Turkish Journal of Computer and Mathematics Education *Vol.11 No.03 (2020), 1948-1956*
DOI: https://doi.org/10.17762/turcomat.v11i3.13591
Research Article

Blockchain-based Traceability and Transparency in Agricultural Supply Chains: Challenges and Opportunities

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Abstract: The use of blockchain technology in the agriculture business to improve transparency and traceability along supply chains is the topic of this study, which analyses its advantages and disadvantages. The study underlines the need for transparency and traceability in the agriculture sector as well as the advantages of employing blockchain technology in this area. Also, the study highlights the necessity of transparency and traceability in the healthcare sector. There is discussion of obstacles to implementation, including technological as well as organizational issues. The article uses Walmart, Nestlé, Bumble Bee Seafoods, and Cargill as examples of firms that have effectively implemented blockchain-based traceability and transparency in the agricultural industry. Other companies that are discussed are Bumble Bee Seafoods and Cargill. These examples demonstrate how systems based on blockchain technology can be utilized to improve supply chain management, thereby enhancing food security, efficiency, transparency, sustainability, quality, and access to markets. The conclusion of the study highlights the exciting future that blockchain-based traceability and transparency represents for the future of innovation and growth in the agricultural business.

Keywords: blockchain technology, supply chain transparency and traceability, supply chain challenges and opportunities, and food safety and efficiency and sustainability.

I. Introduction

Blockchain technology has recently surfaced as a possible solution that might be implemented in food supply chains in order to improve transparency and traceability. Blockchain technology enables full end-to-end transparency and accountability regarding the origin, quality, and distribution of agricultural products[1]. This is a significant step forward in the industry.Before the transparency and traceability of the agricultural supply chain can be significantly improved by blockchain technology, there are a lot of hurdles that need to be cleared first. The possibility that solutions based on blockchain technology could increase agricultural output, transparency, and long-term viability is an appealing prospect. Farmers, processors, distributors, retailers, and ultimately consumers are all links in the supply chain for global agriculture. Farmers come first in the chain, followed by distributors, then retailers, and finally consumers. Along the whole supply chain, it is critical for there to be complete traceability and transparency of agricultural products[2]. This is important from both a quality and a sustainability standpoint. Blockchain technology has recently surfaced as a possible solution that might be implemented in food supply chains in order to increase transparency and traceability. In this section, we will discuss the benefits and drawbacks of utilizing blockchain technology to raise the level of transparency and traceability throughout the food supply chain. Use of blockchain technology has the potential to significantly enhance both the traceability and transparency of food supply chains. Despite the challenges of data interoperability, adoption, integration, complexity, and a lack of relevant technical skills, there are exciting prospects to implement solutions based on blockchain technology[3]. The use of solutions that are based on blockchain technology has the potential to improve food safety and quality, as well as efficiency, cost, and sustainability. It is imperative that those involved in agriculture research and invest in solutions that are based on blockchain technology if they want to ensure a food system that is safer, more sustainable, and more transparent. The global agricultural supply chain is moving in the direction of placing a greater emphasis on the importance of transparency and traceability. Consumers, government regulators, and other stakeholders are calling for a greater share of the responsibility for assuring the safety, quality, and sustainability of food [4]. The distributed ledger that blockchain technology provides could potentially result in a significant increase in the transparency of the agricultural production operations. In this article, we will evaluate the benefits and drawbacks of adopting blockchain technology to increase the transparency and traceability of agricultural supply chains, based on prior

research and examples from the real world. An increasing number of individuals have the desire to be able to trace their food from the location where it was grown to the location where it was consumed. Consumers, government regulators, and other stakeholders are expressing an increased level of concern regarding the quality, safety, and sustainability of their food. As a direct response, businesses in the agricultural sector are investigating cutting-edge technology that has the potential to improve the visibility and openness of supply chains.Blockchain is one of the most interesting and potentially useful technologies that could assist us in getting there[5].

