

Blockchain Adoption in Supply Chain in Industry 4.0

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Abstract—In recent years, companies have been adopting new cutting-edge technologies into their supply chains. This paper aims to examine the possibilities and ways of adopting blockchain technology within the supply chain processes. The research methods include desk analysis, comparative analysis of literature and analysis of relevant case studies. The results reveal different ways in which blockchain can be utilized within supply chains and how the adoption of blockchain improves the performances of supply chains. Examples of supply chains from different industries that use blockchain are also given.

Keywords - blockchain, supply chains, industry 4.0.

I. INTRODUCTION

The first association most people have about blockchain technology is most often associated with cryptocurrencies. The mass media often gives complex and not-so-well-defined explanations of what this technology is and how it can be adapted in different industries and companies. When simplified blockchain is just the next evolutionary step of the simple database, it represents a system of distributed databases. Blockchain is one of the main technologies of Industry 4.0, as well as being one of the catalyzers for digital transformation.

By analyzing data on the adoption of cutting-edge technologies into the supply chain, it was found that by 2021 blockchain was adopted by 10% of supply chains, with a trend of growth stating that by 2026 the adoption of this technology will reach 68% of supply chains [1].

In 2022 a survey about leading trends anticipated to impact supply chains by 2025, with 261 responses from experts from different industries, placed blockchain adoption in the twelfth position [2]. The prospect of adapting blockchain into supply chains is not something new, a survey from 2019, stated that 40% of supply chain leaders had responded that their companies are planning the adaptation of blockchain [3].

Nowadays, the development of industry 4.0 technologies, such as blockchain brings new challenges and opportunities for supply chains. The first implementation of blockchain technologies that weren't used for cryptocurrency was in retail. Company Walmart represents the pioneer among its peers when it comes to innovations and accepting new technologies, and thus was among the first retail companies to adopt blockchain into their supply chain. Following retail many other industries started adopting blockchain, such as agriculture, food, mining, pharmacy, logistics, automotive and others. Cross-examining and comparing the data from the most recent research studies that analyze different industry case studies about blockchain adoption in supply chains can be found in [4,5].

Thus, a new question arises: How did the adoption of blockchain affect the supply chains? To answer the research question, both the theoretical papers have to be analyzed but also the practical case studies of companies using blockchain in their supply chains need to be found and examined.



Using Google Scholar's web portal as the main search engine with the combination of two primary keywords blockchain and supply chain, the first search resulted in a huge number of papers (232 00), that were sorted by publication date. The main limitation that had to be met in order for the research paper to be considered was that the observed paper must contain a DOI number. This was followed by additional scoping by adding keywords for each of eight supply chain processes determined by the Global Supply Chain Forum (customer relationship management, customer service management, demand management, order fulfillment, production process management, supplier relationship management, product development and commercialization, reverse flow management). Once again papers were sorted by date and checked for DOI numbers. The selection of papers was focused on quality, and having in mind the goal was to find credible sources to conclude how blockchain has been adopted in supply chain processes. On the other hand, the practical case studies used in the paper are selected from leading multinational companies that have proven their innovation and pioneered the digitization of supply chains in their industries.

The remainder of the paper is organized into four sections. Section 2 is designated for the theoretical background, while the possibilities and benefits of using blockchain within the supply chain processes are analyzed in Section 3. The examples of supply chains that use integrated blockchain in their supply chains are presented in Section 4. Finally, the conclusions and directions for further research are given in Section 5.

II. THEORETICAL BACKGROUND

The first form of blockchain technology was firstly used as the foundation for the world's first cryptocurrency Bitcoin. A simple way to explain blockchain is that blockchain is a system of distributed databases that record all transactional data or other information. Its database security mechanism is ensured through cryptography, and access to the data is managed via a consensus mechanism [6].

The main characteristics of this technology are [7]:

- It is designed to be distributed and synchronized across the entire network;

- It relies on using “smart contracts”—pre-agreed arrangements stored on the blockchain, through which transactions can be conducted. These contracts represent protocols through which transactions are verified, validated, and executed as agreed in advance;
- Transparency—the network is built with a Peer-to-Peer (P2P) architecture, meaning that the agreement of all relevant participants is required for any transaction and its terms;
- Data immutability—it is impossible to delete a completed transaction from the network, and it remains stored permanently. Furthermore, no retroactive changes to any saved transaction content can be made.

