Project of integration of Blockchain in the supply chain

FEASIBILITY STUDY

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Preface

This feasibility report was prepared as part of the minor assignment at Spark Living Lab. As part of the minor Supply Chain Engineering, we carried out a project on behalf of Spark Living Lab regarding creating efficiency and transparency in the supply chain. We chose this assignment because of our interest in new technology in logistics.

Because of the new technology, this project was different from normal for us and more difficult due to all the corona issues. Sometimes we lost our attention to the project because we were working remotely. Nevertheless, we have achieved good results, thanks to the excellent help and support we have received.

In particular, we will thank our mentor Maxime Bouillon, our supervisor Christiaan Verhoef from Spark Living Lab, and our supervisor Peter Schuurhuis from Windesheim University of Applied Sciences. In addition, we would also like to express our gratitude to the Andrea d'Auria of TNO and the students at Spark Living Lab.

Management summary

In our unstable environment, the collaboration between supply chain partners is one of the main strategies to improve overall performance. However, the supply chain encounters problems of transparency and trust between its players. That is the field of blockchain action, and companies could benefit from the implementation of this technology to achieve a more transparent, secure, and efficient supply chain.

Lamb Weston Meijer, DLG, and Lineage Logistics, respectively producer of frozen fries, carrier, and cold store, face a problem of sharing and trust in temperature information. As soon as the products leave the manufacturing plant, there is no monitoring of the compliance of the cold chain. Without clear evidence, it can be unfortunate not to be able to determine the liability for the damage.

Spark Laboratory Living Laboratory commissioned this study to answer the question of the role of this technology in the supply chain, especially for condition goods monitoring. We also want to know if it would bring real added value to the stakeholders of our case study.

Based on our research and our discussions with Living Lab experts, this study is mainly qualitative in this field. We have chosen to break the work down into two parts. On the one hand, we are studying the feasibility of different temperature measurement technologies and, on the other hand, the feasibility of managing temperature data with blockchain technology.

Finally, this study offers an analysis of the impact of blockchain technology in the supply chain and an analysis of existing alternative solutions. We were able to show that there are many advantages for the company to use Blockchain combined with sensors. These streamline exchanges and transactions and serves as tangible proof in the event of a dispute. However, there are also limits regarding this technology and still interrogations on the requirements of this technology implementation, on the adequate type of sensor, and the concrete return of investment of such a transformation of the supply chain.

Definitions

Application: software that implements business logic. Applications access resources that are needed to achieve the goal of the business logic through services. Applications can also provide services. (IEEE, Standard Glossary of Software engineering Terminology, 1990)

Block: Blocks are records that make up a blockchain. A block is a file that contains network-related data that cannot be changed. (MBN, tarih yok)

Device: a technical physical component (hardware) with communication capabilities liking it to other IT systems. A device can be either attached to or embedded inside a physical entity or monitor a physical entity in its vicinity. (IEEE, Standard Glossary of Software engineering Terminology, 1990)

Hardware: physical equipment used to process, store or transmit computer programs or data. (IEEE, Standard Glossary of Software engineering Terminology, 1990)

Internet Of Things (IOT): type of network to connect anything with the Internet based on stipulated protocols through information sensing equipments to conduct information exchange and communications in order to achieve smart recognitions, positioning, tracing, monitoring, and administration. (Patel & Patel, 2016)

Node: A blockchain node is a cross-platform, open-source runtime that allows developers to build various services. The P2P protocol lets nodes in the network connect with one another and share information about transactions and new blocks. (InfoQ, 2021)

Server: A computer or computer software that controls access to a network resource or service.

Introduction

Background of study

Lamb Weston -the company that provides delivery of frozen potatoes- expects to make digital of its supply chain to avoid mistakes and inaccurate data caused by human factors. Moreover, if there are more stakeholders, suppliers, or delivery way, it will be easier to manage the system with digitalization. The company is looking for technologies that can help it maintain control over its supply chains regarding product traceability, transparency between actors, and safety. Control of the supply chain significant for the company because it helps the company ensure that product quality is maintained.

Spark! Living Lab has investigated the implementation of Blockchain Technology in the Supply Chain for Conditioned Goods. There is a great deal of research into blockchain technology in the Supply Chain, but none, especially for Conditioned Goods. On the other hand, Spark! Living Lab wants to do a feasibility study for Conditioned Goods using the knowledge acquired on the implementation of blockchain technology in the Supply-Chain.

Conditioned Goods refers to goods that have been subjected to a specific condition, such as temperature. Lamb Weston-Meijer needs to keep the temperature of the frozen potatoes at -18 degrees Celsius not to lose the quality of goods. With Traceability, Transparency, Security, and Sustainability features of Blockchain can help the agriculture sector improve the chain.

Traceability is the ability to document and trace a product history through the whole of a production chain.

Transparency allows all network stakeholders to access information on the product they request in the supply chain network without delay or distortion.

Food security is a term used over time to mean different things; it generally is used to describe access to enough food to meet dietary energy requirements. It could describe the food availability in a country or explain the nutritional security of products.

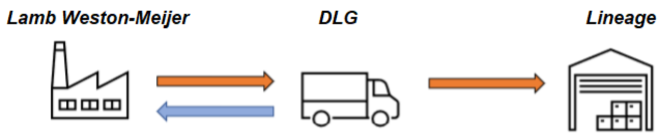
Sustainability commonly refers to how the needs of the present human generation can be met without compromising the ability of future generations to meet their needs. It includes environmental aspects and a social dimension. It is also related to waste and refrigeration related to storage and foodservice operations during preparation and service. (Jan Kajkowski, 2020, s. 4)

So, spark! Living Lab has started a feasibility study on blockchain technology. This project focuses on the applicability of Blockchain technology in the supply of Condition Goods and the above objectives.

Statement of the problem

Today, the supply of products is planned traditionally. This traditional way is prone to human error due to the lack of digitization. But today, organizations and partners need to be always in transparent communication with each other. Transparency provides more accurate information about the goods and prevents disputes. For this, a transparent, secure, and traceable environment should be prepared by taking advantage of the features of Blockchain technology.

The main problem is the temperature loss of Lamb Weston-Meijer goods (frozen potatoes) from the production site to the cold store. Lamb Weston Meijer works with Lineage Logistics and Daily Logistics Group (DLG) on this transport process. Lineage Logistics receives stores and distributes goods transported by logistics service provider DLG from the production site of Lamb Weston-Meijer. At minus 7-8 degrees Celsius, Lamb Weston-Meijer produces frozen fries. The fries are then delivered to a cold storage facility. It will be kept in the cold store for a few days until it is cold enough to be sent to final customers. The goods must be minus 18 degrees Celsius to begin delivery. (Farax, Blockchain Application in Cold Chain Logistics, 2020-2021, s. 5)



When the goods arrive at the cold storage facility at a higher temperature than the agreed-upon temperature, the issue arises. This phenomenon may cause the product to require more energy to cool down, reduce its quality because it does not have the required temperature, and dispute between the partners.

Spark! Living Lab and Lamb Weston-Meijer wants to know how the application of Blockchain Technology can be of any use for this situation.

Objectives of study

The study objective is to make a feasibility study of the combination of sensor technology and blockchain technology. The feasibility study is about whether the sensors are suitable for this role, their prices are affordable, how these sensors can help solve the problem, and the added values. Besides, it is crucial to make the system secure, so the other objective of this study is whether Blockchain can be used for this expectation.

Scope

The investigation scale needs to be demarcated to a more realistic scope. Lamb Weston-Meijer wants to explore the opportunities of Blockchain Technology across multiple modalities and locations. However, in this research, the focus in the company's supply chain will be on the process from the production site until the cold storage by trucks.