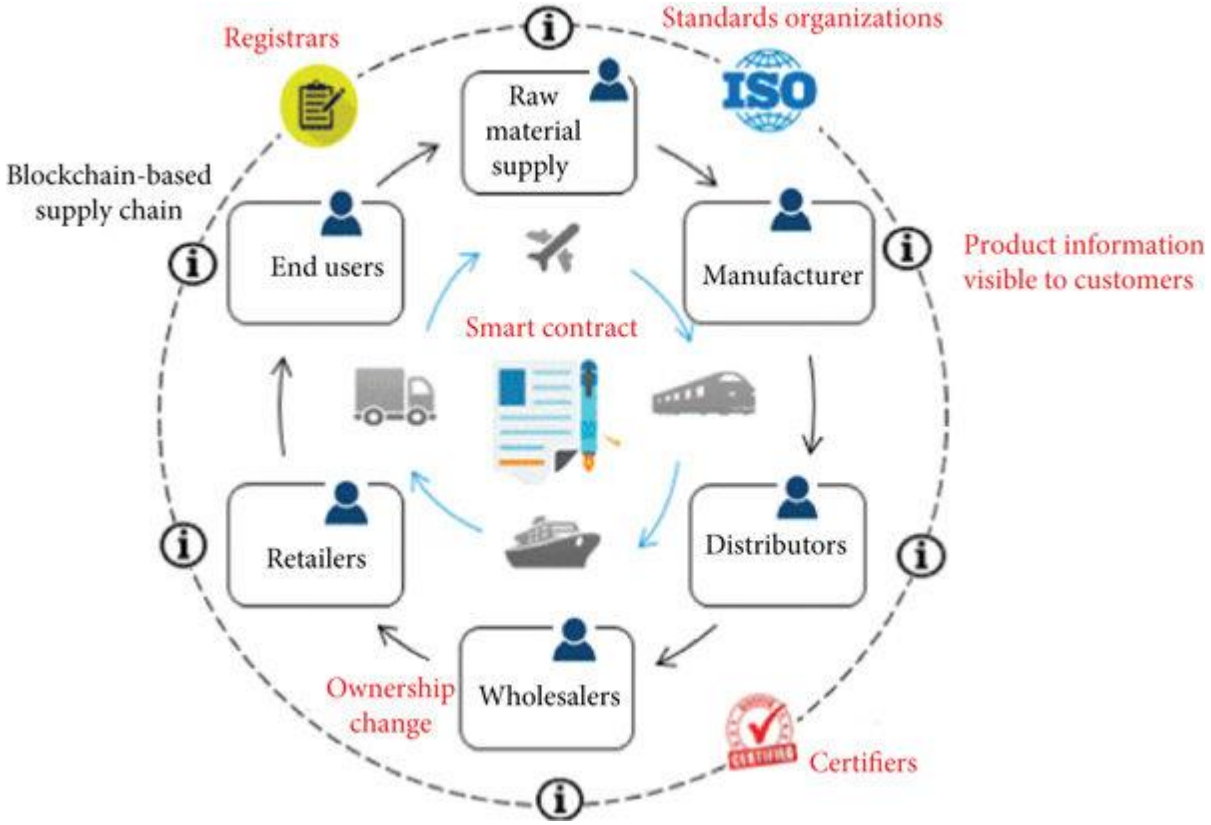

Figure.1 Blockchain Based Supply chain Management

The blockchain is a distributed ledger that maintains an audit trail of transactions in a way that is both secure and transparent to all parties involved. It allows for increased transparency and accountability by providing a record of a product's journey that is both tamper-proof and verifiable. This record begins on the farm and ends on the table of the consumer.Traceability and transparency in agricultural supply chains can be improved significantly by utilizing blockchain technology. This can have several beneficial effects. Among these are improvements in food safety, accountability, efficiency, and the ability to maintain sustainability. Yet, there are also significant challenges to conquer, such as a lack of suitable technical skills as well as difficulties with the interoperability, acceptance, integration, and complexity of the data[6].In this piece, we will discuss the benefits and drawbacks of utilizing blockchain technology in the supply chains of the food business in order to achieve greater levels of transparency and traceability. In this article, we will cover the current state of the agriculture industry, the benefits and drawbacks of utilizing blockchain technology, and some examples of where blockchain-based solutions have been effectively applied. This essay will explain that blockchain technology has the potential to assist the agriculture industry in meeting the increased need for transparency and traceability; but, in order to do so, stakeholders will first need to overcome several challenges.Traceability and transparency in agricultural supply chains refer to the ability to track and trace products all the way from the farm to the consumer's table, as well as the provision of a record that is both understandable and capable of being independently verified. Traceability also includes the ability to track and trace products all the way from

