ROLE OF BLOCKCHAIN TECHNOLOGY ON SUPPLY CHAIN

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Abstract

Coordination and collaboration within the supply chain are crucial components of the effective and the efficient supply chain. Supply chains have become longer, larger and more complex, that is why end-to-end transparency is critical in the operations of supply chains. Information processing and analytics can increase supply chain transparency using appropriate technologies such as RFID, IoT and blockchain technology. Blockchain technology has a potential to solve the problem of achieving end-to-end transparency. It represents a decentralized environment for transaction, where all entries are recorded on a public or private ledger that is visible to users. Integrated with other technology, the blockchain technology could be used to create a record of every moment of a product flow in the global supply chain. The purpose of this paper is to present the way in which blockchain technology is likely to use supply chain operations and practices. A further aim of this study is to identify potential fields of supply chain where blockchain technology is recommended.

Keywords: supply chain, logistics, blockchain technology

1. Introduction

On 2 July 2019, Mearsk (one of the world's largest shipping companies) announced that Hapag-Lloyd and the Singapore-based Ocean Network Express (ONE), the world's 5th and 6th largest shipping firms, also joined TradeLens, the blockchain-based digital platform that Mearsk had developed jointly with IBM (MAERSK.com). A year earlier, the Harvard Business School published a case study by Rajiv Lal and Scott Johnson entitled: "Mearsk Betting on Blockchain" (HBR 9-518-089). The question arises why the blockchain technology, which became known upon the appearance of the bitcoin (cryptocurrency), also hit the area of logistics and supply chain. In research conducted by Clohessy – Acton (2019), one of the participating companies said the following: "Blockchain enables you to do something that you have not done before. Therefore, the fundamental question for your business prior to adoption should be: what problem are you trying to solve which can only be solved by blockchain?"

The goal of the study is to provide an outline of the opportunities to apply blockchain technology in the case of supply and logistics chains as well as to specify the areas that may be relevant from the viewpoint of the topic. It is important to point out that blockchain technology not only hits the area of the supply chain (based on its characteristics that are introduced later) but it can also be applied in several other areas like the financial sphere (banks, insurance companies), state administration (e.g. individual identification of citizens, military logistics), health (e.g. medical history, clinical research, health insurance), Chain of Things (Internet of Thing, Industrial Internet of Thing) or Cyber-Physical System (CPS) (Kovácsházy, 2017 and Szarvas et al., 2018).

There is significant interest in the blockchain, as a new technology in supply chain-related areas, both in business and in the academic sphere. This is well shown by the results of the survey of 299 papers by Gurtu and Johny (2019) based on the EBSCO database. In 2016, only one article presented the blockchain research into the area of supply chain and logistics, while in 2018 seventeen articles were published in these two areas (13 on supply chain and 4 on logistics).

The technologies related to Industry 4.0 may promote the development of new business models. Numerous new, digital technologies are emerging in the field of production and the supply chain. It is a great challenge for corporate leaders to know which technology to invest in, and when. Blockchain technology is an important technology and is being applied more and more for process digitalization (Queirez et al., 2018). One of the reasons is that blockchain technology itself helps to solve the problems incurring in supply chains, e.g. controlling more and more complex networks, considering the critical criteria (e.g. transparency, speed, agility) that characterize supply chains these days (Ganeriwalla et al., 2018).

1.1. Supply chain management

The widely accepted definition of supply chain management was defined by the Council of Supply Chain Management Professionals (CSCMP) in the following manner:

"Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies" (CSCMP, n.d.).

As can be seen, the supply chain is nothing else but the entirety of all organizations / companies that directly participate in the supply and the distribution of products and/or services and in the related IT and financial processes, from the source up to the end consumer. However, the supply chain not only describes the network of the organizations active in the supply chain, but it is the conscientious management of the supply chain aimed at improving the joint performance and thus the competitive edge of the participating companies (Demeter, 2014). This is also supported by the a.m. definition that, on the one hand, highlights that the coordination and cooperation of the members of the supply chain, i.e. the suppliers, cooperators, logistics service providers and consumers, also forms a part of the supply chain management. On the other hand, it integrates both the supply and the distribution activities within the company and among companies. In order to work out integration among the members of the supply chain – without the common ownership of the companies – the members need to establish trust among themselves at a level that is able to support the sharing of the available information among the companies. On the other hand, the implementation of information sharing needs IT system(s) that is/are also able to provide this in the global, complex supply chains.