Based on availability, there are four types of blockchain networks [8]: public, private, hybrid and consortium blockchain.

Public Blockchain suppose an open network, allowing anyone to participate in transactions without prior permission. It features a high level of decentralization, transparency, and strong security while ensuring data privacy and requiring cryptocurrency usage. Its main disadvantages are high energy consumption and slow transaction processing speed.

Private Blockchain suppose network that provides a high level of privacy, with closed access that requires permission from an existing member. It does not necessitate the use of cryptocurrency and features low decentralization. Its advantages include low energy consumption for maintenance, suitability for closed systems such as supply chains, high data security, and increased transparency in data exchange between members, such as in supply chains, along with faster transaction processing. A drawback of this type is the need for trust between participants and potential participants. Additionally, the low or centralized decentralization of this network poses a risk of third-party hacking. Companies typically use private blockchain networks in supply chains.

Hybrid Blockchain combines the previous two, allowing participants to choose whether parts of the data are publicly available or require authorization. It operates within both centralized and decentralized systems. Using this model can

enhance the network's security and transparency.

Consortium Blockchain assume a semi-decentralized structure, enabling network activities to be conducted even by a single organization. This type is also known as a "federated blockchain". It is most commonly used in the banking industry or governmental organizations.

The introduction of blockchain technology into supply chains was explained and illustrated by Casado-Vara and his colleagues through an example of the traditional supply chain in the agricultural industry and its transformation following blockchain implementation [4]. The primary change observed is in the method of transmitting and storing information, where blockchain ensures that information from the product's origin to its retail placement is transmitted and stored within the blockchain network [9].

The promising advantages of applying blockchain technology in supply chains include [10-14]:

- Transparency and immutability of data and records.
- Blockchain application improves the operational efficiency of supply chains and helps reduce costs across the supply chain.
- Enhanced data and communication security.
- Increased collaboration between supply chain members.
- Enables accurate tracking of data and/or products and provides historical traceability by storing all records related to a specific product.
- Improves sustainability, by facilitating better compliances with environmental regulations and verification process of sustainable practices.
- Has a positive impact on adaptability to future technological advancements. This characteristic stems from the now-standardized documents and data sharing amongst supply chain members. Additionally, adapting future technologies will be easier because of the enhanced transparency, traceability,

and higher levels of trust and safety that the blockchain provides.

The potential disadvantages of blockchain technology application in supply chains are [15-17]:

- High initial implementation costs.
- Technically complex introduction process.
- Scalability—the number of transactions that can be processed within a given time frame is limited.
- Regulatory challenges—varying laws may hinder the application of this technology in international supply chains.
- The technology is currently energy-inefficient—it requires powerful computers and consumes large amounts of electricity.

III. APPLICATION OF BLOCKCHAIN TECHNOLOGY IN SUPPLY CHAIN PROCESSES

Using the Global Supply Chain Forum classification [18] of supply chain processes, this subchapter is meant to represent the use of blockchain in each of the eight processes, using the literature review method.

The use of blockchain was found to significantly improve and simplify the customer relationship management (CRM) process. After implementing blockchain, companies now have all the transactions with their customers recorded in the form of a transparent and immutable record. Having these transparent records, allows customers to track the origin and journey of the products they purchase. The introduction of this technology increases customer trust and satisfaction. Other key benefits of use from the company's perspective, besides the increased customer trust and satisfaction, is the greater security and efficiency of data transfers between supply chain members or company sectors [13].

The use of blockchain technology resulted in significantly enhanced and simplified customer service management. Blockchain provides customers with precise and up-to-date insights into the status of their orders and expected deliveries. Using blockchain, companies can quickly and efficiently resolve disputes or issues reported by customers by providing them with

evidence of delivery and product quality. Key benefits of the use of blockchain are the reduction of the statistical possibility of fraud, the increase of customer satisfaction as well as trust, and also enhancement of the security of customer data [15].