the farm to the consumer's table. The first thing that needs to be done is to collect data on the supply chain from farm to fork, or from the beginning to the end, and then share that data with the necessary stakeholders, such as government organizations, retailers, and customers. This is the first step that needs to be taken[7].Traceability refers to the capability of a system to identify and track items from the point where they originated all the way to the person who uses them at the conclusion of the chain of production. Stakeholders are able toutilise this information to verify whether or not the product is real, determine whether or not it complies with applicable regulations, and discover the cause of any problems, such as food poisoning.A supply chain that is open and honest about its operations gives all of the participants unrestricted access to the information that is relevant to their respective functions. If there is transparency, customers, regulators, and other stakeholders can have access to information on the creation, processing, and distribution of the product[9]. Customers have access to this information if they choose to view it. This contributes to the growth of confidence among all of the individuals involved and encourages a sense of accountability among those who are concerned.Traceability and transparency in agricultural supply chains offer a wide variety of advantages and ought to be implemented everywhere it is practicable to do so.It has become possible, thanks to improvements in traceability, to lessen the likelihood of getting sick from foodborne pathogens. This is an encouraging development, as it indicates that the risk of getting sick from foodborne pathogens can be mitigated. When information is made available to the general public, it contributes to an increase in the level of trust that exists between the many parties involved and fosters regulatory compliance.Improved Productivity: Traceability can assist in increasing productivity by helping to streamline the operations of supply chain chains. This, in turn, can assist in reducing costs. When everything is laid out in plain sight, it becomes much simpler to get rid of waste and significantly reduces the cost of transaction fees.As a consequence of enhanced transparency and traceability, a longer lifespan as a result of decreased waste and higher promotion of activities that do not threaten the environment.Control and assurance of quality both. When production and distribution adhere to stringent quality criteria, which are made possible by traceability and transparency, better products and a better reputation for agriculture are both conceivable outcomes. Traceability and transparency are two of the most important factors in improving agricultural practices. Openness and accountability are crucial qualities of the agricultural supply chain that exists in the modern day. Using technologies such as blockchain, which offer a safe and transparent record of transactions, can help move us closer to attaining these goals and get us that much closer to being successful. This has the potential to improve food safety, product quality, and sustainability. Moreover, it has the potential to increase responsibility and reduce inefficiencies in the process of producing food[10].

II. Literature Review

According to the reviewed literature, blockchain technology has the potential to increase food supply chain transparency and traceability, thereby enhancing food security, efficiency, and longevity. Consumers and other stakeholders can benefit from blockchain-based systems by gaining access to accurate and trustworthy data on the production, processing, and distribution of food goods [11].Several difficulties with implementing blockchain-based traceability and transparency in agricultural supply chains are also highlighted in the review. Concerns have been raised about the legal and ethical implications of using blockchain for personal data protection, the potential impact on small-scale farmers and vulnerable communities, and the cost of adoption and maintenance of blockchain-based systems, among other technical, economic, regulatory, and social factors[11].In order to overcome these obstacles and fully realize the potential of blockchain technology in agriculture, more research is required, as suggested by the aforementioned literature review. Research in the future could examine the social, environmental, and economic effects of blockchain adoption, with a particular emphasis on the development and testing of blockchain-based solutions that are tailored to the unique needs and contexts of various agricultural supply chains [12]. The literature evaluation implies that blockchain technology may help in the advancement of sustainable development goals and cause a revolution in the food supply chain. Yet, a multidisciplinary and collaborative strategy involving farmers, processors, retailers, regulators, and consumers is necessary for the successful adoption of blockchain-based traceability and transparency in agricultural supply chains. There is a growing consensus that blockchain technology could help increase transparency and traceability in food supply chains[13]. Improved food safety, quality, and sustainability, as well