More and more end consumers seek information about the origin of the product, e.g. what raw material the given product was made from, where and under what circumstances was it manufactured. All this presumes transparency of the supply chains, i.e. the companies that are active in the chain should know each other and share the required information (Bateman – Bonnani, 2019), which means that trust should be built among the companies. The need for the transparency of supply chains is all the more justified since they are becoming larger and more complex. The transparency of supply chains can also reduce risks for the members and the final consumers (Zelbst et al., 2019). The lack of transparency in supply chains may also cause business problems, e.g. the given cargo is not permitted to move on if the origin document is missing. Bateman and

Bonnani (2019) raise the question: why is transparency and trust introduced into the supply chain so slowly if they are so important. Their answers are as follows: (1) the supply chains were not designed in that manner; (2) there is no relevant information, it cannot be collected, it does not exist or it is erroneous; (3) the financial investment into transparency does not always meet the short-term necessities.

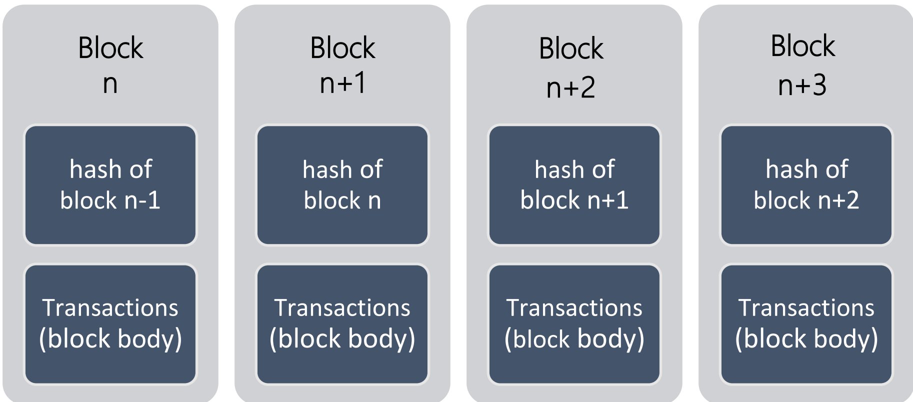
1.2. Blockchain

This term has no generally accepted definition (Seebacher – Schüritz, 2017) regardless of the fact that the foundations of blockchain technology were already laid down in Nakamoto's article (Nakamoto, 2008) in 2008. In his article (2018) Szarvas et al. calls it a half-baked technology and classifies it as DLT (distributed ledger technology). Having gone through the related literature, Seebacher and Schüritz (2017) defines blockchain technology as follows:

"A blockchain is a distributed database, which is shared among and agreed upon a peer-to-peer network. It consists of a linked sequence of blocks, holding time stamped transactions that are secured by public-key cryptography and verified by the network community. Once an element is appended to the blockchain, it can not be altered, turning a blockchain into an immutable record of past activity" (Seebacher – Schüritz, 2017).

Therefore, blockchain is an IT terminology that stores data in blocks and forms a checking code, what is called a "hash" code, which is typical for the relevant data set [1]. This checking code is inserted at the beginning of the next block, then the data set is stored and its checking code is formed in the next block etc. (Sík, 2017), as is also shown in Figure 1. It is an important feature that any data appearing in a digital form can be stored in the blocks (Tarcsi, 2017).

Figure 1:
A simple blockchain setup



Source: Queiroz et al., 2018.

Therefore, a chain of data sets is established in the case of block chain technology, i.e. the blocks are connected to each other, the blocks contain the transactions (data), the timestamp and the hash code of the previous block (individual sequence), which is formed in one way, can be formed from the data of the block but cannot be decrypted. Therefore, the technology is capable of making an irrevocable chain, thus the data cannot be changed retroactively either intentionally or by accident. Therefore, the blockchain is a distributed ledger technology, currently its unique feature is – as against central database technologies – that it cannot be turned

[1] cryptography-based code formation

off, annihilated or modified (Sík, 2017; Lányi, 2018). As a result of its decentralized feature, blockchain is safer than central data storage, and it can be better protected against external attacks. Since the whole database is distributed and exists in several places, the network continues to be operable even if one or more players opt out. In addition, it is permanent, there is only affixing and reading (immutability of data), there is no modification or deletion. It is important to highlight that blockchain technology is open and transparent, i.e. all transactions can be seen in time, they are transparent, can be traced and controlled by anyone, but cannot be necessarily interpreted. The technology is capable of implementing transactions that can be carried out automatically and that can be checked (e.g. smart contract) (Tarcsi, 2017). Table 1 summarizes the main characteristics of blockchain technology, highlighting two main areas, on the one hand, trust and, on the other hand, decentralization.

