the supply chain. IBM Food Trust initiative, a part from Walmart, involves prominent players in the food industry, like Nestle and Unilever.



Figure 6.1 Carrefour board informing about Blockchain (source: own)

In addition, the French supermarket giant Carrefour, founder of IBM Food Trust, launched the first European food traceability blockchain for its Quality Line farm chicken from Auvergne (France). The project aims to provide customers with visibility over the entire supply chain by showing origin and processors and distributors involved. Consumers can use a mobile app to scan a QR code and have access to information such as how each animal was reared, the farmer's name, what they fed the chicken, treatments used (for example, antibiotic-free), any quality labels and the slaughter location. Carrefour is also using blockchain for tracing tomatoes and they are aiming to widen its use to its 300 fresh products across the world by 2022.

Provenance and Viant

Provenance and Viant are two promising startups aiming to provide the tools to embrace blockchain technology to retailers and small producers beyond big companies.

Provenance is developing a service designed to make supply chains more transparent in order to build greater trust between companies and customers. The London-based startup's platform blends blockchain, mobile, and social to allow companies to show consumers the entire journey a product takes while also allowing the customers to contribute and verify information as well. It has signed up more than 200 retailers and producers to its platform in industries as food, beverages and fashion.

The platform allows consumers to contribute comments, reviews, or personal stories via a mobile app that get verified and attached to the product. This further builds data as well as the stories around a product.

For its part, Viant in collaboration with World Wild Fund for Nature, has as objective improving fish traceability through blockchain to ensure products come from sustainable fishing. The process starts with the individual labelling of fishes in the moment they are

captured, identifying them with a unique, irrefutable and immutable code that once introduced in the system allows groups in charge of the care and defence of the natural environment like WWF or SeaQuest to verify its sustainable provenance. Viant build its blockchain platform base on Ethereum with the help of Microsoft Azure and beyond food traceability is also offering solutions for the pharma industry.

Sawtooth

Hyperledger Sawtooth, an enterprise blockchain solution owned by Intel, successfully tested Pacific Tuna seafood verification in 2017 (Sawtooth’s plan). After this initial approach, Sawtooth is now enabling users to design custom solutions for their supply chain in order to improve processes by merging the digital and physical worlds. It records the journey of seafood from ocean to table with IoT sensors that provide trackable ownership, possession, and telemetry parameters such as location, temperature, humidity, motion, shock and tilt. The final buyer can access a complete record of information and trust that the information is accurate and complete.

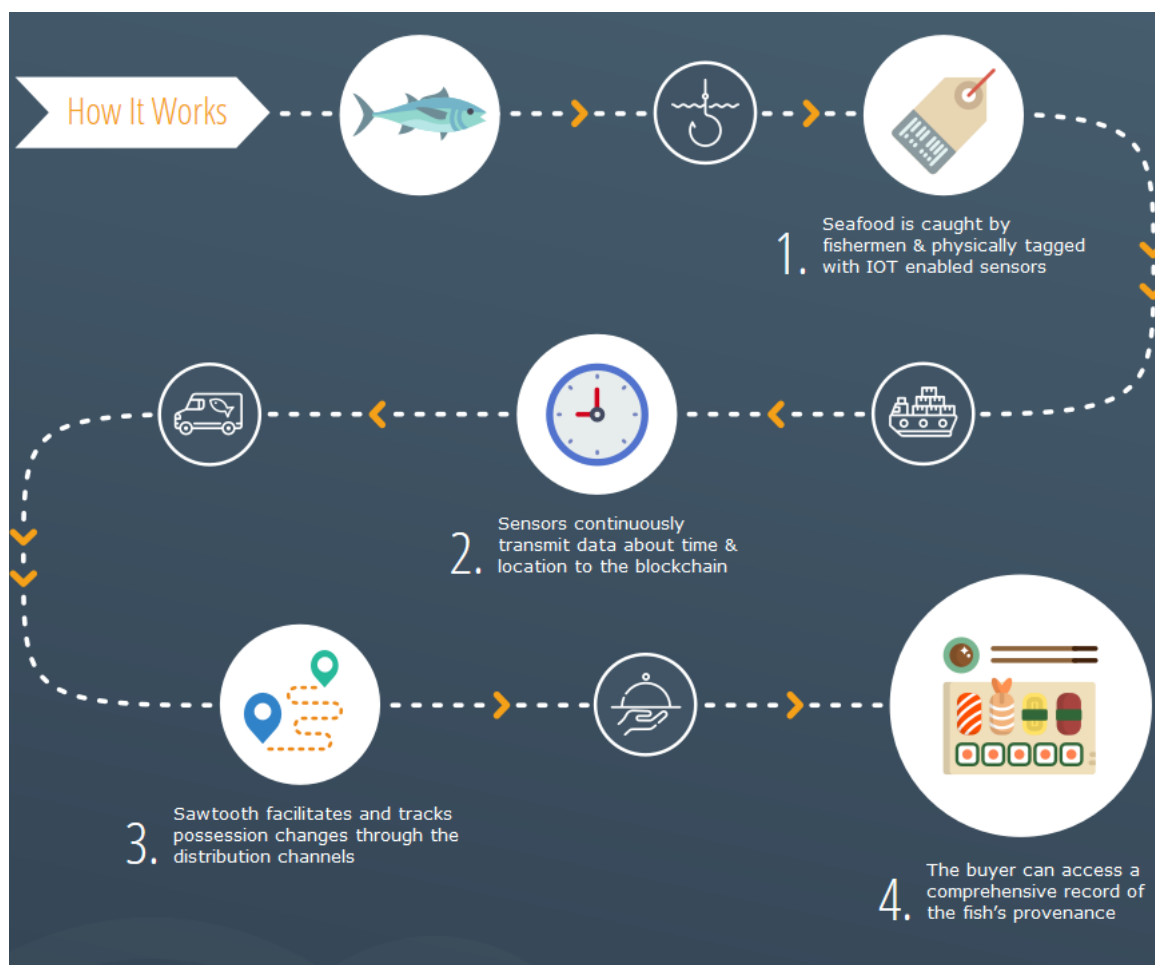


Figure 6.2 Sawtooth Blockchain in a seafood supply chain, Sawtooth

SAP Cloud Platform

In a similar way to Sawtooth, the German company SAP has developed a blockchain cloud platform. One of its applications is being used to minimize risks and proof origins of Norway salmon after different cases of mislabelled fish have been found. The solution tracks each fish along its supply chain, creating a digital twin for each fish, a data point that gives salmon producers, retailers, restaurants, and consumers more confidence in the product. As part of the solution, they have created an app that allows consumers to rate their fish on a scale from one to five. That data can be shared using an open, public blockchain that suppliers can access and take any necessary action to increase customer satisfaction.

There are many other traceability-focused initiatives. A few noteworthy ones include Ambrosus, which provides tracking for both the food and pharmaceutical industries with a variety of IoT devices; BeefLedger, an Australian beef traceability initiative focused on exports to the Chinese market; the Chai Vault, a UK-based wine initiative focused on verifying the provenance of investment-grade wines; OwlTing, founded by an ex-Google employee in Taiwan in 2010 to enable consumers concerned about food safety to buy directly from farmers; TE-FOOD, focused on providing farm-to-table traceability in emerging markets; and Zest Labs, a US company that uses sensors to collect data that enables companies to reduce food waste.

These are some examples, that simultaneously to hundreds of startups and platforms, underline the increasing movement to a blockchain adoption from the food industry.

The business case addressed in this project took some of these initiatives as a starting point to deploy a working solution for a particular seafood company.

7. Case study: implementing blockchain in Maresmar

The objective of the case study that follows is to implement an integrated solution of blockchain combined with IoT technologies in the seafood company Maresmar. First steps involve having a clear idea of Maresmar business model and how its supply chain is currently working. To do so, different interviews have been conducted with General Director and founder of Maresmar, Jordi Cubells, and other employees of the company. With a general idea of the ASIS situation of Maresmar, it has been studied the different applications blockchain can bring, the possibilities to provide notable improvements and how to apply them. A series of benchmarks have been deployed, regarding type of network, platform, improving areas, etc., where each decision directly affected the following ones.

The business case aims to be used as a base to establish a working method to develop a blockchain model with standardized features for a future implementation into other companies of the industry.

7.1. Maresmar: a seafood company

Maresmar is a Catalan company founded by Jordi Cubells Agramunt in 1987 that has expertise in the import and distribution of every kind of live, fresh, cooked and frozen seafood coming from all around the globe. In addition, it produces its own ready-to-eat products based on seafood. Since 1987, Maresmar has always strived for excellence in all its activities, and to achieve it, the company has established a rigorous control of all its supply chain, from the point of origin to the client's distribution. [9]



Figure 7.1 Maresmar logo

Maresmar is ranked at the 25th position on the Spanish seafood sector ranking with a turnover of 80 million euros in 2018 coming from: live seafood (50%), frozen seafood (25%) and fresh seafood (25%).

7.2. Maresmar current business model

Maresmar ownership is centralized on the figure of Jordi Cubell Agramaunt, who at the same time is the owner of two direct partners of the company, Scotwest and Marescot, both located in Scotland.

On the other hand, Maresmar is proprietary of the Danish company Vikingmar and 50% owner of another Scottish company, Macmar.

All this group of companies belong to Maresmar partners and close providers but the company also trades with many other providers around the globe. This group of suppliers englobe the upstream network of the supply chain. In terms of trust with this suppliers, Maresmar benefits from years of close relationship between companies, even if it is true that every new provider goes through a trial trading period with Maresmar before starting new businesses.

Maresmar headquarters are located in Mercabarna, Barcelona, and operate as a main distributor with almost every product being processed in these central production plants. Once seafood has been treated and inspected it is mainly distributed in the Spanish territory with a part of it sell in Denmark through Vikingmar company.

The company's supplied seafood embraces live, fresh, frozen, cooked and processed products of a wide range of crustaceans, bivalves, cephalopods and fish. Distribution of seafood is focused on shellfish with a 65% of the total volume, different types of fish with the 35% and few years ago opened a new elaborated product line made of these products.



Figure 7.2 Origin of Maresmar suppliers

A part from the adequate devices to manipulate fresh seafood from suppliers, Maresmar plant has a set of refrigerators and freezers, kitchens and working spaces to provide a final consumer good. Maresmar is currently working with hundreds of species in Mercabarna plants with a 24/7 operation system organized in different work shifts to satisfy a daily demand for seafood.

Monday is the weakest day of the week followed by Tuesday and Friday, with Wednesday and Thursday the days with major workloads. During weekends, there is no product flow and is the time when controls and checks are done over machinery and plants.

Despite almost every seafood and fish can be caught all the year round, each species has their particular season to go fishing. Consequently, production is based on that seasonal currents and products that are not available on a determined month of the year are frozen in order to have a stock able to satisfy the demand. Previsions on demand variability are based on previous year sells and particular demands from specific clients.

Maresmar operates principally on a B2B (business to business) model as direct sales to customers is done on a minor part. Thus, downstream areas can be classified in three main groups.

First marketplace encompasses supermarkets, restaurants, hotels and fishmonger. Major supermarket chains include *Mercadona*, *Alcampo*, *Bonpreu*, *Condís*, *El Corte Inglés*, *Dia* and *Consum*. This group of clients make purchase orders with a quite stable and fix demand that generally meets with Maresmar forecasting. This demand varies during the year with a considerable increase in specific periods like Christmas, Easter or holidays, factors already anticipated in the forecast.

A second point of sale is, a fish market (*El Mercat del peix*) next to Maresmar plants in Mercabarna where a hundred of seafood wholesalers sell and distribute their products during midweek early mornings. Maresmar owns four stands in *El mercat del peix* where its sales are mainly focused on restaurants.

Finally, with a lower sales impact, products are also sold in a physical store situated in the Mercabarna plant. In the store can be found the wide range of prepared food as well as fresh products.

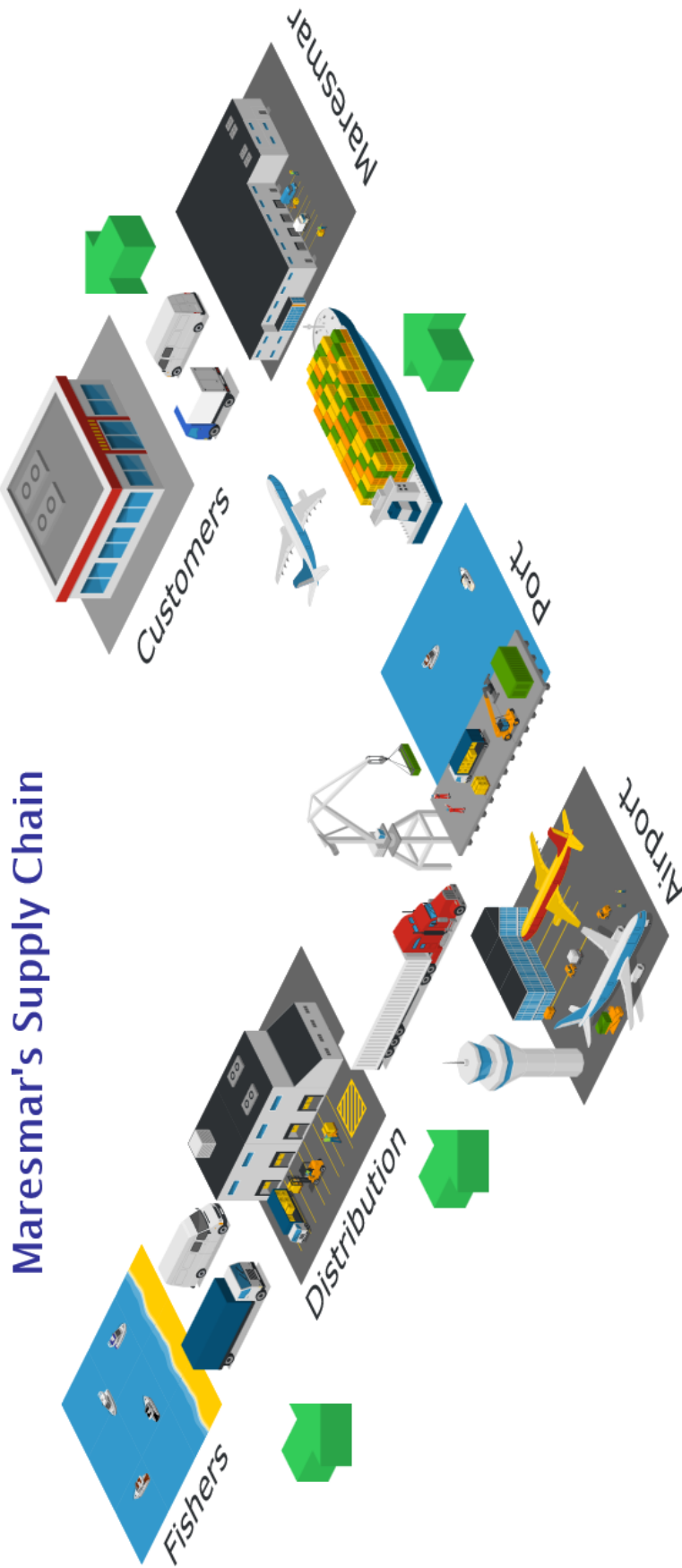
A fourth marketplace, e-commerce online via Marisco Planet, was also available. At the moment it is paused due to logistic issues as well as for the confidence difficulties it presents towards consumers selling fresh seafood without seeing the product before buying it.



Figure 7.3 Maresmar marketplace

7.3. Current supply chain of Maresmar

Nowadays supply chain of Maresmar can be described as in the diagram in the next page. It can vary from one product to the other depending on their provenance and specie but for most of their products it shares similarities. For daily products is used airplane transport while for products that can last more days, ferries are the ones in charge of transporting them.



Fishing

The supply chain begins with the fishing of the animals with the appropriate technique for each one, which go from using pots and traps, gillnets, hand fishing, snag-line, trawling and many others. In order to avoid illegal fishing, each boat has to comply with some regulatory frameworks and need to be accredited to be able to execute a certain type of fishing. Imports are only authorised from approved vessels which have been inspected by the competent authority of the exporting country and found to meet EU requirements. When it signs the export health certificate, the authority is certifying that it provides the necessary guarantees, carries out regular inspections of vessels and establishments and takes corrective action, if necessary. A list of approved vessels and establishments is maintained by the European Commission and is published on its website.



Figure 7.4 Maresmar fishing boat

Besides, each specie has a determined fishing area where it comes from which has been classified by the Food and Agriculture Organization of the United Nation and are known as FAO zones. These portions of the sea are used to track back origin of seafood and must be printed on every batch according to European Union Regulation No. 1379/2013.

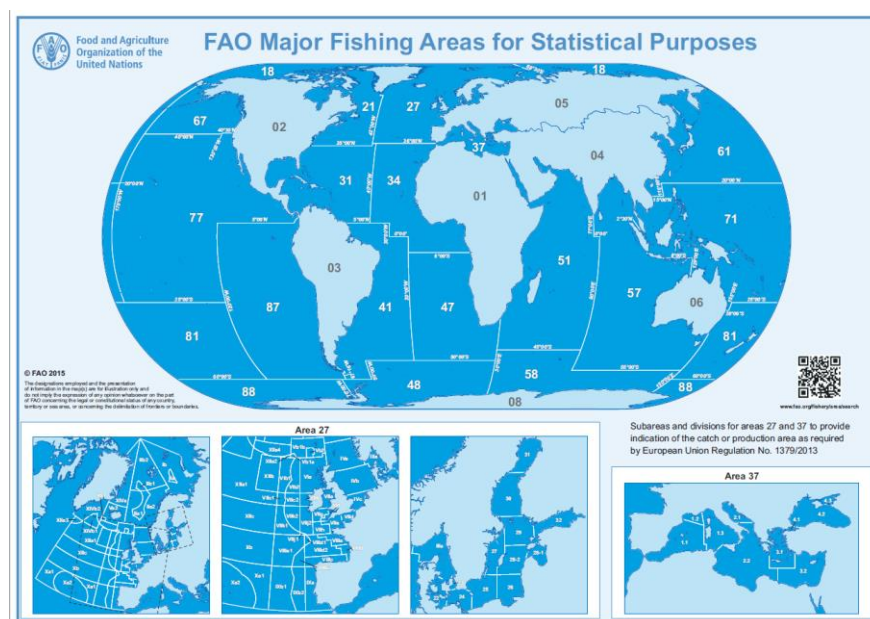


Figure 7.5 FAO Fishing Areas – Food and Agriculture Organization of the United Nations

Distribution and transportation

Once seafood has been captured, it is brought to a distribution facility centre, still on the country of origin, where it is classified and introduced in special bins with water. These bins are then covered with wet paper or wet gauze together with ice packs. Some products are transported with these bins while others are introduced into boxes, but in both cases they are labelled with the required information to comply with the EU law including mandatory and voluntary information as in the sample below (see Figure 7.6). Any batch without this information is rejected by the corresponding authority. It must be highlighted the importance of including the lot number, as every intermediary of the whole supply chain has to provide it. Government agencies use these numbers to access traceability of every product all along their supply chains. In addition, a delivery note is included with the number of species in each bin and some providers add a QR code to fasten the capture of data. Moreover, each box has stuck a paper delivery note with the total shipment they are carrying.

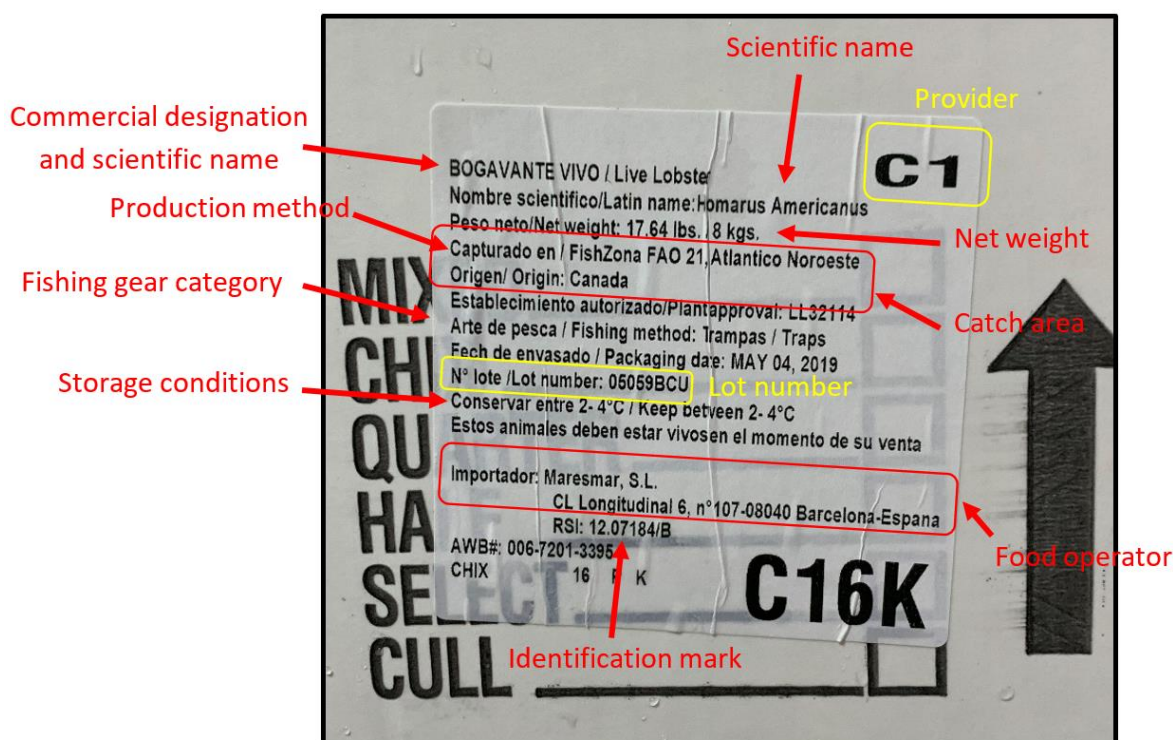


Figure 7.6 Box label with required information

Some species do not require to be transported by plane or ferry if they have a proximity origin to the plant or if they can last longer without losing their freshness, but the majority demand for a fast moving transportation right after being captured.