Security and transparency will be the project's focal point, and the combination of sensors and Blockchain will provide this.

Methodology

This study was carried out based on scientific articles and theses. As for the specificities of the project, we referred to the exchanges with the parties involved and to the interviews with the experts, students of the laboratory. This is an essentially qualitative study: our analysis tools were SWOT analysis, the 5W method, and the consumer value.

Review of literature

In 2008, blockchain technology was created as a mechanism to manage transactions for the cryptocurrency bitcoin. Since then, a lot of research has been done on this topic to see if there are any new applications for this technology, such as in logistics. It was revealed that Blockchain could be utilized to tackle a variety of supply chain management challenges, including a lack of traceability and the excessive quantity of paperwork needed in exporting goods. From the initial step of acquiring raw materials to the final delivery to the end-user, a supply chain is a method for producing and delivering a product or service. (Corporate Finance Institute, tarih yok)

One of the most revolutionary technologies changing digital supply chain management is Blockchain. As supply chains become more complicated, including various stakeholders and relying on several external intermediaries, Blockchain has emerged as a strong competitor for untangling all of the data, documents, and communication exchanges that occur within the ecosystem. (Medium, 2019)

On the other hand, smart sensor and supply chain integration can lower operational costs, improve asset efficiency, improve demand forecasting, and provide crucial insight into customer behaviour. Companies should start thinking about how to better sensor-enable their supply chains from end to end as centralized platforms and communication networks for Internet of Things (IoT) devices continue to emerge. (Deloitte, tarih yok)

Legal study

Blockchain in the Netherlands is an emerging market in many public and private sectors, including financial technology, trade finance, energy, entertainment, cryptocurrency, real estate, healthcare, logistics, and the arts. In reality, the Netherlands is a global front-runner applying blockchains in many industries, supported by a tradition of public-private partnerships, technology-neutral legislation, and high-quality digital infrastructure. (Christian Godlieb, Willem Röell, 2021)

The current attitude of the government and regulators to the use of blockchain technology

The Dutch government and financial authorities – the DNB and the AFM – are enthusiastic about blockchain technology and its uses. The Dutch government has set aside funds to conduct intensive research into blockchain technology. Furthermore, the Dutch government's Digitalization Strategy, which was established in June 2018, encourages the creation of innovative blockchain-based applications. The Dutch government is engaged in public-private partnerships for this aim, and the Dutch Blockchain Coalition was created (in collaboration with market parties) for this goal. In the financial industry, DNB and the AFM have established the Innovation Hub, which includes a regulatory sandbox, to support market participants with their innovation projects. DNB is also investigating whether blockchain solutions might improve the efficiency of payment and securities transactions in collaboration with the Ministry of Finance. (Christian Godlieb, Willem Röell, 2021)

Agreements in the Netherlands are, in principle, form-free. No specific legal characteristics apply to smart contracts. Agreements stored on blockchains (smart or otherwise) are allowed, and formal requirements are usually not an obstacle for forming agreements stored on blockchains (but, in specific instances, can be). There are usually two types of agreements via Blockchain that can be distinguished:

- Agreements established by communication via a blockchain (where the conditions of the agreement can be recorded in an electronic deed);
- Agreements that are established and recorded via a blockchain are also partly executed via a blockchain (smart contracts).

In principle, normal contract law applies to both. In the Netherlands, as in most European jurisdictions, a court will determine the meaning of a contract based on the contract's text and take into account all relevant circumstances. Consequently, the code that forms and executes a smart contract may differ from the legal meaning of the smart contract (as determined by the court, taking into account all relevant circumstances). This is important to consider when writing (developing) smart contracts. (Legal500, tarih yok)

Technical study

Measurement of the temperature with sensors

A sensor is a device that converts a physical phenomenon into an electrical signal. Sensors are the interface between our physical world and electrical devices such as computers (WILSON, 2005). In our study, connected sensors will be employed to measure the temperature of the goods during the entire process. These measurements will be useful for monitoring the goods' condition. There are different options that we distinguish into two types: reusable and single-use technologies.

Reusable technologies

Classical connected sensors

This type of sensor is connected to a router that transmits the data to the data storage /management solution. Different networks can operate the transmission between sensors and connected devices. Generally, it can occur by Bluetooth connection, Wi-Fi, or RFID/ NFC. However, it depends on the model, and this type of sensor requires several installations of antenna, routers, connected devices to ensure the transmission and extraction of data.

It is mainly necessary to check the following technical information to choose a suitable temperature sensor (Emerson, 2014):

- Temperature range
- Accuracy (for good conditioning it is more or less 0,5°C);
- Stability;
- Linearity;
- Sensitivity;
- Autonomy;
- Resistivity.

Smart sensors

Furthermore, to ensure temperature monitoring, it is also possible to use smart sensors. It is a more advanced version of sensor technology. According to the Institute of Electrical and Electronics Engineers, the smart sensor (or intelligent transducer) is defined as a sensor able to provide more functions beyond those necessary for generating a correct representation of a sensed or controlled quantity. This function typically simplifies the integration of the transducer into applications in a networked environment (IEEE, Specification 1451.2). Indeed, smart sensors have integrated hardware and a processor that give them more functionalities and make them more manageable. This way, contrary to a classic sensor, it can store the data.

At the end of the travel, it will be able to communicate it all. In addition to this, smart sensors can provide (Ashlin, 2020):

- Multi-sensing measurement (interesting for smart contract coding with the location, for instance)
- Self-calibration
- Communication
- Accuracy with less noise
- Quick response
- Computation (they can perform certain functions like logic functions two-way communications and are capable of making decisions)
- Low power consumption
- Remote diagnosis
- Network of sensors.

To choose a smart sensor, we must consider:

- The self-calibration capability
- The accuracy
- The self-diagnosis ability
- The information processing
- Area coverage
- Fault tolerance
- The ability to operate in a harsh environment
- Reliability
- Service life (in general between 8 and 10 years like a classic sensor).

So, on the technical plan, classic sensors and smart sensors have the same principal function. Nevertheless, smart sensors require less work and human intervention, from installation to maintenance.

Single-use solution

Data Lodgers

If the temperature information can only serve as a simple control element, in this case, there is the data lodger, which will just record the temperature data. This data is readable thanks to a smartphone or a USB, key depending on the model. Just like the smart sensor, this technology does not require any special installation on the process. However, data extraction is done by smartphone or USB. Depending on the model chosen, the data can be retrieved afterwards on a database.

Reserve question

From a technical point of view, with these solutions, it is feasible and easy to extract and manage data from them, whether in real-time or at the end of the travel. However, we can face the issue of the Faraday effect with the sensors. Indeed, in the metallic box, the wave transmission is less effective. The main problem with sensors is transmitting real-time information. For the moment, in the literature, the sensor node can be located outside the container, with the sensor probe into the container through a hole in the body to avoid the faraday cage effect. The alternative is to install the entire node within the container. This way, at the end of the travel, it will be able to communicate the data directly with Blockchain or the database. (Wisense, tarih yok)

Conclusion

Thus, smart sensors are our first recommendation on the technical plan because it is more accurate, faster, has more functionalities, and its installation requires fewer steps than a classical sensor. Furthermore, it can solve the problem of a poor connection and automize the transmission without human intervention. The other solutions are technically feasible, but they will require more human interventions, constituting a fraud possibility.

Concretely, this use is a little process, with two nodes, so the classical sensors are sufficient, and we will see later that it is the less expensive option. However, in the case of growth, the stakeholders should consider smart sensors.

What is a smart contract?