Table 1:
Characteristics of blockchain technology

Trust	Decentralization
Transparency - Shared & public interaction - Low friction in providing information	Privacy - Pseudonymity of participants
Integrity of data - Peer verification of transactions - Security through cryptography	Reliability - Redundancy of data - Potential use of automation
Immutability - Tamperproof architecture	Versatility - Peers participate in development

Source: Seebacher – Schüritz, 2017.

As is summarized in table 1, trust derives from transparency, data integrity and immutability, while decentralization provides for privacy, reliability and versatility. The listed characteristics of blockchain technology are the ones that make it capable – at a global level – to store documents, transactions and dates produced upon the logistic and supply chain processes and to digitalize the whole process (Lányi, 2018). Concentrating on the supply chain context, Cole, et al. (2019) summarized the characteristics that provide the relevance of applying blockchain technology in the case of supply chains. These are as follows: (1) Distributed and synchronized across networks, (2) use of smart contracts, (3) based on P2P (peer-to-peer) networks and (4) Immutability of data.

1.3. Materials and Methods

This study is a literary and theoretical approach, an analysis synthesizing the relevant sources. Its goal is to explore relations and trends; thus it is suitable for founding primary research.

2. Results and Discussion

2.1. Types of Blockchain Technology

There are several types of blockchain technologies, one group differentiates solutions based on access, i.e. public (”permissionless”) solutions, where all transactions are public but the users are anonymous (e.g. bitcoin), as well as private (”permissioned”) solutions, where an invitation or permit is required for joining. In the latter case, access control can be consortial (consortium) or controlled by an organization (private) (Wang et al., 2019).

SAP differentiates four types of blockchains based on their control: (1) consortium blockchains, (2) semi-private blockchains, (3) private blockchains and (4) public blockchains. Primarily the consortium and semi-private blockchains are used upon business operations, experience shows that the consortium blockchain is currently the most accepted business model, which is controlled by a group of specific organizations (SAP.com, n.d.)

The feature of a public blockchain is that it has several unknown participants, anyone can read and write and it works based on the Proof of Work consensus. As against this, in the case of a private blockchain solution the participants are known, basically they belong to one organization, the writing and reading authorization can be monitored centrally and consensus is reached through various algorithms. In the case of blockchain-based technologies run by a consortium, the participants are known, they belong to several organizations, the consent of several participants is needed for writing, reading can be public or restricted and consensus is reached through various algorithms (Tarcsi, 2017). Table 2 compares the blockchain types:

Table 2:
Comparison among public, private and consortium blockchains

Key feature	Public blockchain	Private blockchain	Consortium blockchain
Efficiency	Low	High	Medium
Performance	Low	High	Medium
Privacy	Low	High	Medium
Operations cost	Low	High	Medium
Centralization	No	Yes	Partial
Consensus determinants	All miners (permissionless)	One node (organization)	Selected set of nodes
Read permission	All nodes (public)	Restricted/Controlled	Restricted/Controlled
Immutability	Hard to be tampered	Could be tampered with	Could be tampered with

Source: Chang et al., 2019, pp. 1716.

It can be stated in general terms that blockchain solutions applied in business processes, thus also in supply chains and logistics, primarily belong to the types subject to permission, i.e. to private or consortial solutions, by applying various access mechanisms (Cole et al., 2019).

2.2. The Importance of Blockchain Technology in the Supply Chain

In their literature review, Gurtu and Johny (2019) summarized the key features of blockchain technology, which can justify its introduction to the supply chain. These are, on the one hand: the use of smart contracts and the opportunity of supply chain finance and, on the other hand the increased need for transparency and traceability in the supply chain. Global supply chains have multiple participants and all participants have their own abilities and limits that determine their competitiveness. Due to their set-up and operation, the current, traditional, global supply chains have typically several steps, the lead times are very long and require a lot of time, which influences the level of service to the end consumers. Blockchain technology helps to streamline supply chains as the role of some participants is terminated in the supply chain. Each key participant of the supply chain can be integrated into a safe network, thus enhancing the service level of the entire supply chain, which is advantageous both for buyers and sellers.

In a literary review, Wang et al. (2019) concluded that the application of blockchain technology in the supply chain is explained by the following drivers: (1) Trust: reliability and security of information, (2) Supply chain disconnection and complexities, (3) Product safety, authenticity and legitimacy (4) Public safety and anti-corruption.

Szarvas et al. (2018) highlight that blockchain technology is capable of storing logistic events/transactions in a standard form, therefore, it can provide appropriate input for what is called online analytical processing (OLAP[2] – On Line Analytical Processing). Blockchain technology helps to retrieve all data in order to analyze the operation, the reliability and the ability of the supply chain and, based on this, development and transformation projects can be launched to enhance the efficiency of the supply chains.