Transportation can happen via airplane for long distances, for example, the American Lobster that comes from Canada and USA, or via ferry like the seafood coming from

Scotland. Therefore, seafood is brought to the airport or port, depending on their shipping mode, where first inspections occurs. Compliance with EU laws requires from a competent authority to perform official controls to guarantee credible public health and animal health attestations in the health certificate that accompanies fishery products. An official veterinarian from the departing country verifies the product with a systematic documentary check, identity check and, as appropriate, a physical check. The frequency of physical checks depends on the risk profile of the product and also on the results of previous checks. In the case of Maresmar, physical checks are held on every shipment due to the high-risk related with shellfish. The veterinarian takes a sample and analyses its properties on a rather fast procedure which, however, delays the departure by approximately two hours due to the amount of paperwork involved. Once the product arrives to the destination country, it undergoes through a similar control by a veterinarian.

With all verification and relevant documents, seafood still on the bins is collected by Maresmar refrigerated vans from the airport for products coming by plane. On the other hand, for maritime transport, Olano, a carrier company, and MacNeil, one of the providers, are in charge of the freight of the product by embarking their refrigerated trucks in the ferries and making it arrive to Barcelona plant. As happens with fisher providers, transporting parties have to state their lot number on the batches too. Seafood is maintained refrigerated and oxygenated at every moment and the whole shipment process do not last more than one day, meaning products keep their freshness to ensure quality.

Property transfer between parties happens once the product is delivered, checked and is confirmed with a signature from both parts. In the case of a delay there is not an economical sanction. However, in the case the provider or the carrier spoilt a shipment, each party has their assurances to cover the related costs. In order to avoid problems, there must be communication between stakeholders, which in Maresmar supply chain happens via phone calls, email or even physical meetings in some cases.

Maresmar's processing plant

Advancing on the supply chain, next step refers to the seafood processing in the main plant. When products arrive, first action is to examine and weigh each bin. Weights are taken of the full bin, the bin without water and the freight without dead animals. It is assumed that a certain amount of the goods will be dead when arriving to the plant, but if a prearranged percentage of dead animals is exceeded, the provider is in charge of the expenses.

All this information is filled in control sheets along with different parameters regarding the number of animals, weight, size, temperature, colour, number of claws, freshness, etc. of each animal.

For the temperature control it is used a thermometer that is pricked in the boxes right after arriving to the plant. There is a lobster supplier that includes a thermometer with a USB connection that records temperatures during the entire journey of the shipment and allows checking that the cold chain has not been broken.

LOBSTER CONTROL			Control tamaño-mortalidad-peso neto/ Size-dead-net weight control																						
Supplier	ISL	8	SIZE	HARD	HARD	HARD	HARD																		
Proveedor			weight/piece	OK16	OK16	OK15	OK15																		
Fecha de control	29/04/2019	4/29/19	PIECES/BOX	16	16	15	15																		
Fecha de recepción	29/04/2019	4/29/19	PESO BRUTO	10,45	10,55	10,45	10,5																		
Fecha de vencimiento	006-7215-0201 LBCN08		TARA	2,7	2,7	2,75	2,75																		
Transporte	DELTA AIRLINES		Net WEIGHT	7,75	7,85	7,7	7,75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Origen	BCN		WEIGHT PXP	7,75	7,85	7,8	7,8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Destino	28049BU		1	0,55	0,45	0,5	0,45																		
Operador	WFS		2	0,55	0,6	0,5	0,45																		
Logística	Logisticos/Logistic parameters		3	0,45	0,5	0,5	0,5																		
Material	OK Plastico/Plastic		4	0,45	0,55	0,5	0,5																		
Estado	Bien/Ok		5	0,5	0,45	0,5	0,5																		
Etiquetas	Plástico/Plastic OK		6	0,55	0,45	0,5	0,5																		
Fecha de etiquetado	Correcta/Ok		7	0,5	0,45	0,5	0,5																		
Fecha de recepción	28/04/2019	4/28/19	8	0,45	0,5	0,45	0,55																		
Fecha de vencimiento	FLEJE/STRIP		9	0,45	0,55	0,55	0,55																		
Fecha de recepción	GASA/GAUZE		10	0,45	0,6	0,55	0,55																		
Fecha de vencimiento	Separador/Slotted		11	0,45	0,55	0,55	0,55																		
Temperatura	8,4 °C	47,1 °F	12	0,5	0,4	0,55	0,55																		
Gel packs	2 ice packs	Congelada/Frozen	13	0,55	0,45	0,55	0,55																		
Agua interior caja	150q16/140cx		14	0,45	0,45	0,55	0,55																		
Parámetros producto/Lobster parameters			15	0,45	0,45	0,55	0,55																		
Hard Shell			16	0,45	0,45																				
Firm Shell			17																						
Tipo Caja	Quality logo		Number of pieces				OK	DK	OK	OK															
Aspecto	Limpia/Clean		Short weight				-0,25	-0,15	-0,2	-0,2															
Calidad	Dura/Hard		% short				-3,12%	-1,87%	-2,50%	-2,50%															
Color	Oscuro/Dark		Average				0,48	0,49	0,52	0,52															
Viveza	Fuerte/Strong		Right average				0,50	0,50	0,53	0,53															
Gomas pinzas	Limpias/Clean																								

Cajas/Boxes	Tamaños/Sizes	P Neto/Net w.	Vivo/Live	Mts/Kg Dead	Pieces/Pieces Dead	% Mts/% Dead	Merma/Short weight	% Merma/% Short weight	N Pie/ca Number Pc/box	Viveza Live	Dureza Shell	Aspecto Appes.	Clasif. Grading	Peso/caj Weight Box	Mort Mort	Valor Assessment
2	Chix16p Hard	15,6	15,6			0,0%	-0,40	-2,50%	10	9	9	9	8	7,0	10,0	8,8
2	Chix15p Hard	15,6	15,6			0,0%	-0,40	-2,50%	10	9	9	9	8	7,0	10,0	8,8
																0,0
																0,0
																0,0
																0,0
																0,0
																0,0
																0,0
																0,0
																0,0
																0,0

Figure 7.7 Quality control document with USB thermometer

A part from internal quality controls, Mercabarna authorities complete regular quality inspection every week to check the facilities, product and maintenance of the plant.

Afterwards, animals are classified depending on their consumption end: seafood to be consumed alive or fresh, other that are vacuum-packed and then refrigerated or frozen and a third group that is going to be cooked or processed.

Seafood that is alive is preserved in the bins with a constant water circuit until they leave the plant when they are going to be sold. A classification is also made according to male or female species, sizes and range of weights with a sticker specifying it on the bins.



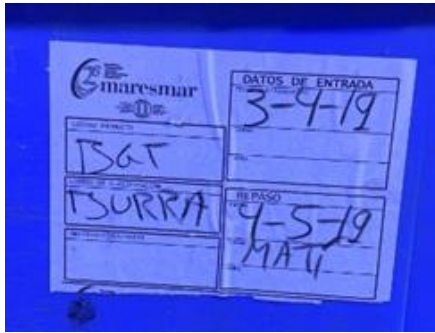


Figure 7.8 Sticker label on a bin



Figure 7.9 Water circuit

On the other side, dead animals are divided according to their condition and the ones that are still fresh are prepared to send them to the client or are put into boxes and brought to industrial refrigerators and freezers as well as to the kitchens where they get boiled and packed.

A third group goes directly to kitchens and processing areas where elaborated products are created like stuffed shellfish, seafood fumet lobster sauce and other ready to eat meals.

Despite dealing with fast perishable goods, Maresmar also works with stock, both alive and frozen seafood, in order to satisfy unforeseen demand or to be able to react to unexpected events.



Figure 7.10 Maresmar plant

Once a client has placed an order or the products are going to be brought to *El Mercat del peix*, animals still alive or fresh ones are packed into plastic or cardboard boxes while elaborated food is presented in their corresponding packaging. A new sticker is pasted on every product with the same relevant information suppliers had to include, but now with Maresmar logo and information regarding processed method and in some species a QR code to access it.

The majority of the production is commercialized from Barcelona to Catalonia and Balearic Islands while a share is taken to delegations and distribution centres around Spain covering Madrid, Zaragoza, Málaga and Galicia areas.

For the purpose of organizing all the company components and optimize resources, Maresmar relies on SAP program as ERP (Enterprise Resource Planning) as well as VIR Audit firm for audit services.

With a clear idea on the company business model and supply chain, the project addresses the pure implementation of blockchain technology and IoT devices aiming to optimize steps and processes efficiently. To obtain a workable solution and develop base model, it has been opted to focus in one particular product, the American lobster.

7.4. American lobster supply chain

The development of the Blockchain system aims to be implemented into the overall of Maresmar supply chain products. However, for the particular case study performed in this project, the seafood's supply chain selected has been the one of the American Lobster or, as they called in Maresmar, Yankee. The reason behind focusing on that product is because American Lobster is the flagship specie of the company as it is daily traded and provides highest revenues, approximately 15% of total turnover. Its supply chain involves different parties and factors to be considered and adopting an optimized solution for this product could lead into a wider scalable adaptation to the rest of products' supply chains.

Before focussing on the pure implementation of the solution, a special remark must be done on the Yankee's supply chain. It works similarly to the generic supply chains of Maresmar products but with some differences. When the species are fished, they are brought to a fishpond in Canada where they are classified according to weight, size, quality, etc. and then boxed. From that location, they are transported with refrigerated trucks to Halifax (Canada) that serves as a distribution point to different airports in Montreal, Toronto and the United States. After the relevant checks, they fly to Barcelona inside Delta Airline aircraft cabins where they are picked up by Maresmar carriers. In the main plant they are classified again and distributed to the different clients within the following hours.



Figure 7.11 American lobster (Yankee), Maresmar

7.5. Rethinking the American lobster supply chain

Blockchain would mean considerably changing how the company is currently working due to the direct impact on supply chain flows of this new technology. Materials flow is not going to be affected as Maresmar will keep handling and trading with this particular seafood in a similar way. However, relationships among partners and suppliers will experiment profound changes as it will arise a transparent flow and monitoring of real-time information that will lead to an improved business to business communication and transactional methods. Not only is real-time state-of-network analysis a feature, it also facilitates time-traveling to the state of transactions at any point in the past, building a high-fidelity system.

The business case studies the implementation into the American lobster supply chain. Two main solutions are found: the first one aims to embrace all the possible benefits blockchain can provide to Maresmar supply chain while the second one constitutes a Minimum Viable Product (MVP). The MVP can serve as a starting point as it gathers enough features to satisfy early customers, and provides feedback for future product development in order to get to the broader solution.

Both solutions share implementation procedure when deciding on the infrastructure of the blockchain and the way to implement it. With the mere intention of reaching the most suitable solution, the project develops a series of benchmarks to compare blockchain features and companies offering this technology. The approach taken implies taking decisions that guide the solution to a way that cannot be undone. For example, selecting one type of network implies selecting a particular company that can implement this type of network and not another one.

7.5.1. Critical drivers and potential use cases

Blockchain can bring considerable improvements to the American lobster's supply chain in many forms. This part of the project describes some of the key points and potential use cases of implementing a blockchain system into Maresmar supply chain while setting priority for the critical ones. Features' feasibility / criticality is handled from two points of view: benefits and complexity.

The following cross diagram from the Capgemini Research Institute helps to locate strong points of a blockchain implementation in Maresmar supply chain as it identifies 24 blockchain use cases across the value chain for different companies.[8]

Basing blockchain adoption on previous companies experience and how they are facing emerging complexities provides a clearer path for a cost, time and error reduced implementation.

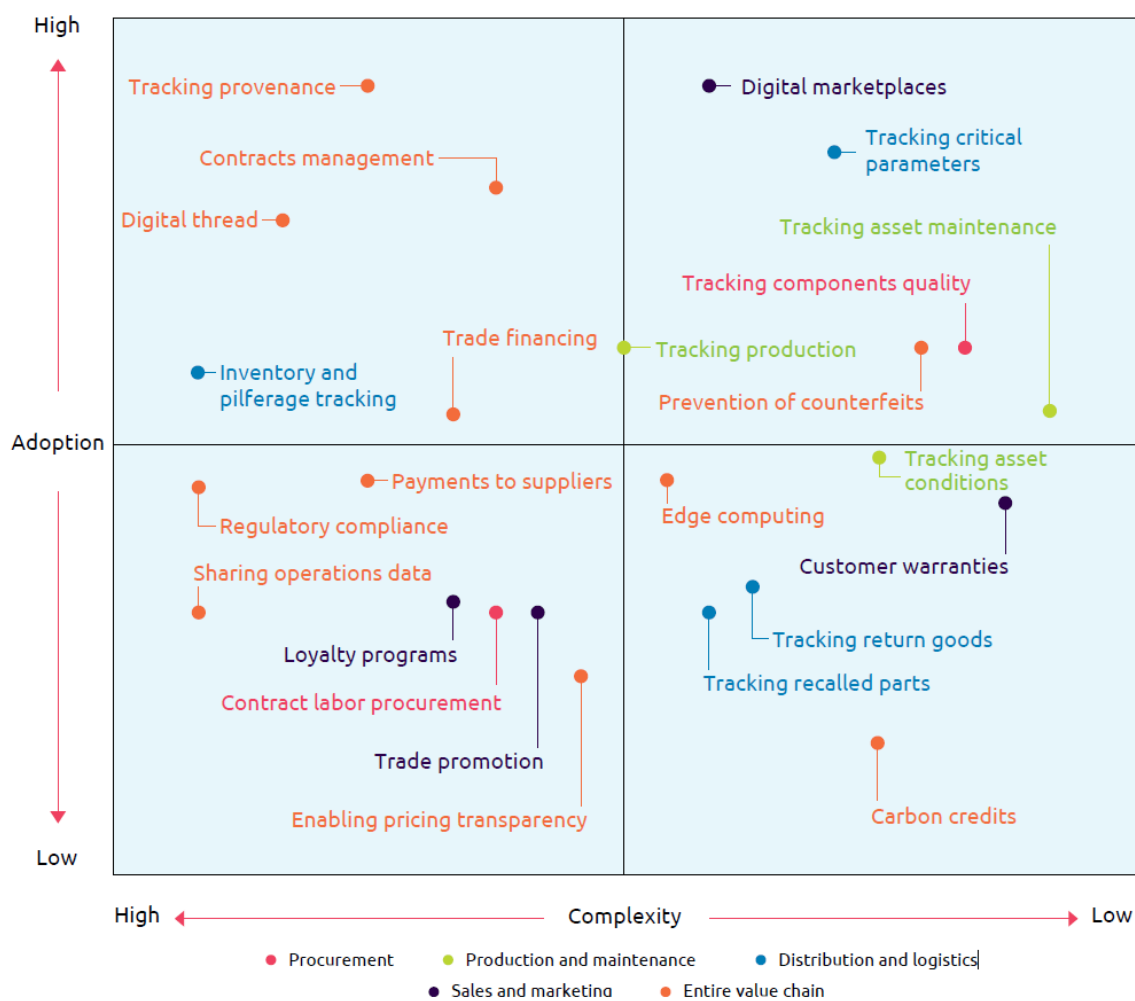


Figure 7.12 Capgemini Research Institute Report

Moreover, in order to choose in which areas the solution should focus, various decision models from IBM and J. Gardner studies as well as a Maturity Assessment model developed by KPMG have been considered. The table below provides a portfolio of blockchain features particularised for Maresmar business case according to a 1 to 3 scale in terms of feasibility and ease of adoption.

Feature	Description	Feasibility
Traceability	Blockchain will allow <i>Maresmar</i> and the rest of stakeholders of the supply chain to trace the American lobster origin, attributes, and any change of ownership.	1
Auditability and transparency	End-to-end visibility from suppliers to retailers ensures transparency and authenticity where multiple suppliers are involved. Besides, audits can be done in a clearer and easier way.	1
Automation of processes	Automating processes will reduce human interaction and errors attached to it as well as cut down manual and administrative costs implying greater speed.	1
Trustful shared database	By locking product's information in the blockchain, every participant can be sure that once data is uploaded and verified no one can change it and is open and accessible for them to consult.	1
Regulatory compliance	A blockchain can maintain the product's entire history and allows regulators to determine whether that product has been manufactured and handled in a compliant manner.	1
Reducing risk	Blockchain helps to establish the proof of ownership of a product. This allows organizations to extend warranties to customers with genuine products and avoid losses in warranty frauds and reduce insurance costs.	1
Being customer centric	Satisfying and adapting to customers' demand from products reviews and feedback provides increasing levels of loyalty to the company. Moreover, introducing loyalty programs can be used to create a single wallet for loyalty rewards.	2

Reducing waste	With an exhaustive control of every batch the number of dead lobster will be reduced or, at least, it will be clearly stated which actor of the supply chain is responsible for it.	2
Bypassing intermediaries	Trust in the intermediary (marketplace) is replaced with trust in the underlying code and consensus rules. Blockchain technology allows this verification to be undertaken at minimal cost, even at scale.	2
Data management and analytics	Having the ability to freely access data of the overall of the supply chain bring the possibility to analyse it to detected weaknesses and improve processes.	2
Increasing food quality	Quality can be increased with a deeper control over the product and with reduced unexpected events that can affect it.	2
Creating new business opportunities	Blockchain can open new business opportunities in the digital economy world with online payments and e-commerce. Maresmar already tried to sell products online but without success by the moment.	3
Tracking recall products	Blockchain enables product or component tracking by recording a product's entire manufacturing journey, from the origin of its components until the product reaches the consumer.	3
Preventing counterfeit products	With the ability of blockchain to track the origin of each part of a final product, it is possible to have an audit trail that is visible to all relevant parties. This ensures the authenticity of goods and reduces counterfeiting.	3

Table 7.1 *Potential use cases for Maresmar ordered according to feasibility*

Feasibility level 1

Traceability is the main point for moving to a blockchain model. Within Maresmar supply chain, some traceability systems, like the labels on every batch with product information, are already employed but recording all this data in secured way will bring major knowledge of where each lobster has been at a particular time and not in a general way as it is currently done. Maresmar will have the certainty of their lobster's provenance and could reaffirm it to customers not only by word but with actual facts and reliable data. In terms of complexity of adoption, different levels can be undertaken. A basic one could consist on relying fisher's word regarding origin and upload this information into the blockchain. An improved alternative could add coordinates from the boat GPS once the lobster has been captured. These solutions will not considerably increase complexity on how origin tracking is been done. For a deeper approach on traceability it could be posed integrating smart tags such as RFID tags and QR codes linked to every batch. However, this will imply major complexity in programming the blockchain to be able to link and update the information to it as well as requiring devices to read the tags and codes being connected to the system.

Looking for an extended but consequently more complex solution, a smartphone App can be developed to provide access to customers to a detailed view of the history of the lobster they are buying.

With a powerful system for traceability it is possible to track every lobster over its supply chain and then having a record that can ease any audit task. Besides, information could be shared or not between parties according to its level of sensitiveness. Maresmar could show the information they want to other stakeholders and clients which will enhance its brand reputation by entailing major degrees of transparency.

Leveraging from the ability to track products, airport authorities and Mercabarna veterinaries could corroborate how the lobsters have been treated during their journey and how safety compliance has been kept all along the way. Achieving regulatory compliance will imply reducing risks, and consequently, insurance costs could be reduced as chances for damaged products will decrease.

Another aspect where blockchain could bring great improvements is in the automation of all manual processes. Paperwork will not be necessary any more as data could be captured via electronic devices that will send it to the blockchain. To do so, it will be necessary to integrate IoT and smart tags that could fastener and simplify all data entry. Even though, it will require from a slower process to start up the blockchain as more programming efforts are required to integrate IoT devices into the system.

Automation could also come in the form of automated payments or actions. As soon as a batch of lobster is delivered, a payment could be executed to corresponding part or a

document could be uploaded to the network.

The base for automating actions resides in smart contracts development. In consequence, full automation like the one described will not come in the first version of the solution due to major challenges it presents to program smart contracts and will be considered in a progressive adoption of it.

Feasibility level 2

Level 2 features are classified as not as relevant as level 1 features or because they imply a more complex integration into the blockchain system. One of this potential use cases considers focussing in customer's figure and satisfy what they are seeking for. American lobsters are going to be sell to customers, and providing information about them and receiving feedback from customers could help to understand better their requirements. A supermarket chain might prefer a big lobster with all their claws and a bright look while a restaurant may not mind about it as they will be using them to cook a lobster soup. By knowing that, they could be associated to different prices.

With a broader implementation in mind into all Maresmar's products, seafood's reviews could improve estimations on demand and orientate demand towards specific targets. The interconnection between customers and Maresmar and the rest of actors could be executed through an App, but, once again, it will increase complexity in the blockchain development.

Just like reducing risk of infections, enabled traceability through blockchain will help to reduce the waste of dead animals as a stricter control will be done over them during the whole supply chain. Moreover, in the case of unexpected events or incompetence, Maresmar and the rest of participants could proof which was the cause that damaged the lobsters and try to fix them in the fastest way possible. In the same way, the actor responsible for it should be in charge for the related losses and Maresmar should not charge with them.

With an exhaustive control over products, every participant in the lobsters supply chain could benefit from captured data and optimize their own processes or work together to develop an interconnected supply chain free of miscommunication and related errors.

Intermediaries will always be present into the American lobster and the rest of seafood supply chains, however, some of them could be by-passed with blockchain. Regulatory bodies could never be overpassed, due to law obligations, but it exists the possibility to integrate them inside the blockchain in order to streamline checking and control processes and facilitate regulatory document expedition.

One of the points where blockchain could jump some intermediaries is in the financial related processes. Blockchain enables digital payments without the need of banks or clearinghouses, which will reduce the cost attached to them. Though, it has not been identified as a priority due the difficulties and uncertainties of these methods and the reluctance it could create to other participants. It rests as an option for future adoption.

Feasibility level 3

Third level of feasibility refer to properties that require for a more complicated adoption and do not drive that much value to the supply chain. Nonetheless, they will be taken into account once the rest will be accomplished.

Global businesses around the world have already moved or are moving to digital economy where online payments and product's exchange have become a daily routine. Maresmar tried to sell online seafood via *Marisco Planet* but issues on delivery carriers and customer's trust and attraction difficult its progression. It should not be seen as a defeat as in recent years every company will have their own e-commerce branch and being starters on this area could differentiate them from the industry competitors. Blockchain can contribute to provide an irrefutable vision of the origin and freshness of the lobsters Maresmar is selling an increase trust over online selling and the brand in general.

Recalls within American lobster supply chain are not really frequents and that is why the ability of tracking them back when a recall situation is launched will not bring that much value to Maresmar. Still, as the project aims to be adapted in other companies supply chains, this feature should not be ignored. Just like recalls, counterfeit products are not a major dilemma as most of lobsters suppliers are known and trust by Maresmar. That being said, other suppliers from other products are not that reliable and, like in any business, could undertake malicious behaviours.

