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# Blockchain for Supply Chain Management: A Literature Review and Open Challenges

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**Abstract**

In the era of digital transformation, supply chain management faces major challenges induced by the lack of transparency and the evolving industry. In this context, blockchain technology has emerged as a possible answer to the future problems of the supply chain. In this paper, we present a systematic literature review on blockchain in the context of supply chains. The goal of our work is to present the factors and capabilities of blockchain technology that contribute to improving supply chain resilience. We also show which supply chain management factors limit the use of blockchain technology. Based on this, we identify various areas and applications of blockchain technology to support supply chains and highlight current work in the field. From the reviewed literature, we deduce a number of open challenges regarding the application of blockchains in the context of supply chains, e.g. the need (a) to improve the implementation process, (b) to make blockchain more cost-effective, (c) to educate potential users regarding blockchain security aspects, and (d) to further digitize supply chains as part of the digital transformation process.

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*Keywords:* blockchain; supply chain management; digital transformation

## 1. Introduction

Increasing digitization has made life easier for many people through new technologies [17]. For example, many new blockchain technologies have entered the market and gained tremendous traction in recent years [25]. Promising new blockchain systems offer new opportunities to revolutionize how decentralized transactions are processed. However, these technologies encounter fundamental problems in transaction management and face major challenges

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[49]. Considering the rapid pace of change in the technology industry, it is both necessary and challenging to thoroughly understand the underlying technologies, especially regarding their data processing capabilities [17, 49]. Various business sectors such as financial markets, insurance, and supply chains have been driven by the advancement of blockchain [46]. This is mainly because it allows the exchange of monetary values and communication between mutually distrusting parties without relying on a trusted person [51]. In addition, a blockchain offers integrity-protected data management and enables process transparency, which is particularly advantageous in the supply chain sector, as increasingly complex supply chains face major issues such as traceability and integrity [51, 16, 38]. Furthermore, despite extensive research, many challenges in supply chain management have not yet been solved. For example, many unanswered questions remain about the transportation process, product supply and information management [55]. Blockchain technology holds great potential for a wide range of industries [38]. Factories are moving in a smart direction and can no longer reconcile existing network security systems with their business and user requirements [15]. The blockchain system guarantees the credibility of all data by making it public, thus achieving consensus and ensuring the consistency of the global state. Blockchain has attracted a lot of attention due to its characteristics such as transparency, decentralization, verification and traceability [59]. However, there is also a need for tools to deploy the new technologies in various sectors to ensure that data stored in blockchain systems can be used, including monitoring, auditing, and ensuring compliance [35]. Because blockchain technology is decentralized, traceable, and tamper-proof, it is well adapted to addressing supply chain issues [34]. The foundation for the overall competitiveness of all companies is supply chain management [60]. Due to the strong cooperation of customers, entrepreneurs, governmental organizations and service providers, business cases are characterized by significant complexity [33]. Supply chain management deals with the networking of plants, manufacturers, distributors and suppliers to provide the materials, such as raw or finished goods, in the right amount, at the right destination and at the appropriate time at minimal cost [43]. With this systematic literature review (see e.g. [50, 48]), we aim to provide a comprehensive overview of blockchain systems and their impact on supply chain management with the following research question:

- RQ1: Which factors and capabilities of blockchain technology improve supply chain resilience?
- RQ2: What supply chain management factors or technologies limit the use of blockchain technology?

This paper makes the following contributions:

1. An overview of the capabilities of blockchain technology in relation to supply chain management is described.
2. A review of the vulnerabilities of blockchain technology and those of supply chain management are outlined.
3. In addition, the resilience of the interaction between capabilities and vulnerabilities is discussed.
4. Open challenges are deduced in order to inspire future research and pave the way to implementing supply chain solutions based on blockchains.

The paper is organized as follows: In Section 2, an overview of related work is given. In Section 3, the research methodology of the review is presented. In Section 4, the results of our study are presented and discussed. Then, in Section 5, our research questions are answered, and our limitations are presented. Finally, future work and identified open challenges regarding the application of blockchain for supply chains are presented in Section 6.

