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Blockchain in Logistics and Supply Chain: A Lean Approach for Designing Real-World Use Cases

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ABSTRACT The Blockchain technology can be defined as a distributed ledger database for recording transactions between parties verifiably and permanently. Blockchain emerged as a leading technology layer for financial applications. Nevertheless, in the past years, the attention of researchers and practitioners moved to the application of the Blockchain technologies to other domains. Recently, it represents the backbone of a new digital supply chain. Thanks to its capability of ensuring data immutability and public accessibility of data streams, Blockchain can increase the efficiency, reliability, and transparency of the overall supply chain, and optimize the inbound processes. The literature concerning Blockchain in non-financial applications mainly focused on the technological part and the Business Process Modeling, lacking in terms of standard methodology for designing a strategy to develop and validate the overall Blockchain solution and integrate it in the Business Strategy. Thus, this paper aims to overcome this lack. First, we integrate the current literature filling the lack concerning the digital strategy, creating a standard methodology to design Blockchain technology use cases, which are not related to finance applications. Second, we present the results of a use case in the fresh food delivery, showing the critical aspects of implementing a Blockchain solution. Moreover, the paper discusses how the Blockchain will help in reducing the logistics costs and in optimizing the operations and the research challenges.

INDEX TERMS Blockchain, hyperledger, supply chain.

I. INTRODUCTION

Blockchain emerged as a leading technology layer for financial applications. Nevertheless, in the past years, the attention of researchers and practitioners moved to the application of the Blockchain technologies to other domains [14], [15]. In this context, Supply Chain and Logistics are the topics paying more attention to the Blockchain, with the creation of several startups [38] and the introduction of the Blockchain in the agenda of countries and companies [1], [13].

The Blockchain is a disruptive innovation, due to its capability of ensuring data immutability and public accessibility of data streams. Moreover, its decentralized and distributed infrastructure prevents the problems of the present centralized approaches, including trust issues, such as fraud, corruption, tampering and falsify information, and their limited resiliency. Centralized systems are vulnerable to collapse since a single point of breakdown might lead the whole system to be crashed. However, since this technology is still in its early stages, it presents some inherent defects and its deployment in factual Supply Chain and Logistics applications is somehow problematic. In particular, there is a general lack in the literature of Blockchain. To the best of our knowledge, just a few papers deal with non-finance implementations.

The literature mainly considers the Business Process Modelling and the Technology Design Process of a Blockchain-based solution [7], [8], [12], [22], [24], [35]. In particular, Weber *et al.* [37] proposed a Blockchain solution for solving the problem of lack of trust in collaborative processes. The authors focused their attention on the representation of the Business Process Model and Notation. The prototype, implemented through Ethereum for the Blockchain infrastructure and Solidity for the Smart Contracts, was validated by applying it to business processes taken from the literature. Guerreiro *et al.* [17] focused on the Business Process Modelling, presenting a meta-model for executing secure business transactions using Blockchain and an Enterprise Operating System. They intended to solve the security risks involved in business transactions executions increasing trust, authenticity, robustness, and traceability against fraud.

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More recently, considerable attention was devoted to applications of the Blockchain to the agriculture and fresh food. The reason is the importance, in these applications, of trust and immutability of the data, the interaction of several actors, and the costs due to the need of creating documentation for the different regulations and to specific accidents, as food contamination. Leng *et al.* [21] proposed a public Blockchain of the agricultural supply chain system based on double chain architecture to enhance the efficiency of Blockchain in the agricultural supply chain. They showed that their solution provides adaptive rent-seeking and matching mechanism for public service platform. It guarantees the transparency and security of transaction information and privacy of enterprise information. Moreover, it can improve the public service platform and the overall efficiency of the system. The main drawbacks come from the size of the underlying Blockchain network and the related performance issues. Moreover, the system is just simulated, and further work should be done to obtain a running application. Mao *et al.* [23] proposed a Blockchain-based credit evaluation system to strengthen the effectiveness of supervision and management in the food supply chain. In particular, they gather credit evaluation text from traders by smart contracts on the Blockchain. Then the text is analyzed by a deep learning method named Long Short Term Memory (LSTM). They show the effectiveness of their method, but they do not consider the overall system costs and benefits explicitly.

As above mentioned, these frameworks lack in terms of standard methodology to design, develop and validate the overall Blockchain solution at the Strategic level. In particular, there is limited evidence of the value for the actors, the overall costs and benefits, preventing the development of real cases. The consequence is that, as highlighted in [11], there are very few Blockchain projects with high longevity. Only the 8% of projects are actively maintained, while the remaining part fails. Linking the Strategic level, and the digital strategy in particular, with the Business Process Modeling and the Technology Design Process is crucial, being the key action to move from the pioneering phase of the Blockchain to a more mature exploitation phase.

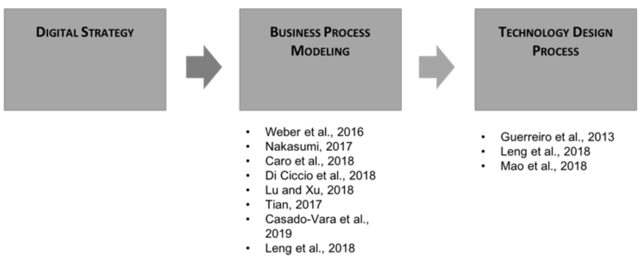

FIGURE 1. Phases of a Blockchain project definition and coverage by the literature.