In the overall, if Maresmar would be able to gather all these potential use cases in a complete blockchain solution, the American lobster supply chain would run in a faster and optimized way. Nonetheless, there exist some intricate points to tackle as passing from a theoretical approach to a practical one will arise major complexities. As it is seen later in the project, a complete solution is studied to comply with the different features just mentioned, but when facing sophisticate complexities, need for resources and economic feasibility, it has been opted for a solution with reduced field of action by only focussing in the level 1 features.

7.6. Benchmarking

This section contemplates and fix decision methods for a variety of requirements within a blockchain implementation. Despite being an emerging technology with few years of development, hundreds of networks, platforms, startups and organisations have proliferated across blockchain environment. Hence, it is important to understand which ones can bring major benefits for the particular business application and undergo different benchmarks to compare and choose the options that fit better at every decision stage.

7.6.1. Decision on the type of blockchain network

Blockchain application is such a vast world that requires some precision regarding the type of network to be used as blockchain comes in many different types: Public, Private and Hybrid. However, even if each blockchain presents its differences they all share common characteristics:

- They are decentralized peer-to-peer networks where each participant maintains a replica of the ledger.
- Maintain the replicas synchronized through consensus.
- They provide certain guarantees on the immutability of the ledger, even when some participants are faulty or malicious.

A Public blockchain is a permissionless blockchain, which implies by design protecting user's anonymity shielding them behind virtual pseudonyms (or "addresses"). Not knowing who a user is does not allow creating permissions and control what data users can read or write. This natural feature is the main reason why we see new emerging cryptocurrencies, like Bitcoin or Ethereum build, on Public blockchains as having anonymity grant anyone to transact without revealing personal information: anyone should be able to own a Bitcoin and to trade with it.

By joining a Public blockchain, participants are automatically given access to read and write as it consists of a decentralized network. It means no one monopolizes control and entry while ensuring data is unchangeable once validated on the blockchain by every participant (nodes).

On the other hand, a Private blockchain is a permissioned blockchain, meaning restrictions are imposed on who can participate in the network and in what transactions. To regulate who is able to read or write on the blockchain, identity is required. Otherwise, it would be

impossible to define rules to participate in the network. The access control mechanism could vary: existing participants could decide future entrants; a regulatory authority could issue licenses for participation; or a group of organizations could make the decisions instead.

Having a clear idea of who each user is and which role plays in the chain drives to determine the level of access they should own. For a business case use, knowing every participant entails everyone is having a good behaviour. If not, it is easily detectable who is improperly acting in order to apply its due consequences.

In Private chains, decentralization does not come in the whole meaning as it is operated and controlled by a single person or organization who imposes the rules. However, once an entity has joined the network, it will play a role in maintaining the blockchain in a decentralized manner.

A variety of a Private system that works similarly is a Consortium blockchain, which instead of having a single controlling authority or company control of participant's access relies on a group of enterprises or consortium that have a common understanding and objectives.

Vitalik Buterin, co-founder of Ethereum, provided a straightforward definition: *“So far there has been little emphasis on the distinction between Consortium blockchains and fully Private blockchains, although it is important: the former provides a hybrid between the “low-trust” provided by Public blockchains and the “single highly-trusted entity” model of Private blockchains, whereas the latter can be more accurately described as a centralized system with a degree of cryptographic auditability attached.*

PUBLIC VS. PRIVATE BLOCKCHAINS

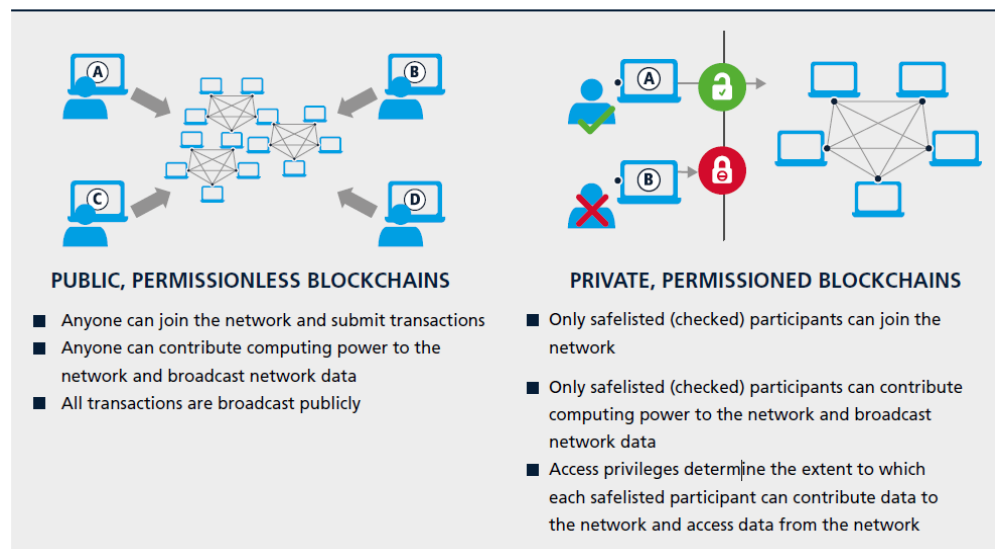


Figure 7.13 Key features between public and private networks, Accenture

Before selecting the type of blockchain to be used on the specific purpose for Maresmar, a third model should be considered: Hybrid blockchain.

Hybrid blockchain combines beneficial attributes of both Public and Private blockchains. This type of networks do not allow anyone to join, being then a permissioned blockchain, while at the same time does not centralize full control of the network to a single entity but rather a group of approved individuals.

The main difference with Private or Consortium blockchains comes in how it maintains immutability and decentralization just like in a Public blockchain. Immutability is reached through non-permissioned third-party validation of transaction content, while keeping data secure like a Private blockchain. Any data placed into the transaction history of a particular node is not shared with the network. However, a cryptographic hash of that data is shared, so that other nodes on the network may corroborate the content of that data, via its hash, without ever actually seeing the data itself.

Basically, a Hybrid blockchain is a Private blockchain running on a Public one. The Private blockchain is used to generate a hash of transactions which is later verified using the Public blockchain.

On the other hand, it allows managing which transactions are viewable and which not while identity is kept secret towards the public and only revealed to the other part with which the transaction is made.

Once the three main networks have been described it is necessary to select the solution that adapts better to Maresmar supply chain's requirements. For this purpose, blockchain characteristics have been ordered according to the level of priority and impact on the company.

High priority

Control access: the aim of this project is the implementation of blockchain by Maresmar a single company working together with its providers and clients. For this reason, it is essential that the company control who can access the network and participate in the exchange of information. A Public blockchain does not give the opportunity to do it due to its openness and that is why the solution should be working with a permissioned chain, either Private or Hybrid. The details on how the access of a new participant is conducted is explained more in depth later in the document.

Privacy: for the enterprise use of blockchain privacy comes as one of its major requirements as private information must be kept away from the rest of parties as long as one of them

wants to share it with a particular party.

Privacy goes together with the previous point, as access to the blockchain could imply access to sensible information. Maresmar, as an enterprise, wants to control who sees what type of information under what circumstances, as well as who is able to write that information onto the blockchain. Therefore, it might be used a permissioned solution again to manage supplier-vendor relationships. Only a particular supplier should be able to see the details of the contract that Maresmar have with them, and not the details of a contract it has with any other suppliers.

Moreover, towards giving a transparent image to clients, the company may wish to share some of this high-level macro data with consumers, so that they can see the origins of the products they're buying, but of course hiding the financials aspect behind all that.

Anonymity (to be avoided): in a business case like the one to be implemented, anonymity should be avoided at all costs. Maresmar will not be dealing with unknown parties like in the cryptocurrency's world like Bitcoin, but with close providers, or sometimes not that close, with which relationship has already been established and anonymity would generate a complete chaos. Once again, Public blockchain should be discarded in order to work with Private or Hybrid blockchains.

Medium priority

Decentralization: the pure necessity of applying blockchain with an enterprise point of view drives to use a permissioned system. As mentioned before, anonymity must be avoided, which directly implies not adopting a Public blockchain and opt for one with a governing party like a Private or Hybrid. This means it will be a partially decentralised structure, which in the other hand is necessary as Maresmar is in the middle of the supply chain and requires control over both sides of it.

Immutability: it has not been classified as a high priority as it is a common characteristic of every type of blockchain. Even though, on a permissioned blockchain where a central authority / authorities have control, data could be changed and deleted. Nevertheless, this would go against the own rules and concept Maresmar is going to achieve by implementing a blockchain system and that is why immutability should not be a worry. Thought, a Public or a Hybrid blockchain presents a major degree of immutability due to their intrinsic validation of data system through validator nodes.

Efficiency: the amount of data to manage with the blockchain implemented in Maresmar will not be as large as the one big players like Walmart or Maersk are dealing with in their

blockchains. Hence, even if efficiency is required to run everything without problems, this property of the blockchain is not listed as critical as privacy or anonymity. Having a deep look on efficiency of the network, it is undeniable that a Private blockchain is the best solution. Efficiency is directly linked with the fact of having less nodes working on the chain as consensus mechanism, in the case it is implemented, does not need from thousands of nodes to validate new information entry. For the same reason, transactions of data and money can be executed much faster.

For Maresmar, it is important to have access to real-time data in the fastest way as possible as well as speed up processes such as customs controls when carrying shipment across borders. Having to wait for minutes as it happens for example in the Bitcoin blockchain would not be helpful to obtain one of the main objectives of adopting this technology which is streamlining the whole supply chain.

But it is not only a matter of time but of computational required too. In a Private chain it is not necessary to solve consuming and computationally intensive consensus mechanism like the Proof-of-Work on Public chains.

Security: the three types of blockchains work by creating blocks that are cryptographically linked into a chain. However, in the case of a Public blockchain it could suffer the 51% attack where a group of miners could be controlling more than 50% of the network's mining hashrate, or computing power. The attackers would be able to prevent new transactions from gaining confirmations, allowing them to halt payments between some or all users. In order to avoid that, working in a business context where it is necessary to protect sensitive corporate information and customer data, a Private blockchain can provide security. Validators are not anonymous as they are pre-selected by the controlling organization and normally known and trusted. Because of this, the chances of someone acting maliciously on the company's network are much less. Also, hack or virus attacks are out of the question which is a major fear in Public blockchains.

Scalability: performance and scalability go hand in hand. Due to the computational power required to run Public blockchains and ensure consensus, they can be difficult to maintain at a large scale. The more users join a Public network, the more transactions they request, the longer it takes for those transactions to be confirmed, and the longer the waiting times during peak hours. For Maresmar purpose it can result in a considerable inconvenient as it might be difficult now to determine how the network will grow or if the company will expand and adhere new participants to the system. A permissioned blockchain solve these problems thanks to its modular architecture, scale-out capabilities, and capacity on demand.

The truth is that for this first approach on the implementation of blockchain into Maresmar supply chain, scalability is not a vital requirement as it is not a multinational corporation with

thousands of partners and stakeholders working together. However, it is always positive to have the chance and infrastructure ready to develop and deploy a larger system in the future, a possibility permissioned chains offer.

Low priority

Improvements: permissionless and permissioned blockchains are currently launched and supported by big companies like Ethereum or IBM which are constantly improving the systems and adding new features and security methods. Certainly, improvements are something to be considered when adopting a blockchain but not with the emphasis of the previous considered characteristics. Nonetheless, it must be highlighted that as Public blockchains is open for developers to join and contribute with their knowledge, improvements come in a major scale than in a closed company working with their own programmers.

In order to establish which type of blockchain fits better into Maresmar necessities, each characteristic has been evaluated with a 1, 2, 3 scale and weighted depending on its priority level for Maresmar business use according to:

High priority → 60% weight

Medium priority → 30% weight

Low priority → 10% weight

The final mark for each type of platform is obtained from the sum of:

$$\begin{aligned} & \text{(Control Access + Privacy + Anonymity) x 0.6} \\ & \quad + \\ & \text{(Decentralization + Immutability + Efficiency + Security + Scalability) x 0.3} \\ & \quad + \\ & \text{(Improvements) x 0.1} \end{aligned}$$

	PUBLIC	PRIVATE	HYBRID
Control access	1	3	3
Privacy	1	3	3
Anonymity (avoid)	1	3	3
Decentralization	3	1	2
Immutability	3	1	3
Efficiency	1	3	2
Security	2	3	3
Scalability	1	3	3
Improvements	3	2	2
RESULT	5,1	8,9	9,5

Table 7.2 Public vs Private vs Hybrid blockchain type

In accordance with the results, it can be confirmed that using a Hybrid blockchain is the solution that fits best for Maresmar application in its supply chain. It must be mentioned that the low mark obtained by the option of a Public blockchain can be explained as the mere intention of using this technology is uniquely business oriented. For other purposes, a Public blockchain can be a perfect solution.

Results between Private and Hybrid options are considerably close. The final choice of the type of blockchain will be reached according to the platform and programming solution chosen based on costs, difficulty of implementation and other aspects analysed more in depth later in this document.

7.6.2. Selecting the blockchain platform

Once the different types of blockchains have been explored and defined a permissioned solution, either Private or Hybrid, as the most suitable for the business purpose, it is necessary to select which platform offers major advantages.

When talking about platform it refers to the different protocols and networks existing on the blockchain space on top of which developers design their programs. Each platform has its particular architecture, consensus, security parameters, etc.

This part of the project assesses the foundational business functionalities for the main blockchain networks: Ethereum, Hyperledger Fabric and R3 Corda in terms of where the software acquires its influence and how the system is overall optimized.

As mentioned before in this paper, blockchain did not emerge for the need of the market but as an underlying technology of Bitcoin. Ethereum Foundation saw the potential of this technology and went a step further introducing smart contracts and other improved features. However, with the full public aspect of the technology, they couldn't use it properly. Therefore, Hyperledger came with the relevant set of privacy a firm could ever need and then later followed by many other companies that focused their efforts on the enterprise's use level of blockchain. The selected networks, including Ethereum, are studied from this point of view, but the truth is that they differ on the offered features. Hence, priorities must be set on the ones that bring more benefits for the project.

ETHEREUM

Ethereum, initially developed by Vitalik Buterin, is an open software application based on blockchain technology that seeks to provide a framework for developers to come up with decentralized applications (DApps). Ethereum blockchain runs the programming code upon which DApps are created. A decentralized application is a special type of application that runs on a peer-to-peer network rather than a single computer with the aim to exist on the Internet and not to be controlled by a single entity.

Actually, Ethereum is a Public blockchain which, however, offers the possibility to build permissioned solutions. Enterprise Ethereum Alliance (EEA), a worldwide group of developers and corporations, was born to take advantage of it in order to customize Ethereum blockchain and help firms to exploit properties like immutability of data, transparency and data integrity.

Over 300,000 software engineers, product developers and enterprise delivery experts are building the infrastructure, developer tools, core blockchain applications and resources to facilitate solution creation, delivery and support.

Furthermore, Ethereum network stands out for having the ability to develop fully customizable smart contracts, which is one of its major strengths.

Architecture - Network peers participation

Depending on the usage of the network three different types of network exists: the main network, which is the current public live network of Ethereum where no restrictions are placed to join it. The test net, a network used to deploy and test smart contracts and DApps before these are deployed to the main network. And then private nets, required when a group of entities want to have a controlled network environment.

In the Ethereum network, all nodes are connected to each other but not every node is connected to whole network. A node is connected to few other nodes, which in turn connects to few other nodes leading to a network where eventually all nodes are connected.

Ethereum has its own discovery protocol. The nodes are gossiping with each other to find about other nodes on the network. There are special nodes, called Bootstrap nodes that can be set in the source code that maintain a list of all nodes connected to them. When a new node connects, it first communicates with the Bootstrap nodes in order to connect and synchronize. (Github-Ethereum, 2017)

In the case of a private network, the nodes that are connected are only the nodes that explicitly get connected manually to a specific node. For example, if the private network consists of nodes A, B, C, D and node B is set as Bootstrap node we can add a new node by manually telling it to connect to node B. As soon as this will be done, the node list that node B holds will be shared with new node E and it will get synched with the network.

On the other side, miners create blocks in which user transactions are hashed and ordered. The node operators validate miner blocks and process users' transactions on those blocks.

In Ethereum, decentralization comes anchored in its architecture as enterprise networks have access to the Ethereum mainnet. This interoperability with the Ethereum mainnet allows data storage across the blockchain and private cloud with customizable privacy.

Immutability happens as in any distributed ledger regarding unchangeability of data and full decentralization. Though, this only applies to the public chain. For a private chain use, just like in the other networks, trust must be placed on the governing authority or the consortium of authorities.

Consensus

Consensus mechanism in the Ethereum network is based in the Proof of Work (PoW) algorithm (see 5. Introduction to blockchain). Basically, PoW uses a 'hash function' to create conditions. A participant solves the cryptographic puzzles and creates new blocks (mining). These blocks are then independently verified by other system participants independently if they are directly involved in the transaction. This consensus algorithm requires a lot of CPU power and that is the reason why Ethereum will migrate to a proof-of-stake (PoS) consensus algorithm in a close future where fewer nodes execute the verification depending on their stake.

Data Security and Privacy

From the data security point of view, being connected to the Ethereum public network means working with the most resilient and hack-resistant blockchain to date. It is supported by worldwide companies that place their trust in Ethereum by processing more daily transactions than any other blockchain

On the other hand, Ethereum platform permissioned solutions offer a narrow range of data privacy, compared to other blockchains like Hyperledger Fabric, as long as it was originally focused on the public chain. However, new frameworks and solutions are appearing to fill this gap such as [evan.network](#) or [Quorum](#). There are many options in the Ethereum ecosystem that are available today or are actively being developed to provide various layers of privacy even if it still a challenge to be tackled.

Smart Contracts

Ethereum smart contracts work as an autonomous agent living inside the blockchain environment that executes a particular code in the Ethereum Virtual Machine (EVM) when triggered by a message or action. EVM is a simple stack-based execution machine that runs bytecode instructions, a series of ones and zeroes that can be read and interpreted by the network to change state. It is fully isolated and the code that runs in EVM has no connection to the filesystem or the network in order to protect data attacks. An Ethereum transaction contract code can trigger data reads and writes, do computations, make calls (send messages) to other contracts, etc.

Smart contracts are the foundation and strong characteristic of Ethereum network that linked with DApps enable a user interaction for them. Despite the complexities attached with Solidity, the programming language employed for smart contracts deployment, it brings the ability for developers to create their own code solution.

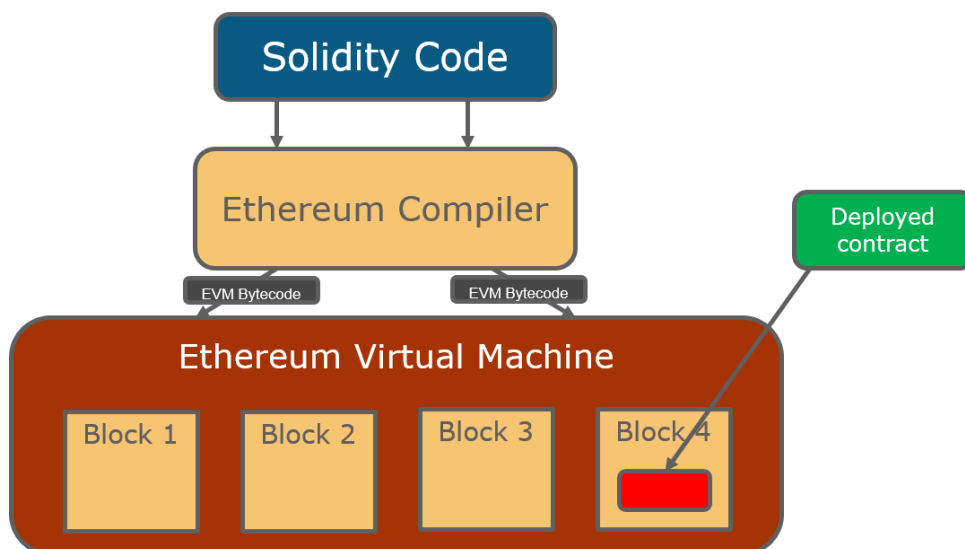


Figure 7.14 Ethereum structure

The major drawback of using Ethereum platform is its associated fees (Gas) charged for every transaction. Gas is the computational cost for processing a transaction or a smart contract. This mechanism avoids infinite loops unleashed by a poorly programmed code that could leave the system unusable.

Smart contracts also provide the ability to connect to IoT, boosting devices to perform actions and gather all the data collected in a secure way. Some IoT oriented companies and startups like Atonomi or IoTeX are based on Ethereum smart contracts.

Built-in coins / digitalization of assets (tokenization)

Ethereum, compared to the other analysed platforms, is the only one with a built-in cryptocurrency called ETH. Its main purpose is to pay rewards to peers that contribute to reach consensus by mining blocks as well as to pay transaction fees within the network. ETH can also be used to perform monetary transactions as it can be exchanged with physical currencies.

Moreover, Ethereum allows creating digital tokens for customized use cases through smart contracts, meaning you can define your own currency.

A part from creating digital currency, Ethereum makes digitalization of assets available. Digitalizing any valuable asset of the supply chain, making it accessible by a broader network, would significate entering into a digital economy where goods are exchanged without the need of intermediaries.

HYPERLEDGER FABRIC

The Linux Foundation established Hyperledger in 2015 to advance cross-industry blockchain technology. It is not a single solution but a hub of companies organized under the umbrella of the Linux foundation. IBM, one of its high-profile participants, initiated, developed and promoted Hyperledger Fabric, one of the major parts of Hyperledger that positions itself as a blockchain for B2B applications. Just like Ethereum, it is an open source platform encouraging developers to come up with applications that offer smart solutions for various industries.

Hyperledger promotes its development through community cooperation, with intellectual property, encouraging open, and over time to adopt different standards.

Moreover, it's designed to suit a higher degree of confidentiality for the platforms due to its permissioned approach as well as a higher performance coming from their basic infrastructure.

The system and the underlying components are designed with a focus on distributed data bases instead of decentralized application platforms itself.

Architecture - Network peers participation

Hyperledger Fabric is a permissioned networks only platform with a particular modular design. This type of infrastructure allows using different components independent of any specific field of application. In other words, it brings the possibility to plug in the feature you want, like a specific consensus or membership services, and start using it. Modularity makes the platform more scalable and resilient so it can easily expand in the future.

The ledger for its part, is formed by the world state and the transaction log. The world state describes the state of the ledger at a certain point in time. The transaction log records all transactions that lead to the current world state and, as such, is a historical record of the world state.