The use of blockchain technology in demand management is currently mostly indirect. Blockchain is used to gain faster access to more accurate predictions, which helps employees manage demand. Since blockchain increases the transparency, traceability, and security of completed transactions, it ensures that data exchanged between supply chain participants is accurate and valid. This technology's undeniable impact is seen in the demand management process, where the delivered blockchain data allows for more precise forecasting and inventory management, aligning with real market needs [17].

The use of blockchain can result in an acceleration of the order fulfillment process. Due to its transparency and data security features, companies have precise and up-to-date information about inventory and shipment statuses. As a result, all supply chain participants have real-time insights into actual inventory levels. Additionally, blockchain reduces the likelihood of errors during order packing and the risk of theft [19].

The use of blockchain technology indirectly facilitates production process management. By forming a blockchain network and connecting with IoT (Internet of Things) devices in production facilities or on products, blockchain can store information about components, materials, and products throughout the production cycle and beyond. One advantage of using blockchain is the ability to identify quality issues with components, materials, or products, as well as production failures in real time [20,21].

The use of blockchain can significantly improve and simplify the supplier relationship management (SRM) process. By using blockchain, companies now have enhanced communication transparency, which results in easier and more transparent agreements established between the company and suppliers. The use of smart contracts increases the trust between the company and suppliers, leading to better and more open relationships, as well as greater supplier satisfaction [10].

The application of blockchain technology to product development and commercialization enhances data exchange and increases the security of sensitive data, such as product prototypes. It also ensures secure information exchange between stakeholders during the design and development phases. All modifications are stored within the blockchain, making it easier to identify and prevent data errors, thus improving the efficiency of new product development. Moreover, blockchain facilitates interaction and data exchange between suppliers and manufacturers, fostering innovation by sharing knowledge and ideas for developing new products. A key advantage is the transparent tracking and recording of intellectual property, as well as all contracts stored on the blockchain network [22].

One of the more interesting uses of blockchain can be seen in reverse flow management process. Blockchain enables in-depth product tracking, which reduces the likelihood of fraud during product returns, and simplifies cost transactions. This technology also increases the efficiency of the entire reverse flow management process. Furthermore, the return process becomes more secure and transparent compared to traditional methods of tracking returned items [16].

IV. EXAMPLES OF PRACTICAL APPLICATIONS

Theoretical literature review provides a deeper understanding of the connection between blockchain and supply chains, exploring concrete practical uses represents the final element to fully understand the connection and integration of blockchain into supply chains.

According to available literature, blogs, and interviews with notable CEOs of various companies, blockchain technology is considered one of the revolutionary drivers of digital transformation and a foundation for entering Industry 4.0. Its application in supply chains significantly enhances transparency, efficiency, and security, allowing companies to track product movements in real time and improve trust among supply chain participants [23,11].

World-renown company IBM known as one of the leading companies in digital transformation and software engineering, has numerous partnership projects for integrating blockchain into different industries' supply chains. The most known partnerships are with

companies such as Walmart, Maersk, Ford and Unilever [24].

American food retailer company Walmart implemented the use of blockchain order to the origin and transportation route of all of food products they sell. The vision behind this transition was to apply blockchain throughout the whole supply chain from the field/farm to the store shelves. This allows faster and much more accurate tracing of products, meaning it makes identifying and recalling contaminated or faulty products easier and safer. Using the mango case study as an example the result of use is represented in decreased waste of uncontaminated food. The secondary result mentioned was the accelerated time needed to find food origin, for mangos it went from seven days to just 2.2 seconds [25].

One of the leaders in the automotive industry company Ford implemented the use of blockchain to track the origin of cobalt that they use in their electric vehicle batteries. One of the main reasons for use was to make the sourcing process of cobalt more transparent, know the company can track from which mine the cobalt came, and with such reassure their stakeholder that the metal was sourced ethically [24].

Global logistics company Maersk and IBM themed up to create a platform based on blockchain technology, to reduce trade frictions and promote and simplify global trade. The TradeLens platform was founded in 2018. with a vision of being a revolutionary push that will help the global supply chain digitalization, with its open and transparent flow of information, while providing high levels of security and traceability of data and information. Unfortunately, this platform was shut down in 2023., due to the lack of global support, and low ROI rate [26].

One of the world's global manufacturing giants company Unilever has implemented blockchain into its supply chain to enhance their sustainability and provide its stakeholders with more transparency when it comes to raw materials. The use of blockchain tracks the sourcing of all raw materials, meaning that the company can show data that proves their production and final products are made sustainably and ethically [27].