To our vision, the Business Process Modeling and the Technology Design Process phases must be preceded by the definition of a proper digital strategy (Fig. 1). In this step, the main actors, their roles, as well as the financial and operational goals and Key Performance Indicators (KPIs) are defined. Moreover, the Business Processes, the information migrating to the Blockchain and the characteristics of the Blockchain in use are designed too.

To the best of our knowledge, this phase is not addressed in the literature. Thus, this paper contributes to the literature along two axes. First, it integrates the other contributions, while proposing a standard and repeatable methodology to address the digital strategy design in Blockchain projects. Second, we discuss the results of a use case in the fresh food delivery, showing the critical aspects of implementing a Blockchain solution. The paper will discuss how the Blockchain will help in reducing the logistics costs and in optimizing the operations, its recent applications, and the research challenges [6], [35]. An essential aspect of the novelty of this paper is that, on the contrary of other contributions based on simulations, our analysis refers to a Blockchain solution that has been really implemented.

II. BLOCKCHAIN AND LOGISTICS: A POSSIBLE MARRIAGE

If Supply Chain Management is an integrating function with primary responsibility for linking business functions within and across companies into a cohesive and high-performing business model, Logistics is considered by the different actors as the "reason to be" of each firm belonging to a supply chain [32]. Without logistics, no raw material can be extracted, transformed and delivered to the final user [9] and [16]. Logistics is evolving rapidly in the past decade, thanks to the introduction of new management frameworks, as the Physical Internet and Industry 4.0, and new technologies, mainly ICT-based, as the Internet of Things (IoT), Business Analytics, Artificial Intelligence, and Blockchain companies [1]. The Blockchain is one of the most promising technologies in Logistics Management and Optimization, thanks to some intrinsic characteristics, as data integrity and decentralized operations. But how to incorporate a Blockchain in a real Logistic system, and how and when this marriage might be fruitful are still open questions [9]. In the following, we give a quick depiction of the requirements of a modern Supply Chain, the characteristics attributed to a Blockchain system and finally, we discuss the issues related to the scalability and the costs of the technology itself.

A. BLOCKCHAIN CHARACTERISTICS

Blockchain can be viewed as a decentralized database in which information can be stored, and that is particularly adaptable to deal with the transaction of assets. However, it is based on important pillars that make it different from a simple database and one of the leading emerging technologies.

From a system design standpoint, the key characteristics of the Blockchain are the following:

- Open distributed ledger. The Blockchain is designed to be decentralized. Thus, the database is distributed, and copies of all information are shared among the participants. They can validate this information without the need for a centralized authority. If a transaction is changed, a new block is created and chained to the previous blocks. Ledger data between nodes of the Blockchain network are matched at random intervals [19]. This randomly matching is what makes this technology secure from hackers, as there is no bank information or identities of the parties and the data is public in real-time. The decentralization combined with the real-time updating of information make Blockchain good in networks involving different organizations. Indeed, its adoption is encouraged in Supply Chain applications.

- Rules to share data. Participants govern the Blockchain. They agreed in advance the types of transaction, which are stored in the chain as smart contracts.
- Few intermediary third parties. A traditional business transaction involves two parts: a public ledger entry about the transaction and private messages between the parties involved about identities, security keys for transactions and location [19]. The combination of these two parts and the decentralization of the system accessible to anyone who validates makes it possible to avoid the intermediary trusted third party (i.e., banks, exchanges, brokerage firms or price reporting agencies), executing a transaction with limited cost and time, and in a secure way.
- Consensus-based and trustiness. As above mentioned, participants independently validate a transaction. Due to the decentralized storage and the presence of more than one copy of the database, participants have to agree by consensus, on the source of truth and thus validate the transaction. The consensus mechanism allows avoiding that mistakes or fraudulent actions could affect the database.
- Cryptographically sealed and Immutability of data. One of the most important pillars of Blockchain is the cryptography. In fact, cryptographic technologies (e.g., the Secure Hash Algorithm SHA-256) are needed for the digital signatures and data integrity, avoiding the manipulation of a block, once the transaction has been validated and recorded. This cryptographic mechanism makes data stored in the Blockchain immutable and unique.
- Time-stamped and Chronological blocks. As its name suggests, Blockchain is composed of chronologically-linked blocks. They let a user create analytics based on dynamic data.

For these reasons, in recent years Blockchain has been applied in different fields, and in particular in the public sector, with focus on the identification of the drivers of costs and benefits [3]. Through the collection and the analysis of data from nine diversified Blockchain implementation, this paper highlights the need to provide insights, based on empirical evidence, on the economic constraints and effects of Blockchain implementation in the public sector.

The need to analyze the benefits of the application of Blockchain to enable government services, focusing on the security implications of the adoption of distributed ledger technologies, arises in [2] and [25]. In these papers, different use cases were examined concerning economic and social benefits. In particular, the study highlights how Blockchain can overcome the security challenges in IoT, such as the identification and trust management of the different devices, the information tracking, the authentication and access control, and the accountability in IoT based applications.

The literature review highlights the lack of publications based on the analysis of use cases in the logistics field. Moreover, there is also a gap of the literature on the methodology to build realistic use cases.