## 2. Related Work

This section surveys related work from the field of blockchain in supply chain and contrasts it with this paper. Mahyuni et al. [37] analyze the research on the potential of blockchain to improve supply chain performance. However, rather than the potential, this paper compares the strengths of blockchain and the weaknesses of supply chain management and how they work together to improve supply chain resilience. The benefits of blockchain for sustainable supply chain management in the agricultural sector have been highlighted by Mukherjee et al. [41]. On the other hand, the present paper highlights blockchain technology in supply chains without further restriction. The authors [42] examined not only the economic impact of blockchain on the environment and population but also the emerging trends in a circular supply chain with the current movements of advanced technologies and their critical success factors. Alkhudary et al. [3] are investigating which supply chain disruptions can be solved by blockchain. Rauniyar et al. [47] investigated blockchain-based strategies used by companies to mitigate risk in supply chains. They identified the

nature of risks in global supply chains, the role of blockchain in mitigating them, and the challenges of implementing them with blockchain. In doing so, they developed a framework for decreasing supply chain risks through blockchain. Research into blockchain technology in supply chains is going in all directions. However, it was concluded that not much is available yet on the impact of blockchain on reducing the risk of supply chain interruptions [3], [47]. Manupati et al. [39] have built a model to anticipate disruptions that may happen in a scenario where smart contracts based on blockchain technology were implemented. In addition, other measures are also presented by Manupati et al. [39] that companies can take to avoid poor performance outcomes.

In examining similar work, it became clear that the areas where blockchain systems have positive or negative impacts on supply chains and improve resilience have not yet been described and need to be further explored. Since the literature to date has only described how blockchain impacts supply chain management in the areas of disruption [3], adaption [42], risks, and challenges [47], but not yet in which areas and use cases blockchain systems have a particularly positive or negative impact on supply chain resilience, we analyze this unexplored area. Furthermore, our paper is differentiated by the use of the supply chain resilience framework, with the help of which we examined the use of blockchain technology in supply chain management.

## 3. Methodology

To access recent and relevant work, a systematic literature search was conducted to obtain papers on blockchain technology related to supply chain management through 16th November 2022. The meta database Scopus was searched with the following search term (abstract, title or keywords):

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(blockchain) AND (database) AND ("supply chain management")
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To ensure that we only use scientific material, we based our search on the Scopus meta-database and used only international peer-reviewed conferences and journals. After a manual review of the 92 papers, we identified 42 as relevant to blockchain databases in supply chain management. The identification was based on a manual decision by two reviewers at a reliability of 96.5%. From the initial result set of 92 papers, papers were excluded based on these exclusion criteria:

- EC1: Work that was too specific and not applicable in all areas of supply chains, e.g. agriculture, fish supply chain, etc.
- EC2: Work where the main focus was not on blockchain or supply chain or only mentioned briefly
- EC3: Meta-reviews on supply chains and/or blockchain

## 4. Results & Discussion

The supply chain resilience framework, proposed by Pettit et al. [45], is used to structure the literature review body shown in Fig. 1.

Pettit et al. [45] have developed the supply chain resilience framework, which helps to manage risks in the supply chain and supports companies and businesses in identifying capabilities and vulnerabilities. In addition, the framework can reveal vulnerabilities in the supply chain. Low capabilities combined with moderate or high vulnerabilities can drastically reduce the resilience of the supply chain. Furthermore, the framework provides an opportunity to develop a strategy to improve supply chain resilience. In this paper, we use this supply chain resilience framework to analyze vulnerabilities and capabilities of blockchain technologies in supply chain implementations (summarised in Table 1). This is done by comparing the capabilities of blockchain with the vulnerabilities and challenges of the supply chain to find out which factors have a particularly positive or negative effect and how blockchain systems differ from normal systems in this area. The vulnerability concept of the supply chain resilience framework includes factors that increase susceptibility to disruption. The capabilities concept includes attributes required to identify and overcome disruptions. To improve performance in the long term, a balance between vulnerabilities and capabilities is required. As the supply chain resilience framework provides insights into strengths, weaknesses, and priorities, we applied it to address our research question and to present the findings in a definite structure [45]. Lohmer et al. [36] have already mentioned the framework for resilience strategies in the context of supply chain in relation to blockchain. Based on the resilience