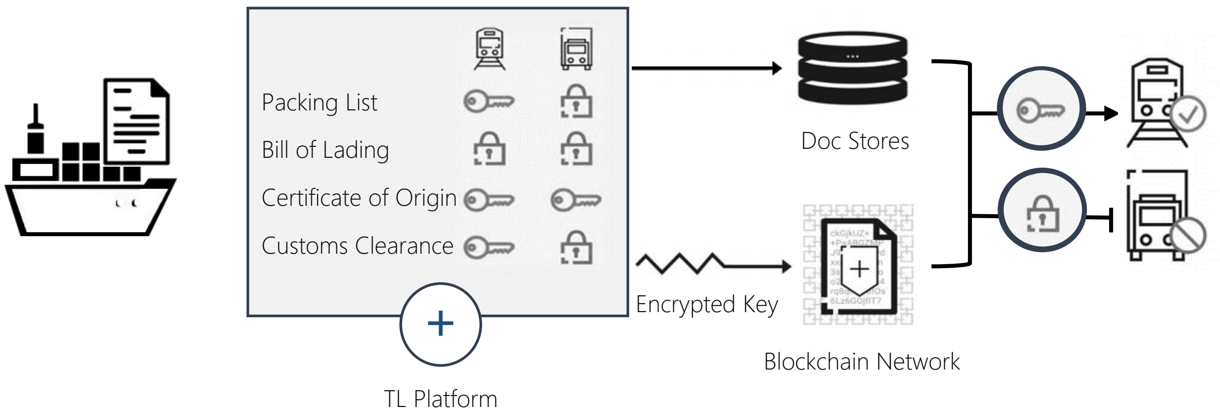
2.3. Blockchain Technologies Applied in the Supply Chain

In their study, Petersen et al. (2017) identified 49 various blockchain-based technologies (applications) in the field of logistics and supply chains, and classified them into three large clusters:

Cluster 1 - "Product Tracking". These solutions are focused on information supply about the shipment or about any other logistics objects, e.g. tracking the product from the shipper to the consignee. The decentralized feature of the blockchain enables the companies of the logistics chain to simply share data, e.g. they can adapt to the changes if a specific shipment is late.

An example of this is the TradeLens platform, jointly developed by Maersk and IBM, aimed at digitalizing global trade, more accurately digitalizing the home-to-home tracking of container shipping by sea. The project had two important pillars: to introduce, on the one hand, a shipping information pipeline and, on the other hand, paperless trading. This enabled the exchange of digitalized documents and increased the transparency of the supply chain. They tried to find a solution that can also be accessed by the members of the eco system connected to sending commodities: carriers, forwarders, ports, shippers/consignees, customs authorities and other shipping companies. Their choice was based on blockchain (Lal – Johnson, 2018). The simplified set-up of the system is illustrated in Figure 2.

Figure 2:
The simplified set-up of TradeLens



Source: TradeLens.com, n.d.

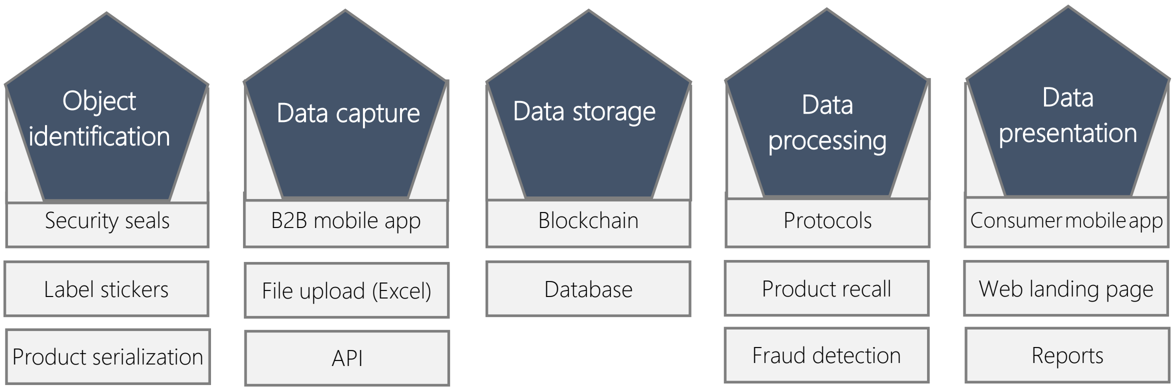
With the application of TradeLens, all data and document information related to the given shipment (container) is written into the blockchain system and the existing contracts are implemented automatically with the smart contract application. After recording the given event, e.g. arrival of the container at the port, the relevant contract gets activated, thus reducing errors, delays or lost documents (Choudary et al., 2019).