B. OPPORTUNITIES IN LOGISTICS

Defining a modern Logistic system is a hard task due to the high interconnection of the different actors in the system and the availability of different technologic frameworks (City Logistics, Physical Internet, Cyber-physical systems).

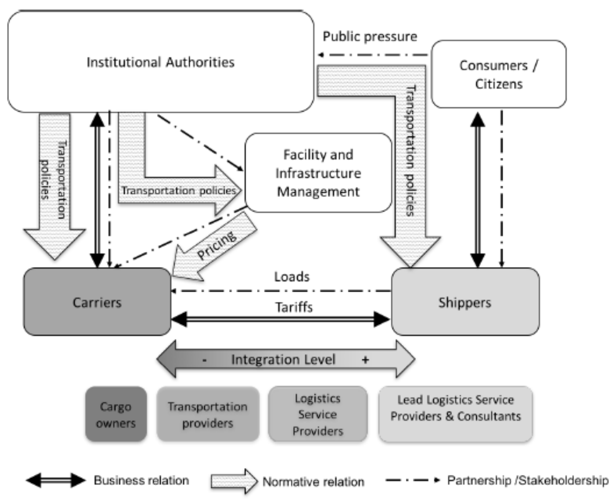

FIGURE 2. A logistic system as a network of actors (Crainic et al., 2018).

Crainic *et al.* [9] present a possible model, where the logistic system is defined in terms of a multi-actor system (see Fig. 2 for a depiction). In details, the figure illustrates this situation and complexity through the Social Business Network (SBN). The SBN represents a complex system in a standard visual manner and is part of the GUEST methodology [30], [36]. The SBN is a graph composed of nodes and arcs. The nodes represent players grouped by type, while the arcs symbolize the relationships between nodes, and their graphical representation is based on their type (i.e., commercial, normative, or stakeholdership). The graph clarifies that a logistic system has an additional level of complexity due to the correlations between the actors. Moreover, this level of complexity is just one of many that come from examining the system from various points of view, including the presence of multiple objectives (e.g., performance-based, economic, environmental, or social) and of different levels of decision making (e.g., real-time, operational, tactical, or strategic).

Thus, logistics and (specifically Intermodal) transportation are complicated systems. This complexity involves several challenges within the following topics:

- City Logistics is the process for entirely optimizing the logistics and transport activities in urban areas while considering the traffic environment, congestion and energy consumption within the framework of a market economy [29], [34].
- Synchromodality is the 5th pathway of ALICE roadmap. It involves a step change from the current system, towards the ultimate vision of the Physical Internet, by synchronizing intermodal services between modes and with shippers [28].
- Physical Internet is an open global logistics system founded on physical, digital, and operational inter-connectivity, through encapsulation, interfaces, and protocols [26].

All these challenges have a common need: the benefits come from the network effect, and this can be obtained only with a proper sharing of the information. On the other side, the data sharing must be secured, distributed (e.g., for optimizing the subsystems locally) and with some automated actions related to the different regulations and negotiations. Thus, Blockchain appears as a natural technology for implementing these common issues. Presently, the main limits are the issues related to the scalability and the costs of the Blockchain and the few use cases with clear costs/benefits analysis.

C. SCALABILITY AND COSTS

In the present, an open question concerns the scalability, which refers to the limits on the amount of transaction that the Blockchain network can manage. The co-founder of Ethereum (i.e., one of the most widely used cryptocurrencies with Bitcoin) coined the term "scalability trilemma" to indicate the difficulty of combine decentralization, scalability, and security. He stated that Blockchain systems could have at most two of these three properties. According to this trilemma, public Blockchains (i.e., anyone can participate), such as Bitcoin and Ethereum, are designed to be decentralized and secure, compromising their scalability. They can achieve only 7 and 15 transactions per second as maximum throughput, respectively [4], [31].

Private or enterprise Blockchain systems (i.e., permissioned Blockchain governed by a restricted group of users), such as Quorum and Hyperledger Fabric, claim a higher number of transactions per second. Quorum stated that tests had demonstrated throughput of dozens to hundreds of transactions per second depending on system configuration [5]. Hyperledger Fabric claims 3500 transactions per second, while IOTA supports 180 transactions per second, with the aim to arrive at 1600 for the end of 2018. Comparing Blockchain performances with those of the mainstream payment processor as Visa credit card that processes 2000 transactions per second on average and a pick rate of 56000 transactions per second, a gap in term of scalability exists [10]. In particular, public Blockchains are far from usable in finance, while with less decentralization, the performance and scalability of enterprise Blockchains, particularly Hyperledger Fabric are more adaptable to be used [31]. However, private Blockchains have different properties and mechanisms not sustainable, wasting a considerable amount of energy [33].

In the remaining part of this paper, we discuss another challenging issue concerning the costs of Blockchain technology. Although different contributions state that Blockchain could dramatically reduce the cost of transactions [18], this technology implies a relevant amount of set-up costs, especially for small-medium sized enterprises.