A smart contract is a digital code that may be used to exchange assets such as shares, money, or real estate without the involvement of any middlemen. Because it is based on blockchain technology, the smart contract is distributed, decentralized, and transparent. (Adapt Ideations, 2019)

Benefits
1. **Autonomy and savings**: Intermediaries are not needed to approve the deal; this eliminates the risk of manipulation, and the absence of intermediaries provides cost savings. (CFI, tarih yok)
2. **Backup:** All documents stored on the Blockchain are copied multiple times so that the originals can be restored in case of any data loss. (CFI, tarih yok)
3. **Safety**: Smart contracts are encrypted, and cryptography protects all files from being tampered with. (CFI, tarih yok)
4. **Speed:** Smart contracts use computer protocols to automate actions, saving hours in various commercial operations. (CFI, tarih yok)

5. **Accuracy**: Smart contracts reduce errors that occur as a result of humans filling out several forms. (CFI, tarih yok)

Limitations
1. **Difficult to change:** It is nearly impossible to change smart contract operations, and any programming fault can be time-consuming and costly to fix. (CFI, tarih yok)
3. **Third party:** Even though smart contracts aim to eliminate third-party involvement, it is a bit difficult to do. Third parties have a different role in conventional contracts than they do in traditional contracts. Lawyers, for example, will not be required to prepare individual contracts; but, developers will require their assistance in understanding the provisions to generate smart contract software. (CFI, tarih yok)
4. **Vague terms**: Smart contracts are not always able to handle ambiguous terms and conditions since contracts involve terminology that is not always understood. (CFI, tarih yok)
5.**Cost:** The development process is not the only factor that affects expenses. Auditing and testing the smart contract code is quite expensive because it needs even more specialized specialist knowledge to detect bugs/faults. (medium, 2018)

As a result, supply networks now are much more complex, fragmented, and harder to comprehend. Supply chain management may be made easier and more transparent with smart contracts. (Adapt Ideations, 2019)

In this case, any temperature violation of the goods triggers the smart contract. All relevant organizations can be notified, or we can program the smart contract to hold all the received funds until a certain goal is reached. For example, if the temperature of the goods is more than minus 8 degrees Celsius, it can directly affect or stop the agreement between the companies with smart contract technology.

Blockchain and traditional database

What is Blockchain?

Blockchain is a distributed ledger technology that allows peers to work together to build a combined, decentralized network. The peers can get in touch and share information or data with the help of the algorithm. Besides, it is unnecessary to need a centralized authority, which makes the entire network reliable compared to other networks.

How does it work?

When one peer sends data to another peer, an operation is created. When an operation is created, the operation has to be confirmed using the consensus algorithm.

Proof of Work is utilized to confirm the work in this situation. It prevents any invalid transactions from being added to the Blockchain. Blocks are the foundation of blockchain technology. They are used to keep track of transactions and other vital data needed to keep the Blockchain running smoothly. (Investopedia, 2021)

How to maintain Blockchain?

Blockchain technology is an innovative breakthrough, but organizations with a working blockchain application must maintain it, keeping in mind that no human creation is perfect. The most important reasons are to detect errors that slow down the network and protect the system from attacks.

Two key areas to consider when protecting any blockchain infrastructure are;

1. System Monitoring
2. Analyzing Potential Threats

Maintenance Resources Required for a Blockchain Application

The resources required to maintain a blockchain server differ from one distributed ledger to the next. In general, servers, blocks, nodes, and databases are the core resources that can be maintained. (iMi Blockchain, tarih yok)

Servers: To begin, we must ensure that the network's servers perform smoothly at all times. When it comes to blockchain application maintenance, servers are crucial. (iMi Blockchain, tarih yok)

Blocks: They are like one-time shots. This means that after they have been distributed, they cannot be modified. (iMi Blockchain, tarih yok)

Nodes: A peer-to-peer (P2P) network is used to run the protocol. "Nodes" make up the architecture. It is necessary to maintain these devices on a regular basis. (iMi Blockchain, tarih yok)

Databases: Databases are used to store files. Because these storages are vital, we must ensure that they are well maintained. (iMi Blockchain, tarih yok)

What is Database?

Unlike blockchains, databases are centralized ledgers managed by a single administrator. Databases have their own set of characteristics, such as the ability to read and write. Only those with appropriate access can write and read data. Databases can also hold numerous copies of the same data as well as their history. This is accomplished with the assistance of a centralized authority that manages the server. The database benefits greatly from centralization. Databases, for example, are simple to manage since the data is centralized. Data access and storage are simple and quick. However, there are also disadvantages. One of the biggest risks is the possibility of the data getting corrupted. Various backups are taken to overcome this risk. Another significant disadvantage is that anyone with access to the database can change the data. Because the database is centralized, this is a possibility. (Oracle, tarih yok)

Comparison of Blockchain and Database

BLOCKCHAIN	V/S	DATABASE
Blockchain is decentralized and has no centralized approach. However, there are private blockchains that may utilize some form of centralization.	AUTHORITY	Databases are controlled by the administrator and are centralized in nature.
Blockchain uses a distributed ledger network architecture.	ARCHITECTURE	Database utilizes a client-server architecture.
Blockchain utilizes Read and Write operations.	DATA HANDLING	The database supports CRUD (Create, Read, Update and Delete).
Blockchain data supports integrity.	INTEGRITY	Malicious actors can alter database data.
Public blockchain offers transparency.	TRANSPARENCY	Databases are not transparent. Only the administrator decides which the public can access data.
Blockchains are comparatively harder to implement and maintain.	COST	The database being an old technology is easy to implement and maintain.
Blockchain is bobbed down by the verification and consensus methods.	PERFORMANCE	Databases are extremely fast and offer great scalability.

(Iredale, 2020)

Authority and Control

When comparing Blockchain with databases, the first thing that comes to mind is how authority is handled. The Blockchain is designed to be decentralized, whereas databases are always centralized. Blockchain's one-of-a-kind feature offers it the edge it needs to become the next generation of technology.

Decentralization allows networks to operate autonomously, eliminating the need for centralized control. On the other hand, databases operate entirely on a centralized basis. Decentralization is not a feature of any typical database. If it is specifically looking for a decentralized database, then Blockchain falls into the category directly (Iredale, 2020)

Architecture

The client/server architecture is the foundation of a database. It is a highly effective architecture that may be used in both local and large-scale settings. The receivers are the clients, whereas the servers function as a centralized processing unit. A secure connection is used to maintain communication between the client and the server.

Blockchain, on the other hand, is based on a network of distributed ledgers. It is a peer-to-peer network that allows users to interact with one another utilizing safe cryptographic methods. Because there is no centralized node, nodes can participate in the consensus procedure collectively.

The database does not need a consensus algorithm and is completely connected to centralized access. (Iredale, 2020)

Immutability and Data Management

Both Blockchain and databases perform differently when it comes to data storage and handling. Data may be easily saved and accessed in a typical database. The information can be created, viewed, updated, and deleted. This also means that, if necessary, data can be deleted and replaced with new values.

When it comes to data storage, Blockchain operates differently. Immutability is a feature of Blockchain, which means that data cannot be wiped or replaced after being written. Immutability refers to the fact that no data may be tampered with within the network.

Traditional databases lack immutability, making them more undefended to tampering by a cheater administrator or third-party hackers. (Iredale, 2020)

Transparency

Another important feature of Blockchain is that anyone with the right tool can verify data once it has been recorded into the public Blockchain. Transparency ensures that the network can be trusted.

On the other hand, databases do not allow for any transparency because they are centralized. If users wish to double-check the facts, they will not be able to. However, an administrator can make a set of data public, but individual data verification is not possible.

