Exploring blockchain adoption for supply chain transformation in industry 4.0

Miljana Luković[1],*, Biljana Cvetić[1], Dragan Vasiljević[1] and Miloš Danilović[1]

[1] Faculty of Organizational Sciences, University of Belgrade, Belgrade, Serbia

* Correspondence: miljana.lukovic@fon.bg.ac.rs

Abstract

By observing the last decade of supply chain transformation amongst different industries, a pattern of adopting cutting-edge technologies can be observed. Industrial leaders are showcasing how any supply chain can be transformed with the use of new technologies in a new digital focused way, that is better suited for all of the challenges and opportunities that Industry 4.0 brings. The intent of this paper is to examine the role blockchain has in the transformation process of supply chains, specifically how is this technology used in various supply chain processes. The research methods used include desk analysis, a comparative analysis of the literature, and an examination of relevant case studies. The findings show that blockchain can be adopted in an assortment of ways within supply chains, and that adopting blockchain technology enhances supply chain transformations. Practical examples of the use of blockchain is highlighted as well.

Keywords: blockchain, supply chains, industry 4.0.

1. 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 (Luković et al., 2024). 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 catalysers for digital transformation.

By analysing 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 (Statista, 2022). 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 (Statista, 2024). 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 (Statista, 2019). Gartner in their report estimates that blockchain as a

technology will significantly increase in value, and by the year 2030 blockchain- based systems will be included in 10% to 20% of all global infrastructure, given by the current trend of adoption and use (Gartner, 2024; Yirrell, 2024).

Nowadays, the development of industry 4.0 technologies, such as blockchain brings new challenges and opportunities to supply chain transformation. 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 analyse different industry case studies about blockchain adoption in supply chains can be found in (Lim et al., 2021; Xia et al., 2023).

The remainder of the paper is organized into five sections. Section 2 is designated for the theoretical background, while the research approach is outlined in Section 3. The possibilities and benefits of using blockchain within the supply chain processes are analysed in Section 4. The examples of supply chains that use integrated blockchain in their supply chains are presented in Section 5. Finally, the conclusions and directions for further research are given in Section 6.

2. Theoretical background

The first form of blockchain technology was firstly used as the foundation for the world's first cryptocurrency Bitcoin. Blockchain can be simple defined as a system of distributed databases that document 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 (Swan, 2015).

The main characteristics of this technology are (Pattison, 2017; Yirrell, 2024):
- It is designed to be distributed and synchronized across the entire network;
- It relies on using "smart contracts" a construal pre-agreed arrangements that are stored on the blockchain. There are essential for all transactions to be conducted. To be precise all protocols for verification, validation and execution are called "smart contracts";
- Transparency, this characteristic is the main attribute connected with blockchain technology. The blockchain network is built with a Peer-to-Peer (P2P) architecture, thus creating the need for of all relevant participants to give their agreement to the terms of a transaction before it can be executed;
- Data immutability, making it impossible to delete a completed transaction from the network. Every transaction and transaction change remains stored permanently on the network. Furthermore, no retroactive changes to any saved transaction content can be made, every change is dated, documented, and can be traced back to the owner of the change.

Based on availability, there are four types of blockchain networks (Paul et al., 2021): public, private, hybrid and consortium blockchain.

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

Private Blockchain refers to a network that provides a high level of privacy, with restricted access that needs authorization from an existing member. It has limited decentralization and is not dependent on the usage of cryptocurrencies. The advantages include minimal energy consumption for maintenance, adaptability for closed systems such as supply chains, high data security, enhanced transparency in data exchange between members, as well as swifter transaction processing. One disadvantage of this sort is the need for trust among participants and

potential participants. Furthermore, the network's poor or concentrated decentralization increases the possibility of third-party hacking. Companies generally utilize private blockchain networks in their 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 improve 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 (Casado-Vara et al., 2018). 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 (Casado-Vara et al., 2018).