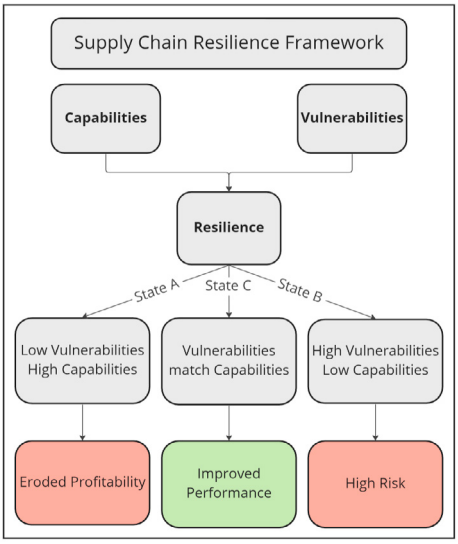


Fig. 1: Supply chain resilience framework for structuring the literature review (in accordance with [45]).

framework, we established the following outline: The capabilities and vulnerabilities of blockchain technology and supply chain management are described. The resilience section highlights the interaction between capabilities and vulnerabilities.

### *4.1. Capabilities*

The adoption of blockchain technology is revolutionizing business process management, transaction processing, and supply chain data management [57]. Furthermore, many other technologies, such as smart contracts, cryptographic technologies, timestamps, and peer-to-peer (P2P) networks, are being integrated using blockchain technology [54]. Blockchain is an immutable ledger that can be used as a database in supply chain applications. This database can be accessed by all peers in a network [2]. Fig. 2. shows how the blockchain works. Each node has a complete copy of the blockchain and is connected to the network with another node. Before a block can be added to a chain, it must be verified, and only then can the transaction be performed [56]. A traceable and transparent supply chain enabled by blockchain technology can reduce trust issues in the supply chain, reduce the likelihood of fraud, and enable better traceability of manufacturing and production. This is achieved by implementing appropriate identifiers along the supply chain [1], [58], [24], [14], [18]. In addition, the identification of key data, made possible by managing transaction information in the digital ledger, enables the traceability of products from the point of origin to the end customer [57]. Blockchain can also improve the security and transparency of data in the supply chain and promotes a sustainable business structure by transforming linear systems into circular systems [1], [22]. Defective and damaged products can be traced back to the responsible entity in the supply chain [26]. Improved traceability and increased resilience to crises such as the COVID-19 pandemic are among the strengths of blockchain implementations in the supply chain [4].

Furthermore, systems for anomaly detection can be implemented, which can increase the robustness of blockchain systems and detect malicious activity [27]. Blockchain systems can also have a positive effect on just-in-time delivery systems. With the use of smart contracts, products can be manufactured and delivered when they are needed, resulting in reduced costs due to better inventory management [8], [12], [23]. In addition, products or even individual items can be traced back to the manufacturer, and the information passed on to the various companies contributes to damage limitation and management along the supply chain [57]. Barbosa et al. [9] explain that blockchain can be used to incorporate sensor data into the supply chain. For example, this could be data on temperature, humidity, time and location. Transparency and safety make it more difficult for a single party to manipulate data and lie about where the product is produced or under which circumstances the product was transported. Another blockchain-based system

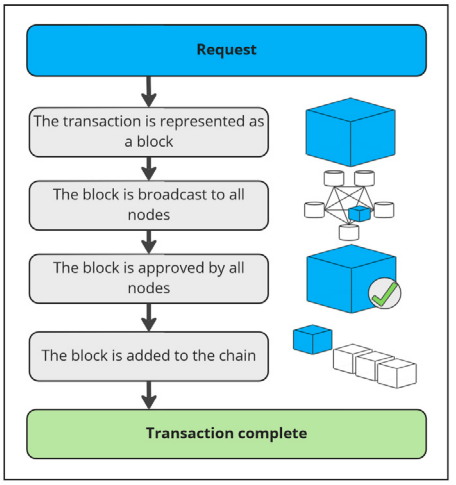


Fig. 2: Blockchain transaction process (in accordance with [56]).