The immutability of the Blockchain allows it to maintain its integrity. Stored data cannot be deleted or modified in any way, ensuring that data integrity is maintained at all times. (Iredale, 2020)

Cost and expertise

A regular database is less expensive to implement than a blockchain. Because Blockchain is a relatively young technology, it is still evolving.

It also means that a business has to do proper planning and execution to apply Blockchain into its operation.

It is simple to set up and scale a traditional database. They are compatible with the majority of existing processes. It is an ideal alternative for enterprises looking to set up their database systems fast and affordably.

However, if we look at the costs associated with each technology over a longer period, Blockchain may prove to be a more cost-effective solution because peers administer the network. Organizations do not have to worry about the additional costs of managing the network, which can save much money.

When it comes to experts, the same cannot be stated. Because Blockchain is a relatively new technology, there is a limited range of people available to deal with practical blockchain applications. The cost of blockchain expertise is likewise high, potentially raising the cost of blockchain implementation and upkeep.

On the other hand, database-related talent is rather easy to come by. They are also cost-effective, so even small businesses may afford to hire a database professional. (Iredale, 2020)

Performance

When comparing Blockchain and databases, the speed of execution is also an important factor to consider. Databases are noted for having a speedier execution time and managing millions of records at once.

When compared to databases, Blockchain is significantly slower. However, this could be due to the fact that Blockchain is a relatively new technology that will take some time to mature and catch up to the standards of more established technologies like databases.

When a transaction is completed in the Blockchain, it performs all of the functions of a traditional database. However, because it is carrying additional operations, such as the following, it has slowed down.

1. Signature Verification: When transactions on the Blockchain are completed, they are cryptographically signed using cryptographic techniques. Because it is a complicated process, it takes time to complete.
2. Consensus Mechanisms: Because Blockchain is decentralized, it is highly reliant on a consensus method to validate transactions. Some consensus methods are faster than others, but they all add time to the process.
3. Redundancy: Blockchain is a network in which each node plays an important function. Each node's transaction information must be kept and confirmed for each node to participate.

These three factors slow the Blockchain. These facts indicate that databases are faster than other types of software in terms of performance. (Iredale, 2020)

Conclusion

The Blockchain is important when taking into consideration innovation, verification, and automation. On the other hand, the database is more useful for utility, speed, and accuracy.

Because of its verification approach, Blockchain has a performance penalty. That obviously indicates that Blockchain should be avoided in situations where speed of execution is critical.

When a crucial business process needs to be supported or scaled simultaneously, databases are an excellent solution. The read and write process is also not straightforward when it comes to the Blockchain, which makes the database more appealing for general-purpose applications. In short, Blockchain is useful if we look for trust, transparency, and verification. On the other hand, a database is optimal for high-performance apps or services.

For our case, Blockchain is pertinent because we are aiming to have concrete proof of temperature data. In general, Blockchain can answer the questions such as transparency and security of logistics. These features will become more important as the number of stakeholders increases. Besides, it is technically feasible, according to experts. There are some companies, consultancy firms, and laboratories that can provide service. However, there are some obstacles due to lack of maturity that companies need to consider. Lack of maturity causes some difficulties. For example, Maintenance can be difficult because finding an expert is not easy. Also, if there is a problem with Maintenance, it can cause the system to slow down. Besides, expert salaries can be high for small companies. The third problem can be the large energy consumption.

Based on this research, we advise the companies to have a proof of concept. This way, they can determine all details and get more concrete answers for the technical feasibility study. After this proof of concept, they can put it to the test to see what kind of risks become a reality. In this way, they see the potential other risks before making the project bigger.

Operational feasibility study

The initial process consists of manual measurement of the temperature and manually enter the collected data into the database at the destination. We have seen above that this is a source of error, fraud, and information asymmetry. In the case of disputes, it is more difficult to show proof of responsibility for the damage caused. Furthermore, it is a repetitive task that employees can potentially neglect. Thus, it is appropriate to mention the requirement of the proposed process, gains that the new process will bring to stakeholders, and finish with the risks.

The process proposed

This study aims at a supply chain 4.0 to expand the network further. Supply Chain 4.0" is the re-organization of supply chains – design and planning, production, distribution, consumption, and reverse logistics – using recent technologies as such as the Internet of Things (IoT), big data analytics, and autonomous robotics (Ferrantino & Koten, 2019). In our case, it would consist of smart sensors and Blockchain. This operational feasibility study as follows is mainly based on this organization.

Requirements

The transformation of the initial process requires material, human, and time resources.

Material:

In addition to sensors, computers, and a stable internet connection, with the adoption of Blockchain, Lineage and Lamb Weston Meijer, companies are expected to have around five servers each. Then, it will be necessary to define the number of sensors required. We know that there are 56 trips per week. We will admit that one sensor per truck is sufficient. The minimum number of sensors required will be defined according to the following parameters:

- The time necessary for Lineage to remove the sensors and return them;
- The feedback frequency of the sensors;
- The resistivity of the captors (frequency of use, harsh environment, bumps...);
- Security blanket;
- The advantages of purchasing.

The number of sensors is questionable and depends on the models chosen. At the state of the project, studies are made to answer.

Time:

The installation of the application of Blockchain takes few hours. The rest of the support requires one or two weeks.

Human resources:

The process workers should be trained to use the application and use the devices for a few hours.

Consequences

Consequently, the organization will be impacted by new needs like Maintenance, human resources, and logistic for the transformation.

Maintenance:

Smart sensors perform self-calibration and diagnostics automatically and require little maintenance. We can ensure Maintenance on remote, and it makes it easier and decentralized. Nevertheless, it will be necessary to define a preventive maintenance plan and determine maintenance places in the network with classic sensors.

Return logistics:

Return logistics should be put in place from Lineage Logistics so that the sensors return to Lamb Weston. As a solution, we can take advantage of the return trips of the trucks currently. In the case of the growth of the network, the delay of return will naturally be longer. The stakeholders will have to determine a frequency of return in one travel to reduce the cost. Nevertheless, they will need more sensors to cover the risks of this delay and get a certain autonomy.

Human resources:

An employee should be assigned to monitor and maintain the servers. This integration of Blockchain can create new jobs or tasks in the company. It is still a hypothesis to confirm.

The operational gains

All of the previous requirements and induced needs represent costs that will have to be taken into account. However, there are future concrete and potential gains.

<u>Concrete gain</u>

We can say with confidence that temperature monitoring will be trustworthy evidence of responsibility in case of a dispute. The temperature will be controlled throughout the process, shared with all of the nodes of Blockchain, and guarantee security. That will be a help for control, but also a proof of audit. Further, this secured transparency could help avoid losses of goods and money.

<u>Potential gains</u>

The following plus-values of the transformation of the supply chain are potential. For the moment, we are not able to quantify them:

- Operationally, the integration of the smart sensor combined with a blockchain would completely automate the information flow of the process. The only human intervention would consist of activating the sensor at the start of the process, checking its working state and the quality of the signal, deactivating it, and putting it away. So, the time taken initially to measure and record the temperature manually will only be used to check the correct functioning of the devices instead. As a consequence, this transformation will represent fluidity and efficient work.
- Knowing the temperature of the commodity could be one of the elements allowing automatic payment to be triggered using blockchain smart contracts. Thus, this

solution will have an impact on other organizational processes and will also allow some of them to be automated. The work of Blockchain will take a long time to begin with, but over time we could master it to automate the interfaces of other digital business processes.

- Thanks to temperature monitoring, it will probably not be necessary to freeze food more than necessary. Ultimately, this could have an impact on the amount of energy consumed by the warehouses.