The promising advantages of applying blockchain technology in supply chains include (Gartner, 2024; Kamble et al, 2020; Lohmer et al, 2022; Mukherjee et al., 2022; Saberi et al., 2019; Sheel and Nath, 2019):

* Transparency and immutability of data and records.
* Cost reduction across the supply chain, as well as improving operational efficiency.
* 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.
* Allows supply chain participates to adjust their business strategy in other to better comply with environmental regulations and verification process of sustainable practices, thus improving their sustainability.
* Creating 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 (Min, 2019; Queiroz and Wamba, 2019; Tian, 2016; Yirrell, 2024):

* High initial implementation costs.
* Technically complex introduction process.
* Scalability is quite limited by the number of transactions that can be processed within a given time frame.
* Regulatory challenges that are caused by varying laws and legislations that may hinder the application of blockchain in international supply chains.
* The technology is currently energy-inefficient requiring the use of powerful computers that consumes tremendous amounts of electricity.

3. Methodology

This study adopted a multi-stage approach with the aim to examine which role blockchain has in the transformation process of supply chains, specifically how is this technology used in various supply chain processes. The research question which arises is: How did the adoption of blockchain affect the supply chains transformation in Industry 4.0? To answer the research question, both academic research papers and companies case studies on

the use of blockchain in their supply chains were collected by using search databases (Google Scholar and Google) and further comparative analyzed (Figure 1).

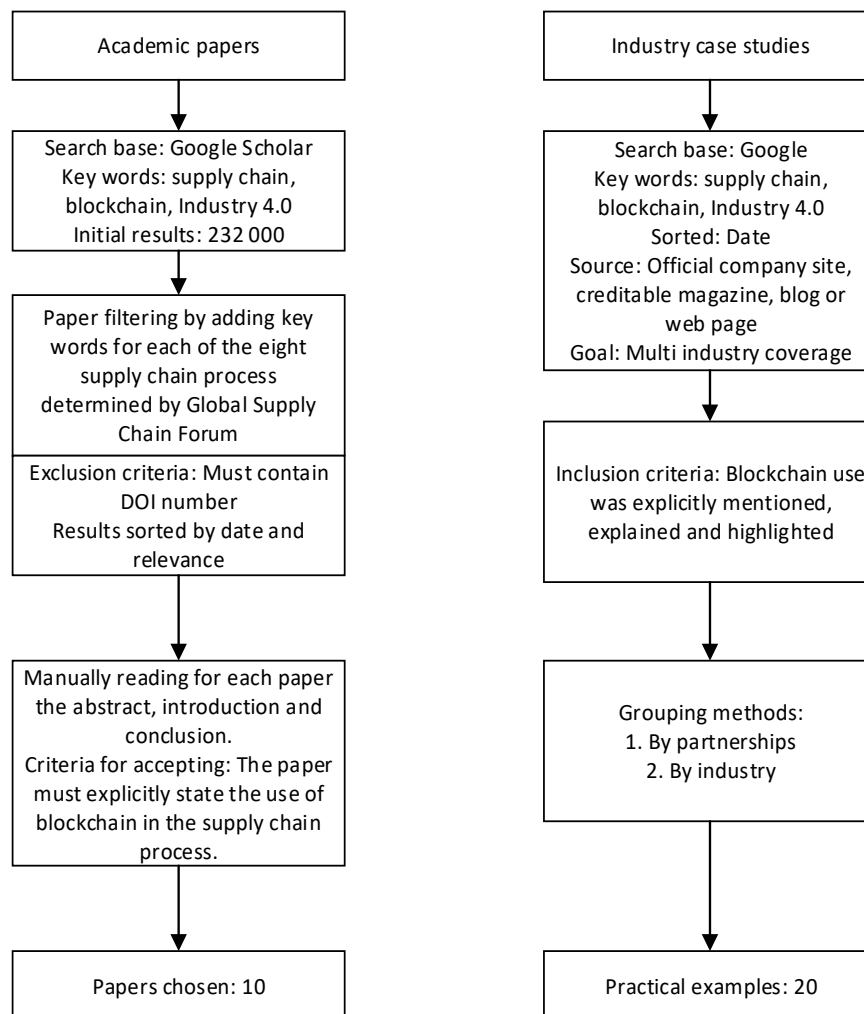| Academic papers	Industry case studies
↓	↓
Search base: Google Scholar Key words: supply chain, blockchain, Industry 4.0 Initial results: 232 000	Search base: Google Key words: supply chain, blockchain, Industry 4.0 Sorted: Date Source: Official company site, creditable magazine, blog or web page Goal: Multi industry coverage
↓	↓
Paper filtering by adding key words for each of the eight supply chain process determined by Global Supply Chain Forum Exclusion criteria: Must contain DOI number Results sorted by date and relevance	Inclusion criteria: Blockchain use was explicitly mentioned, explained and highlighted
↓	↓
Manually reading for each paper the abstract, introduction and conclusion. Criteria for accepting: The paper must explicitly state the use of blockchain in the supply chain process.	Grouping methods: 1. By partnerships 2. By industry
↓	↓
Papers chosen: 10	Practical examples: 20