[2] The basic task of the OLAP systems is to support decisions, to collect information in the long run and to supply it to the decision-makers. The emphasis is laid on gaining information rather than on data input (Sidló, 2004).

Cluster 2 – "Product Tracing" In this case, the goal is to improve information flow and to trace the product origin using the knowledge of the stages of the route covered. This presumes a system approach. Here, it is required to connect the flow of materials and products with the flow of the related professional information, and they necessarily have to move together. This classically includes tracing medicines and foods, which can be supported by the blockchain solution.

An example for this solution is TE-FOOD, created as a result of a Hungarian development to offer a modern and cost-efficient solution for tracing livestock as well as fresh and finished products, from farms up to the end users. The system is a tracing information system covering the whole chain and containing unified logistics and food safety data – its structure is illustrated by figure 3. The blockchain technology was introduced for data storage in 2018, which rendered it impossible to falsify and modify transaction data (gs1, 2019).

Figure 3:
The structure of TE-FOOD



Source: Te-Food, n.d.

Cluster 3 – "Supply Chain Finance" This means an automated payment process with the help of the smart contract application, depending on e.g. the current status of the shipment. This study does not focus on this area of use, therefore we do not cover it in detail.

Based on the systematic processing of sources, Queiroz et al. (2018) pointed out that blockchain technology can induce numerous changes in the field of supply chain management. It can place product tracing on new bases, thus it can enhance the efficiency of decentralized operation and it can reduce the number of the parties cooperating in the supply chain processes together with the transaction costs. Blockchain technology provides the supply chain members with real time data about the origins of materials, purchase orders, inventory levels, about the date and the data of receiving the shipment and about the related invoices. Since a smart contract can be used with blockchain technology, automated orders can be made and automated payments can be launched under previously accepted conditions (Cole et al., 2019).

The "smart contract" is a program (protocol) providing ready-made schemes for simple cases, automating certain processes like the acknowledgment of orders (Cole et al., 2019). In this case, the parties learn and approve the contracting terms in advance. Modifications are only possible with the approval of all participants. Once the given event takes place, the provisions of the contract are automatically fulfilled as well as the prompt and automated payment process is also carried out (Tarcsi, 2017). It is to be noted here that the elaboration of the smart contract concept is attached to the publication by the Hungarian Nick Szabó, however, he made no implementation for this. His topics were digital contracts, electronic trading, cryptography etc. (Kovácsházy, 2017). Table 3 compares the features of traditional contracts and smart contracts in the case of international trading.

Table 3:
Comparison between smart contract and traditional trade contract

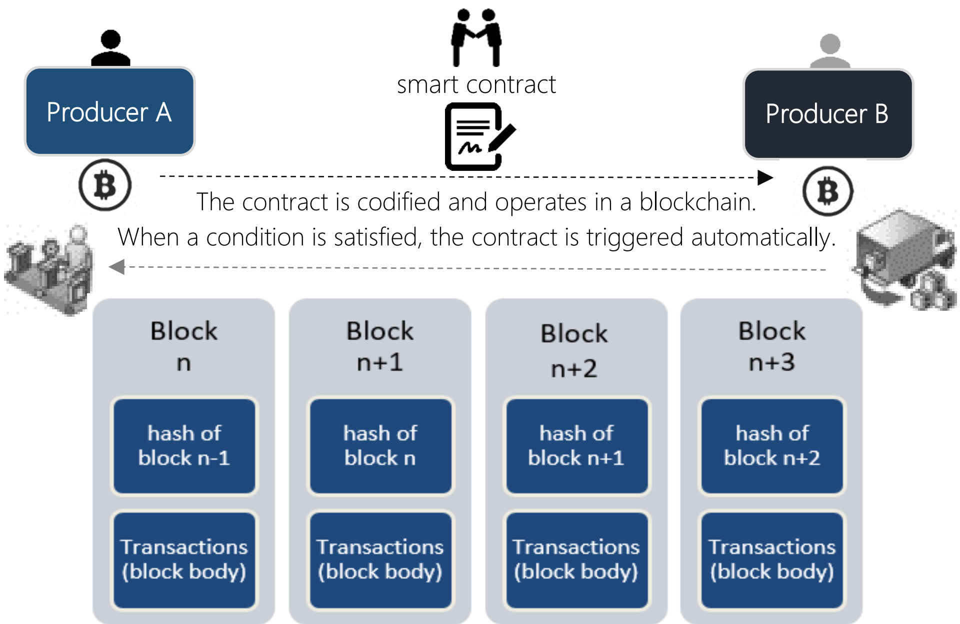
	Smart contract	Traditional trade contract
Execution method (mode)	Automatic execution by preset conditional triggers specified by specific entity, event or time	Execution followed by manual examination and judgement of contract terms and agreements
Execution speed	Within few seconds or minutes	Depending on distance (usually in couple of days)
Data security	Tamper-proof	Vulnerable to tampering, damage and can cause disputes

Source: Chang et al., 2019, pp. 1716.