The potential risks

Technical:

The sharing of information and documents in this process will depend on the stability of the internet connection and the electricity supply.

What will happen if a sensor dysfunction? This question will be a subject of study further.

To finish, for the moment, the network of Blockchain is constituted by three nodes. However, in the case of growth, we are not sure that every partner can afford Blockchain.

Authentication and security:

Once a transaction has been made on the Blockchain, it is possible to trace it and avoid any forgery, but the downside that arises in the case of adding a document to the Blockchain is blocks remains that we cannot be sure that the document in question was not altered before being introduced on the Blockchain (Guilhaudis, 2018) (Bouzidi and Frossard, 2018)

Collaboration

The companies should agree on the information shared. They can face reluctant partners.

Conclusion

This transformation of the process can bring transparent and unchangeable monitoring of the temperature during the process on the operational plan. There may be other earnings thanks to efficiency, automatization, and transparency. The companies would be able to improve their process of transportation, billing, and their mastering of the temperature. However, these potential earnings will be concrete after a precision of the needs of the company; they have to be proved by the experiment of the proof of concept and the current studies bringing expertise on the sensors, the rules of collaboration.

Financial study

Blockchain implementation

In this part, the cost of implementation of blockchain technology will be formulated and conducted.

Generally, blockchain project cost starts at $5,000 and can go as high as $200,000 in total. (Team, 2021)

To cost for implementing blockchain technology in the supply chain of LWM is depends on various factors such as app features, complexity, type of Blockchain, blockchain platform, and other technology stuff. The cost for the blockchain project can be separated into the following categories: Consulting (10%), Designing (15%), Development (50%), Quality assurance (25%), and Maintenance (15%- 20% of the overall project cost). (Takyar, LeewayHertz, 2018)

The cost of blockchain implementation is spent on multiple activities or phases of the project, including:

- **Design:** System Blueprint, user interface/experience design including wireframes, high-fidelity designs with a prototype, and low-fidelity designs with app flow.
- **Development:** Coding and Testing
- **Deployment:** Deployment on Cloud Platforms, Delivery, and DevOps
- **Migration:** Moving the existing solution to the Blockchain platform
- **Maintenance:** Maintaining new updates and testing that the app runs smoothly on every OS release
- **Upgrade:** New features, Changes in Smart Contracts
- **Third-Party Tools:** Hosting, Storage, Notification System, Collaboration (Takyar, LeewayHertz, 2018)

The development of a platform requires developers and experts with a lot of experience. Developing a platform will take approximately three months (95 days), according to the plans below. In these calculations, we specified one developer cost. For the other experts (2 IT specialists, one innovation specialist, one Supply chain specialist), the total cost will be **€152,000** based on €50 per hour and 95 days (8 hours/day). The personnel cost is calculated using FTE and will represent the development costs. Per FTE is equal to 40 hours per week and 760 hours over 95 days.

The day implementation plan is as follows:

- Connecting with actual sensors: 20 days
- Continued development to reach production grade: 40 days
- Code review and resulting fixes: 10 days
- Manual testing: 10 days
- Set-up of infrastructure: 5 days
- Connecting to an enterprise API: 10 days

Total: 95 days

DEVELOPER COST

Based on one developer	Days
Connecting with actual sensors	20
Continued development to reach production grade	40
Code review and resulting fixes	10
Manual testing	10
Setup for infastructure	5
Connecting to an enterprise API*	10
Total	95

* for each involved party that doesn't want to use the web interface

Working hours per day	8
Lower cost(per hour)	€ 75
Medium cost(perhour)	€ 100,00
Upper cost(perhour)	€ 125,00

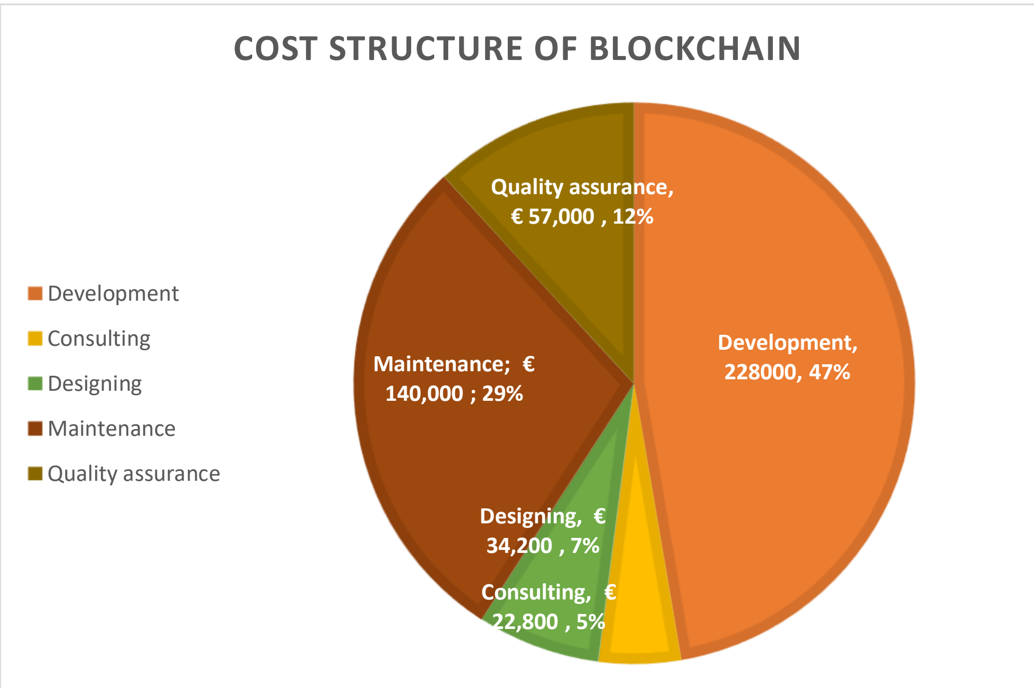
Number of days	Lower cost	Medium cost	Upper cost
1	€ 600	€ 800	€ 1.000
95	€ 57.000	€ 76.000	€ 95.000
110	€ 66.000	€ 88.000	€ 110.000
125	€ 75.000	€ 100.000	€ 125.000
150	€ 90.000	€ 120.000	€ 150.000

*110, 125,150 days randomly added for estimations of new features

Lower cost monthly pay :	€ 19.000
Medium cost monthly pay:	€ 25.333
Upper cost monthly pay :	€ 31.666
Avarage cost monthly pay :	€ 25.333

*The estimation is based on one developer.

The total development cost around **€228,000** (Based on medium cost and total expert cost). After calculating development cost, other parameters can be found as well. Proportions of every category are as follows:



The costs are acquired from the daily rate of the team of experts that would participate in the hypothetical project. Based on their expertise on the activities correlated with the overall development of a blockchain platform, the costs can be reversed calculated. We saw maintenance cost is **€140,000**; we estimate that the cost per server takes €10,000/year. (Graaf, 2021) According to IT students, Lamb Weston needs at least 6 servers, DLG needs at least 4 servers, Lineage needs 4 servers. The total calculations as shown below.

SERVER & MAINTENANCE COST

	Needed servers	cost/year	cost/month
LambWeston	6	€ 60.000	€ 5.000
DLG	4	€ 40.000	€ 3.333
Lineage	4	€ 40.000	€ 3.333
Total :	14	€ 140.000	€ 11.667

Server and maintenance cost €10,000 /year/server

*If the companies want to bigger Blockchain, more servers are required.