With Fabric, peers actions depend on the roles they play: clients, peers or orderers. A client acts on behalf of an end-user and creates and thereby invokes transactions. They interact with both peers and orderers. Peers maintain the ledger and receive ordered update messages from orderers for committing fresh transactions. Orderers, in turn, provide a communication channel to both clients and peers making it possible to send messages containing transactions. Orderers are in charge of collecting transactions from across the network into blocks and distributing these to all peers where they can be verified before being applied to each peer's local copy of the ledger. The only issue here is that there might occur faults in the delivery of messages when many mutually untrusting orderers are employed.

The blockchain network itself is comprised of peers, each of which can hold copies of ledgers and copies of smart contracts (called chaincodes). In this example, the network N consists of peers P1, P2 and P3, each of which maintain their own instance of the distributed ledger L1. P1, P2 and P3 use the same chaincode, S1, to access their copy of that distributed ledger.

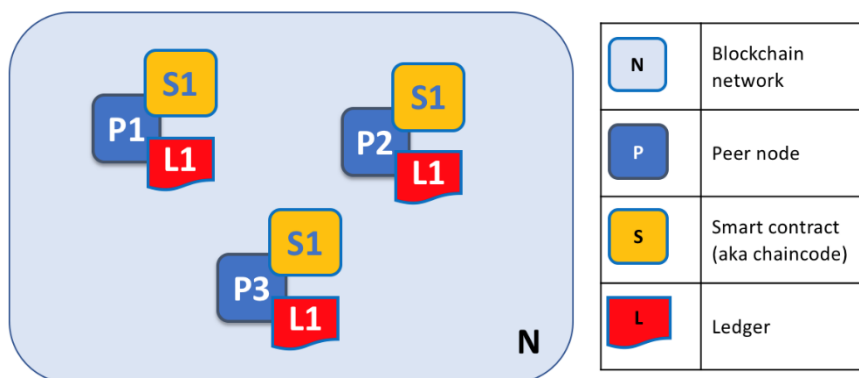


Figure 7.15 Hyperledger Fabric architecture

A peer node can host multiple ledger and multiple chaincodes at the same time, meaning a ledger can be accessed by different chaincodes.

Through a peer connection, clients or applications can execute chaincodes to query or update a ledger. The result of a ledger query transaction is returned immediately, whereas ledger updates involve a more complex interaction between peers in order to validate it.

P2P participation is restricted for a particular ledger as Hyperledger Fabric have multiple ledgers called channels. A channel can be available only to certain members. Hence, peers participation is restricted to the channel where peers belong to.

Organizations contribute with their peers to create the blockchain network even if all their peers are not connected in a particular channel. This is at the heart of what it means for a network to be decentralized.

Consensus

Fabric's understanding of consensus covers the whole transaction flow, starting from proposing a transaction to network community. Peers assume different roles and tasks in the process of reaching consensus meaning not every node has to validate the transaction. This contrasts to Ethereum where all nodes need to perform the identical tasks.

Besides, consensus algorithms under Hyperledger are pluggable, allowing users to select the algorithm of their choice during deployment within the network channel.

Data Security and Privacy

Considering the data security aspect, Hyperledger Fabric is the network offering a wider range of solution. It helps to protect enterprise data through a three-level data flow structure:

- Separate Ledger: Grouping a set of information under separate channels to give access to authorized users only.
- Private Transactions: Introducing additional privacy in terms of keeping data confidential between the parties concerned, not allowing access to the third party, via hash encryption of data.
- Zero-knowledge validation: enables a party who possesses a secret (the prover) to prove to another party (the verifier) that its secret satisfies a certain set of properties (knowledge) without revealing the actual secret (zero-knowledge).

Regarding privacy, the issuing authority of Hyperledger encrypts the identity of each user or peer via a digital certificate which is registered in a registration authority.

Whenever a peer connects using a channel to a blockchain network, a policy in the channel configuration uses the peer's identity to determine its rights. The mapping of identity to organization is provided by a component called a Membership Service Provider (MSP) which determines how a peer gets assigned to a specific role in a particular organization and accordingly gains appropriate access to blockchain resources.

However, the encryption of identity is done in such a way that it remains hidden from other unwanted participants but can be accessed by the regulators. Consequently, fully decentralization is not achieved as happens with any other permissioned blockchain.

Smart Contracts

The smart contract framework of Hyperledger is called chaincode, which runs inside the validating nodes. This is a very fast in execution but complicate in distribution because the code and code-updates have to be deployed manually across all participating peers.

On the other hand, chaincodes lack being deterministic, which present difficulties to prevent negative effects if a chaincode contains errors. So, for instance it's possible to build infinite loops with Hyperledger chaincode.

The chain code can be written in multiple languages. Currently, Fabric supports Go and Java and will release more language support in the future.

Built-in coins / digitalization of assets (tokenization)

Hyperledger Fabric does not have a native currency and does not support tokenization in its core.

It is possible to create token-like constructs through chaincodes but it's not an open standard and therefore limited to the specific use case for what you implement it.

R3 CORDA

Founded on 2015, R3 joins nearly 200 financial giants and Internet giants in its ranks. R3's core function is to research and develop blockchain applications for the financial and commercial industries, and "internally test" blockchain technology to help banks find a suitable distributed ledger system for their needs.

R3 has its own basic platform called Corda. According to R3 insiders, Corda is a "blockchain-inspired" platform, but may not offer a blockchain's full function. The main goal of Corda is to ensure network owners their services are compatible between all network participants.

Architecture - Network peers participation

R3 Corda began with the idea of a global ledger: a reliable single source. In case when the transaction involves a small subgroup of parties, Corda strives to keep the relevant data purely within the subgroup.

But keeping data inside a group of participants is not achieved through channels like in Hyperledger, as such design cannot support a global network that supports multiple interoperable applications and assets. In order to do so, the foundational object is a state object that records the existence, content and current state of an agreement between two or more parties. It is intended to be shared only with those who have a legitimate reason to see it. To ensure consistency in a global, shared system where not all data is visible to all participants, Corda relies heavily on secured cryptographic hashes to identify parties and data. The ledger is defined as a set of immutable state objects.

The platform borrows heavily from the UTXO model used in Bitcoin transactions where state is defined by a series of inputs and outputs and the varying reconfigurations of the inputs can dictate the state of the output.

The R3 Corda architectural framework relies upon a nodal structure that is reliant on submodules called notaries that help maintain the validity of a network similar to validator structures in other platforms.

Consensus

In Corda, there are two aspects of consensus:

- Transaction validity: parties can reach certainty that a proposed update transaction defining output states is valid by checking that the associated contract code runs successfully and has all the required signatures; and that any transactions to which this transaction refers are also valid.
- Transaction uniqueness: parties can reach certainty that the transaction in question is the unique consumer of all its input states. There exists no other transaction that consumes any of the same states.

Consensus over transaction validity is performed only by parties to the transaction in question. Parties can agree on transaction validity by independently running the same contract code and validation logic. However, two valid transactions could conceivably exist at the same time and so participants need a way to determine which will be regarded as having come first. At this point is where a predetermined observer, a notary, comes into action.

A notary is a network service providing uniqueness consensus for a given transaction; without a notary signature a transaction is not valid. The notary mechanism can be seen as a kind of trusted third party that mediates a transaction between two users, a fact that goes against the fundamental innovation of blockchain of trustlessness and the removal of third-party reliance.

Corda has pluggable uniqueness services. This is to improve privacy, scalability, legal-system compatibility and algorithmic agility. These uniqueness services are required only to attest whether the states consumed by a given transaction have previously been consumed but they are not required to attest as to the validity of the transaction itself, which is a matter for the parties to the transaction.

Data Security and Privacy

In terms of privacy, Corda enables a broad range of identities to participate in transactions, from institutions to individuals. An identity in Corda is represented by a certificate, signed by a suitable authority, representing a named real-world actor.

The pluggable uniqueness service in Corda and the use of shared cryptographic hashes to ensure restrictive viewing of transactions tackle the privacy issues.

Smart Contracts




Corda's smart contracts work similarly Hyperledger but have the particularity of being written in legal prose to be legally enforceable. The smart contract links business logic and business data to an associated legal prose in order to ensure that the financial agreements on the platform are rooted firmly in law and can be enforced in the event of ambiguity, uncertainty or dispute.

The truth is that Corda contracts are mainly used as a validation procedure which under-utilizes the technology as they are not use for value transfer purpose like in Ethereum.

The virtual machine selected for contract execution and validation is the Java Virtual Machine where a variety of programming languages can be used. However, virtual machine has been augmented with a custom sandbox that is radically more restrictive than the ordinary JVM sandbox, and it enforces not only security requirements but also deterministic execution.

Built-in coins / digitalization of assets (tokenization)

As happens with Hyperledger Fabric, R3 Corda does not actually have a build-in cryptocurrency as they use consensus-building mechanisms that don't require mining. However, R3 does not contemplate creating cryptocurrencies or digital tokens.

	 ethereum	 HYPERLEDGER FABRIC	 r3 c.rda
Use cases	Popular with generalized applications and mostly used for B2C operations	A preferred platform for B2B operations, mainly used in enterprises	Transaction oriented. Financial businesses
Confidentiality / Privacy	Private transactions among participants in the private chain	Only people involved in a given project can access data in a network Trust relies on the owner of the BC	Only individual parties privy to the transactions are able to access the information (uniqueness)
Data Security	Less extensive range of solutions than Hyperledger Fabric	Trust in the owner of the BC	Highest standards of privacy and security
Immutability	Full immutability, linked with Public network	Data cannot be changed (inherent in Apache Kafka system)	Blocks linked to each other

Consensus	Proof of Authority	Not all nodes in a network must take part in the consensus process (no mining)	Individual consensus within parties involved in the transaction
Programming language	Solidity	Google's Golang	Kotlin
Smart contracts	Integrated in Ethereum architecture. It allows smart contracts (Dapps)	It allows smart contracts using Chaincode	Smart contracts in legal prose
Cryptocurrency	Powered by Ether native currency	Does not have a native currency (can be created via chaincode but for specific use cases)	Does not have a native currency
Digital assets (Tokenization)	Able to create digital assets (accessible by broader networks) - bigger strengths	Able to create digital assets (only in Fabric platform)	Not able
Performance / Scalability	Not the higher but great functionality	High performance between a closed group of companies	High performance between a closed group of companies

Table 7.3 Ethereum vs Hyperledger Fabric vs R3 Corda

Taking every feature into consideration and the capabilities of each platform, the final decision is made on using Ethereum network as it gathers all the blockchain technology benefits and it is not just an improved distributed ledger.

Ethereum brings major degree of decentralization, even if an authority is always necessary on permissioned networks. Moreover, it integrates a built-in cryptocurrency (ETH), whereas Fabric and Corda do not, for a wide range of uses as well as the possibility of tokenization of assets, features that could have direct benefits on a supply chain ecosystem. In the deployment of smart contracts, Ethereum provides a series of toolkits and DApps that make it the most interesting platform and could help to fastener processes all along the supply chain.

Despite the inconvenience that presents not offering a higher level of privacy or scalability due to the use of PoW consensus, Ethereum benefits from a large experienced team of developers on the Enterprise Ethereum Alliance (EEA) that are constantly bringing

improvements and solutions to current blockchain problems. Support from EEA can streamline the implementation of specific features inside the blockchain such as the IoT gadgets adoption or an App development for the consumer end use.

Besides, access to open-source code and connection with the public mainnet equips each private Ethereum solution with global reach, extreme resilience, high integrity, and access to the vast Ethereum ecosystem.

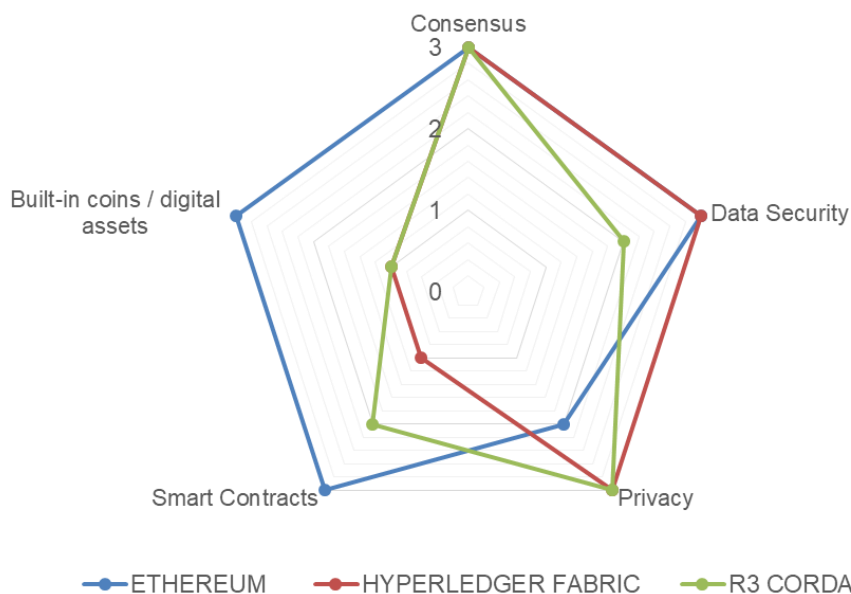


Table 7.4 Evaluating platforms main features

7.6.3. Project implementation

With a decision made on the use of Ethereum network on account of the wide range of opportunities it offers, next stage on the decision process is determining the project implementation to be used on the implementation of the blockchain model. The following benchmark compares different alternatives: incorporating a group of developers to program and build a whole blockchain from zero, externalizing the development of a customized solution with a consultancy group or using a Baas (Blockchain as a Service) platform. Decision will be based on price, time, level of customization and ease of use.

As in any emerging technology, the number of developers able to implement blockchain is still reduced and mainly searched by big firms, which consequently increase the price of contracting their services exclusively for a particular company purpose. Price, as in any

business application, always plays a decisive role on carrying out a project, therefore, an equilibrium between price and capabilities of applying this technology will be a critical aspect to consider. The analysis is just focused on the deployment and maintenance of the network, as IoT and other features expenses are not considered. A more detailed view of this point can be found later on this project.

Internal consulting

The following covered option of contracting a group of developers means building the desired solution from the beginning, without any previous infrastructure but with the possibility of creating a blockchain on demand. In this case, blockchain developers would be incorporated into Maresmar staff.

As previously mentioned, blockchain experts are rare to find at the moment and meet with developers that ensure a seamlessly solution could be a hard task. Regarding the economical factor, wages are much higher than for an ordinary software developer. According to the consultant group Burning Glass Technologies, specialized in analysing employment data, the average salary of a Blockchain developer engineers in the United States is 130.000 \$ per year compared to 105.000 \$ from a software developer. In Barcelona salaries are much lower and blockchain developers earn around 60.000 € a year. Even if cheaper blockchain developers can be found, paying a considerable amount of money should be a guarantee to obtain a quality solution. These salaries refer to full-time employees while a freelance consultant charges an average of 150 \$ an hour according to Upwork, a portal specialized in independent workers. For an implementation from zero, it would be necessary to include developers in the company staff and freelance consultants should only be considered for punctual cases.

Creating the network from the beginning allows having a decision-making power that other solution do not grant as every parameter (consensus, number of nodes, security, privacy, etc.) can be choose according to the company priorities. Though, it also requires from a large period of time to set everything up as well as the requirement of human resources for the maintenance and to fix problems that would certainly turn up.

Despite the possibilities of a fully customized result from relying on a team of developers, this option must be rejected due to the heavy expenses it entails and the considerable amount of time before being able to work with a viable blockchain system.

External consulting

As an alternative to hiring a team of blockchain developers, the solution could be to completely externalize the installation of the blockchain with a consultancy group. Big consultancy firms have recently launched programs and initiatives to incorporate blockchain technology into their provided services. Most of them are coming up with consortiums alongside technological companies (e.g. IBM) or banks (e.g. JPMorgan) to benefit from the auditing capabilities blockchain can offer. In this way, an example can be found on the creation of Rubix Core by Deloitte, a broad network of labs around the world specialized in creating decentralized apps (DApps) build on Ethereum as well as working as intermediary between blockchain startups and clients by leveraging from business negotiating experience Deloitte has. And this is the strong point from hiring consultancy services due to their major knowledge of the enterprise world and not just limiting their field of activities to the blockchain technology as such. Nevertheless, when it comes to this project, working with intermediaries is not really necessary as ideas on where to conduct the blockchain adoption are clearly stated and middle intermediators would mean increasing the budget unnecessarily. Consultancy companies generally provide end-to-end solutions with maturity assessments, comparatives analysis and deep studies of alternatives. In this project, all the previous work on how blockchain works and how to benefit from it has already been conducted as well as benchmark studies on networks, platforms, IoT gadgets, etc. Therefore, consultant's tasks can be skipped.

Accomplishment of demanded requirements could be done just like in the previous option of hiring a team of developers but adding extra coordination and technological providers coming from a vast network of contacts and companies a consultancy group manages. Consequently, duration to create and launch the workable and trouble-free solution would be shortened by benefiting from prototypes and previous implementations on supply chains many consultancy firms have already worked on.

Another argument endorsing consultancy alternative comes in terms of responsibility. Completely externalizing the solution carries all the responsibility on the consultancy company who takes charge of all unexpected events during the development.

In the overall, externalizing the project to a consultancy group is the way to not worry about all the background and issues of the implementation processes and just enjoying the working solution. However, it has attached a higher budget that can be avoided to pay by precisely executing a previous study like the one conducted during the whole project to achieve an optimized solution.

BaaS (Blockchain as a Service)

Blockchain as a Service (BaaS) is an offering that allows customers to leverage cloud-based solutions to build, host and use their own blockchain apps, smart contracts and functions on the blockchain while the cloud-based service provider manages all the necessary tasks and activities to keep the infrastructure agile and operational.

This kind of solution can be compared with a web hosting provider. When setting a website there is the possibility to host and run that website on your own computer/server and take care of all the maintenance by your own. However, another option is to host the website on an external web hosting provider like Amazon Web Services which handles all infrastructure and maintenance issues. BaaS operates in a similar way, offering all the advantages and functionalities of the blockchain technology by paying a fee without worrying about the underlying complexities involved in creating, configuring, and operating the blockchain, and maintaining its infrastructure. BaaS platforms deal with the hosting and security issues of the system while providing tools (tokens, smart contracts, nodes of the block chain, programming language, etc.) and a friendly environment to work with as well as support on the development of a tailored solution.

Main advantages of using BaaS come from having a low-cost access to technology focusing on the pure core business of the company, massive scalability, increased data security, compatibility with other firms and full access from anywhere. It should also be highlighted the rapid deployment of a blockchain with a BaaS, without too many faults and with the opportunity to do backups and reverse to previous version without hurting any data in case of any bugs.

Another point to consider is the possibility of testing the product as many BaaS platforms allow experimenting with blockchain innovations prior to making a more considerable investment.

However, these kinds of solutions are still incomplete, as blockchain expert developers are required to manage the set of tools provided by the BaaS provider in order to obtain an operative solution. An analogy can be found on Ikea's furniture: you get all the pieces and instructions but you still have to assemble it by yourself.

A critical point of working with a BaaS comes when selecting in which framework or network (Ethereum, Hyperledger, etc.) to work as once the blockchain is deployed, BaaS solutions have limited flexibility to move from one to another.

From the pricing point of view, most of the BaaS companies offer a variety of pay-per-use alternatives: fix price per membership + usage fees & support options, fix price for a

maximum number of nodes + pay per extra node or fix price with unlimited features and nodes. Cheapest options start from 1000 \$ per month but it can easily increase as more competencies the system is able to cover.

Because of Maresmar not being a technological enterprise, IT developers are not familiarized with blockchain technology and implementing it from scratch, even if recruiting blockchain experts, could result in a hard and costly task. For the same reason, contracting a consultancy group should be discarded as budget will be considerably increased. Besides, once the solution would be adapted, consultancy firms would not provide the same level of support a BaaS can bring. For instance, considering the case of introducing a new participant to the network or solving punctual problems would mean hiring a consultancy company or developers again with the costs involved. Likewise, dealing with a BaaS company who is entirely into blockchain technology and not having it just as another service like in a consultancy means working with an organisation strongly related with the blockchain world and with experience in implementing business cases like the one to be adopted in Maresmar.

Taking everything into account, the option of working with a BaaS arise as the most suitable for a cost-efficiency and carefree solution, which in the end, is what every company seeks for.

When selecting with which BaaS to work, two main routes should be examined. First one regards large technology companies that have already started offering blockchain as a Service: Microsoft offers blockchain on its Azure platform, IBM is focusing its efforts on building private blockchains or Amazon partnering with Kaleido startup proposing a web-based user interface. Relying on big firms brings a level of security, performance and the experience gathered from previous use cases as well as a constant improvement of the technology. Moreover, tech giants offer already made templates and tutorials that boost the whole process of adapting blockchain to your company.

On the other side, a vast amount of startups have emerged with more personal and flexible solutions not just aiming for big enterprise but medium ones or even retailers.

As using a BaaS platform has been selected as the alternative that fits best, on the next section is discussed which BaaS to use from the wide range of options.

7.6.4. Blockchain as a Service (BaaS)

Blockchain as a Service solutions are available in many companies and forms: from big technological firms to recent created startups each of them focusing their efforts on particular field of the blockchain capabilities. For Maresmar business case needs, there exists some firms specially dedicated in issuing trusted certifications rapidly, others in the auditability and traceability competences and others in the IoT fusion with the blockchain technology. Nonetheless, there is not a single organization assembling all these different properties into a unified solution. Thus, BaaS selection would be focused on the company that provides efficiency in one of these features as well as the possibility of integrating the others capabilities benefiting from openness of its infrastructural code and the ability to program over it.

Despite being a recent technology, firms offering BaaS rise up to hundreds, which makes it difficult to opt for one rather than another. Companies here presented and compared are restricted to Ethereum based protocol as it has been selected the best positioned. Moreover, selection of the BaaS is based in its capabilities to integrate IoT and blockchain solutions into supply chains. Some companies are already providing their own smart devices integrated in their network while others have the ability and resources to make them interact with their own network.

First decision point entails leaning to a startup company or a big tech giant. Startups provide particular use cases with innovative ideas for a supply chain management but can lack from the human and knowledge resources a big company can offer. Furthermore, the wide network of partners and the experience gained supports selecting a big tech company as they provide a series of toolkits and more adaptable solutions than a startup. Despite relying on a big company, it has been considered interesting to adopt some promising ideas from startups like Chronicled, Temco, VeChain, Waltonchain, Fishcoin, Vottun or Ambrosus among others.