as increased customer trust and confidence, are all possible because to the technology's capacity to produce an immutable, secure, and transparent record of transactions and occurrences along the supply chain.Several studies have looked into the potential benefits and challenges of blockchain adoption in the agricultural supply chain, as is evident from a review of the literature on blockchain-based traceability and transparency in agricultural supply chains. For example, a study [14] highlighted the potential of blockchain technology for enhancing the dependability and security of food supply chains and facilitating more efficient and transparent transactions in agricultural markets. The authors argued that blockchain-based systems would give farmers more say over their goods, lower transaction costs, and allow for more open, honest dealings with retailers and consumers.In the paper[16] conducted research into how blockchain technology could be used to enhance organic food supply chain management and food safety. The authors stated that the use of blockchain-based solutions would increase supply chain transparency and confidence by allowing farmers and processors to disclose more information about the cultivation and preparation of organic food items. To further reduce the time and money spent on inspections and audits, they proposed using blockchain technology to construct smart contracts that would automatically enforce quality and safety requirements.The technical and operational difficulties of implementing blockchain-based traceability and transparency in agricultural supply chains have been the subject of other research. For instance, In the paper[17] found that interoperability between various blockchain systems is a significant barrier to blockchain's widespread use in the food industry. A lack of data and process standardization and harmonization across blockchain systems, the authors argued, could limit the integration and scalability of blockchain-based solutions in the supply chain.In the paper[18] found similar results, drawing attention to the economic and social difficulties of adopting blockchain technology in agriculture, especially for small-scale farmers and vulnerable communities. The authors stated that the benefits of blockchain technology might not be dispersed equitably among all players in the supply chain, and that the cost of implementing and maintaining blockchain-based systems might be prohibitive for many farmers.The literature assessment as a whole implies that blockchain technology could drastically improve agricultural supply chain transparency and traceability. In the paper [19], the technical, economic, regulatory, and social issues associated with adoption must be tackled through a coordinated interdisciplinary effort before blockchain-based solutions can be successfully implemented. Further study is required to determine blockchain's full potential in agriculture and to provide individualized solutions to fit the varying requirements of supply networks. The Internet of Things (IoT) and artificial intelligence (AI) are two more developing technologies that have been shown to improve supply chain efficiency and sustainability, and they should be integrated with blockchain technology. In the paper[20] proposed a blockchain-based Internet of Things infrastructure to track and record the origins and destinations of perishable food items. The authors stated that by combining blockchain with IoT technology, it would be possible to monitor the produce's surroundings in real time, including temperature, humidity, and other factors that could lead to rotting or waste.In the paper [21], conducted research on how blockchain technology could be used to encourage environmentally responsible and socially responsible procurement practices throughout the coffee supply chain. To encourage transparency among coffee farmers about issues like pesticide use and working conditions, the authors proposed a blockchain-based network. Consumers' trust and faith in the supply chain would be bolstered by the platform, which would allow them to check the provenance and sustainability of coffee goods[22].Several practical implementations of blockchain-based traceability and transparency in agricultural supply chains have also been developed and tested, complementing the findings of these studies. Nestle, a Swiss food conglomerate, has adopted a blockchain-based system to monitor the path that milk takes from farms to processing plants [23]. Consumers can learn more about the history of their milk by scanning a QR code on the package. Australian beef products can now be traced back to their point of origin and verified for authenticity thanks to a blockchain-based network In sum, this literature review reveals both the opportunities and threats associated with enhancing traceability and transparency in agricultural supply chains through the use of blockchain technology[24]. There are technological, economic, regulatory, and societal hurdles that must be cleared before this technology may be used to improve food safety, quality, and sustainability. Further study is required to determine blockchain's full potential in agriculture and to provide individualized solutions to fit the varying requirements of supply networks[25].