The server maintenance could be one server for each company, but if the server breaks, nothing will work anymore. Thus, we used more servers as a precaution; it also increases security. According to our design (which has not been tested yet), a new stakeholder would need 4 servers. If more stakeholders join, the Blockchain will become bigger, meaning that other stakeholders must upgrade their server.

Digital solutions can also complement the blockchain project. The costs for implementing sensors in the trucks or pallets can range from an additional €5.700 – €25.500 in total for hardware, installation, and configuration. The graphs of a variety of sensors will be shown below.

Finally, every category was added up, and an estimated 29% of the overall cost would be necessary for Maintenance. Totalling the blockchain project costs to be **€507,500.**

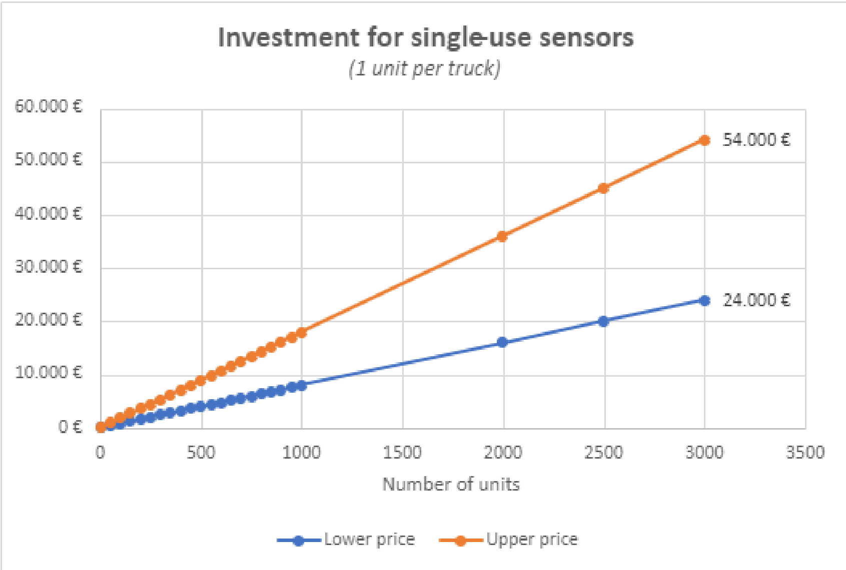
The journey to implementing Blockchain technology can take various forms, each with its own set of costs. Each organization will take a different route than the next, meaning that the expenses of implementing Blockchain are not precisely fixed expenses.

Sensors

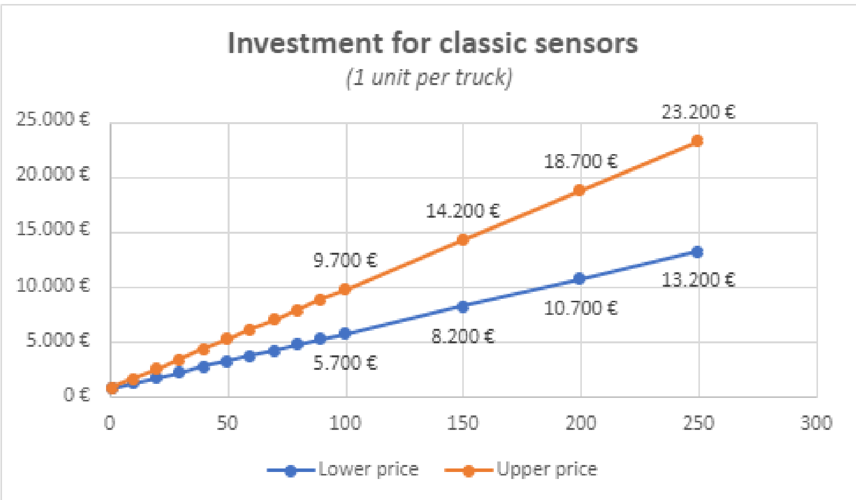
For sensor technology, we take parameters as follows,

- Per day, the number of trucks is 4, and travel/truck is 2.
- The number of travels per day is 8, in a week is 56, in a Month is 224, and in a year is 2920.
- The number of sensors per trucks is one.

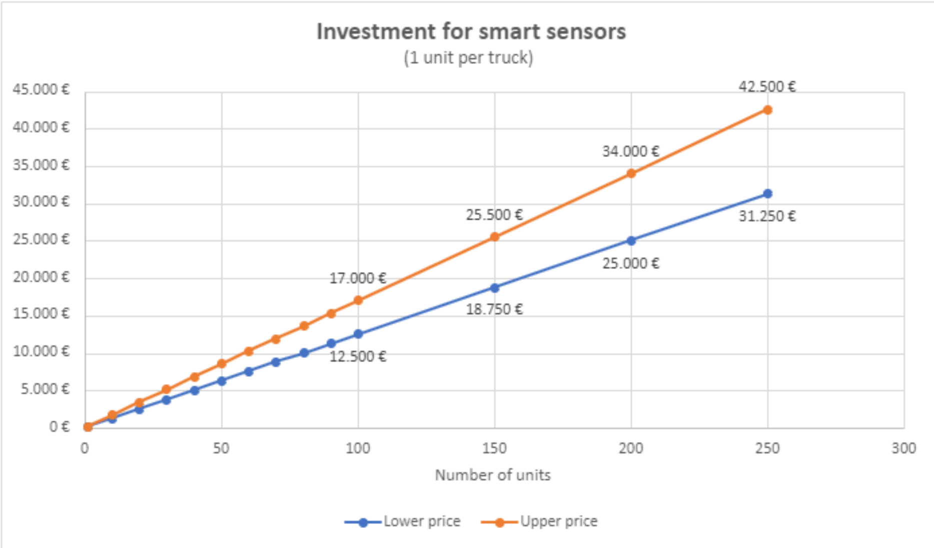
In this study, three kinds of sensors were evaluated, and their cost is estimated.



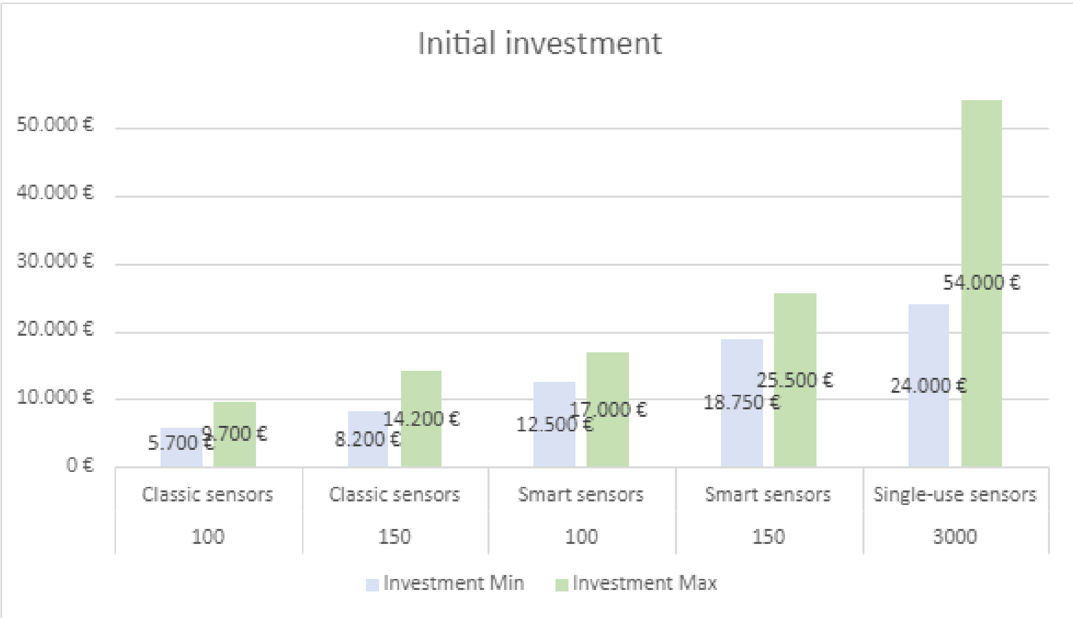
*Lower price/unit: €8 Upper price/unit: €18



* Lower price/unit: €50 Upper price/unit: €90



* Lower price/unit: €125   Upper price/unit: €170



*Classic and Smart sensors based on 100 and 150 units, while Single-use sensors 3000.