	 CHRONICLED	 TEMCO	 vechain	 Waltonchain	 Fishcoin	 VOTTUN <small>certify + trace + track + verify</small>	 Ambrósus
Traceability	✓	✓	✓	✓	✓	✗	✓
IoT integration	✓	✓	✓	✓	✓	✗	✓
Regulatory compliance	✓	✗	✓	✗	✓	✓	✗
Token use	✗	✓	✗	✓	✓	✗	✓
DApp	✓	✓	✓	✓	✓	✓	✗
Business use	✓	✗	✓	✓	✗	✓	✗
Pilot / prototype	✗	✓	✗	✗	✓	✗	✓

Table 7.5 Startups features comparison

The following are the most relevant features from startups that will be adopted into the model of the project business case:

- Track and synchronize chain of custody of physical object and digital record with IoT and attestation-driven approaches.
- Have a proof of each participant in the chain touching the shipment with a vendor ID.
- Upload key audit, legal, and financial documents into the chain of custody
- Documents uploaded from cryptographic accounts and hashed into the chain of custody are time-stamped and impossible to edit or delete.
- Integration of IoT gadget (NFC, RFID, Smart Tags, etc.) and smart thermometer to track and monitor shipment through all the supply chain and ensure compliance. Possibility of reading the information via mobile App scan.
- QR code print in end-consumer packaging accessible by a mobile App.
- Customers rewards via tokens for using the App and posting products reviews.

Deeply comparing tech giants, two are the main firms dominating the BaaS business marketplace: Amazon and Microsoft.



Amazon Web Services integrates a wide variety of solutions where within the blockchain field, their most popular product is the AWS Blockchain Templates. These templates allow AWS users who are working on blockchain apps to set up Hyperledger Fabric or Ethereum networks in a faster way.

The AWS also gives its users access to affordable resources that can help them quickly deploy blockchain networks.

Main feature of AWS blockchain are:

- It offers security to the companies as users can add permissions to control the access to the AWS resources. Companies can also access the resource activity at any time which is logged in AWS CloudTrail.
- The service is offered as a pay-as-you-go service, so you only pay for the services you use and the amount of time you used them. This makes AWS resources affordable. You also do not have to pay any termination fees or upfront fees as there is no long-term contract between AWS and the user.
- AWS also offers a wide range of options when it comes to blockchain frameworks, which in the business case is Ethereum, as well as partner solutions for the company.
- With AWS Blockchain Templates, users can quickly deploy secure blockchain networks.

The AWS Blockchain Template is their primary product that allows users to take Ethereum open source frameworks to deploy secure blockchain networks in a fast way without worrying about slow set up processes and with a series of tools to monitor, browse and manage the blockchain.

AWS provides features like smart contract functionality, distributed consensus algorithms, access control, and other core blockchain features.

Other than using AWS Blockchain Templates, AWS also allows its users to choose from a wide range of AWS Partner Solutions for blockchain deployment. This enables users to

select one that fits their needs as they offer specialized blockchain solutions for specific industry.

AWS stands out for quickness on the deployment of a blockchain solution and the pay per use system. However, it does not offer any dedicated blockchain workbench like the one offered by Azure. For managing and developing blockchain applications, you need to rely on conventional AWS services or delegate it to one of its partners.



Microsoft Azure BaaS

Microsoft Azure

Microsoft Azure was the first major tech company to announce BaaS functionality to companies and developers. The company claims to provide low-risk, low-cost, fast, and fail-safe blockchain solution as BaaS.

Microsoft Azure highlights for:

- Reducing the development time by offering users pre-configured networks and infrastructure. This allows users to begin with the development of the decentralized applications instantly.
- With the help of Built-in connections to Azure tools, users can validate and iterate blockchain developments faster and easier.
- With the help of a globally available cloud platform, it keeps data secure. The solutions are also scalable that allows to expand at any time.

Azure has its Microsoft Azure Blockchain Workbench that enables users to create end-to-end blockchain applications through a smart contract builder as well as an admin console. The visual machine learning interface provides an experience of creating and implementing codeless models with drag-and-drop capabilities, making it much easier just like in other Microsoft application.

The WorkBench toolset currently works with Ethereum, either with the built-in ledger that you can deploy as part of Workbench, or with a 'bring your own ledger' capability that lets you deploy a multi-member network. This option allows customers to create a consortium network across multiple organizations, each with distinct administrative control over their nodes.

As well as in AWS, in Azure works with different partners that offer the solution that is more personalized for unique needs.

From the pricing point of view, it can vary according to the plan and services acquired but always under a pay-per-use model.

Comparing these two BaaS providers for a deep blockchain implementation, Microsoft Azure is a more complete option with major developers' toolkits as well as with more non-Blockchain functionalities that could be used like for example, data management and analytics. In the same way, Microsoft has already an Internet of Things Hub that allows connecting and monitoring IoT assets and which could be easily linked with the enterprise blockchain network. Besides, Microsoft offers the possibility to contract a developer as well as included support in their offer.

Taking everything into account, the final solution will be installed with Microsoft Azure BaaS with customization features adopted from ideas provided by the startups above mentioned.

7.7. Implementing Microsoft Azure Blockchain

Microsoft Azure Blockchain is the platform where the solution is going to be implemented to take advantage from the wide range of integrated Microsoft modules that simplify building a customized result. This section is addressing the technical challenges associated with the implementation but without going into the details. It just shows the basic infrastructure and how to benefit from it, as the important part of the project is the application of the blockchain itself.

The entire execution will be supported by a Microsoft developer in every moment as a small part of the budget is designated for this purpose. Despite Microsoft BaaS providing a large number of guides and tutorials, it will be necessary the support from this developer to clarify and coordinate with current IT technicians in Maresmar, as templates and pre-build configurations are not enough for a complete implementation. Moreover, a blockchain developer is also required in order to program and integrate the different modules and obtain a tailored solution. The Microsoft developer will help to understand how the Azure Blockchain works, but when aiming for a full implementation in a B2B and B2C network is necessary to lean on a blockchain expert.

For the App development it has been considered the idea of hiring a mobile App developer as Azure Blockchain is able to integrate Apps within its system, which in this case, will be DApps.

Azure Blockchain architecture

Microsoft Azure Blockchain is based on APIs that provide an interface for users to replace or exploit multiple blockchain technologies, storage, and database solutions. Azure brings the possibility to use the Azure Blockchain Development Kit, which contains samples for integrating, connecting, and using modules to interact and streamline blockchain development. It incorporates Azure services for key management, off-chain identity and data, as well as for monitoring and messaging APIs.

The blockchain integration of the different services and technologies is based on the following scheme provided by Microsoft in its resource files.

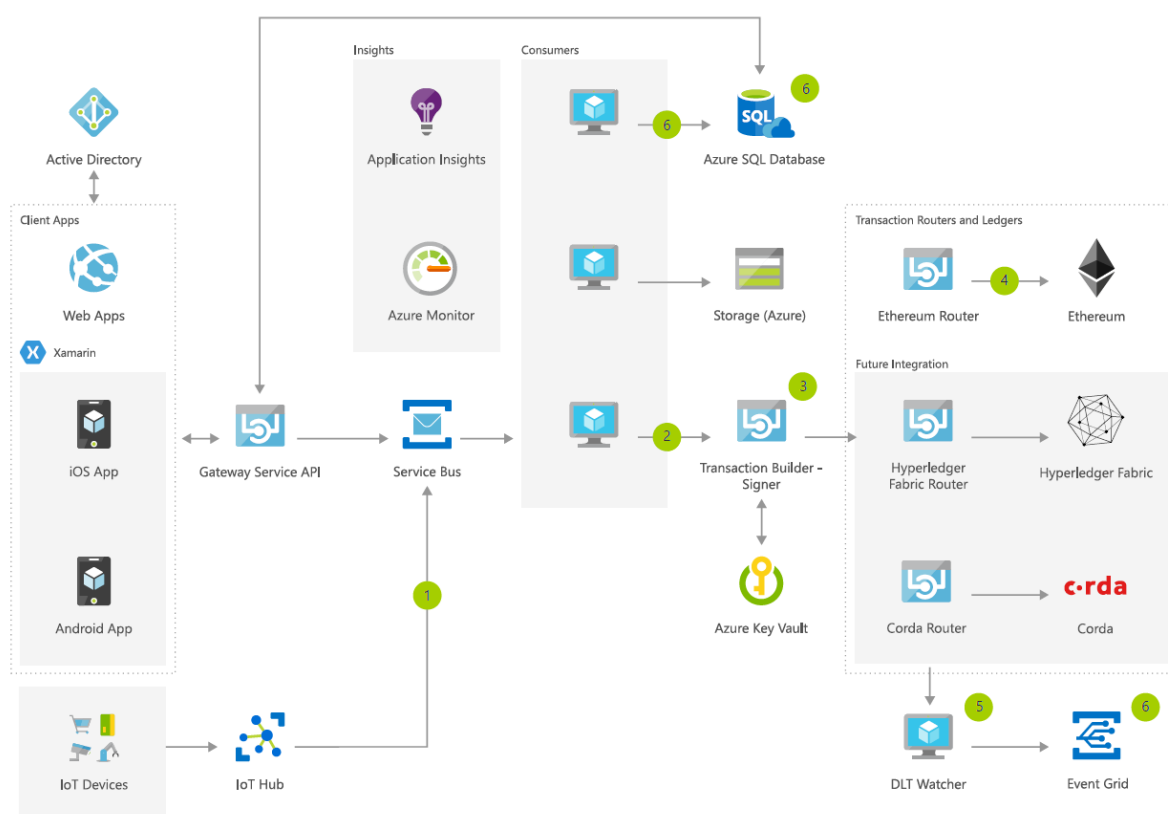


Figure 7.16 Azure Blockchain network, Microsoft resource files

Architecture overview

1 IoT devices communicate with IoT Hub. IoT Hub as a route configured that will send specific messages to a Service Bus associated with that route. The message is still in the native format for the device and needs to be translated to the format used by Azure Blockchain Workbench. An Azure Logic App performs that transformation. It is triggered when a new message is added to the Service Bus associated with the IoT hub, it then transforms the message and delivers it to the Service Bus used to deliver messages to Azure Blockchain workbench. The first service bus effectively serves as an "Outbox" for IoT Hub and the second one serves as an "Inbox" for Azure Blockchain Workbench.

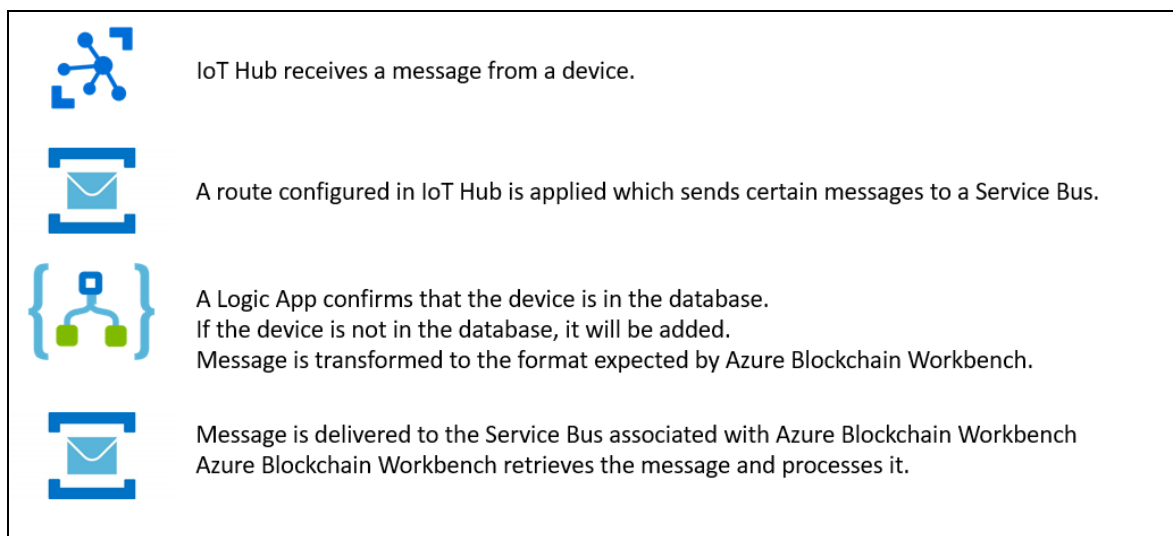


Figure 7.17 Azure IoT connection

- 2 DLT Consumer fetches the data from the message broker (Service Bus) and sends data to Transaction Builder and Signer.
- 3 The transaction Builder and Signer assembles a blockchain transaction based on the data and the desired blockchain destination. Once assembled, the transaction is signed. Private keys are stored in Azure Key Vault.
- 4 The signed transaction gets routed to the blockchain (Private Ethereum Consortium Network).
- 5 The DLT Watcher monitors events occurring on the Blockchain Workbench. Events reflect information relevant to individuals and systems. For example, the creation of new contract instances, execution of transactions, and changes of state. The events are

captured and sent to the outbound message broker (Service Bus), so they can be consumed by downstream consumers.

6 DB consumers send confirmed blockchain transactions to off-chain databases (Azure SQL Database). The Azure SQL database attached to Blockchain Workbench stores contract definitions, configuration metadata, and a SQL-accessible replica of data stored in the blockchain. This data can easily be queried, visualized, or analysed by directly accessing the database. Developers and other users can use the database for reporting, analytics, or other data-centric integrations.

7 Information can be analysed and visualized using tools such as Power BI by connecting to off-chain database (Azure SQL Database).

8 Events from the ledger are delivered to Event Grid and Service Bus for use by downstream consumers. Examples of "downstream consumers" include logic apps, functions or other code that is designed to take action on the events. For example, an Azure Function could receive an event and then place that in a datastore such as SQL Server.

Regarding storage and database, the diagram refers to Azure modules (Azure SQL and Azure storage) but any other storing solution can be adopted to locally store data and documents. In the case of Maresmar, all the information will be handled by the IT department through their current local storage. Each stakeholder should manage storage by their own to effectively work with a distributed ledger, either with physical servers or purchasing cloud services like Amazon's AWS, Google's Google Cloud or Microsoft's Azure Storage.

Local storage is used to store contracts and metadata associated with contracts. From purchase orders and bills of lading, to images, videos or documents which are not appropriate to place directly on the Ethereum blockchain. Blockchain Workbench supports the ability to add documents or other media content with blockchain business logic. A hash of the document or media content is stored in the blockchain and the actual document or media content is stored in a local or cloud server. This kind of distributed peer-to-peer storing is called Interplanetary Files System (IPFS).

The main reason to save documents locally is because store data permanently on Ethereum is extremely expensive. Thus, it has no sense to use Ethereum to store data. Rather, it should store only the required data to work properly and delegate the storage to other solutions.

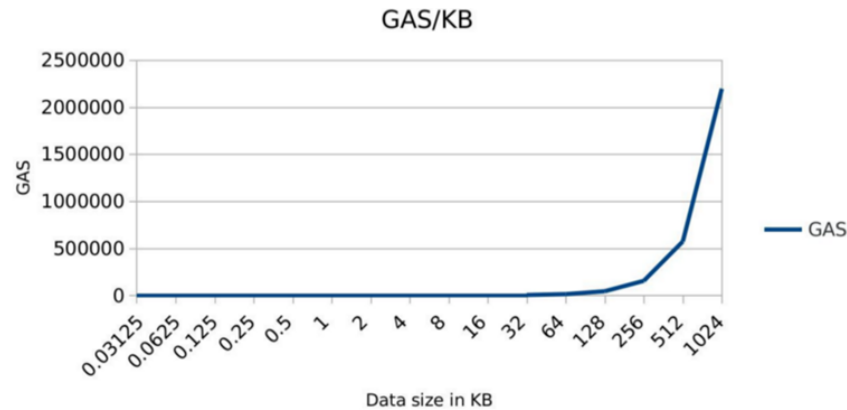


Figure 7.18 Storage data size per GAS (unit with its equivalent in ETH). [10]

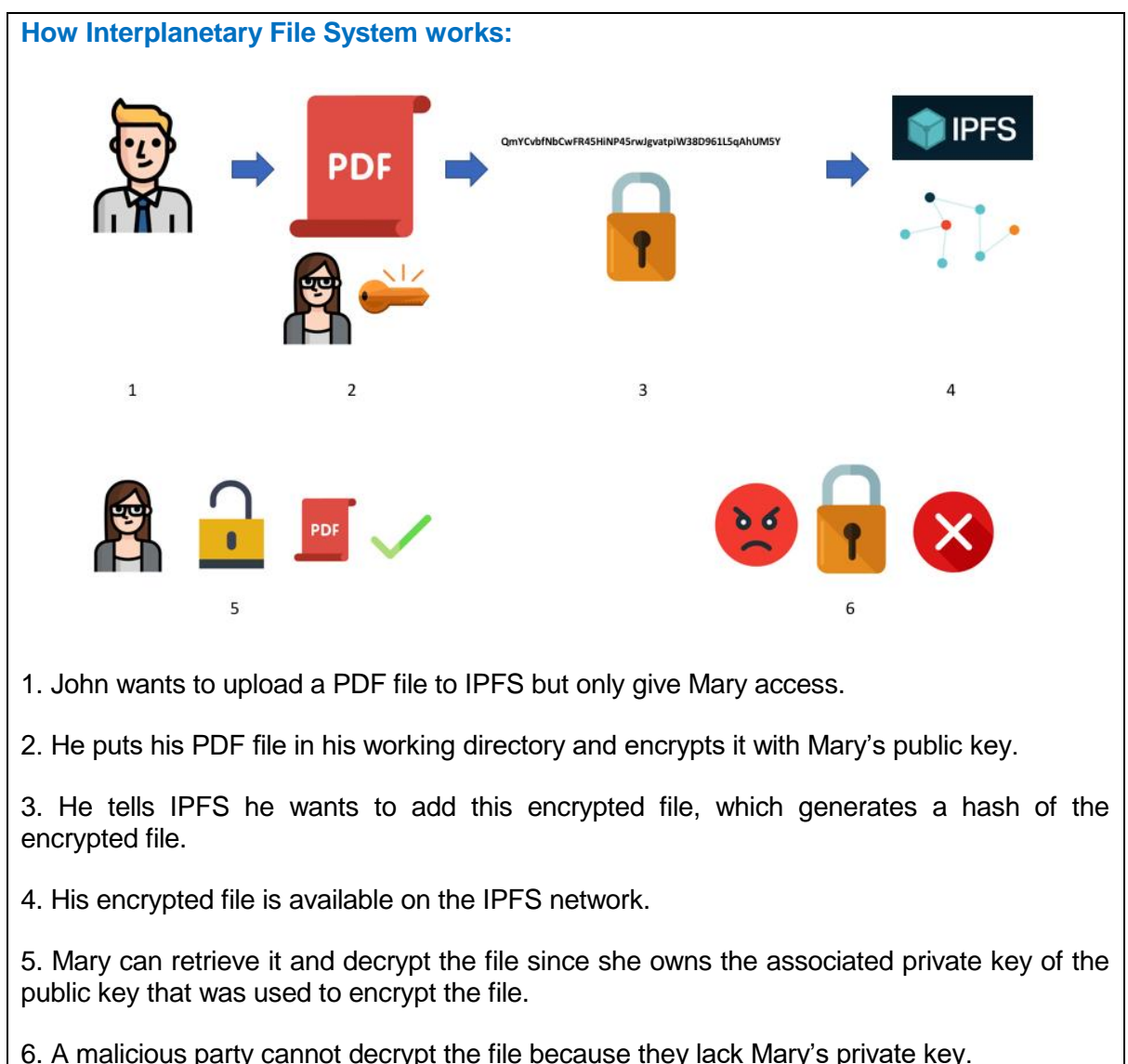


Figure 7.19 Explaining blockchain storage: IPFS [11]

Consortium Blockchain

The Azure Blockchain consensus is based on Proof of Authority mechanism (PoA), which has been previously explained. Without the need for mining like in the Proof of Work mechanism, Proof of Authority is more efficient while still retaining Byzantine fault tolerance. As PoA is used, Azure Blockchain is a Consortium platform rather than a Hybrid one. When discussing which type of network to implement (see 7.6.1 *Decision on the type of blockchain network*), Hybrid solution was the best suited, but for implementation and platform reasons of using Microsoft's solution, consortium network fits better.

The Azure consortium blockchain is limited to specific participants in the network. Only participants in the private consortium blockchain network can view and interact with the blockchain. Consortium networks in Azure Blockchain Service can contain two types of member participant roles

Administrator - Privileged participants who can take consortium management actions and can participate in blockchain transactions. An administrator can invite members, remove members, or update members' roles within the consortium.

User - Participants who cannot take any consortium management action but can participate in blockchain transactions.

Consortium networks can be a mix of participant roles and can have an arbitrary number of each role type. There must be at least one administrator.

Private Blockchain Consortium



Figure 7.20 Private Consortium, Azure Blockchain documentation

In the PoA consensus there is no need to wait for a fleet of miners or voters to decide what's authentic and what's not. Within this protocol, validator nodes take the place of traditional miner nodes. Each validator has a unique Ethereum identity that gets added to a smart contract permission list. Once a validator is on this list, it can participate in the block creation process. Each consortium member can provision two or more validator nodes. Validator nodes communicate with other validator nodes to come to consensus on the state of the underlying distributed ledger. To ensure fair participation on the network, each consortium member is prohibited from using more validators than the first member on the network (if the first member deploys three validators, each member can only have up to three validators).

In addition to validator nodes, each member can have up to ten transaction nodes, which are in charge of sending blockchain transactions to Azure Blockchain Service. By adding transaction nodes, it can be increased the scalability or distribute load.

For this particular business case, consortium administrators will be Maresmar company, distributors and carriers while fishers and government authorities will act as validators but just as user members and not administrators.

Security

In terms of security Azure Blockchain Service uses several Azure capabilities to keep data secure and available. Data is secured using isolation, encryption, and authentication.

Azure Blockchain Service resources are isolated in a private virtual network. Each transaction and validation node is a virtual machine (VM). VMs in one virtual network cannot communicate directly to VMs in a different virtual network. Isolation ensures communication remains private within the virtual network.

User data is stored in Azure storage. User data is encrypted for security and confidentiality using Azure storage set of security capabilities.

Azure Active Directory (Azure AD) uses an authentication mechanism where the user is authenticated by Azure AD using Azure AD user credentials. Azure AD provides cloud-based identity management and allows customers to use a single identity across an entire enterprise and access applications on the cloud.