developed by Bhosale et al. [10] allows all farmers to determine the minimum price for agricultural products. Furthermore, such blockchain systems could be complemented with other technologies, such as the Internet of things, to improve error resilience [10], [19]. One capability of the blockchain is its decentralized architecture, which frees it from the system and the known limitations of a central instance, such as security gaps, bottlenecks, and access to networks. In addition, both historical and current data and any changes are recorded transparently, making them publicly available for anyone to see [28]. Moreover, data exchange, operations and transactions in the blockchain are much cheaper and faster than in traditional systems [28]. One reason for using blockchain technology in supply chain management is to simplify transaction processes, reduce time and costs, and improve reliability [29], [31]. The data generated during the distribution process is uploaded to the blockchain, which increases the reliability of the products by seamlessly tracking various information about the products, such as origin, delivery process, or warehouse status. It ensures that accurate supply chain data is entered into a decentralized ledger and validated [29]. One of the key aspects of blockchain is to maximize the security of information and transaction management. Counterfeiting can be prevented with the help of blockchain because there is a very high reliability of the stored data without relying on third parties, as well as the consensus mechanism. By implementing blockchain technology in supply chain management, therefore, the cost, productivity, profitability, and performance of supply chain management can be monitored with fewer errors [29], [30].

### *4.2. Vulnerabilities*

#### *4.2.1. **Supply Chain***

The supply chain consists of a network of people, organizations, resources and activities involved in the life cycle of a product. The life cycle of the product goes from the delivery of raw materials to the manufacturer, to the production of the product, to the sale and delivery to the end consumer [40]. Companies are constantly striving to improve the performance of supply chain management. Topics such as the regulation of supply chain operations or the process of an organization are covered in supply chain management [56]. Furthermore, efficiency is very important. The key point is to visualize the entire process in one system. In this way, the companies involved in the supply chain can work efficiently and eliminate redundancies and inefficiencies even between partner companies [29]. However, there are some weaknesses in supply chain management. For example, lack of management, lack of visibility and assets, improper handling of data, and inefficient risk management [40]. Providing products and raw materials while ensuring the appropriate quality of safety is an important task for companies that cannot be accomplished without traceability information. The sustainability of supply chains also plays an important role for companies, but without the traceability of raw materials, sustainability cannot be optimally implemented [6]. In addition, the logistics industry is highly vulnerable to unforeseen situations such as natural disasters, the outbreak of a pandemic, or unplanned customs

and freight payments [57]. The records in databases or government systems can be easily falsified. For example, in the vehicle industry of many countries, vehicle data is not made publicly available, so falsification cannot be traced [56]. Large companies use central platforms to capture and manage information. However, if the central party holding the information accidentally deletes it or cannot find it again, this is not transparent to all project stakeholders and jeopardizes data security. For this reason, to manage supply chain data and improve supply chain performance, there is a need for a decentralized network [30].

#### *4.2.2. **Blockchain***

Blockchain databases face several challenges and vulnerabilities, primarily scalability, speed, interoperability, security and privacy [2]. Other weak points of the blockchain are the high power consumption and the high costs of setting up the hardware. In addition, it requires a high data storage capacity, as each block replicates the previous block's data [32]. In order to apply blockchain technology to supply chains, key organizational challenges must be overcome. Most importantly, supply chain services, sustainability measures, and information management technology must be improved [57]. In addition, the transport infrastructure must be better developed and managed. This includes, for example, road transport, harbours, airports, and message management. Blockchain technology has great potential in the area of digital infrastructure if these transportation infrastructure issues can be addressed [57]. One of the problems with monitoring the supply chain is that an individual product must be identified and tracked. Data that is recorded must be inherently trustworthy, making it difficult to track a product using blockchain [21]. Since the blockchain is essentially a shareable database, the data stored is open, transparent, and tamper-proof, but this aspect also poses risks to consumer privacy. Consumers are increasingly concerned about these risks, but companies are trying to get customers to understand that if theft occurs, it is easier for businesses to help them [58]. Awalu et al. [7] describe that with centralized blockchain systems, the problem arises that the central authority must be fully trusted. This problem of centralized blockchain goes against the very characteristics of decentralized blockchain systems. Amin et al. [5] concluded that blockchain applications alone may not be sufficient to be used in supply chain management. Blockchain technologies may need to be combined with other technologies, such as big data, to achieve the desired result.