III. DESIGN METHODOLOGY

The GUEST methodology [30], [36], used in this paper for the use case design, has been developed by a pool of researchers from the Politecnico di Torino. GUEST aims to provide companies with an innovative framework for business management. The aim is to provide an easy-to-understand methodology, applicable to the entire decision-making process, to increase efficiency and improve quality for the companies. The GUEST methodology controls the process, from the original idea to its implementation, providing conceptual and practical tools to the different actors involved, enabling them to communicate their vision, difficulties, and opportunities within the same structure. The methodology is articulated in five steps (GO, UNIFORM, EVALUATE, SOLVE, and TEST), and each step allows the actors to monitor their projects and, at the same time, grants the standardization of documents and tools that should be used to evaluate ideas, successes, actions, and results.

In order to correctly apply the methodology, the first step is to define the different actors involved in the process, identifying for each actor the jobs (what are they trying to achieve in their work), the gains (the concrete benefits that they are seeking), and the pains (problems connected with their work).

Once the jobs, gains, and pains for each actor have been collected, it is possible to prioritize them to highlight the more important or urgent ones, and visualize them through the Value Ring, a graphical tool able to show quickly and immediately the real needs of the actors. The Solution Canvas, an analytical tool used in the GUEST methodology with the intention of outlining the chosen solution to apply it, will address these needs. The Solution Canvas is divided into nine sections:

- **Decision makers**: who makes the decisions listed in the proposed solution, their hierarchy and, if possible, the timing.
- **Constraints**: actions necessary to implement the solution, how they will be carried, their target and the possible technological constraints.
- **Decisions**: decisions taken, specifying their characteristics, priority, and methods for the implementation.
- **Information & Resources**: sources of the information that led to the solution chosen, also specifying the level of detail of the information available and the level of uncertainty.

- **Users/Decision makers relationships**: relations between those who took the decisions and who will make use of them.
- **Users**: actors involved in the solution, those who will benefit from the solution implemented. It is essential to engage the final users in the process, in order to avoid dangerous phenomena of resistance at the corporate level.
- **Channels**: channels through which actors will be informed of the change due to the proposed solution, and the channels through which the solution will be implemented.
- **Goals/Objectives**: objectives to be achieved through the implementation of the solution, defined by Key Performance Indicators (KPIs) identified in the previous Evaluate phase.
- **Costs:** list of the set-up costs to implement the proposed solution and its maintenance costs. Furthermore, this section considers also the negative impact that the company would incur not implementing the proposed solution.

IV. FRESH FOOD USE CASE

In this section, we apply the GUEST methodology to design the use case related to an e-commerce food retailer located in Europe. In particular, in Subsection A, we present the company and the as-is process with the focus on the inbound operations. Then, in Subsection B we discuss the main steps of the methodology, applied to our case. First, we define the actors and the value proposition that a Blockchain-based solution could offer to them. Then, we depict the solution canvas. Finally, we present the solution from a technological viewpoint.

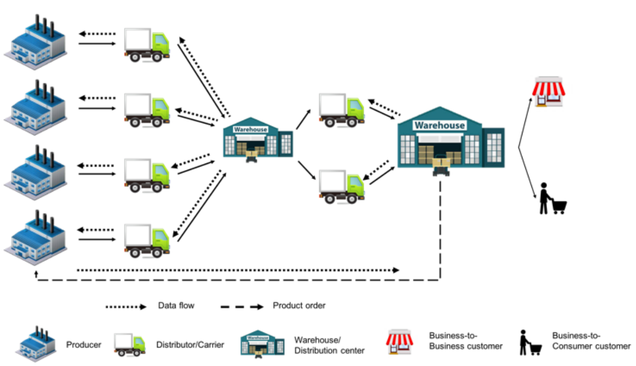

FIGURE 3. Inbound supply chain process.

A. THE COMPANY AND AS-IS PROCESS

The use case refers to an e-commerce food retailer located in Europe (10 warehouses and 3 distribution centers), with suppliers situated worldwide. Suppliers can deliver either at a cross-docking center or directly at selected warehouses, and a specific carrier is contracted by the retailer to ensure deliveries from the cross-docking center to the warehouses and from warehouse to warehouse for inventory balancing and out-of-stock emergencies. Fig. 3 shows the simplified structure of the supply chain, highlighting both the flows of physical goods and data.

Inbound operations begin with the Product Order (PO) confirmation. The POs can be regular or urgent based on the in-stock situation and forecast accuracy. Once the supplier confirms the PO, regarding quantities and delivery date, either supplier-owned transportation or third-party carriers are in charge of picking up the truckload. Based on the PO request and the agreements between supplier and retailer, a destination warehouse or distribution center is selected for the delivery. An Advanced Shipment Notice (ASN) is then created, which is an Electronic Data Interchange (EDI) document containing details on the delivery. Thanks to the ASN, the receiving warehouse should have visibility of the incoming goods as soon as the delivery is planned. The retailer's warehouses are quite small and only have from 2 to 5 dock doors for truck unloading, so the carriers must request and book a time slot for delivery. Once the booking is confirmed, the carrier can plan its delivery to the distribution center or warehouse.

When the truck arrives at the warehouse, inbound physical operations take place: unloading, scanning shipment barcodes, the signature of the Bill of Lading and shipping documents, placing the load on the inbound dock. The inbound operations are considered as finished when the operators scan the delivered product. This process can be furtherly optimized considering potential drawbacks in the different steps, such as inaccurate quantity information, delays (caused by traffic, custom operations, weather conditions, etc.), wrong or inaccurate information about incoming goods.