Figure 1. Methodology for collecting papers and case studies

The additional narrowing the scope done by adding keywords for each of eight supply chain processes that are determined by the Global Supply Chain Forum (Lambert, 2005) (customer relationship management, customer service management, demand management, order fulfillment, production process management, supplier relationship management, product development and commercialization, reverse flow management), was with the intent to identify credible sources that are used to conclude how blockchain has transformed supply chain processes. The chosen industry case studies all showcase how some of the leading multinational companies have adopted blockchain and used it in an innovated way, as well as showcasing them as pioneers of the digitization of supply chains in their respected industries.

4. Application of blockchain technology in supply chain processes

Using the Global Supply Chain Forum classification (Lambert, 2005) 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.

It has been revealed that using blockchain greatly enhances and streamlines the customer relationship management (CRM) procedure. Companies who have used blockchain now have a transparent and immutable record of all transactions with their clients. Customers can follow the origin and route of the items they purchased as a result to these transparent records. The utilization of this technology enhances consumer satisfaction and trust. Additional noteworthy advantages of use from the company's perspective, in addition to enhancing customer trust and satisfaction, are the greater security and efficiency of data transfers throughout supply chain members or organizational sectors (Saberi et al., 2019).

The use of blockchain technology can significantly improve and simplify customer service management. Blockchain can provide 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 (Min, 2019).

The use of blockchain 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 (Tian, 2016).

The use of blockchain technology 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 (Francisco and Swanson, 2018).

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 (Lohmer and Lasch, 2020; Zhang et al., 2023).

The use of blockchain can significantly improve and simplify the supplier relationship management (SRM) process. By using blockchain, companies now have enchanted 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 (Kamble, 2020).

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 (Benzidia et al., 2021).

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 (Queiroz and Wamba, 2019).

5. 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.

Based on existing literature, blogs, and interviews with prominent CEOs of different organizations, blockchain technology is seen as one of the transformative 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 (Sultana et al., 2022; Lohmer et al., 2022).

Multinational tech giant IBM, has been a leader when it comes to providing guidance and support for other companies in their journey of transforming their supply chains, by providing them with the necessary skills, technologies and know-how. Over the past decade IBM has partnered with industry leaders and well know companies, creating custom project for them to adopt blockchain in there supply chains. IBM event created its own product named IBM Food Trust that is specialized in food supply chains, companies such as (Apps, 2019): Walmart, Nestlé, Golden State Foods, Dole Foods and other, have joint this venture. Partnerships further explored in this paper are with companies such as Walmart, Maersk, Ford, Unilever and Nestlé (Freeman, 2023).

American well known food retailer company Walmart implemented the use of blockchain in order to trace the origin and transportation route of all of food products they sell. Their vision is 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 (Hyperledger Foundation, 2023). Walmart expended there use of blockchain even further, with IBM as their partner, they collaborated with the famous Chinses university Tsinghua, and created a blockchain ledger, making it possible to trace the origin of pork all across China. The firmer need to scan their certifications and know every piece of pork is traced form witch farmer it came from. This created the perfect ecosystem for all pork providers, connecting not only the supplier and buyer, but also the rest of the supply chain participants. There biggest accomplishment to date is the collaboration with other well-known supply chain companies, and creating a network that can trace over 25 different products, making it possible to track down even the origin of the products ingredients (Sristy, 2021).