### *4.3. Resilience*

#### *4.3.1. **State A – Low Vulnerabilities & High Capabilities***

The resilience factors were classified based on the vulnerability and capability factors in [45]. Blockchain faces several difficult problems, primarily scalability, complexity and the need for large networks. The large and complex networks are mainly due to the increasing complexity of the "Proof of Work" system that many blockchain systems use; over time, the complexity and computing power requirements increase [11]. "Proof of Work" also faces the following problems: (1) If an entity controls more than 51% of the network, that entity can corrupt the network and would have control over the blockchain network. (2) The "Proof of Work" principle becomes slower and slower due to the increasing complexity and requires more time and resources. Other algorithms, such as "Proof of Stake" promise better performance with lower resource consumption [11]. Although the benefits of blockchain systems are widely known, less attention is usually paid to the adoption process and implementation. As a result, many of the benefits of blockchain can be difficult to implement in practice [13]. Most of the proposed blockchain systems related to supply chains are in a research status and are mostly used for academic purposes only. More work on tools and architectures is needed for blockchain systems to find their way into a larger number of organizations [20]. In response to RQ2, we can conclude that implementation emerges as a limiting factor for blockchain due to challenges in scalability, complexity, and the predominance of research-oriented systems, coupled with insufficient focus on adoption processes [11, 13, 20].

#### *4.3.2. **State B – High Vulnerabilities & Low Capabilities***

High-quality requirements and price wars in the service sector or in production companies have frequently led to conflicts in recent times. Customers are increasingly faced with broken or damaged products, late deliveries, poor product quality or even the wrong product. This causes customers to lose interest, which in turn translates into a decrease in overall supply chain management revenue. Moreover, in these cases, a lot of time and money is usually invested without offering a solution to the customers, and they provide negative feedback [53]. The implementation

of blockchain technology in the supply chain is seen as a critical challenge. As a result, the impact of blockchain and supply chain collaboration is not as readily apparent. Readiness for the technology and the ability to use it are critical factors to consider when blockchain and supply chain work together [52]. It is still unclear why blockchain technology should be the technical solution to improve supply chain management. It has been confirmed that a single source of truth is sufficient for most supply chain management functions [51]. Regarding RQ2, our analysis reveals that blockchain currently offers insufficient capabilities for addressing the vulnerability of resources, i.e. resolving supply chain conflicts and dealing with damaged or inadequate deliveries. This limitation extends to the implementation process, making resources and implementation limiting factors.

#### *4.3.3. State C – Vulnerabilities match Capabilities*

Supply chain management needs blockchain technology to simplify the transaction process, reduce time and cost, and improve reliability. In this regard, blockchain supports the optimization of the entire supply chain management. This includes connecting information and processes. Strengthening reliability and transparency, maximizing the use of existing legacy systems, material supply, quality management and maintenance area. Because blockchain digitizes entire distribution processes and connects them across countries or origins, data can be used in various forms and preserved as immutable data. In addition, blockchain technology can be used to track the entire process of a commodity from production through transportation, storage, distribution and consumption [29]. The use of blockchain applications in supply chain management will result in significant time and cost savings for both the contractor and the customer and improve data security and accuracy. Because blockchain technology provides a decentralized system for managing electronic documents where all parties can collaborate and validate information in the decentralized environment before it is stored in the distributed ledger, it is the key solution. Blockchain technology enables perfect notarization for every creation, deletion, and update of information. Blockchain in supply chain management promotes traceability and thus strengthens trust between all parties involved [30]. Blockchain helps supply chain management to document transactions permanently and decentrally in one record and to monitor them securely and transparently. This leads to a reduction in delays and eliminates further human error. In the supply chain, blockchain is also used to reduce costs and labour and to validate the authenticity or that the status of products is fair trade [28]. It can be concluded that the traceability of products becomes easier with the help of blockchain. Goods are tracked in real time and can be confirmed by all parties along the transport route. Thus, the supply chain becomes more transparent with the help of blockchain. Since blockchain is a decentralized record system, the risk of counterfeit or unlicensed products is reduced. Most importantly, inventory can be properly managed using blockchain, as all parties involved in the transaction can share and verify the information. Blockchain simplifies the contracting process of supply chains by eliminating unnecessary and complicated documents through a smart contract that all parties must review within the blockchain system. Supply chains that use blockchain reduce costs through efficient inventory management using traceability and security features [44]. In addressing RQ1, this demonstrates that blockchain technology enhances supply chain resilience by fostering transparency and traceability, leading to improved trust, reduced counterfeit risks, and efficient inventory management [30, 28, 29, 44].