B. USE CASE DESIGN

The following subsections outline how the different steps of the GUEST methodology described in Section III have been applied to the use case of the e-commerce food retailer.

1) ACTORS

The first step is devoted to identifying the main actors involved in the process, their jobs, gains and pains, and the value proposition in terms of the gain creators and pain relievers that the solution based on the Blockchain technology could offer.

In particular, as highlighted in the Fig. 3, we identify the following key players:

- Producer, who represents the supplier of the product.
- Warehouse manager of the e-commerce food retailer and intermediary facilities. It is responsible for all the aspects related to the supply chains and manages the warehouses and inventory levels at all the concerned facilities, and packaging issues.
- Distributor/carrier. It is in charge of the transportation and logistics activities along the entire chain. In particular, it ensures deliveries from the cross-docking center to the warehouses and from a warehouse to another for inventory balancing and out-of-stock emergency.
- Final user. The two main customer segments of the e-commerce retail are the Business-to-Business

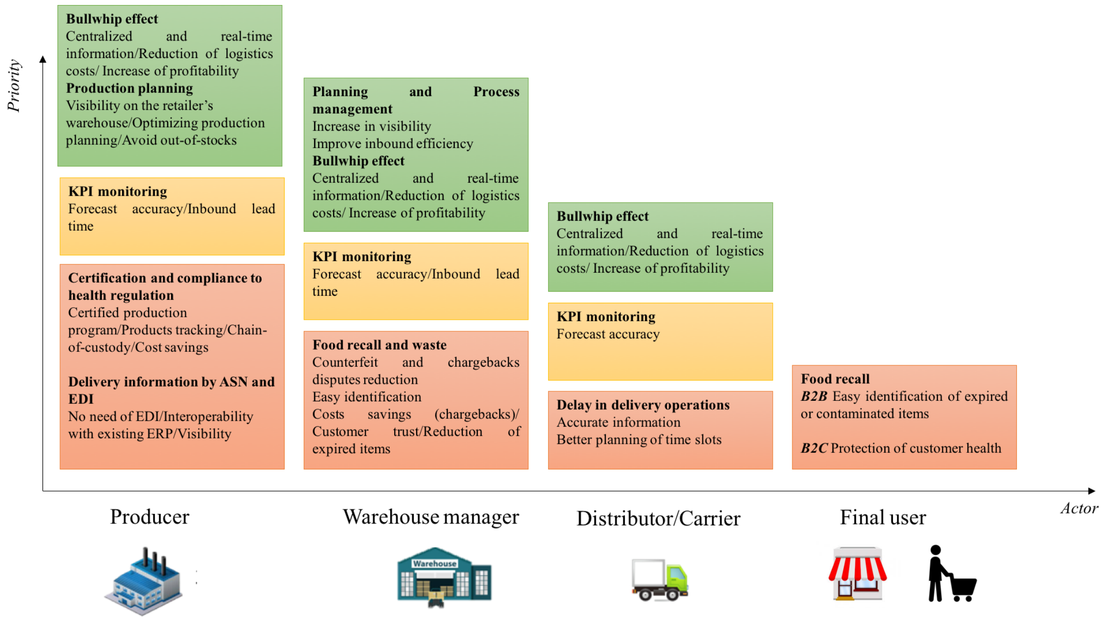

FIGURE 4. Value Ring.

represented by retailers, food store, and the Hotel/ Resturant/Cafè (HoReCa) companies, and finally, the Business-to-Consumer that includes the individual final user of the product.

Fig. 4 shows the Value Ring (that for the convenience of the reader we illustrated as a chart with two axes) and depicts the value proposition that the adoption of the Blockchain technology could offer to the above-listed actors.

In particular, in the horizontal axis, these actors are ordered according to their importance to the chain, while the vertical axis describes the priority of each gain creator or pain reliever.

The first actor that plays a central role in our use case is *the producer*. As described, the inbound process implies that the producer generates an ASN with the detailed information on the delivery to the receiving warehouse. Based on the technology the supplier uses, the receiving station will be able to receive information by scanning the ASN at a pallet level, since the pallet barcode contains Stock Keeping Unit (SKU) level details, or the pallet will have to be unpacked and each SKU will have to be scanned individually. However, small-sized producers might not use the EDI system and the information in the barcodes and ASNs might be inaccurate. Thus, from a technological standpoint, the Blockchain could guarantee the end-to-end integration, and transfer of information flow concerning items and batches, by providing interoperability within the existing systems and Enterprise Resource Planning (ERP) software.

One of the most critical issues that the producer has to face regards the certification of its product that given its relevance can be considered as a priority. Producers can request the certification and authentication of its product units, regarding the provenance and the compliance with the health regulations. Producers are thus in charge of creating unified batches of units and storing the information in digital format, generating the equivalent token. Moreover, the batches are tracked at the transformation nodes, where they are used as input for other products.

In a medium-term perspective, the inaccuracy of information regarding incoming goods affects the computation, evaluation, and monitoring of the Key Performance Indicators for both the producer, the warehouse management and the distribution/carrier companies. On the contrary, having visibility of the whole supply chain and avoiding to provide inaccurate or trustworthy information, could help to reduce the chances of human errors, counterfeits, while improving the forecast. As a consequence, the producer can optimize the production and planning processes, anticipating a situation of out-of-stock and reducing the bullwhip effect. It refers to the phenomenon of demand variability amplification as moving up in the supply chain, due to several factors as demand forecasting updating, order batching, price fluctuation, rationing and shortage gaming [20].