Company Ford, one of the leaders in the automotive industry, has adopted blockchain technology to trace the provenance of cobalt utilized 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 (Freeman, 2023).

Global logistics company Maersk and IBM themed up to develop a blockchain-based platform TradeLens to reduce trade frictions and promote and facilitate global trade. This platform was created 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 (Maersk, 2022).

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. By using blockchain technology to track the origin of all raw materials, the company provides evidence that their finished goods are produced in an ethical and sustainable manner (Unilever PLC, 2022).

Similarly, 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 (Freeman, 2023).

Nestlé with IBM created a pilot blockchain platform in 2018 for their French customer buying Mousline purée, and in 2020 expanded the platform by adding their coffee brand Zoégas. In 2020 they partner up with the Rainforest Alliance, that provides the needed certification for their coffee beans, making it traceable and transparent (Nestlé, 2020).

When it comes to the beverage industry company Coca-Cola used a different take when it came time to incorporate blockchain into their operations, 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 (Chavez-Dreyfuss, 2018).

One of the largest mining companies in the world, BHP uses blockchain for tracing the origins of their minerals through the 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 (Aschcroft, 2021; Freeman, 2023).

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 analysing and organizing product-related data between manufacturers, distributors and pharmacies (Bambysheva, 2024).

The MediLedger uses blockchain in three distinct ways (Wolfson, 2019):

- 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 (Cocco et al., 2021), 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 (Cocco et al., 2021) 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 (Liu et al., 2023; Wong et al., 2020): increased transparency, increased security, competitive pressure and advantage, improving operational efficiency. The negative factors influencing blockchain adaptation are (Liu et al., 2023; Wong et al., 2020): high complexity, high initial investment

high cost of development and maintenance, and lack of resources and support. 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.

The use of blockchain has rapidly expanded, creating a new blue ocean niche for start-up companies to take advantage of. The start-up VeChain is a pioneer when it comes to blockchain-powered logistics and supply chain adoption. VeChain created a slightly robust ecosystem that appealed to several Fortune 500 companies, in various industry niches (Samudera, 2023). One of the fastest growing start-up company that has won seven prestigious awards, the most recent ones being the Blockchain supply chain platform of the year award" for the year 2023 and 2024, is the start-up Morpheus. Network. Morpheus has a partnership with almost every global giant in the tech industry (IBM, Microsoft, SAP, Plug and Play, Master Data, IOTEX and many other). One of the smallest companies to join global alliances such as Blockchain in Transport Alliance, (BiTA), Enterprise Ethereum Alliance (EEA), International Association of Trusted Blockchain Applications (INATBA), Canadian Food Innovation Network (CFIN) and other smaller ones (Milestones - Morpheus.network, 2024).

Other start-up that are also successfully creating blockchain solutions for the supply chain transformation are (Calibraint, 2024):

* OriginTrail – used in pharmaceutical supply chain for the prevention of counterfeit medicine;
* Provenance – collects data and verifies the origins and claims of the sourced product;
* ShipChain – tracking shipment in the food supply chain,
* Everledger – for luxury goods and other high-value assets. Mainly used for verifying, tamper-proofing and ensuring ethical practices were used;
* Ambrosus – for ensuring quality of the cold supply chain, mostly used for seafood and dairy products;
* TE-FOOD – focuses on food supply chains, mostly used by Asian supermarket chains;
* TrackX – created a blockchain platform for the reverse flow management process for returnable transport items (RTIs).

6. Conclusion

The focus of 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 chain transformation. The use of blockchain establishes a more transparent, secure and traceable network. This technology has the potential to improve not just the relationship between companies and their customers, but also the collaboration of different supply chain participants.

This study is limited by the use of only a portion 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 transformation 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.

References

Apps. (2019). List of IBM Food Trust Customers. Appsruntheworld.com. https://www.appsruntheworld.com/customers-database/products/view/ibm-food-trust, Accessed 13 September 2024.

Ashcroft, S. (2021). Blockchain "key to supply transparency" - mining giant BHP. https://supplychaindigital.com/sustainability/blockchain-key-supply-transparency-mining-giant-bhp, Accessed 10 September 2024.