An important feature of the smart contract is that it allows for streamlining the supply chain and thus reducing its complexity as the number of the cooperating organizations is reduced and certain routine tasks are performed by the system (e.g. checking compliance with the contracting terms), and, as a result, the freed human resource can be re-grouped to value-creating processes. The consequence of automated routine tasks is that the quality of work performance may improve (e.g. by completing more creative tasks) and this may provide supply chain workers with dynamism that can enhance the efficiency also in itself (Szarvas et al., 2018).

Figure 4 gives an overview of the operation of the smart contract. If the parties agree on the conditions, the contract is signed. Then the contract is coded and stored in the blockchain structure. The contract gets activated if an event takes place that complies with the conditions. Afterwards, both the product flow and the payment process are implemented under the contracting terms. This requires no mediating party, so not only the speed of implementing the transaction is increased, but the transaction costs are also reduced and trust among the participants is also raised as the copy of the ledger about the transaction will be available for all participants.

Figure 4:
Smart contract example in the Supply Chain context



Source: Queiroz et al., 2018.

In their study, Cole et al. (2019) also identified and summarized possible ways of further use of blockchain technology in the field of supply chain and operations management. Potential uses for blockchain technology in Operations and Supply Chain Management are as follows:

1. To enhance product safety and security by providing records of safety testing;
2. To enhance quality management by providing visible and easily accessible information about batches, aiding recalls and improving service;
3. To reduce illegal counterfeiting by providing information of the origin of a product;
4. To improve and automate contracts and reduce the need to develop trustworthy supply chain relationships;
5. To improve inventory management;
6. To reduce the need for intermediaries thereby reducing the complexity of the supply chain;
7. To accelerate work on design and new product development by improving efficiency and delivering greater transparency between teams;
8. To revolutionize IT in Operations Management by boosting access to tools and new practices, such as smart manufacturing;
9. To reduce the cost of transactions through automation, enabling real time auditing via time-stamping.

2.4. The Relationship of Blockchain Technology with Industry 4.0 and with Smart Technologies

Blockchain technology is not an independent technology, its operation significantly depends on the availability of data in an appropriate quantity and quality, therefore, it is also necessary to jointly apply other tools, e.g. the big data or the internet of things (IoT). To ensure that logistics and supply chain processes are tracked, and their transparency is increased through blockchain technology, e.g. GPS or RFID (radio frequency identification) tools must be integrated into the system to supply input data to blockchain technology. Since the blockchain is a metatechnology, other technologies (e.g. IoT) will always have to be applied (Sheel – Nath, 2019).

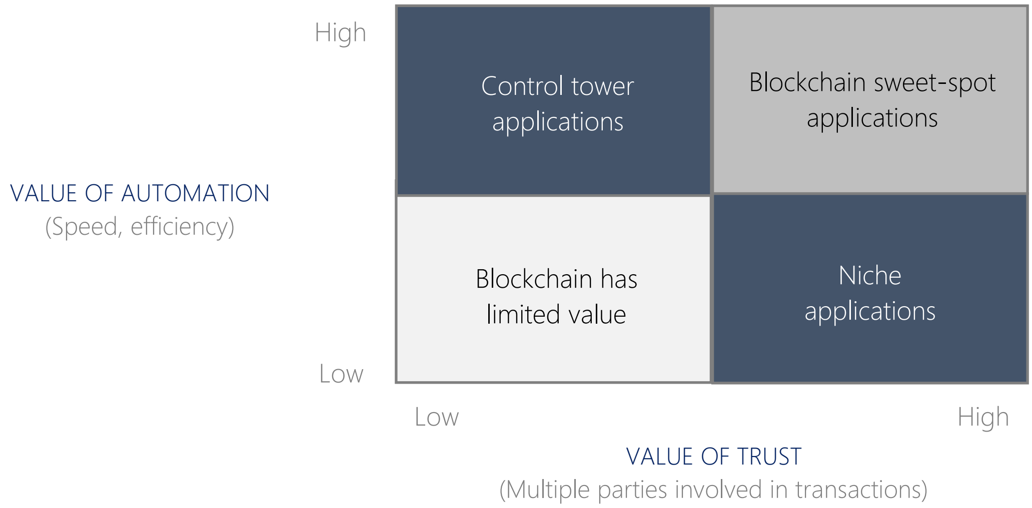
The research by Zelbst et al. (2019) highlighted that the RFID technology serves as a basis both for the IIoT (industrial internet of things) and blockchain technology in supply chains. In addition, IIoT technology supports the implementation of blockchain technology. Using the RFID in itself only allows for data collection but if it is integrated with other technologies – e.g. IIoT, which forwards data, and with blockchain technology, through which the data becomes accessible – a whole system is created to support supply chain transparency. The research by van Hoek (2019) processing case studies also pointed out that blockchain technology is a complementary rather than a replacement technology, since it has to process input data by applying already existing technologies like the RFID or the barcode. Cole et al. (2019) also arrived at the same conclusion, i.e. the blockchain is not only a complementary technology but it needs to be combined with other technologies. For example, the RFID will be the system that performs tracing-related tasks (e.g. identification, sensor activities), while the smart contract is automatically checked, and the payment obligation can be fulfilled through the ERP (enterprise resource planning) system.