Higher inventory levels to increase protection against the bullwhip effect could be reduced, resulting in decreased total logistics costs and increased margins and profitability. The producers would benefit from the highest savings since its position upstream in the supply chain would mean higher bullwhip effect: thanks to greater visibility of the whole supply chain, this issue would be reduced. Although, the most visible decrease in demand standard deviation occurs for the producer, the warehouse manager, and distributor/carrier are also affected by the bullwhip effect reductions, but to a minor extent.

Concerning the *warehouse manager*, in doing its jobs that mainly consists on the planning and the management of inventory levels at all the facilities, detailed information about incoming goods are crucial for the capacity and labor planning. Thus, the adoption of the Blockchain technology could improve inbound efficiency regarding the optimization of planning decisions, thanks to the access to certified data and information, and the visibility of the whole supply chain and thus, on inbound processes and inventory status.

In a short-term perspective, one of the more critical pain for the e-commerce retailer is the fight against counterfeit and expired products (i.e., with exceeded sell-by or use-by date), or waste caused by not correct preservation or unsafe storage conditions (i.e., wrong packaging, wrong transportation conditions, late delivery at the retailer's warehouse). Indeed, one of the principal cause of food recalls in our context is the bacterial contamination due to unsanitary product handling and pest infestations.

All these issues compromise the selling of products, generating waste time in paperwork and cost due to the food recall campaign and the chargeback disputes regarding the responsibility of the conditions mentioned above. If a live tracking of the products is available, each participant would have access to the single version of the truth and chargebacks would be assigned to the responsible party, with no need for more extended investigations and exchange of unnecessary paperwork.

Thus, a certification system and the tracking of goods becomes necessary to ensure the compliance with health regulation and a fast response in case of a food recall. If the contamination occurs, for example, in some warehouses or trucks, it is possible to track and identify the batches of product and safely remove from the market only the affected ones.

Implementing a Blockchain-based solution is an opportunity for both producers and warehouse managers, in terms of fast actions that must be planned to prevent further contaminations, with quick recalls and costs savings. In fact, the costs related to the notifications, include the campaign to find the contaminated units, and the additional costs for chargeback disputes.

Using the Blockchain technology, in the medium and long-term, the *distributor/carrier* benefits from the reduction of the bullwhip effect and the forecast improvement, as above discussed. In the short run, the most critical aspect for the distributor/carrier is represented by the delays in delivery operations.

The distributor/carrier has to request a time slot for delivery batches in the warehouse. Once a time slot is booked, the distributor/carrier can plan its delivery to the distribution center or warehouse. However, traffic situation, customs operations, and unexpected weather conditions can lead to a delay in delivery operations and cause missed timeslot appointment, with delay costs and paperwork.

Details on incoming products and trusted real-time information are thus crucial for the planning of time slots and future adjustments regarding appointments in the warehouses when needed.

Finally, the most critical issue that affects the *final user* concerns the problem of bacterial contamination and food recall. However, the value proposition that Blockchain offers is different depending on the customer segment. Indeed, the Business-to-Business segment benefits from the easier identification and removal of unsafety or expired units and batches that such technology guarantees. While for the Business-to-Consumer the primary value proposition is represented by the health protection and the reduction of potential issues related to the contaminations.

2) SOLUTION CANVAS

This section is devoted to analyzing the solution canvas designed for our use case, and shown in Fig. 5.

The decision maker is represented by the e-commerce food chain retailer and specifically, its supply chain and warehouse management that should foster and promote the adoption of Blockchain technology.

The users of the Blockchain-based solution are the actors presented in the previous subsection and thus, the producer, warehouse managers, distributor/carrier, and final users. Besides, certifiers and auditors, which are the inspectors of standards can be considered as a user. They are interested in trusted data concerning the method of production and the provenience, to assign certification (e.g., organic or bio labels).

Regarding the relationships between the decision maker and the users, the warehouse managers interact with the producers to obtain detailed information, optimizing and planning the inbound flows. As above discussed, in this direction, the Blockchain could increase the visibility of the whole network of producers and warehouses on inbound processes and inventory status.

Moreover, the distributor/carrier interact with the warehouse managers to book the time slot, and delivery the incoming products collected from producers.

The solution could be implemented by means of a pilot project promoted by the e-commerce food retailer that selects a group of producers and distributors/carriers, which are willing to adopt the Blockchain technology. The pilot project represents an implementation and decision channel, as it allows to adopt the system on a smaller scale, to demonstrate the increase in visibility in inbound processes and the insight on forecasting future product orders, as well as reducing chargebacks and paperwork costs to confirm the return on investment.

Moreover, in addition to the digital security that Blockchain guarantees, a ''Consortium'' can be set up grouping some participating actors that have access to the data and trusted to read and write, with a combination of public and private keys.