When provisioning an Azure Blockchain Service member, an Ethereum account and a public and private key pair is generated. The private key is used to send transactions to the blockchain. The Ethereum account is the last 20 bytes of the public key's hash. The private

key is encrypted using the password entered when the blockchain ledger service is created. Private keys are used to digitally sign transactions. A smart contract signed by a private key represents the signer's identity.

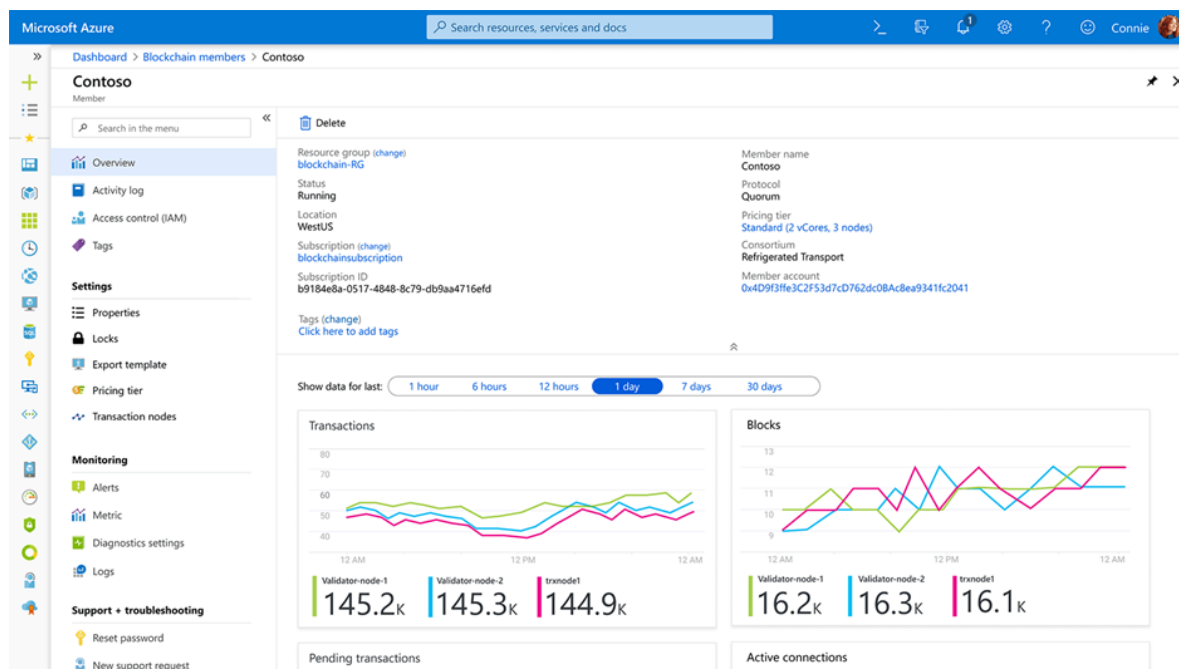


Figure 7.21 Azure Blockchain Web App

7.8. Developing an end-to-end solution

The final objective of this project is to get to a complete end-to-end solution to solve and improve major inefficiencies of Maresmar supply chains. Particularized for the American lobster product, this section goes as far as possible of the blockchain and IoT capabilities to cover the potential use cases mentioned in the *7.5.1 Critical drivers and potential use cases* section.

With a focus on developing a model that could be exported to other companies of the industry, the complete solution does not take into consideration limitation in the budget. Despite this being impossible, as Maresmar would fix a top investment, developing the end-to-end solution settles the arrival point to get by a progressive adoption. As limitations will arise, the model non-essential features will be omitted. The reason behind it, is that the mere intention of the business case is to build a prototype that could be adopted by other companies of the seafood industry in the future.

7.8.1. Blockchain ecosystem

The blockchain model for an end-to-end implementation has been based on one of the startups projects studied, in particular, the one developed by Temco. [11] Some ideas from Temco, like the vendor verification system or consumers' reviews, will be adopted in the developed solution.

As it was already observed, the American lobster implies different actors interacting within its supply chain, from fisher to consumer. The following diagram shows how these actors will be integrated into the blockchain.

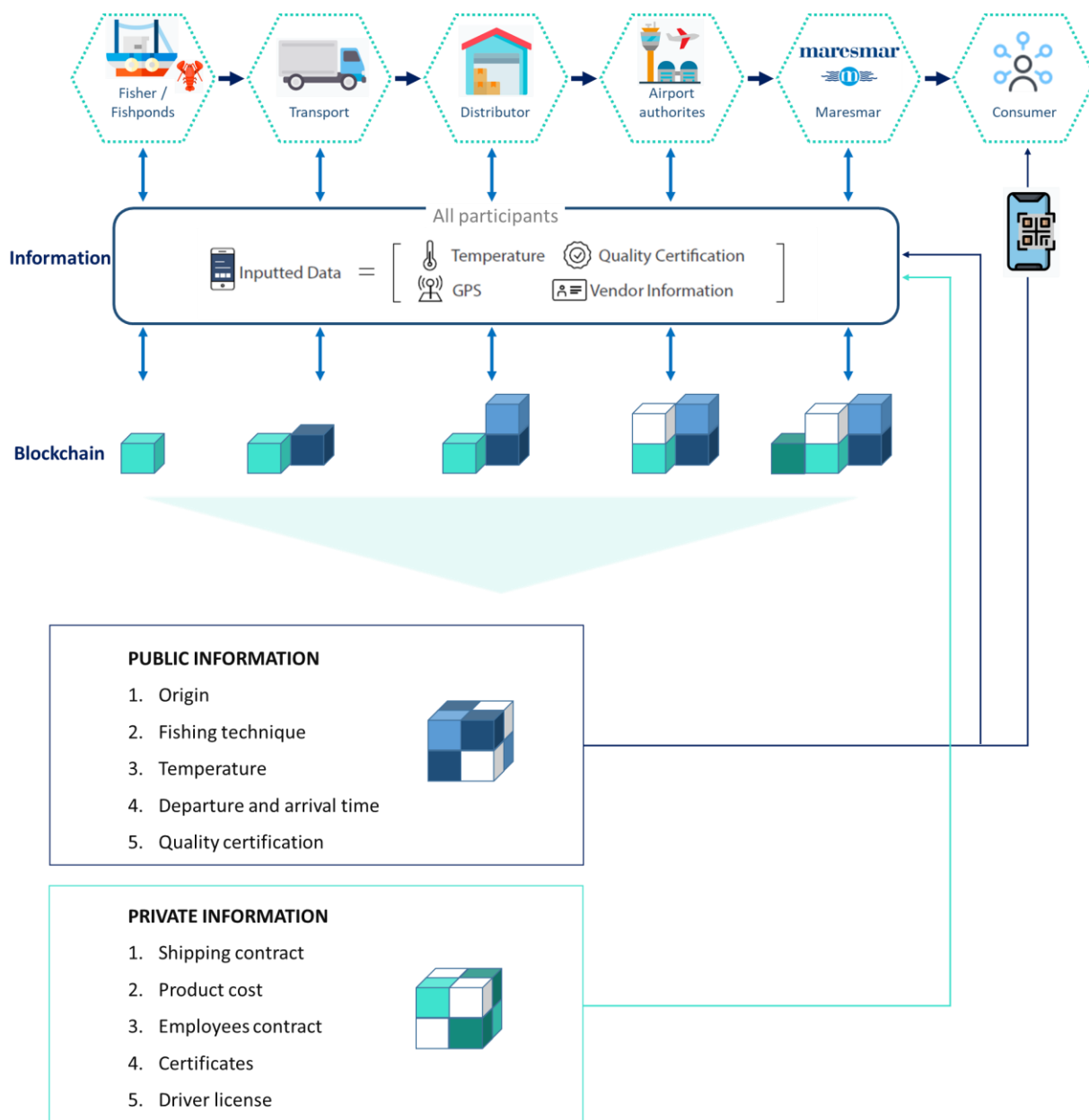


Figure 7.22 Blockchain model ecosystem

The Blockchain will operate through a vendor verification system, information storage, authorities' verification, evaluation, and customer access to information. Through each process, fishers, warehouses, transporters, distributors, and consumers are connected to each other and the creation, verification, storage, evaluation, and utilization of supply chain information takes place in real-time.

Vendor Verification System

Vendor verification systems will identify each manufacturers, warehouses, and distributors as well as Maresmar company. It will work similarly to Egesdoc, a document management service employed by many enterprises where all legal related information is stored and easily shared. Through the vendor smartphone application, vendors will be verified according to business registration, factory registration, quality certification, etc. depending on the company.

Each vendor will have an account and ID with a personal password and only certified vendors will be able to communicate with consumers by using the supply chain management solution services. Other participants of the supply chain and consumers will see the exact information of the vendors through the consumer smartphone DApp and know what vendor the product was purchased through by simply scanning a QR code printed on every package.

Private information for internal supply chain participants could include shipping contract and product cost as well as employees related information such as employment contract of each worker, driver license for carriers or a food-handling certificate in order to ensure everything is done within the law. Product related information will include details about temperature, humidity, time, location, etc. on each point of the supply chain.

Acceptance and inclusion of the different stakeholders into vendor verification system should not involve major difficulties as they are most well-known from years of relationship with Maresmar enterprise. The problematic could appear on convincing government authorities issuing certificates to trust on the system and the benefits it can bring to both parts.

Supply chain information flow and storage

All the information from the vendor verification system will be stored in the blockchain to undergo data verification. In order to verify every supplier, a previous work by Maresmar is needed to gather individual companies' details, although most of them are already available, and ask providers to keep them updated in the blockchain.

Once the fish supplier has handed over the product to the distributor vendor and the process is complete, it will request verification through the vendor application. As the distributor company acquires the product from the fisher and controls and checks from the distributor have been successfully completed, it tags a NFC code of the product into the smartphone application that verifies and approves the data. Consequently, temporary

ownership pass to the distributor and is reflected in the blockchain network. To do so, each batch of American lobsters will have a strip of a NFC tag that will link them to a digital representation into the blockchain.

The distributor manages and packages the product in accordance with Maresmar requirements and ship it to the transportation company requesting approval from the carrier. Once again, product's information and transfer of ownership is updated into the validation system and the blockchain via smartphone tagging.

The freight's flow continues passing through airport authorities' validation, air transport and finally arriving to Maresmar plant in Barcelona. At every stage, products and delivery and legal information and documents are loaded into the system.

Depending on the information, it will be stored in two different ways:

Public information like origin, temperature, departure and arrival time, quality certification or product information will be stored in the blockchain with free access. This information will be shared and accessible by everyone who desires.

Private information like shipping contract, purchase agreement, details of transfer process, product cost or personal information will be stored in the blockchain with particularised layers of privacy. All this sensitive and confidential information is cryptographically hashed and stored and only specific users with permission are allowed to view the stored data.

The data will be distributed along each participant database in order to maintain decentralization, verifiability, and transparency, features blockchain pursues.

Maresmar, as well as the rest of actors, can analyse all this data to tackle inefficiencies in the supply chain as well as to detect unexpected events in real-time and set predefined alarms into weaker points of the distribution system.

7.8.2. Smart tagging and smart devices (IoT)

Smart tagging

Linking physical products and their related digital identity to the blockchain implies tagging them. Many types of tagging technology are available, with their strengths and weaknesses.

QR code

The QR code is an improved version of the one-dimensional code. A one-dimensional code like a barcode only has horizontal information, whereas a QR code has two dimensions; vertical and horizontal information. This makes it better than the one-dimensional code in terms of fault tolerance and data volume.



Figure 7.23 QR code

QR code tag is already used within Maresmar supply chain which would ease its implementation. They will be used to connect the information they contain to the blockchain. Once the code is printed, information cannot be changed and it is accessible by an optic scanner. Moreover, it can also be easily scanned by a smartphone enabling a direct link to the consumer App. Because it requires from clean environment and close scanning (50cm maximum) to be read, it will be printed in the final package for information delivery to consumers.

One advantage of QR codes is that tags can be prepared in rolls ready for application in the production line with no impact the production speed.



Figure 7.24 QR code rolls

NFC

Near Field Communication (NFC) chips are based on radio-frequency waves. They provide improved features than QR codes as they allow updating data in a secure way in order to reuse them as long as they are not completely damaged. However, NFC is designed to be used only at very short distance (8cm maximum) to prevent them being remotely switched on and making it difficult to detect, steal or tamper with its information.



Figure 7.25 NFC chips

NFC chips are contained in strips that will be attached to American lobster bins with the purpose of being read by every participant on the supply chain and facilitating them to update new product related data via smartphone App. It should not imply difficulties as the majority of smartphones have NFC technology and already existing iOS/Android apps allow programming NFCs tags.

The intention of using NFC technology is to substitute QR codes that are currently being employed in the upstream sector in order to move their use exclusively to the downstream area for end-users. By doing so, tag related damages will be prevented as NFC are more resistant than QR and more suited for an aquatic environment like the one of the lobster supply chain.

RFID

Radio Frequency Identification Device (RFID) work similarly to NFC via radio-frequency technology. Compared with a QR code or an NFC chip, the communication distance is much longer (up to 10m) while the capacity, copying difficulty and environmental tolerance are a lot higher. RFID stands out for enabling the identification of multiple RFID tags

simultaneously by a proper reader. Due to its features, these chips will be used in the distribution centre as well as in Maresmar central plant in Barcelona to effectively managed storage and access control of shipment. For example, when batches arrives to Maresmar, a RFID reader could quickly identify them and push a notification like an email or SMS to the workers at the offices.



Figure 7.26 RFID chip

	QR code	NFC	RFID
Batch scanning	Single item	Single item	Multiple item
Reader	Optic scanner / Laser	NFC specific scanner	RFID specific scanner
Distance	Short: < 50 cm	Very short: < 8 cm	Long: < 10 m
Reading / Writing	No writing	Dynamic read/write capability	Dynamic read/write capability
Environment	Clean / Daylight	Dirty / Daylight - Night	Dirty / Daylight - Night
Durability	More sensitive to degradation, but if a little damaged, still readable	Updatable and reusable, but if damaged, then completely unreadable	Updatable and reusable, but still readable if a little damaged
Consumer use	Easy to read with smartphone	Easy to read with smartphone	Impossible to read with smartphone
Production	Direct printing on label	Print label and combine it with antenna	Print label and combine it with antenna
Implementation	Single step: can be easily printed on box during manufacturing	Currently requires two steps: tag creation and tag attachment	Currently requires two steps: tag creation and tag attachment

Figure 7.27 Smart tags features

Smart devices

Data about properties and environment of the product is going to be captured by different smart devices. The IoT hub from Microsoft will be in charge of gathering this data and send it to the service bus who makes it available in the blockchain.

Smart thermometers

The American lobster provider is already including a thermometer which allows checking temperature along the way but only when it arrives to destination and not in real time. Using smart thermometers connected to the blockchain brings major visibility and accessibility in any moment.



Figure 7.28 Swarm Temp

The company SensorSwarm provides a SwarmTemp BASIC Package which includes temperature data storage, unlimited alerts, data downloads, alert storage, text / email alerts. These services could be integrated into the Azure Blockchain as custom development and app enhancements is available.

A part from the sensor a Temperature Sensor Access Point (SAP) will be necessary to connect with the devices and to the system with two models for each location:

Model SAP-AP-3G - Cellular Temperature Sensor Connectivity: For locations that have no WiFi or do not allow connection to corporate network. Supports up to 10 sensors. This model will be installed in the transportation vehicles such as the carrier trucks or the airplane.

Model SAP-AP - WiFi Access Point: For locations that have wired ethernet connectivity and access to the internet but no WiFi. This model will be used in the distributor and *Maresmar* plants as products are fix in the location.

Besides, SensorSwarm company provides online ordering which will facilitate its acquisition as well as free lifetime warranty and battery replacement.

Smart hygrometers

Similar to smart thermometers, hygrometers will be also used to record and real time access to humidity conditions of the product. There is a company providing an all in one device, DataLong16, with temperature, humidity and location, but as long as price was not accessible, it has been discarded for the moment.

GPS tracking

The idea of using a GPS tracking is the same some big logistics companies like Amazon use to know in real time where the good is located. With the vendor verification system each participant updates information of time and place where they deliver the product but this information could be verified by automated GPS connection. Trust will not be put on human workers but on technological devices that will be included in each batch of products.

The company Transpoco has been selected to provide this service as it offers SynX Move, a fleet management system with features such for locating vehicles, generating journey and working reports, optimising routes or setting up driving style alerts. With SynX Move provides a 24/7 fleet control from a cloud computing software or a smartphone.



Fig. 7. GPS tracker

The breakdown of prices for each of the above-mentioned tags and devices is included later in the investment section.

Real-time data provides confidence in the supplier to Maresmar and to the authorities ensuring temperature remains inside a maximum-minimum range and that the cold chain has not been broken, with the process operating under the stated requirements of the company and in accordance with the law. On the other hand, stablishing alerts through SMS, email, push notification via app and optional phone call can help to tackle problems as soon as possible to prevent greater damages of the product. Additionally, it can help to adjudicate responsibilities to each part and together with smart contracts can unleash automate consequences. In addition, with all the data collected, an aftersales analysis can help to improve process management efficiency and business decision making.

7.8.3. Tokens and cryptocurrency (ETH)

Ethereum network and Azure Blockchain allow the implementation of digital asset with smart property, which are basically the digital representation of assets with value attached to them, in many cases monetary value. Furthermore, these digital assets can be exchanged within the blockchain environment.

For the business case studied, the American lobster batches could be represented in a digital format. Consequently, when the fisher enterprise delivers the physical shipment of American lobsters to the distributor and once validated by both parts, the digital representation will shift ownership and it will be clearly stated in the network. Following the shipment journey, digital asset ownership will change from one stakeholder to the other until it gets to Maresmar ownership. In the last step, property will pass to client and the cycle will be completed with a visible legal ownership transfer from origin to store shelf or consumers.

With this methodology value of physical goods can be digitally transferred without the need for trusted third parties to verify, record and coordinate transactions as all these requirements are ensured by the timestamping capability of blockchain.

On the other hand, Ethereum incorporates its own digital currency (ETH) that can be used as an alternative to traditional money to reduce the cost of transfers. By adopting the ETH, payments could be done instantly without the intervention of banks. As soon as the lobster shipment passes from one hand to the other, the corresponding payment for the service will be launched. For international transactions outside the SEPA zone, like the one here studied, SWIFT standards must be followed which involve considerable delays on payments that can go up to five days. Moreover, monetary transactions through SWIFT messaging system have associated fees, around 20€ per transaction, that together with currency exchange imply additional costs that might be overpassed.

Delays can also come from inaccurate management of bills from sending and receiving parties with errors in the details of the consignee person or faulty content among others.

In order to avoid delays and reduce costs, transactions will be streamlined by automatizing payment processes with cryptocurrencies that, in turn, can be exchanged by physical money once received. Despite exchange fees being unavoidable, working with digital currency streamline payments and it can be used in smartphones similarly to how banks apps work. Instead of working with IBAN or BIC, it is used the Ethereum address of the receiver. Different platforms and apps could be use with online or physical wallets to transact with cryptocurrencies. Each participant could choose the platform they prefer as money can be send between wallets despite not being supported by the same transactional company as the Ethereum wallet address is the only requirement to use them.

7.8.4. Smart contracts

As previously explained in this paper, a smart contract is a collection of code (its functions) and data (its state) that resides at a specific address on the Ethereum Blockchain. This tool, together with smart tags, IoT gadgets and digital assets will optimize the supply chain as processes will be triggered automatically when required conditions are met.

When the airport authority examines samples of the American lobster before and after the airplane transfer, an internationally recognized quality and safety certificate is issued for the corresponding batch. By including the corresponding authority as a node inside the blockchain, it could expedite authoritative third-party certification in a secured and immutable way as soon as the product is checked and without delaying the departure even more. Smart contracts will enable this operative as a simple click on a computer or app will be necessary to give permits to the airplane to take off. In the same way, long waiting queues of different companies and carriers waiting at Barcelona airport for their shipments could be easily bypassed as the American lobster batches from Maresmar will appear as confirmed on the authority software.

Digital assets transfer can directly benefit from a precise smart contract implementation. When a batch delivery from one party to the other is confirmed, a smart contract action is triggered and ownership instantly shifts hands. With this change in property of the good, the established payment in cryptocurrency for the service is also automatically executed.

With this procedure no human interaction is required and errors and misunderstandings are completely vanished.

Smart contracts fusion with smart tags and IoT takes advantage from the amount of data that is obtained. For instance, when the product is out of temperature or humidity range for a significant period of time or a RFID seal detects a batch has been improperly opened, a smart contract could trigger an economical sanction to the guilty party.

Likewise, the GPS tracker could send an instant message to Maresmar headquarters and other parties when a carrier deviates from its stipulated route or if the product remains for a hazardous long period of time immobile in a place. With Maresmar notified, they could ask to the carrier to justify this undue action and know if the cause was a traffic jam or any other reason.

Consequently, everyone in the supply chain will make special effort to satisfy conditions and operate in a proper manner.

7.8.5. Customer's access to information

With a simple scan of the QR code on every package, customers will be able to learn more about how the products are managed as they flow from manufacturer to end-user by including properties such as temperature, humidity, location, times, etc. at every stage of the supply chain of the product they have in front of them. A brief description and a picture of the fishers and workers who have managed the product and its company will also be included as well as quality certificates issued for this product. All this information will be gathered inside the customer's DApp and will allow consumers to obtain more transparent and reliable information

Since Maresmar direct consumers sales are limited to the physical store in Mercabarna, all their packages should include the QR codes for clients. For the sales directed to supermarkets, restaurants, hotels and fishmonger, an agreement could be reached to include them too as it will end up being beneficial for both parts. For example, restaurants could include the QR code in their menus so clients could access to information right before ordering, which could promote selecting this product, and consequently gaining the client confidence.

Taking advantage of the interoperability with customers the DApp provides, a review platform will also be included. Consumers will be able to evaluate products (in this business case only American lobster) through the consumer application after purchasing them. Evaluation will comprise satisfaction evaluation, reviews, etc., that in the case of implementing blockchain in various products could disclose a product ranking according to consumer evaluations. It will not be an absolute evaluation standard but could help the different participants of a specific product supply chain to receive more feedback information in order to accurately and quickly identify and improve upon consumer demands.