Bambysheva, N. (2024). Forbes Blockchain 50 2023. https://www.forbes.com/sites/ninabambysheva/2023/02/07/forbes-blockchain-50-2023/, Accessed 1 September 2024.

Benzidia, S., Makaoui, N., & Subramanian, N. (2021). Impact of ambidexterity of blockchain technology and social factors on new product development: A supply chain and Industry 4.0 perspective. Technological Forecasting and Social Change, 169, 120819.

Calibraint. (2024). Top 10 Supply Chain Startups Using Blockchain - Watch Out For Them in 2024. Calibraint. https://www.calibraint.com/blog/top-10-supply-chain-startups-using-blockchain, Accessed 25 August 2024.

Casado-Vara, R., Prieto, J., De la Prieta, F., & Corchado, J. M. (2018). How blockchain improves the supply chain: Case study alimentary supply chain. Procedia computer science, 134, 393-398.

Chavez-Dreyfuss, G. (2018). Coca-Cola, U.S. State Department to use blockchain to combat forced labour. https://www.reuters.com/article/world/coca-cola-us-state-department-to-use-blockchain-to-combat-forced-labour-idUSKCN1GS2PL/, Accessed 15 July 2024.

Cocco, L., Mannaro, K., Tonelli, R., Mariani, L., Lodi, M. B., & Melis, A. (2021). A blockchain-based traceability system in agri-food SME: Case study of a traditional bakery. IEEE Access, 9, 62899-62915.

Francisco, K., & Swanson, D. (2018). The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency. Logistics, 2(1), 2.

Freeman, O. J. (2023). 10 Companies Using Blockchain Technology for Sustainable Supply Chain. https://shorturl.at/KXIzH, Accessed 1 July 2024.

Gartner, (2024). Blockchain: What It Is, How It Works, Why It Matters. (2024). Gartner. https://rb.gy/68s38w, Accessed 10 July 2024.

Hyperledger Foundation. (2023). How Walmart brought unprecedented transparency to the food supply chain with Hyperledger Fabric. https://www.hyperledger.org/case-studies/walmart-case-study, Accessed 15 August 2024.

Kamble, S. S., Gunasekaran, A., & Sharma, R. (2020). Modeling the blockchain-enabled traceability in agriculture supply chain. International Journal of Information Management, 52, 101967.

Lambert, D. (2005). Supply Chain Management: Processes, Partnerships, Performance. 2nd ed. Florida, USA: Supply Chain Management Institute.

Lim, M. K., Li, Y., Wang, C., & Tseng, M.-L. (2021). A literature review of blockchain technology applications in supply chains: A comprehensive analysis of themes, methodologies and industries. Computers & Industrial Engineering, 154, 107133–107133.

Liu, W., Liu, X., Shi, X., Hou, J., Shi, V., & Dong, J. (2023). Collaborative adoption of blockchain technology: A supply chain contract perspective. Frontiers of Engineering management, 10(1), 121-142.

Lohmer, J., & Lasch, R. (2020). Blockchain in operations management and manufacturing: Potential and barriers. Computers & Industrial Engineering, 149, 106789–106789.

Lohmer, J., Ribeiro, E., & Lasch, R. (2022). Blockchain Technology in Operations & Supply Chain Management: A Content Analysis. Sustainability, 14(10), 6192–6192.

Luković, M., Cvetić, B., Vasiljević, D., & Danilović, M. (2024). Blockchain adoption in supply chain in Industry 4.0. Proceedings of the 6h Virtual International Conference Path to a Knowledge Society-Managing Risks and Innovation (PaKSoM) (pp. 3-9). Belgrade: Mathematical Institute SANU.

Maersk. (2022). A.P. Moller - Maersk and IBM to discontinue TradeLens, a blockchain-enabled global trade platform. https://www.maersk.com/news/articles/2022/11/29/maersk-and-ibm-to-discontinue-tradelens, Accessed 1 August 2024.

Milestones - Morpheus.network. (2024). Morpheus.network. https://morpheus.network/milestones/, Accessed 12 September 2024.

Min, H. (2019). Blockchain technology for enhancing supply chain resilience. Business Horizons, 62(1), 35-45.