The objectives of the adoption of the Blockchain technology in the solution are:

- create a network of producers, distributors, certifiers, and final retailers and customers;
- create a certified and distributed data center by distributed ledger, which collects data and tracks batches of products from the producer to the final customer;

Constraints

- IBM Blockchain Platform as an Enterprise Membership program
- Retail and all the suppliers and actors must adopt the Blockchain and track products, in terms of batch ID, all transformations along the chain
- Setup overall volume controls. No untracked products
- Permissioned Digital Ledger
- Consensus structure based on participants in a transaction
- Scalable structure (public and private Blockchain)
- Interoperability with existing ERPs

Decisions

- Tracking products
- Avoid inaccurate information flows
- Visibility on inbound processes and inventory status
- Forecast improvement and inbound efficiency

Information/Resources

- Hyperledger fabric distributed ledger
- Batch as unit
- Token

Decision makers

- e-commerce retailer
- Warehouse managers

Users/DMs relationship

- Producers → Warehouse managers
- Distributors/Carriers→ Warehouse managers

Solution channels

- Pilot project
- Consortium for digital security

Users

- Warehouse managers
- Distributors/Carrier
- Final user
- Producers
- Certifiers & Auditors

Costs

- Development costs
  - Implementation of Blockchain and Integration with current ERPs
  - Technical IT experts and Project managers
  - Hardware and Software (IBM Blockchain platform)
- Cost of the introduction of the solution
  - Training and integration with existing software and IoT network
- Maintenance costs
  - Machines of the system in Amazon AWS
- Costs for not introducing the solution
  - Food waste, sanitary recalls, document checking

Objectives

- Create a network of producers, distributors, certifiers, and final retailers and customer
- Create a certified and distributed data center by distributed ledger
- Compliance with health regulations, reduction of counterfeit, waste and expired products
- Forecast improvement and inbound efficiency

FIGURE 5. Solution Canvas.

- monitor and certify the respect for regulations in terms of safety, expiration date, certifications, all along the supply chain;
- improve the food supply chain in terms of efficiency and speed, supporting and optimizing the forecast activities and the warehouse management.

The main decisions that must be taken are related to the key elements of the solution. Thus, decisions regard to the mechanism of tracking of products, the accuracy of the information flow along the supply chain, and the visibility of inbound processes and inventory status to guarantee the forecast improvement and efficiency.

To implement the solution, the principal resource needed is the Blockchain technology. In particular, among the different technologies, in the use case proposed in this paper, Hyperledger Fabric has been adopted. It provides a modular architecture that allows a variety of implementations on cryptography, identity and consensus algorithms that can be adapted to the needs of the Consortium. More details about the solution from a technological standpoint will be provided in the next subsection.

Another relevant resource concerns the token that in our use case represents the digital equivalent of the batch of goods, with the additional parameter of the certification.

The solution implies some constraints that must be considered in the implementation phase. They can be summarized as follows:

- adopt the IBM Blockchain Platform already available as an Enterprise Membership program. The platform is built on the latest code and ensures enterprise-level security, data integrity, scalability, and performance. The membership cost guarantees technical support and a cloud-based option that is enterprise-ready in terms of managing a secure business network across multiple organizations.
- Producers and the other actors involved in the chain must adopt the Blockchain and track products, in terms of batch ID and all transformations along the chain.
- It is thus necessary to set up overall volume controls to verify that no untracked products are inserted in the supply chain along the processes. Algorithms can be

implemented in each step to guide the upload of correct information and reduce human error.
- Consensus structure based on participants in a transaction: producer, distributor/carrier, certifier, retailer.
- Permissioned endorsements allow a distributed trust among participants.

The solution must be scalable with the possibility of inclusion of private Blockchains.
- Data models need to be designed so that the information flow can be transferred electronically end-to-end to secure interoperability within Blockchain and existing ERPs.

Finally, the last building block of the solution canvas concerns the costs of the solution.

TABLE 1. Costs and revenues.

Costs	Value[a]	Revenues	Value[a]
IT Team	130	Inbound Efficiency	45
BC Platform	240	Waste of goods	450

[a] Values in K€.

They can be grouped in four main categories:
- Development costs that are related to the implementation of the Blockchain and its integration with current ERPs and systems of the organizations involved. These costs also include the personnel costs for technical IT experts and project managers, as shown in Table I. Moreover, they include the expenditure for hardware and software assets (e.g., IBM Blockchain Platform license and member subscription).
- Cost of the introduction of the solution. It refers to the training costs of all the operators.
- Maintenance costs. As the term suggests, they refer to the cost of maintaining the whole infrastructure and guarantee its correct functioning. Thus, they include the maintenance of the system in Amazon Web Services (AWS).
- Cost for not introducing the solution. It refers to all the inefficiencies along the supply chain that determine additional economic efforts. For example, the costs for food recall campaigns, products waste (e.g., expired items or caused by unsafe stocking conditions), and time and cost spent on chargebacks disputes.

3) SOLUTION DESIGN AND TECHNOLOGY

The Blockchain technology, based on a Hyperledger Fabric network over the Amazon AWS Cloud, is applied in the fresh food company with the aim to increase the efficiency and reduce the costs. Moreover, the visibility of the supply chain can benefit the entire business. For this purpose, as mentioned before, the general requirements are:
- Create a network of producers, suppliers, distributors, certifiers, and final retailers;
- Track batches all along the supply chain, to create a digital ledger of the products;
- Monitor and certify the respect for regulations in terms of the expiration date and certifications;
- Monitor and certify the respect of specific requirements all along the supply chain.