Analysis

To understand the financial benefits of blockchain technology for LWM, the return on investment will be calculated. The following factors will consider ROI calculations to comprehend the blockchain influence on LWM's existing market. These factors are:

- **The market growth**: The market growth forecast for the potato production industry is, according to the organization "Mondor Intelligence" (Mondor Intelligence, 2016), to be around 1% per year from 2016 until 2026;

- **The revenue of LWM**: The total revenue of LWM in the year 2020 was around 693 million euros, a 16% decrease compared to the year before due to Covid-19 (Kloosterman, 2020);
- **Cost-saving through BCT**: The cost savings through BCT would be around 12% per year in the logistic sector annually according to Blockchain and IT experts (Pals, 2019). However, in the case of LWM, the cost-saving through BCT will be around 5%.

Having formulated the main factors to calculate the ROI of BCT, a few assumptions need to be added as well. Eventually, it will be up to the organization to determine how it wants to allocate its finances. However, in the following situation, the next assumptions for LWM are made:

- The profit of the margin amounts to 3% of the overall revenue.
- An investment budget of 1% annual profit will be released for the implementation of BCT.
    - An estimated €12,500 per month (€12.500 x 12) will be considered for Maintenance and other extra costs. That will directly be subtracted from the investment budget.

The cost for maintenance p.m. will be slightly lower during the implementation than during development. (Farax, Thesis Blockchain Application in Cold Chain Logistics, 2021)

Year	Revenue(31-12)	Markt Growth	C.S. % through BCT	Profit Margin	Investment budget	Annual costs	Investment Cum.
2020	€ 693.000.000,00	-16%	0%	€ 20.790.000,00	€ 57.900,00	€ 150.000,00	€ 57.900,00
2021	€ 582.120.000,00	1%	0%	€ 17.463.600,00	€ 24.636,00	€ 150.000,00	€ 82.536,00
2022	€ 587.941.200,00	1%	0%	€ 17.638.236,00	€ 26.382,36	€ 150.000,00	€ 108.918,36
2023	€ 593.820.612,00	1%	0%	€ 17.814.618,36	€ 28.146,18	€ 150.000,00	€ 137.064,54
2024	€ 629.449.848,72	1%	5%	€ 18.883.495,46	€ 38.834,95	€ 150.000,00	**€ 175.899,50**

Total return on investment period is approximately **four Years**

Having established the return of investment of BCT for LWM in the visual above. It can be concluded that the return-on-investment period will take approximately **four years**.

Conclusion

After establishing the implementation plan, it can be estimated that the project will have a duration of two years, with one year dedicated to platform implementation. Communication must be direct and effective at the same time to avoid setbacks and misunderstandings.

Estimate calculations demonstrated that the application of Blockchain in the supply chain of LMW proves to be a real benefit with realistic assumptions. With these strong assumptions, the cost savings could be more financially sustainable in the future. The ROI period is also relatively short compared to other expensive assets, which take more than 10 years of investment returns.

Conclusion

When it comes to innovation, verification, and automation, Blockchain is critical. On the other hand, a database is more valuable in terms of utility, speed, and accuracy. Because we want to have concrete verification of temperature data, Blockchain is a good fit for us. In general, Blockchain can provide answers to concerns like logistical transparency and security. However, there are significant challenges that companies must evaluate due to a lack of maturity. Based on our findings, we recommend that businesses conduct a proof of concept to determine all elements and obtain more concrete answers for the technical feasibility study. Combined with smart sensors, the solution able to support and facilitate the process in case of growth. After this proof of concept, they can put it to the test to see what kinds of hazards become a reality. They can see potential extra dangers in this way before expanding the project.

The transparency brought by the Blockchain and smart sensors will be tangible and unchangeable proof for dispute management. This combination would bring some fluidity to the process and be a basis for continuous improvement. By extension, it can help to realize savings. However, for the moment, these gains are not measurable and can be discussed. So, the feasibility study will depend on the measurements and results we will be able to find with a concrete experiment and studies on the technologies used, with a precondition of precision of the needs for the stakeholders to access these technologies.

At the end of this analysis, we could do estimations of blockchain technology cost. It is hard to determine an exact, precise price for Blockchain. It depends on so many parameters such as app features, complexity, type of Blockchain, Blockchain platform etc. According to these parameters, we estimate the close prices. Even including sensors price, implementation of Blockchain technology does not expensive as it seems. Investment return is relatively short compared to other expensive assets such as machines that can take 10-20 years to have the investment return. Finally, the application of Blockchain seems good and fast to gain revenue potential.

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Appendix

Appendix I: Spark! Living Lab Interview with Andrea Auria- Expert in Blockchain- May 2021

General questions:

What is your personal experience with blockchain coding?

I developed my master thesis in an Italian consultancy company where I could develop hands-on experience with Ethereum, Hyperledger Sawtooth Seth, and Algorand, and I'm currently working with Corda within TNO.

Is it your first project of such a scale?

No, within TNO, I'm working on another blockchain project related to logistics (FEDeRATED).

How will the experience of your team impact the project? What are the risks?

If you mean "your TNO team": I don't see risks related to our internal team, we have all the expertise we need, and we are on-point enough to learn by ourselves where we lack. Besides my personal experience, we can count on colleagues like Erik de Graaf (my counterpart on the Blockcert use-case) with nearly five years of Blockchain coding experience – which is a lot, given that the first Blockchain (Bitcoin) went online in 2009 – as well as others highly skilled scientists.

If you mean "your Windesheim students team": The risks are related both to the team skills and knowledge and to my role within the team. In the past semester, students had problems in delivering a full PoC or setting up a network because they were lacking coding experience – I mean it in a non-judgmental way: blockchain coding isn't easy, and it takes time to understand all the implications and trade-offs.

Up to this semester, I had a "side" role as a technical consultant, so I'm helping students to make their decisions, but I'm not actively writing code or forcing a development direction.

The main risk is that students may not be able to deliver on time because technologies out there are still young and, sometimes, bugged and not ready to be used. During this semester, it has been clarified that I'll have a role as technical lead, which will make me able to better steer the project. This way I'll be able to act more directly on the code and will mitigate possible risks students-related.

That being said, I want to stress that for this semester, students are performing well, being successful both in general and also where previous teams weren't.

What is your perception of the project? Under which point of view?

My general perception of Spark is that it addresses a very relevant topic, and by focusing on Blockchain in logistics it is very “on point” with respect to current research – Blockchain is the main technology considered for supply chain visibility.

As for CG, I see it as a nice playground to show not only the capabilities of Blockchain and the possibilities that it opens, but also as an opportunity to push further possible integrations with IoT, experiment with that, and learn.

How can you make the project real (roughly)?

The hardest barrier is the one of companies accepting to share their sensitive data. This is why at TNO we are developing on Corda, because it offers a fairly high degree of privacy, despite being a DLT. Companies will have to change a bit their mindset and understand the value of sharing, the value of decentralization, and of automated contracts.