Similarly, to Unilever one of the world's largest food and beverage companies, Nestlé also implemented blockchain to enhance the

sourcing of raw materials in their production lines. The implementation of blockchain into the supply chain, enchanted the sustainability of the final product, parallel helping prevent and reduce deforestation and promote responsible agriculture practices [25].

When it comes to the beverage industry company Coca-Cola used a different take when it came time to integrate blockchain into their business, they used the power of having a transparent, secure and trackable database, to form a secure registry of their worker working in the bottling plant in the Philippines. Coca-Cola uses the potential and power of blockchain to promote and ensure ethical labour practices [28].

One of the largest mining companies in the world, BHP uses blockchain for tracing the origins of their minerals, more precisely they implemented a blockchain-based platform called Prosperity. Prosperity's design uses blockchain to track and ensure accurate traceability within the mining supply chain. The key reason for using this platform, is to ensure sustainability and ethical practices are being implemented while mining, so that the miners are not exploited nor is the environment harmed [29,24].

Pharmaceutical giants Pfizer, Johnson & Johnson, and AstraZeneca use MediLedger which is a blockchain network. The primary functionality of this ledger is to help with the prevention of counterfeit medicine and increase the overall speed of medicine production in the supply chain, by eliminating unnecessary paperwork and increasing the processing time for analyzing and organizing product-related data between manufacturers, distributors and pharmacies [30]. The MediLedger uses blockchain in three distinct ways [31]:

- Synchronizes public data.
- Holds immutable records of all transactions with a high level of confidentiality.
- Utilizes smart contracts to enforce rules and the integrity of the system.

A common denominator for all of the mentioned companies when it comes to adapting blockchain is the strategic partnerships done with a large tech company most popular IBM. Logically and business-wise, a known fact is that larger companies have more resources, one of

them being a dedicated budget for innovations and investment projects for integrating new technologies or partnering up and creating something new.

Considering the current global market there isn't a ready-made solution for just adding blockchain to an organization. An organization that wants to adopt blockchain and use all of its potentials, has to go through a detailed and expensive design and implementation period. This lack of cost-affordable solutions can be classified as one of the main reasons that SME companies aren't using blockchain as of now. A team of academics adapted blockchain technology in a small Italian bakery, in their simulation case study [32], they described the process of designing and implementing a blockchain network in tracking the origin of manufactured products from raw materials to the end customer. The paper [32] shows all of the steps they took to create a blockchain network for this bakery, in the main problem that occurred was the lack of space for all external data, and storing large amounts of data is expensive for any company let alone an SME. Different studies have been published regarding which factors are to be used in consideration when it comes to SME companies. Positive factors for adopting blockchain are: increased transparency, increased security, competitive pressure and advantage, improving operational efficiency [33,34]. The negative factors influencing blockchain adaptation are: high complexity, high initial investment high cost of development and maintenance, and lack of resources and support [33,34]. Adaptation of blockchain into SMEs is an interesting approach that with yield a lot of benefits if the SME has high funding and a proper support system with expert guidance, the adaptation can be done, but for the majority of SMEs is just not cost-effective for now.

V. CONCLUSION

The motivation behind this paper was to explore practical adoption and use of blockchain in supply chain processes. The paper highlights the various ways blockchain is used in supply chain processes as well as how different companies integrate blockchain into their business models and supply chains. It gives the main conclusions in how the adaptation of blockchain affects the supply chains. The use of blockchain establishes a more transparent, secure and traceable network. This technology

can improve the relationship between not only customers and the companies but as well can enhance the collaboration between different supply chain parties.

This study is limited by the use of only a fraction of all the available materials that tackled the topic of rapidly increasing use of blockchain in the supply chain. A significant limitation of our research was the scarcity of studies that provide concrete data about the benefits and improvement results after adopting blockchain in supply chains. In the future, a more rigorous review should be conducted to provide in-depth insight into how blockchain adoption at different levels of implementation impacts the supply chain as a whole. One of the future research paths can be to conduct an in-depth cross-examination for the adoption process within different industries, as well as the differences in the adoption of blockchain between smaller and larger organizations.

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