Mukherjee, A. A., Singh, R. K., Mishra, R., & Bag, S. (2022). Application of blockchain technology for sustainability development in agricultural supply chain: Justification framework. Operations Management Research, 15(1), 46-61.

Nestlé. (2020). Nestlé Expands Blockchain to Zoégas Coffee Brand. Nestlé Global. https://www.nestle.com/media/news/nestle-blockchain-zoegas-coffee-brand, Accessed 25 August 2024.

Pattison, I. (2017). 4 characteristics that set blockchain apart. https://architectingthecloud.com/2017/04/27/4-characteristics-that-set-blockchain-apart/, Accessed 1 July 2024.

Paul, P., Aithal, P. S., Saavedra, R., & Ghosh, S. (2021). Blockchain technology and its types—a short review. International Journal of Applied Science and Engineering (IJASE), 9(2), 189-200.

Queiroz, M. M., & Wamba, S. F. (2019). Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA. International Journal of Information Management, 46, 70-82.

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. International Journal of Production Research, 57(7), 2117-2135.

Samudera, M. (2023). VeChain: Supply Chain Innovation with Blockchain Technology. Pintu. https://rb.gy/8kk0m5, Accessed 30 August 2024.

Sheel, A., & Nath, V. (2019). Effect of blockchain technology adoption on supply chain adaptability, agility, alignment and performance. Management Research Review, 42(12), 1353-1374.

Sristy, A. (2021). Blockchain in the food supply chain - What does the future look like? Walmart. https://tech.walmart.com/content/walmart-global-tech/en_us/blog/post/blockchain-in-the-food-supply-chain.html, Accessed 26 July 2024.

Statista (2024). Disruptive technologies for supply chain by 2025. https://www.statista.com/statistics/1182110/global-supply-chain-disruptions-technologies/, Accessed 5 September 2024.

Statista. (2019). Supply chain: investments in blockchain 2019. https://www.statista.com/statistics/1095144/global-supply-chain-blockchain-investment/, Accessed 5 September 2024.

Statista. (2022). Technology adoption by supply chain companies. https://www.statista.com/statistics/1182124/global-supply-chain-technologies-adoption/, Accessed 5 September 2024.

Sultana, J., Teoh, S. Y., & Karanasios, S. (2022). The impact of blockchain on supply chains: a systematic review. Australasian Journal of Information Systems, 26, 1-38.

Swan, M. (2015). Blockchain: Blueprint for a new economy. O'Reilly Media.

Tian, F. (2016). An agri-food supply chain traceability system for China based on RFID & blockchain technology. Proceedings of the 13th International Conference on Service Systems and Service Management (ICSSSM) (pp. 1-6). Kunming: IEEE.

Unilever PLC. (2022). SAP, Unilever pilot blockchain technology supporting deforestation-free palm oil. https://www.unilever.com/news/press-and-media/press-releases/2022/sap-unilever-pilot-blockchain-technology-supporting-deforestationfree-palm-oil/, Accessed 25 August 2024 .

Wolfson, R. (2019). Pfizer And Others Join Working Group To Use Blockchain Protocol For Supply Chain Management. https://www.forbes.com/sites/rachelwolfson/2019/05/02/pfizer-and-other-healthcare-companies-aim-to-bring-blockchain-based-chargeback-protocol-to-market/, Accessed 15 August 2024.

Wong, L. W., Leong, L. Y., Hew, J. J., Tan, G. W. H., & Ooi, K. B. (2020). Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs. International Journal of Information Management, 52, 101997.

Xia, J., Li, H., & He, Z. (2023). The Effect of Blockchain Technology on Supply Chain Collaboration: A Case Study of Lenovo. Systems, 11(6), 299.

Yirrell, S. (2024). Blockchain Statistics: Top Stats, Facts and Trends for 2024. Global Technology Industry Association. https://gtia.org/blog/blockchain-statistics, Accessed 5 September 2024.

Zhang, G., Yang, Y., & Yang, G. (2023). Smart supply chain management in Industry 4.0: the review, research agenda and strategies in North America. Annals of operations research, 322(2), 1075-1117.