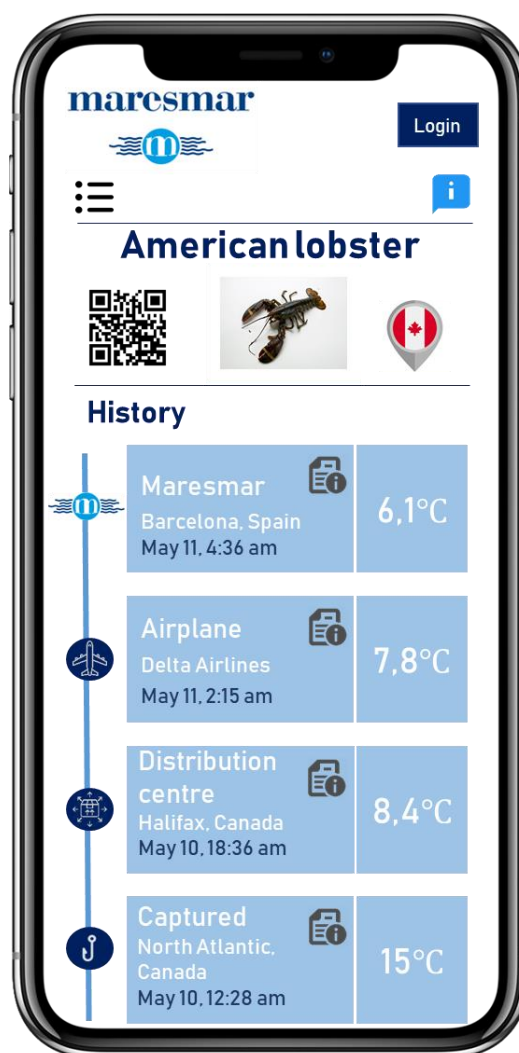


Figure 7.29 Smartphone App concept

With the purpose to promote active participation in the platform. (eg. QR scan, product reviews, customer data sharing, etc.) consumers might be rewarded every time they interact by doing some of these actions. Rewards could come in the form of tokens to buy inside Maresmar platform or discounts. This last point is just an idea as a completely new business case should be necessary to address it.

Connecting the different parts of the supply chain, from fishers to end-consumers, enables consumers to serve as major contributors to the quality of the supply chain information and lead to consumer confidence in the brand and products.

7.8.6. Total Cost of Ownership (TCO)

This section provides an estimate breakdown of the Total Cost of Ownership (TCO) of starting up the model described above. TCO is regarding infrastructural costs such as Azure Blockchain's implementation, smart tags, IoT devices; development costs of the blockchain and smartphone App and educational costs for starting up the solution. Costs have been calculated considering the network and devices are running 24 hours a day and can be separated in four groups: onboarding costs, cloud costs, ongoing maintenance costs and monitoring costs.

Estimations on some of the costs, for example monitoring costs, are based on a model developed by EY where different Total Cost of Ownership scenarios were studied for implementing a blockchain solution. [13]

Onboarding costs

Onboarding cost include the costs related with the deployment of the network and Apps as well as all hardware and devices required. Moreover, educational costs to initialize participants to use the new system are also considered.

ONBOARDING COSTS	
Blockchain developer	25.000 €
Smartphone App developer	10.000 €
Education costs	5.000 €
Smart tags	7.500 €
IoT devices	1.009 €
TOTAL	40.000 €

Table 7.6 Onboarding costs

The blockchain developer will be necessary to program and coordinate the integration of Azure's Blockchain into Maresmar. Despite working with a BaaS such as Azure brings nodes and basic infrastructure already build, the blockchain developer will help to deploy smart contracts, synchronize IoT devices and scanners with the network, and set up all the different features the complete solution will have. For these tasks, it has been estimated five months of work that correspond to 25.000 €.

Regarding the App development, the smartphone App developer will be working side by side with the blockchain expert as developing a DApp implies a more complex process than a simple App and some blockchain knowledge is required. It has been estimated three months of work that will be mainly focussed in interface development and not that much in internal development as this will be done by the blockchain developer.

Education costs involve introducing the different participants of the supply chain to the change it will mean moving to a blockchain system. A group of workers from Maresmar should be visiting the different actors and teach them about the blockchain solution that is going to be started and how they are going to collaborate into it. Therefore, these costs include the different trips to Canada with all related expenses.

Smart tags and IoT devices costs have been estimated on the number of shipments done every day (200 – 500 boxes per day) and considering some extra gadgets in case of damaging them. QR codes are not included as Maresmar and its suppliers are already working with them. In the *Annex 3* can be seen the breakdown of smart tags and IoT devices costs.

Cloud costs

For *Maresmar* no cloud costs have been included as it will be using its own physical servers, while for the rest of actors, approximately 4.000 € per month should cover storage demand.

CLOUD COSTS	
Maresmar	0 €
Distribution centre and fishers	4.000 €
TOTAL	4.000 €

Table 7.7 Cloud costs

Ongoing maintenance costs

Maintenance costs include Azure modules described below for blockchain and IoT implementation as well as punctual technical support required to fix problems and unexpected events that may occur or to change any features after its initial implementation.

Ongoing maintenance costs	
Microsoft Azure modules	88.184 €
Technical support	6.000 €
TOTAL	94.184 €

Table 7.8 Ongoing maintenance costs

Below are depicted the Microsoft Azure modules costs that are needed for Maresmar particular business case together with its functionalities.

Microsoft Azure Estimate

Service type	Description	Estimated Cost
Azure Blockchain Service	Standard tier, 7 Member(s) X 3 Nodes per member X 1 Months	6.004,96 €
Logic Apps	10,000 Action Executions x 31 day(s),	1.111,26 €
Azure IoT Hub	Standard Tier, Free: 500 devices, Hub Device Provisioning: 5,000 Operations	0,42 €
Azure IoT Central	50 devices, 0 additional messages	74,46 €
Service Bus	Standard tier: 10, 1,000 brokered connection(s)	8,27 €
Azure Active Directory	Premium P2 tier	64,93 €
Support	Support	84,33 €
	Monthly Total	7.348,64 €
	Annual Total	88.183,69 €

Table 7.9 Microsoft Azure Estimate, Microsoft calculator



Azure Blockchain Service: this is the basic module of the blockchain system implementation. It offers a 3 nodes per member plan, 1 transaction node and 2 validator nodes. It will be possible to add additional transaction nodes after provisioning if desired. Storage in this line refers to the network database storage as documents, information and other files will be externally stored by every participant. It includes seven members which represent: fishers, distribution centre, carrier, Canadian authorities, Spanish authorities, Maresmar and Mercabarna authorities.



Logic Apps: Enterprise connectors provide *triggers*, *actions*, or both. A *trigger* is the first step in any logic app, usually specifying the event that fires the trigger and starts running the logic app. Other triggers wait but fire instantly when a specific event happens or when new data is available. Actions are the steps that follow the trigger and perform tasks. All these triggers and actions can be connected to enterprise systems which in the case of *Maresmar* will be SAP. In order to do so an Integration Account is required to link it to the Logic App. The Intergration Account is where is possible to create, store, and manage B2B artefacts, such as trading partners, agreements, maps, schemas, certificates, and so on. At the same time, the integration account is the one that increases the price of Logic Apps module but which is necessary to integrate with SAP.



IoT hub: This module allows to connect, monitor, and control IoT assets running on a broad set of operating systems and protocols. Through a per-device authentication it enables securely establishing reliable, bi-directional communication with these assets, even if they are intermittently connected, to analyse incoming telemetry, synchronize device management workflows, and send commands and notifications as needed. For the American lobster supply chain no more than 500 devices will be used.



Azure IoT Central: it is a fully managed SaaS (software-as-a-service) solution that makes it easy to connect, monitor and manage IoT assets at scale. Azure IoT Central simplifies the initial setup of the IoT solution and reduces the management burden, operational costs, and overhead of a typical IoT project. For this particular business case, it has been estimated the employment of 50 devices.



Service Bus: Azure Service Bus is a multi-tenant cloud messaging service that allows to send information between applications and services. The asynchronous

operations gives flexible, brokered messaging, along with structured first-in, first-out (FIFO) messaging where client and service do not have to be online at the same time. Service bus will be used to connect product information and messages from smart tags and IoT devices to the different network consumers.



Azure Active Directory (AD): this tool is highly available identity and access management cloud solution that combines core directory services, advanced identity governance, and application access management. Azure Active Directory also offers a rich, standards-based platform that enables developers to deliver access control to their applications, based on centralized policy and rules.

All the participant identities will be secured stored and managed through the Azure AD connected with the Ethereum network. It has been selected the Premium P2 tier as it provides Advanced reports and improved features than other Azure AD plans.

Last line of the budget refers to support provided by Microsoft experts. Support comes in different plans and the one chooses provides 24/7 access to Support Engineers via email and phone as well as billing and subscription support, online self-help, documentation, whitepapers, and support forums for a production workload environment.

According to Microsoft definition, it has been considered a business application with a Severity level A business impact: *Customer's business has significant loss or degradation of services, and requires immediate attention.* For this severity level, Microsoft Standard support provides a rapid response in less than one hour.

Monitoring costs

It has also been included a monitoring cost that will consist on an annual network assessment to check performance, bugs and vulnerabilities of the system as well as possible points of improvement. It has been estimated according to other IT projects from other companies.

MONITORING COSTS	
Annual network assessment	1.000 €
TOTAL	1.000 €

Table 7.10 Monitoring costs

TOTAL COST OF OWNERSHIP	Year 1	Year 2	Year 3
Onboarding costs	40.000 €	0 €	0 €
Cloud costs	4.000 €	4.000 €	4.000 €
Ongoing maintenance costs	94.184 €	94.184 €	94.184 €
Monitoring costs	1.000 €	1.000 €	500 €
TOTAL	139.184 €	99.184 €	98.684 €

Table 7.11 Total Cost of Ownership

The total cost of ownership has been calculated for the first three years after implementation. The TCO is 139.184 € for the first year while second year after investment it will be reduced to 99.184 as onboarding costs will not be required anymore. In the third year, monitoring costs could be reduced due to an increase in the system performance after two year of working with it.

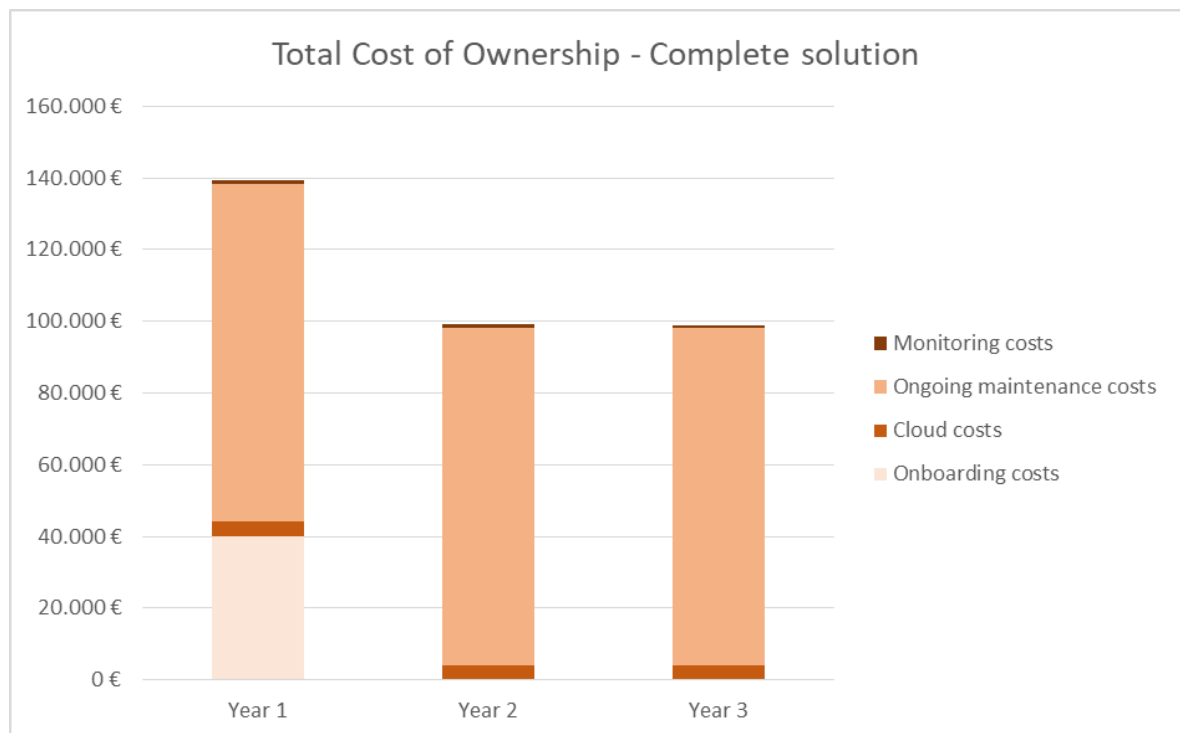


Figure 7.30 Total Cost of Ownership

7.8.7. Project feasibility

The Total Cost of Ownership implies an initial investment of almost 140.000 €, which questions its feasibility in a medium sized company like Maresmar. This section studies the advantages of implementing the complete solution presented before and examines to what extent it is viable.

Directly focusing into economic benefits it can bring to Maresmar investing in a blockchain application, it is observed that different areas can get improved by reducing costs and increasing sales.

Reducing administrative FTEs

One of the advantages of automating and streamlining processes can pull a reduction in the administrative staff required by reducing their working times or FTEs.

Full time equivalent (FTE) is the ratio of the total number of paid hours during a period (part time, full time, contracted) by the number of working hours in that period Mondays through Fridays. Basically, the number of employees working on a period.

In Maresmar there are currently working five employees on administrative tasks like transport management, verifications, claims resolution, and mainly, all the paperwork of transferring data from delivery notes and shipment notes to a digital support. By implementing a blockchain, many of this administrative work will be automated and self-executed, meaning these employees might not be necessary anymore. The estimation that has been considered is that the first year after the adoption of the new system, one of the administrative employees could be terminated in order to reduce FTEs. Aiming to have a progressive reduction of the staff, the following year, it will be proceeded in the same way with another administrative employee.

Reducing FTEs	Year 1	Year 2	Year 3
Salary per employee	22.000,00	22.000,00	22.000,00
Nº of employees reduced	1	2	2
Savings	22.000,00	44.000,00	44.000,00

Table 7.12 FTEs reduction over first three years

Reducing payment delays and related fees

One of the stated advantages of blockchain was the ability to execute payments without third-parties intervention. Then, payments to fisher, distributor and carrier in the American lobster supply chain will be done instantly without extra charges from any financial institution. Spanish banks are currently charging 40€ per international transaction under the SWIFT protocol. By entering the payment system of the blockchain, the only charges will be the exchange fees. Consequently, 2.400 € could be saved on payment fees.

Payments fees	
Nº of payments per year	60
Fee per payment	40 €
Total	2.400 €

Table 7.13 Current international payment fees

Reducing dead lobsters

Maresmar recalls are mainly focussed in retiring dead American lobsters once they arrive at the client, while recalls due to contamination or infection outbreaks are less common to occur thanks to the strict safety and quality controls the product is submitted. Both types of recalls imply refunding the price of the batch to the client together with their discontent and the damage it provokes to the company. However, once batches are controlled at Maresmar plant, dead species are retired before proceeding to sell them. These lobsters are set to be sell as fresh products or to elaborate cooked products with them.

Approximately, an average of the 2% of pieces of American lobster are retired every year from batches at the plant as they are found dead. It means Maresmar stops invoicing around 430.000 € for selling alive lobsters. Nonetheless, it must be mentioned that dead animals do not mean they are waste, as they are reused either frozen or for cooking other products, but being sold at lower prices for that reason.

With the blockchain solution, it will be easier to identify in which point and which was the reason why the seafood has been found dead and charge to the guilty party the losses it produces to not selling them. The fact of having dead animals will always be present, but a solid tracking system could considerably detect its causes and tackle them in a more efficient way.

Dead lobsters	
Nº of dead product per year	28.800,00
Price / unit	15 €
Total of dead lobsters	432.000 €

Table 7.14 Total number of dead lobsters per year

Increasing demand

Consumers increasing tendency on claiming for more product's information and traceability systems will be satisfied through the implementation of this solution. Clients, either supermarkets, restaurants or at *El Mercat del Peix*, will appreciate the effort of providing deeper description and details of the American lobster whole supply chain. Consequently, blockchain will provide a competitive advantage that will make Maresmar stand out within its competitors. Estimations consider an increase in American lobster sales due to this plus.

Adoption among consumers will increase progressively and not right after implementing the blockchain as first years will be plenty of scepticism. Demand within current clients will increase as long as they start discovering the potential of applying this technology, and even new clients could enter Maresmar's target attracted by this new way of managing supply chains.

American lobster implies the 15% of the annual turnover which results in 11.000.000 € approximately.

Sales increase	Year 1	Year 2	Year 3
Percentage of sales increase (%)	5%	7%	10%
Invoice	11.550.000 €	11.770.000 €	12.100.000 €

Table 7.15 Progressive sales increase

The different results obtained can be seen as an estimation to have a general idea of the positive effects of implementing a blockchain solution in Maresmar. Many factors may influence the new technology adoption, but in general terms, it provides a reduction in costs and could bring an increase in sales by increasing brand reputation for the use of blockchain.

A part from the economic benefits, it will bring improvements in the management of the supply chain and different new features mentioned at the beginning of the business case.

Despite the numerous advantages, it is undeniable that starting a blockchain approach requires from a considerable investment to start with. Given the fact Maresmar is promoting the implementation of a blockchain in the American lobster supply chain, it should be itself in charge of all the different expenses and investments required. The small fishers in Canada will not or could not probably bear part of the costs, due to its limited revenues, whereas the distribution centre could contribute, for example in cloud costs, and some agreement might be reached. Either way, Maresmar will sustain the major costs of implementation and maintenance.

For Maresmar, which is not a multinational company with all the economic strengths to invest, an effort to see beyond their current supply chains is needed. The TCO contemplate various initial investments to deploy the blockchain from zero, including all the fix costs and support required for the American lobster case. Hence, the initial cost goes up to 140.000 €, which becomes rather inaccessible for Maresmar.

Moreover, maintenance costs are still elevated for working with a feasible solution, which is not a particularity from Microsoft Blockchain but a general situation within BaaS companies. An alternative could be thought of implementing the entire network without using a BaaS but with internal group of developers, which, as it was already studied, will delay its implementation and increase onboarding costs. Under these conditions, as long as Blockchain as a Service providers do not offer more competitive prices, developing a blockchain model like the one studied in this project is not sustainable yet.

Even if some costs could be shared with some of the rest of stakeholders of the American supply chain, directly aiming to develop a complete solution would not be the ideal procedure as Maresmar will not be able to manage the amount of investment required. Besides, rethinking and changing how the actual supply chain works will bring considerable difficulties for adoption to deal with. Consequently, considering the different hurdles of adopting this model, it has been opted to tackle the implementation from another point of view by developing a starting blockchain solution with much simple features than the complete solution but with the possibility to progressively adopt the rest of them. This alternative is studied in the following section.

Although the model with all the features and implementations will not be implemented from the early stages of the project, it can be seen as a concept model for bigger companies, which in the end, was one of the initial objectives of this project.

A complete solution like the described in this project could be adopted by some of Maresmar supermarket chains clients, like *Mercadona* or *El Corte Inglés*, as they have greater capabilities to perform it. These big companies are focused on offering customer service at a higher level and bringing the solution straightforwardly to them by the hand of Maresmar's blockchain could result them interesting. They will be able to show where they products come from without requiring specialists to develop their customized solution as it will come already build.

Moreover, this model could even be exported to other companies in the seafood or food industry aiming to provide traceability and visibility to their supply chains. They should not be worrying about all the previous work of studies and comparison in a deep way and just focus on its adoption for their particular business case.

Entering the blockchain can make companies be reluctant for being an emerging technology with some uncertainties attached yet. Problems and hurdles will arise, but the potential of this technology is undeniable. In a near future it is estimated that everything will be running in blockchain networks and being an earlier adopter provides an inestimable competitive advantage for any company. Slow manual processes must be left behind and entering into a real-time connected world and into the digital economy blockchain offers should not be think twice.

As a conclusion to this chapter, it can be stated that developing an end-to-end model with entire features is not feasible for Maresmar. Therefore, a simplified model will be developed. The section that follows will examine how to implement it and the viability for the American lobster business case.

7.9. Progressive adoption of the end-to-end solution

The end-to-end solution brings a series of difficulties and complexities that make it unfeasible for short term adoption. As long as Blockchain as a Service does not reduce its maintenance costs, working with a blockchain system is still unrealizable for a medium company like Maresmar in the case of being the unique company to be in charge of it. Therefore, it has been considered appropriate to develop a Minimum Viable Product (MVP) with which Maresmar could start working with. It does not go as far as the exhaustive solution already explained with all the features and ameliorations as it aims to be viable in few months of implementation.

Once the MVP will be developed and correctly functioning, Maresmar could contemplate moving further and implement IoT, develop a smartphone App and deploy smart contracts to automate processes. All these advances have been studied from a progressive perception to achieve them in different phases described below.

Phase 1: developing an MVP

The main purpose of deploying an MVP is to make it available and affordable to Maresmar. It will consist of a model that will cover the main points and use cases described as level 1 in the *7.5.1 Critical drivers and potential use cases* section.

The first phase will start with the blockchain network development, based on Azure Blockchain, where there will interact only three members: Maresmar as administrator and the distribution centre company and Canadian authorities as users. By doing so, Azure's membership costs will be considerably reduced compare to the full model version. It has been opted to involucrate Canadian governmental authorities and not Spanish ones as not doing it could imply major trust issues. In the beginning, for Barcelona airport authorities, expedited regulatory documentation could be directly uploaded to the blockchain by Maresmar but with the aim to introduce Spanish supervisory bodies in the future.

With the intention to reduce costs, a part from reducing the number of memberships to pay, the verification system will not be supported by a smartphone App, in order to save developer's costs, but every member will be adding new information and blockchain addresses will identify who is responsible for these actions.

The fishers will update information regarding American lobster fishing conditions and properties, the same as in the complete solution, but now through the distribution centre member user. Nevertheless, all this information will not be in real-time as IoT devices are

not contemplated into this initial MVP. To have a temperature record during transportation, it will also be included these data as the American lobster carriers are already providing the temperature recorder with USB connection, which, in any case, is real-time but uploaded once it gets to Maresmar plant.

Moreover, a geolocated picture at the moment of fishing, able to be done with any smartphone, could be updated to the network to provide major traceability to the system as long as real-time information will not be available yet.