The number of products to trace is of the order of 1000000 per day, with peaks of transactions in the order of 5000000. Not all the data related to the process can be migrated in the Blockchain. The data stored in the Blockchain are the ones relevant, from a legal point of view, for the official documents automatic creation by Smart Contracts and the certification of the regulations on the cold chain. The remaining data are still in the legacy systems of the different actors. In a second phase of the project, it will be through the full migration, but this is still far to come, due to the present performances of the different available Blockchain systems.

The choice of Hyperledger Fabric comes from the industrial-level implementation of the code, the possibility to easily integrate analytics and deep learning, as well as the compatibility of Hyperledger with the existing network of sensors monitoring the fleet and the operations on the products (temperature in particular).

The adoption of the Blockchain technology is aimed at the creation of a distributed ledger that collects data all along the supply chain and tracks each batch of product from the producer to the final customer. A further objective is to improve the food supply chain in terms of efficiency and speed, supporting and optimizing warehouse management, and ensuring respect for regulations. The main benefits of the adoption of the Blockchain technology are:
- Improvement of the inbound efficiency, in terms of workforce and capacity planning;
- Reduction of expired items or waste caused by unsafe stocking conditions;
- Improvement of the accuracy in the tracking of ingredients, to ensure the compliance with health regulations.

Moreover, the benefits of the adoption of the Blockchain in the supply chain could result in an increase in sales, mainly driven by the reduction of the counterfeits and the improvement of the customer trust.

C. RESULTS

We identify two main types of results: the first are related to the Blockchain solution, while the second concern the methodology adopted to build the use case.

Notice that, due to the coverage of the methodology and that the solution is actually implemented in the company, we provide high-level results, while precise figure cannot be disclosed for confidentiality reasons.

Concerning the first type of results, the case study shows that the cost of implementing Blockchain is highly sustainable when compared with the resulting benefits. Assuming the adoption of IBM Blockchain Platform, the company exclusively needs an internal IT support team made of 5 people (3 technical experts and 2 project managers). In this case, the total yearly costs are fully covered by the cost savings, as shown in Table 1. Savings come from the increase of the inbound efficiency, given by 850 working hours saved by the optimization of operations, the transfer of 2 operators to a different area, and the increased accuracy of the data (and consequent reduction of recovery actions). The main savings are generated by the reduction of the waste of goods thanks to the better management of use-by-date information, and the identification of possible unsafe storage conditions. To these savings, extra value may come from an increase of the market share (+10 of revenues by the counterfeit reduction and the increase in brand image and customer affection for certified products) and the reduction of the impact of the costs given by the recalls for possible contaminations (from more than 1M€to about 600K€).

The final cost, spread among the actors, becomes of about 1000€ per month per actor, paid by sharing the possible savings. On the contrary, the main thread for the adoption of the Blockchain is actually the need of having all the actors involved.

Concerning the results related to the methodology, we can draw some managerial insights.

Before the technological aspects and business process modeling, it is necessary a preliminary design and deployment of a digital strategy. In this phase, the actors, their gains, and pains, and their advantages in using Blockchain technology must be identified and sized.

Starting from the value offered to each actor represents a key factor in the implementation of a successful and efficient Blockchain solution represents a key factor.

In our use case, the methodology adopted allows to transit from the assessment of the digital strategy to the implementation of the solution in 4 months (thanks to the advanced IoT system). Moreover, the focus on the actors allows identifying from the beginning the benefits of the Blockchain solutions, increasing the stakeholders' willingness to participate. The subsequent monitoring of the KPIs has exposed unexpected benefits for some actors.

The system must be monitored continuously to identify unexpected gains not emerged before. For example, at the beginning of the project, the distributor/carrier perceived the Blockchain as a mandatory solution. While, with the development of the project, they understood the gains in term of efficiency obtained from the adoption of such technology.

Finally, although we are in an early phase, it is crucial to focus on the performance aspects and to evaluate which part of the process to migrate to the Blockchain.

Replacing the whole process and legacy system on Blockchain is not reasonable, due to the integration with the other business processes and the willingness-to-share of the actors. Thus, in the preliminary phase, the assessment of which parts of the process and information to move to the Blockchain is needed.

In our case, initially, there was the intention to move all the information and data from the IoT network to Blockchain. Later the actors decided to record on Blockchain only the information on critical events in terms of safety.

V. CONCLUSIONS AND FUTURE DEVELOPMENTS

The adoption of the Blockchain technology in the supply chain is a promising enhancement, suitable to provide benefits to all the different actors involved in the process.

One of the most critical issues to be addressed in the implementation of Blockchain in the supply chain is the need to include all the different actors. Moreover, the sharing of the information along the entire Blockchain could lead to inertia in adopting the solution. For this reason, a correct implementation of the Blockchain technology in the supply chain must start from an analysis of the needs and the objectives of the different actors involved, with the aim to create a business model capable of highlighting the returns (both in economic and customer satisfaction terms) of this solution.

Future work concerns the integration of our methodology with the Business Process Modeling, to guide the Blockchain projects from the value definition to the implementation. Moreover, a future direction of our research is devoted to extending our methodology to other applications. In particular, a possible application will be the automotive industry, with a focus on the vehicle identity and integration Vehicle-to-Vehicle, Vehicle-to-Infrastructure for autonomous driving and data exchange purposes.

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