2.5. Limits of Blockchain Technology

Like any other technologies, blockchain technology cannot always be applied. Ganeriwalla et al. (2018) determined a matrix where one dimension is the value of automation and the other one is the value of trust. Based on this, it can be defined – as is also shown in Figure 5 – in which case blockchain technology should be applied and in which cases other solutions are recommended. Blockchain technology is worth using if the value of automation and trust is high. In this case, speed and efficiency are of prime importance as a large amount of transactions need to be implemented. There are many participants in the supply chain, they may even be exchanged many times, therefore trust must be created among the members.

Figure 5:
Value of trust and automation matrix for blockchain

Blockchains make sense when automation and trust are of high value



Source: Ganeriwalla et al., 2018.

Cole et al. (2019) summarized – as follows – the cases where the application of blockchain technologyis recommended and when it is not recommended. Two main aspects were identified: the feature of the product and the complexity of the supply chain. Blockchain technology is recommended if the product carries some critical feature, e.g. its safety is critical (e.g. medicine, food), there is a high risk (e.g. diamond) or withdrawal is possible (cars) or if the supply chain is extended and there is a global, multi-stage and complex product flow and there are many suppliers. This solution is not expedient in a contrary case, e.g. in the case of local, short supply chains.

Ganeriwalla et al. (2018) drew up a checklist to help companies determine whether blockchain technology is suitable for them or not. Blockchain technology is recommended if:

1. The secure capturing of shared data, transactions, records or contracts is required;
2. Many supply chain members/participants give or call data in order to carry out the transactions;
3. The members of the supply chain do not know or do not trust each other and there is no central party to provide this trust, or it would be very expensive;
4. A high-cost or critical product is manufactured in the complex value chain.

2.6. Features of Introducing Blockchain Technology

The research conducted by van Hoek (2019), based on case studies, identified the features that characterize the implementation of blockchain technology in the context of the supply chain. The analysis started out from the framework system of Reyes et al. (2016) and compared it to the introduction of the RFID systems. Table 4 presents the results.

Table 4:
Similarities and differences between RFID and blockchain implementation

	Similar to RFID implementation	Unique to blockchain implementation
Drivers	Customer considerations are important…	• …but less of a customer requirement, more of a market potential perspective; • …but internal drivers are more prominent.
Leadership commitment	Top and middle management support enables implementation of blockchain like it does of RFID…	• …but executive engagement can greatly accelerate pilots; • …and 2–4 engaged partner may suffice initially.
Barriers	• Relevant to consider barriers upfront; • Lack of understanding is equally prominent in blockchain consideration.	• For a pilot a formal business case is less needed and; • There is less upfront investment needed for blockchain.
Implementation	Implementation levels can vary from supply chain to supply chain…	• …but actual blockchain implementation levels are limited to date; • …making it unclear of blockchain will be as scalable as RFID.
Benefits	Visibility and traceability stand out as similar benefits/functionalities, confirming the overlapping functionality and potential to complement RFID with blockchain…	• …less of an inventory tracking and recording focus, more of a dissemination benefit; • …benefits may be more narrowly defined.

Source: van Hoek, 2019, pp. 847.

Table 4 goes to show that the features of implementing the two technologies are mostly identical but there are factors that are only typical of blockchain technologies based on our current knowledge.

Clohessy and Acton (2019) examined the adaptation of blockchain technology along organizational factors, highlighting three factors: organizational size, top management support and organizational readiness. Through their research they processed the case study of 20 Irish companies. Their key finding was, on the one hand, that key decision makers play an important role in deciding whether the organization applies blockchain technology or not. On the other hand, large companies are more likely to adapt blockchain technology than small to medium-sized enterprises (SMEs). One of the reasons for this is that the companies who decided to introduce blockchain technology were basically motivated by the reduction of the complexity of the supply chain and supply chain-related investment costs. Traditional supply chains have typically high costs and time needs for their operation as well as many participants in the supply chain. These are the factors that induce companies to apply blockchain technology. Against this, the SMEs who did not introduce blockchain technology did so because they work in a small supply chain that does not require the introduction of this technology. On the other hand, those companies that introduce blockchain technology were most probably more in favor of IT innovations. Table 5 summarizes the findings of the research.