Instead of introducing all these data via a DApp, it will be used a spreadsheet that will be uploaded to the blockchain allowing a working method similar to a how Excel Online works in OneDrive or Google Drive platforms, where every participant can simultaneously manipulate it, but with the advantage of immutably distributing information across participants.

As IoT devices will not be employed, to easier programming procedure of the blockchain and attached costs, smart tags will neither be used for the same reason. The only tags to operate with will be QR codes as they are already employed in the supply chain. They will include information regarding size, weight and quality of every batch of lobsters and a code to identify them, similarly to how it is currently done, but with the advantage of uploading and securing all these data to the blockchain so everyone can access it.

On the other hand, QR codes on end-user's packaging will serve to link all the product's information into a PDF document for customers to consult it. No customer's App will be required as IT staff in Maresmar are already able to do it just like they do with the rest of QR codes they work with.

This initial Minimum Viable Product bring restricted characteristics compared to the broad model but at the same time simplifies its adoption and considerably reduces costs as it can be analysed hereunder.

Total Cost of Ownership

The total cost of ownership of this solution will be considerably lower than the one from the complete model as many of the components have been omitted. Once again, the TCO is divided into onboarding costs, cloud costs, ongoing maintenance costs and monitoring costs.

Onboarding costs

For the MVP, onboarding costs could be reduced in comparison with the full solution due to a simplification of the blockchain network and interactions. In the end, it will require less time to program everything and with two months of work the blockchain developer could finish it. Furthermore, as an App will not be developed, the App developer is not necessary. In the same way, the around 8.500 € of smart tags and IoT devices costs from the complete solution are neither included. Finally, education costs will be lower as task performed by the different participants will be much simpler and easier to teach them. Therefore, the onboarding costs will be of 11.000 €.

Onboarding costs	
Blockchain developer	10.000 €
Education costs	1.000 €
TOTAL	11.000 €

Table 7.16 Onboarding cost for the MVP

Cloud costs

With less data generated within the supply chain, less storage will be required and consequently, less cloud costs will be assumed.

Cloud costs	
Maresmar	0 €
Distribution centre and fishers	500 €
TOTAL	500 €

Table 7.17 Cloud cost for the MVP

Ongoing maintenance costs

Regarding onboarding costs, main savings come in the Azure's subscription for the different modules. First of all, working with three members instead of seven implies a reduction of almost 3.500 € per month in Azure Blockchain Service fees. Likewise, not integrating IoT devices eliminates the need for the modules required for this purpose such as the IoT Hub, IoT Central and the Service Bus, as well as reduces the Logic Apps interactions. The sum of all these simplifications implies technical support will not be required so often as in the complete solution and interventions to solve problems will be reduced and easily solved.

Ongoing maintenance costs	
Microsoft Azure modules	43.186 €
Technical support	3.600 €
TOTAL	46.786 €

Table 7.18 Ongoing maintenance cost for the MVP

Microsoft Azure Estimate		
Service type	Description	Estimated Cost
Azure Blockchain Service	Standard tier, 3 Member(s) X 3 Nodes per member X 1 Months	€2.573,55
Logic Apps	10,000 Action Executions x 31 day(s), 0 Standard Connector Executions x 31 day(s)	€875,98
Azure Active Directory	Premium P2 tier	€64,93
Support	Support	€84,33
	Monthly Total	€3.598,80
	Annual Total	€43.185,54

Table 7.19 Microsoft Azure estimate for the MVP

Monitoring costs

Simplifying the overall of the blockchain and related system characteristics will also simplify monitoring task and the annual network assessment will be cheaper.

Monitoring costs	
Annual network assessment	600 €
TOTAL	600 €

Table 7.20 Monitoring cost for the MVP

The Total Cost of Ownership has been considerably reduced, from almost 140.000 € in the full features model to around 60.000 € in the Minimum Viable Product. As it happened with the complete version, ongoing maintenance are still the higher costs but they have been significantly reduced due to the non-utilisation of IoT and the adoption of a three-member model instead of seven. Therefore, it is a more viable solution to assume for *Maresmar* where the investment should be thought in a long-term perspective from a broader and deeper adoption in the rest of their supply chains.

TOTAL COST OF OWNERSHIP	Year 1	Year 2	Year 3
Onboarding costs	11.000 €	0 €	0 €
Cloud costs	500 €	500 €	500 €
Ongoing maintenance costs	46.786 €	46.786 €	46.786 €
Monitoring costs	600 €	600 €	300 €
TOTAL	58.886 €	47.886 €	47.586 €

Table 7.21 Total Cost of Ownership for the MVP

This model, will be focussed on the integration and adaptation of the American lobster supply chain into a blockchain system where extra features non-blockchain related will not be relevant by the moment. It will help to progressively understand how blockchain works and how Maresmar and the rest of participants can take advantage from it.

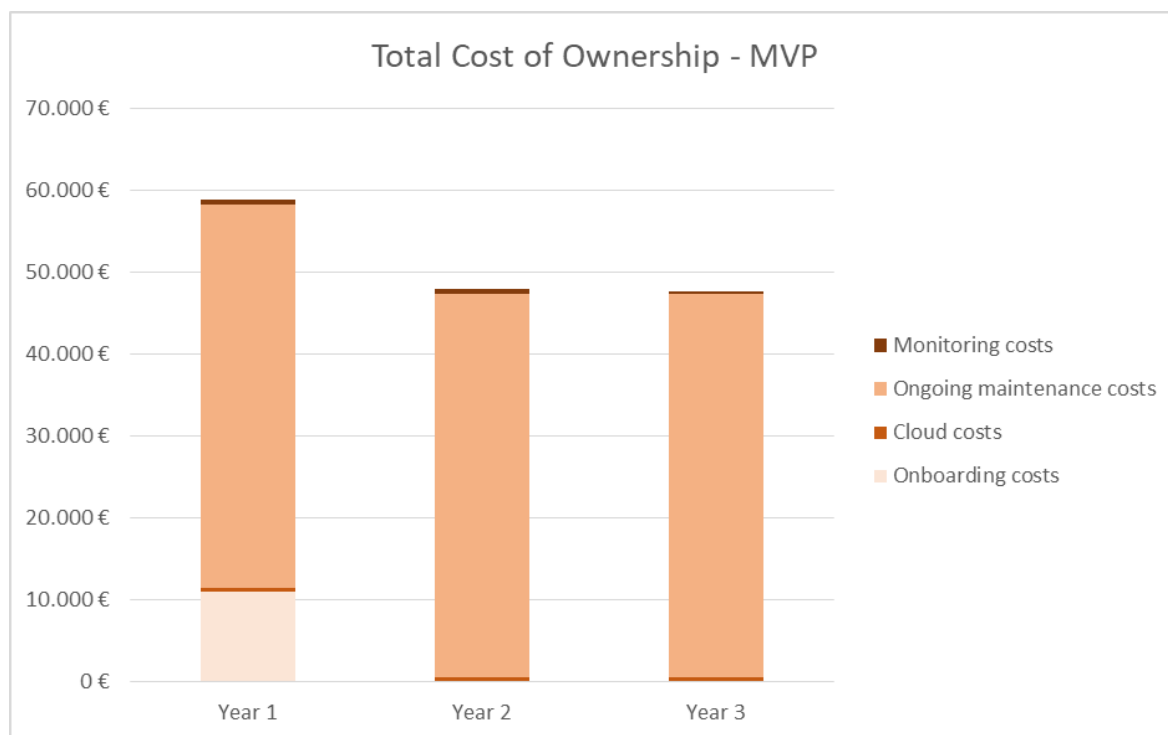


Figure 7.31 Total Cost of Ownership for the MVP

Phase 2: integrating IoT

After two or three years of the first investment, it is reasonable to believe that blockchain as a Service companies will be offering blockchain solutions with lower fees due to the increase in demand this technology will have. Hence, it will be possible to add new memberships to the consortium network in a more economical way and ongoing maintenance costs will be lowered.

In the same period of time, towards the progressive adoption of the model with all the features, IoT integration could be possible. The different devices already described will empower traceability and tracking procedures by integrating them to the blockchain.

Phase 3: developing the vendor and customer's DApp

The third phase will consist on the DApp and vendor verification system development. This will be executed as it was described for the complete solution and will bring major workability for the whole solution.

Phase 4: deploying smart contracts

The final stage will imply de smart contract deployment once the rest of software has been correctly functioning for some years. Smart contracts will be integrated into the DApps and will require a profound study on which critical points it could help. And that is the reason why it has been left as the last integration as it requires from the previous ones to be implemented. Besides, as blockchain technology will advance and improve, smart contracts will be easier to program and provide powerful application, and that is why an immediate deployment at the moment is not the best option.

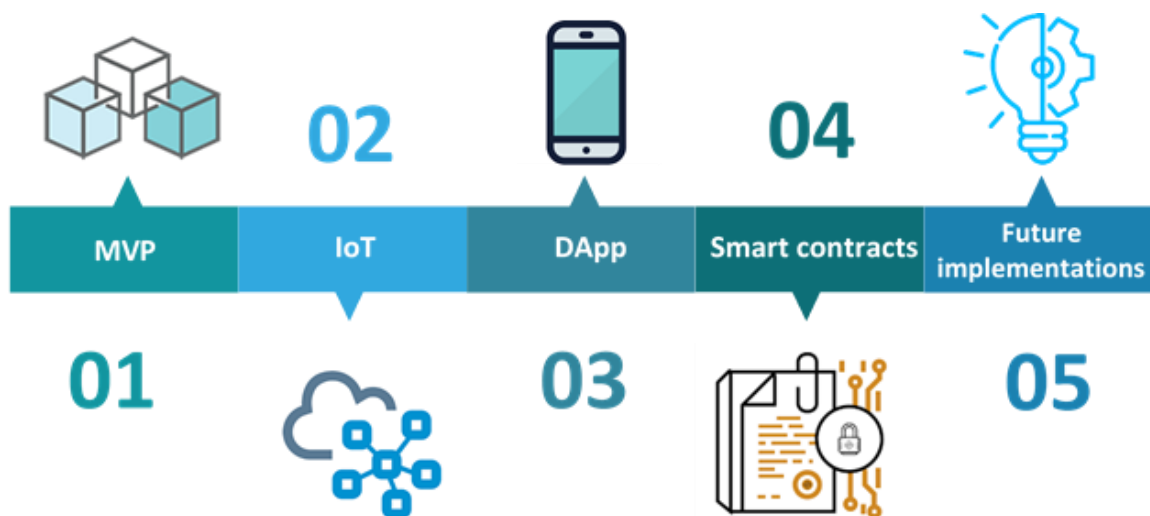


Figure 7.32 Progressive adoption of the end-to-end model

A fifth phase has also been contemplated which could be implemented after the rest of phases and once the model provides reliable performance in the different features. In the *Annex 5* can be appreciated this fifth phase in detail which includes new verifications methods, seafood DNA testing or *Marisco Planet* reactivation among others.

The progressive adoption of the various features to get to the end-to-end solution will help to manage cost in a more feasible way than investing a large amount of money in the early stages of adoption. The MVP will state the viability of adapting blockchain technology in Maresmar and the possibilities it can create to expand it to other products. Thinking broader, it can be used as a base to start a deeper change in how the company is currently working in all their areas. Once a solid solution will be working, expenses to start a blockchain adoption in the rest of products will be much lower and only variable costs will be assumed for the maintenance of the network and memberships.

This business case refers only to American lobster supply chain, however, with all the infrastructure already build, it provides the perfect environment for a scalable solution to be adopted in the rest of products' supply chains of the company. The American lobster case can be seen as a pilot to develop a much more extended network of suppliers, carriers, distributors, etc. all working together hand by hand inside Maresmar ecosystem.

Conclusion

The project serves to extract conclusions from two points of view: the feasibility for a general adoption of blockchain in a supply chain ecosystem and the viability for Maresmar to develop a particular solution in its American lobster supply chain.

Blockchain performance levers and challenges

Blockchain potential in the supply chain field is unquestionable, bringing traceability tools, trust and connectivity within supply chain actors into levels never seen before in the food industry. However, some points must be evaluated in accordance to the business value they provide and the intrinsic complexity attached to them to find an equilibrium of forces. In addition, the lack of largescale implementations can hamper a broader adoption.

The disruptive technology blockchain represents can transform existing business models by connecting independent actors to share and trust a record of digital assets, transactions and information with a common trust on the network. Consequently, it arises greater transparency and accountability in the overall of the supply chain, opening the possibility to major cooperation and collaborations between participants.

As technology for traceability data capture and blockchain require from important investments, a business case like the developed in this project can help businesses to detect what value blockchain can unlock by testing and developing prototypes before implementing an end-to-end solution.

Furthermore, it must be taken into account that developing an end-to-end blockchain system with full coverage of the entire supply chain, as it happened with the American lobster business case, may not result feasible. However, organizations can reap blockchain advantages in particular areas of the supply chain where impact and benefits justify the investment. That was the main point of developing a minimum viable product focussed in certain segments after the unsuccessful and unfeasible attempt to deploy an end-to-end solution for Maresmar business case. This minimum viable product can be used as a starting point for a broader adoption of blockchain by understanding which values can leverage in an enterprise's supply chain before increasing participation and investment.

For a blockchain-based system an important technological deployment is necessary. It is crucial for data capture at the initial stages of the supply chain in order to have certainty of products origin and properties and proof them to the rest of stakeholders as well as recording information throughout the whole product's journey.

Hence, setting up a blockchain traceability system requires a degree of digital transformation. In order to achieve a widespread adoption, it is essential to prioritize digital infrastructure furnishing at baseline levels for involved key actors to update products information that ensure a complete track-back to origin capabilities. It is more important to provide enabling technologies such as smartphones, tablets, scanners, sensors and GPS devices to farmers or fishers at the first levels of the supply chain than to middle actors that can get by with cheaper alternatives. At the same time, low level participants tend to be more technologically disconnected and education, support and incentive efforts are required to integrate and convince them to participate in data provisioning as they are fundamental to build a powerful and trustful traceable system.

Building a successful blockchain application resides in a precise planning and coordination of the different actors involved and the statement of their responsibilities. Communication and collaboration play a vital role to support each other. Therefore, promoters of a blockchain adoption, usually large enterprises at the top of the chain, should set a supportive ecosystem where every participant feels comfortable to interact with it and eliminate barrier to participate.

Moreover, before implementing a blockchain based system, rules, governance and data entry should be clearly defined as sensitive information shared along the system could compromise some of the actors. Only indispensable data should be shared for traceability purposes and privacy layers must be placed to determine which actors have access to certain product information. To do so, a consortium blockchain is the one that fits better due to its intrinsic infrastructure despite not providing full distributive properties blockchain technology stands for. Each type of blockchain, public, private/consortium or hybrid, have their unique strengths and weaknesses and it is necessary to clearly define the objectives of a blockchain implementation to accordingly select the type. Afterwards, the selection of the platform to build the solution requires from an intensive benchmarking on which fits better for the particular business case from the hundreds of startups and companies offering blockchain solutions. It is not the same selecting a platform for its regulatory compliance aptitudes than a platform that enables IoT integration.

The key factor for a proper blockchain end-state solution resides in an incremental and iterative approach of this technology. Food supply companies should not be aiming for an immediate solution but for a progressive adoption in order to reduce risk. First years should consist on proof of concept, pilots and testing to proof blockchain business benefits until a fully developed solution could be reached. As times goes on, complexities and barriers will decrease with its consequent lowering of cost of adoption and development. In the same way, as blockchain technology gains visibility and relevance, organisations will become less reluctant to adopt it and enter the new world of possibilities it offers.

An analogy can be seen in how the Internet was launched in 1983. In its first years it did not gain companies' attraction and it took seven years to fully understand Web potential (1994-1997). Similarly to how nowadays the Internet is used by millions people, blockchain will be adopted and used in the same way in a multitude of fields. Bitcoin took three quiet years (2009-2015) before it came more visibly known to the general public. In the supply chain territory, blockchain widespread adoption will take some more years until companies realize from its potential but it is undoubtedly that will become a booster for traceability and digital transformation of companies' business models.

One of the major challenges for global blockchain implementation is the lack of interoperability. A particular industry may be involving several blockchain platforms that might be incompatible between them. For example, a company selling elaborated meals might be using an Ethereum based traceability solution for one ingredient and a Hyperledger Fabric application for another ingredient resulting in incompatibility to offer a flexible system to trace their products. As long as there is not a key player winning the supply chain marketplace, every company works with the network they prefer and a unique global solution or interoperability between networks is not existing. Some organisations like Black Insurance, an insurance focussed company, are promoting network compatibility, but within supply chain area there is still a gap to fill.

The American lobster business case

Straightforwardly focussing into Maresmar business case studied in this project for the American lobster supply chain, various conclusion can be extracted.

Blockchain can bring major levels of traceability than the currently working system used in Maresmar. Regulatory organisms are already requiring for particular methods to determine origin of the company's products, but a deeper information sharing could be achieved enabled by blockchain. The solution with all the features enters traceability requirements at different stages of the American lobster supply chain with real-time access to products information and a verification system that puts trust in reliable data as a top requirement. Besides, it offers an end-to-end model that integrates every actor and connect them with customers via a DApp that allows them to receive feedback and reviews about the lobsters.

Certainly, this solution sounds appealing and could be for great interest for Maresmar purposes as it will tackle some of the critical drivers such as traceability, cutting manual processes or bringing major auditability tools and adding at the same time a customers' centric vision through their information access. Nonetheless, this project has also proved that the solution with full features is still not feasible for an instant implementation where

instead, it is better to adapt a limited version with reduced field of action by just focussing on traceability. This initial minimum viable product can serve as the starting point for a wider adoption of the rest of features.

Blockchain will develop in the next decade just like the Internet did, and being pioneer in its integration within their own supply chain could bring substantial benefits to Maresmar before their competitors start looking at this technology. First years should be seen as a testing and piloting period to really understand blockchain features and potential to drive value to the different participants of the supply chain. Once a simple blockchain network will start working, features could be progressively adopted in order to develop the end-to-end solution that was not viable at the beginning.

This project has also shown how difficult is to start a blockchain from zero as different considerations must be take into account regarding the type of blockchain, consensus, governance, privacy layers, etc. that make Blockchain as a Service (BaaS) a more attracting solution for not worrying about all of them and just focusing on the business use. But the truth is that companies offering BaaS are still expensive due to maintenance costs as they provide an already build network, which in the end, turns them inaccessible for a large implementation in medium sized companies like Maresmar.

In a non-distant future, challenges will be tackled and blockchain will become more accessible with cheaper fees and straightforward deployment while more blockchain expert developers will appear and their exclusivity will disappear.

The model developed in this project can be taken as a prototype model to export into other seafood and food companies with higher disconnection or trust issues that may be willing to incorporate traceability and supply chain actors integration in their organisation. In many cases, these companies tend to be large supermarket or final vendors that are looking for higher degrees of customer service provisioning. Therefore, the model should be addressed to them.

Project challenges and limitations

During the different phases of the project there are many challenges and limitations that represented a difficulty and restricted the result of the same. Access to information has implied a major difficulty as the incipient rise of blockchain technology makes it hard to find a reliable source of information due to the lack of a manual or standardized guide to implement it and, in many cases, obligates to get information from not consolidated sources of information like blogs and forums.

On the other hand, access to some sensitive information regarding Maresmar was not possible and some estimations had been based on other companies IT and blockchain projects found in the Web.

Acknowledgements

I would like to thank my tutors, Ferran Vilà and Emilio Rosico, for the support, knowledge and help they provided all along the realisation of this project.

Secondly, I would like to thank Jordi Cubells father and Jordi Cubells son for opening me the doors of Maresmar to develop this project and for all support I have received from them.

Finally, I want to thank my brother Marco for introducing me to blockchain world and for the different advices he gave me during the elaboration of the project as well as for the gift *The Business Blockchain* book.

Bibliography

- [1] <https://www.gartner.com/en/newsroom/press-releases/2018-10-15-gartner-identifies-the-top-10-strategic-technology-trends-for-2019>
- [2] MICROSOFT, *How blockchain will transform the modern supply chain*, 2018
- [3] <https://www.theguardian.com/uk/2013/feb/15/horsemeat-scandal-the-essential-guide#106>
- [4] HEALTH & CONSUMER PROTECTION, *Food traceability*, 2007
- [5] TNS OPINION & SOCIAL AT THE REQUEST OF THE EUROPEAN COMMISSION, *Europeans' attitudes towards food security, food quality and the countryside*, 2012
- [6] BASHIR, I., *Mastering Blockchain*, 2017
- [7] BARTOLETTY, M., & POMPIANU, L., *An empirical analysis of smart contracts: platforms, applications, and design patterns*, 2017
- [8] CAPGEMINI RESEARCH INSTITUTE, *Does blockchain hold the key to a new age of supply chain transparency and trust?*, 2018
- [9] <http://www.maresmar.com/>
- [10] <https://comunidadblockchain.com/analyzing-ethereum-storage-cost/>
- [11] <https://medium.com/@mycoralhealth/learn-to-securely-share-files-on-the-blockchain-with-ipfs-219ee47df54c>
- [12] TEMCO *whitepaper*
- [13] EY, *Total cost of ownership for blockchain solutions*, 2019

Additional bibliography

WILLIAM MOUGAYAR, *The Business Blockchain*, 2016

<https://www.investopedia.com>

<https://blockgeeks.com>

<https://oceana.org>

<https://fishcoin.com>

<https://www.sciencedirect.com>

<https://www.foodsafetymagazine.com>

<http://www.fao.org>

<https://blog.labelinsight.com>

<https://www.herbstsoftware.com/impo/>

<https://ec.europa.eu>

<https://www.seafish.org>

<https://www.bcg.com>

<https://www.mckinsey.com>

www.kpmg.com

<https://www.forbes.com>

<https://www2.deloitte.com>

<https://www.accenture.com>

<https://www.logisticsbureau.com>

<https://www.investinblockchain.com>

<https://www.ey.com>

<https://hackernoon.com>

<https://medium.com>

<https://101blockchains.com>

<https://www.miethereum.com>

<https://blockchainhub.net>

<https://www.bbva.com>

<https://www.corda.net>

<https://www.ethereum.org>

<https://www.hyperledger.org/>

<https://www.ibm.com>

<http://www.ethdocs.org>

<https://www.edureka.com>

<https://docs.microsoft.com/en-us/azure/blockchain>

<https://aws.amazon.com>

<https://ambrosus.com/>

<https://www.multichain.com>

<https://www.chronicled.com>

<https://kaleido.io/>

<https://www.blockchaindevelopments.io/>

<https://coincentral.com>

<https://www.cbinsights.com>