<u>About blockchain technology:</u>

We will use sensors to measure the temperature and Blockchain to manage the Data:

- How will you make the connection between these two technologies? How will they work together?

A blockchain protocol must run on top of the internet, so in an ideal scenario, each sensor should be part of an IoT device which sends data autonomously over the internet.

Depending on how flexible the device is, architecture data (aka a transaction) can be sent to a specific hardcoded node or a random node selected after network mapping via some routing algorithm.

- What will be the role of the coding spark team on the Blockchain? What will be your process exactly?

When you want to develop a decentralized application (on Blockchain), the first choice you must make is whether you want to use a public or a private blockchain. For this use-case a private blockchain is the most suitable solution.

The main design/activities to take care are:

- Network Design and configuration
- Coding of the smart contracts (the back-end of the application)
- Coding of the client (UI, or a webpage, for instance) And for our use-case:
- Set-up of IoT device (design/choice/coding)

The first two goes hand in hand because they may easily affect each other. The design of the network is the part where you choose who is going to run a node, and you define roles (and all the technical activities related to the actual configuration and server management). The smart contract is where you code the actual application behavior, you define and code what data looks like (the data model) and the functions that one can use to interact with such data.

For our use case, there are additional tasks to carry on because we want the system to be as autonomous as possible, hence we foresee the use of IoT devices that automatically send data to the Blockchain – such devices must be designed (or chosen) and programmed.

- If we use the platform Hyperledger Fabric, why are your coding skills necessary?

Whether my coding skills are *necessary* or not will mostly depend on students' skills :D I haven't coded chaincode in Fabric, but I have general experience in coding smart contracts on different platforms and languages. What I think is the most valuable contribution from my side, more than practical coding, is an overall lead on decision making, because I have a good overview of blockchain technologies, and I've already faced some of the trade-offs that need to be managed. Ideally, it shouldn't be necessary for me to put my hands on the code, but I will still perform code reviews and protect code quality.

What is the best combination (sensor + Blockchain) for this project of supply 4.0 and why?

I can't answer for the sensor as I'm not an expert on that side, but I can draw rough guidelines (it must be able to send data over the internet, there must be a way to effectively power it, it should be programmable…).

We, as TNO, suggested Corda as the blockchain platform, because it offers a higher degree of customization in terms of privacy design, however the students preferred to go for Hyperledger Fabric for this semester, which is an equally legitimate choice, as long as you are aware of the trade-offs.

***Some sensors are delivered with an application of tracking for measurement.* If it's possible for all stakeholders to have access to this kind of app, why use Blockchain?**

Platforms like that work with a central database. The main reason why you want to use

Blockchain is that you don't want to have data in one place, and you want everyone to be able to control data integrity – normally because different parties don't trust each other. You can't do this if the database is someone else's.

What are the risks of using Blockchain?

I wouldn't call them "risks", I would say there are trade-offs. The more you stay on the "private database" side, the more privacy you have, but also the less transparency and decentralization. Conversely, the more you stay on the "blockchain" side, the more

transparency and decentralization (and control, and immutability) you have, but you must give up some privacy. You can read something about this trade-off on spark blog.

A non-technological risk is that companies would be afraid of showing too much of their data and will be reluctant to join the network.

About code production:

On what type of machine? With what type of coding?

The only thing you need is administration rights on your laptop.

The programming language depends on the Blockchain you're using, for Fabric it can be Go, Javascript and some others, for Corda is Kotlin and Java, for Ethereum is mostly Solidity.

What do we need? What does it require to produce (software, hardware, engine, condition, room, specifies, people, (by extension) money, …?)

I cannot answer properly to this; everything varies a lot depending on the project and outcome desired, and even when you know that exactly it's hard to make estimations.

How will be the control checking? (Who, when)

If you mean the "maintenance" after being gone into production, I would dare to say that's a never-ending process, especially considering that some applications will need to be upgraded throughout time.

In a scenario where a consortium runs a private blockchain and every party runs a node, each party is responsible for its own node functioning.

If you mean "code quality" it depends: for the CG use-case in this semester I'm performing reviews on students' code and providing feedback. Internally at TNO, depending on the project and skills, we may make reviews on each other's code, or we may have a lead scientist checking it.

Installation of Blockchain:

Do you need to get investment from the companies or any support from the government to install the Blockchain?

For a Proof of Concept: maybe. For real use: yes.

What will be the process of installation in the stakeholders' process?

This depends on the technology used, in Corda for instance, the software of the node is a java application. Each party running one (or more) node(s) needs to set up the server to make the java application run. Conversely, for public blockchains like Ethereum, the infrastructure is "already out there", and you might even not need to set up a server to make the infrastructure work – more likely, backend functions will be extremely reduced because the main logic will be running in the smart contract.

Who will install the technology? (Student? Technicians? others…)

Within the spark project we are developing proof-of-concepts, students collaborate and contribute to that. Of course, the actual set-up and configuration of nodes will be the responsibility of those hosting them – likely: companies and their (or outsourced) technicians.

What material will need stakeholders to get for the installation? What will they have to invest in?

Servers, their Maintenance and management.

Will they need specific software?

Most of the blockchain software and platforms are open source, although some organizations (like R3 with Corda) offer a paid version with enhanced features.

<u>Data management:</u>

How will be trackability assured during the transition?

Most companies (especially SMEs) don't actually have any reliable, real-time tracking system, so there won't be any overlap. For those that have one, *I think* that they'll want to keep the two systems alive at the same time, and after confirming that there aren't discrepancies and the tracking works fine, they'll just shut down old systems.

<u>Maintenance:</u>

After the installation of Blockchain in the process, will it need Maintenance? (on software, sensors ?)

In addition to what I've already said above: of course, also sensor can get damaged and would need to be replaced and/or reprogrammed to account for upgrades.

Which frequency of Maintenance? By whom? How?

It's hard to say; it's not like a car that you know already that you need to make a check-up every N years. The Maintenance of a server is a continuous process.

Which software are used to improve the system?

Not sure what's the focus of this question. What do you mean by "improve the system"? If it's "making upgrades to smart contracts" then the framework is the same you use to design and code the system (Corda, Hyperledger Fabric, etc.). If you're referring to monitoring software, then it depends on the platform and what you exactly want to monitor – for instance: if you want to monitor transactions and your platform is Corda, you can use the Corda Node Explorer.

What are the steps of the project (from your point of view) and what do they consist in?

For the development of the Proof of Concept I would say (roughly):

- Coding and testing in dev environment
- Creating a simulation network
- Real-world testing

How many hours/time of training will be required by the stakeholders employees to use the product/technology? (to have an idea of the accessibility of the end product)

If you're referring to supply chain visibility, then it's just about using a website and know where things are, not that big of a challenge, I'd say. End users don't need to know/understand the underlying functioning.

Developing the skills for the technicians who'll have to take care of the monitoring and Maintenance while in production (and upgrades) will definitely be more demanding – but I can't come up with a number.

Appendix II: Comparison between sensors

Type of sensors	Advantage	Inconvenient
Single-use data lodger	- Not sensible to faraday effect and can be used in planes - No external power needed - Credit card size - No reverse flow	- Data more or less manageable depending on the model - Price each year equivalent to 100 smart sensors - More polluting solution
Classical sensor	- Less expensive solution	- Less trustworthy for the lower model - No real solution for faraday effect because no memory - Need of multiple external devices - Reverse logistic
Smart sensors	- Multi-sensing - More accurate and quicker - Can make decision - Remote control - Automatic communication - Automatic maintenance - Cost-effective - Easy to install and connect - Less ecologic impact - Less energy used - Computing can compensate Faraday effect	- Price 2 times higher than classical sensors - Reverse logistic