Table 5:
Summary of main blockchain organizational adoption considerations

Organization	Adopted – deployment and rationale	Non-adopting rationale
Large	Multiple instances of fully deployed and functional blockchain applications; Private permissioned blockchains; Initial blockchain prototyping to create business use cases; Availability of cloud-based blockchain development tools; Supply chain transaction innovation: • cost reduction, • enhanced security, • enhanced transparency, • enhanced efficiency.	Lack of internal IT adoption coordination; Blockchain technological complexity; Lack of specific industry business cases and standards; Lack of government incentives; Lack of blockchain top management awareness; Lack of internal staff with requisite; blockchain skills and competencies; Lack of supply chain organizational buy in.
SMEs	Single instance of a fully deployed and functional blockchain application; Public permissioned blockchains; Provision of new innovative services; Availability of cloud-based blockchain development tools; Availability of publicly available business use cases.	Lack of blockchain awareness; Lack of specific industry business cases; Challenges sourcing employees with requisite blockchain skills and competencies; Challenges sourcing blockchain educational resources.

Source: Clohessy – Acton, 2019, pp. 1474.

It is also pointed out by the research results (see Table 5) that the set-up, type and operation of the supply chain has a major impact on the introduction and the application of blockchain technology in a large corporate environment.

2.7. Possible areas of research into the relationship between blockchain technology and supply chain research agenda

In addition to the presented research work, most of the processed literature also highlighted further research areas for examining the relationship between blockchain technology and supply chain. We emphasize two works, one is focused on supply chain management and the other one jointly deals with the supply chain and the area of operations management. The latter extension is important as the value creating processes cover both areas.

Based on the systematic literature review, Wang et al. (2019) defined possible research areas with regard to supply chain and blockchain technology:

1. Cryptocurrency and supply chain finance (for example payment process, blockchain-based financial service platforms);
2. Disintermediation and reintermediation (for example elimination of intermediaries, extinction of certain types of intermediaries);
3. Digital trust and supply chain relationship management;
4. Blockchain, inequality and supply chain sustainability;
5. The dark side of blockchain (for example governance, ethics, law, crime security, privacy);

6. A design perspective on a blockchain-enable supply chain:
    a. Selecting a blockchain's entry point to the supply chain;
    b. Building a blockchain ecosystem;
    c. Articulating the platform value;
    d. Establishing the governance model;
    e. Exploring legal implications;
    f. Scaling up a blockchain-enabled supply chain network.

Cole et al. (2019) extended the potential research areas not only to the supply chain but also to the area of operations management as follows:

1. Blockchain technology development for Operations and Supply Chain Management;
2. Incentivizing blockchain technology adoption in the supply chain;
3. Trade-off considerations affecting the adoption of blockchain technology;
4. Blockchain technology implementation in complex supply networks;
5. Supply chain relationships;
6. Theory application and development for blockchain.

3. Conclusion

This study has pinpointed the major areas of the relationship between blockchain technology and supply chain. Our review identified the factors that influence the introduction of blockchain technology into supply chain processes. In summary, it can be stated that the opportunities of potentially using blockchain technology in the area of logistics /supply chain are primarily related to tracking some object (e.g. container, shipment) and providing object-related information (e.g. date of arrival of the container at the port). In addition, it may play a significant role in verifying the product origin (e.g. medicine, diamonds, food), i.e. in preventing the marketing of fake products and in identifying the circumstances of manufacturing (e.g. the product was manufactured in a country where no child labor is permitted). In the area of the supply chain structure, the complexity of supply chains can be reduced with smart contract protocol, supported by the blockchain, i.e. streamlining can be carried out by reducing the number of the cooperating organizations or the operation of certain cooperating organizations becomes unnecessary. As a result, the transaction costs and the lead times of the supply chain are reduced, thus raising the service level of the supply chain (Lányi, 2018; Cole et al., 2019). The study by Hald and Kinra (2019) looked at the impact of the blockchain on the performance of supply chains. They specified the following four areas of the blockchain that enhance the performance of the supply chain: (1) information lighthouse, (2) exploitation technology, (3) exploration technology and (4) relationship-building technology. In addition, they also highlighted three areas that may lead to a lower performance of the supply chain: (1) domination technology, (2) straitjacket, (3) deskiller.

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