Table 1: A summary of resilience factors and their associated subfactors.

| **Resilience Influence factor** | **Subfactor** |
|---|---|
| Capabilities | Traceability [29, 30, 44, 1, 58, 24, 14, 18, 57, 26, 27, 31],<br>Transparency [28, 44, 1, 58, 24, 14, 18, 22, 8, 12, 23, 9, 10, 19, 29, 30] |
| Vulnerabilities | Resources [53, 11, 32, 21],<br>Implementation [13, 21, 53, 52, 51, 11, 2, 57, 21, 58, 7, 5, 6, 57],<br>Management [40, 57, 30] |

## 5. Conclusion & Limitations

After a detailed discussion and elaboration of the topic, the first research question “Which factors and capabilities of blockchain technology improve supply chain resilience?” can be answered as follows. Blockchain technology

has a very large potential to improve supply chains in many ways, such as traceability, transparency, and as a result, reliability, security, sustainability, and the ability to mitigate human error. However, the adoption of blockchain technology presents not only advantages but also challenges, as the implementation process is considered critical. To answer the second research question "What supply chain management factors or technologies limit the use of blockchain technology?". It has been confirmed that a single source of truth is sufficient for most supply chain management functions. Moreover, there are hardly any standardized technologies in the supply chain field and without unified technologies, the process of connecting blockchain technologies would be a huge effort for all companies along the supply chain. This process would take enormous resources, which would be a barrier for many companies. Such highly complex requirements and a lack of standards and guidelines could lead to high costs for companies and organizations. In addition, supply chain managers need extra training to work with the new requirements and techniques. Other IT specialists must also be involved in the process to ensure smooth operations. We reviewed relevant existing peer-reviewed literature on blockchain and supply chain and structured our findings according to the supply chain resilience framework. We highlighted the vulnerabilities of supply chains and blockchain, the opportunities of blockchain, and highlighted the role of blockchain in supply chain management, resulting in an up-to-date summary of the state of research and disclosure of unexplored areas. Because the analysis was limited to the Scopus metadatabase, other databases that published work of interest may have been excluded from this review. This excluded material could contain unfavourable or nonconforming results that could bias the publication. An additional limitation of this work is that it did not consider approaches that were too application-specific since those are not fully generalisable to all applications. However, it is important to note that some approaches have interesting solutions to supply chain problems that must be generalised or standardised, which could contribute to the development of more comprehensive and universally applicable solutions.

## 6. Future Work & Open Challenges for Applications

Since we have identified many open challenges, future research could focus on finding ways to better implement blockchain technology in supply chains. Blockchain technology is a promising area with regard to supply chains. However, it became clear through our research that there are still difficulties in implementing the systems. Many blockchain applications are only used in academic research and often have great success there. However, there is a lack of frameworks and methods to convert this academic knowledge into production systems effectively. Such frameworks and systems would be necessary so that the research can be effectively applied in practice. There is also still a need for faster and more cost-effective blockchain algorithms to mitigate the system's weaknesses and build on its strengths. Due to the high power consumption, high cost of setting up the hardware and high data storage capacity, the cost of using blockchain technology often exceeds the benefits that the technology provides for supply chain management. Future research could also focus on making blockchain technology more accessible and cost-effective for smaller-scale processes. In addition, blockchain technology still has many vulnerabilities and open challenges, such as security and data protection. Further research could also focus on improving the security of transactions and selectively releasing information only to authorized persons so that no unauthorized persons gain access and fraud attempts can be prevented. This could also increase consumer security, as many consumers are fearful for their privacy. Another high research need is to improve the supply chains. Here, new methods could be designed to identify each individual product more quickly, as the infrastructure still has problems with this process. In addition, the transport infrastructure would have to be further developed, as there is still too little transparency in this area. In summary, we identified the following open challenges regarding the real-world application of blockchain in supply chains: (1) The implementation process of blockchain solutions should be further optimized, and the entry costs should be reduced. (2) Blockchain technology should be made more cost-effective, as costs currently exceed benefits for many applications. (3) Potential users should be educated regarding the security aspects of blockchain. (4) Supply chains and transport infrastructure need to be better digitized, as there is still too little transparency in these areas. (5) The current lack of frameworks and methods should be addressed to effectively translate academic knowledge into production systems.

As a final remark, we found that blockchain technology offers potential for some of the current challenges of supply chains, for example, regarding transparency and transaction security. Yet, there are also numerous challenges in the field of supply chains that will not be solved by blockchains. Examples are the general need to increase the digitization level and the vulnerability of modern supply chains caused by global crises.

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