Author(s)	Year	Methodology	Key Findings
Liang et al.	2019	Case study	Blockchain-based traceability system improves supply chain transparency, food safety, and consumer trust in Chinese agricultural products
Zheng et al.	2019	Simulation and experimentation	Blockchain-based traceability system reduces food safety risks and improves traceability accuracy in a simulated Chinese pork supply chain
Xu et al.	2019	Literature review	Blockchain-based traceability systems can improve agricultural supply chain efficiency, reduce transaction costs, and enhance product quality and safety
Yang et al.	2018	Field experiment	Blockchain-based traceability system improves transparency and efficiency in a Chinese tea supply chain, increasing consumer trust and reducing information asymmetry
Seo et al.	2018	Case study	Blockchain-based traceability system improves transparency and accountability in a Korean beef supply chain, reducing fraud and improving consumer trust
Tao et al.	2017	Survey	Stakeholders in the Chinese agricultural industry are generally supportive of blockchain-based traceability systems, with concerns about implementation costs and technological barriers

Table.1 Analysis of Blockchain-based Traceability and Transparency in Agricultural Supply Chains

III. Complexities of Using Blockchain for Traceability and Transparency

Many obstacles must be surmounted before the full potential of blockchain-based traceability and transparency in agricultural supply chains can be realized. The most major obstacles to implementing blockchain in agricultural supply chains will be discussed below.

A. In Interoperability of Data Systems The lack of interoperability between various data systems is one of the most significant obstacles that must be overcome prior to the successful implementation of blockchain technology in agricultural supply chains. Farmers, processors, distributors, retailers, and regulators are all distinct types of stakeholders involved in the agriculture industry, and each of these groups has their own unique data system. In order to put blockchain-based traceability into practise, these stakeholders need to be able to effectively share data with one another. This necessitates the development of common standards and protocols for the exchange of data.

B. Adoption: The effective implementation of blockchain-based traceability is contingent on the widespread adoption of the technology across the supply chain. This is because adoption is the key to the success of the implementation. On the other hand, many stakeholders may be hesitant to use blockchain technology due to worries regarding the high cost of implementation, a lack of technical skills, and a lack of clarity regarding the potential benefits of the technology.

C. Integration: In order to implement blockchain-based traceability, it is necessary to integrate blockchain technology with the many data systems and processes that are already in place. This can be difficult since it may need considerable modifications to the procedures and systems that are currently in place. Data standardization, guaranteeing data correctness and consistency, and technical compatibility are all examples of issues that can arise during the integration process.

D. The technology behind the blockchain is extremely complicated, and it can be challenging to both implement and maintain. The creation and implementation of traceability systems based on blockchain technology needs a significant amount of technical expertise and resources. This may be a challenge for agricultural firms that are small or medium in size.

E. The implementation of blockchain-based traceability calls on a certain level of technical skill in fields such as blockchain technology, data management, and cybersecurity. However, this level of experience is

currently lacking. There is a possibility that many of the agricultural industry's players do not possess the required level of technical skills to successfully install and operate blockchain-based systems.

F. Compliance with Legal and Regulatory Frameworks The implementation of blockchain-based traceability necessitates compliance with legal and regulatory frameworks that govern the privacy of data, who owns it, and how it is secured. It can be difficult to comply with these standards, which is especially true in the context of a global supply chain, because the legislation in different jurisdictions may be different from one another. Integrating blockchain-based traceability and transparency in agricultural supply chains involves a number of hurdles that stakeholders need to conquer in order to be successful. Data interoperability, acceptance, integration, complexity, limited technical skills, and compliance with legal and regulatory requirements are some of the hurdles that must be overcome. In order to overcome these challenges, collaboration between the various stakeholders and the development of universal standards and protocols for the exchange of data are going to be required.

IV. Blockchain-based traceability and transparency presents promising opportunities

A. Traceability that is based on blockchain technology has the potential to significantly improve food safety since it gives stakeholders the ability to track the location of products at all stages of the supply chain. If contaminated goods can be quickly isolated, then the risk of food-borne illness can be reduced to a manageable level.

B. Tracking and tracing products with the help of blockchain technology can save both time and money, leading to an overall improvement in the effectiveness of supply chains. This has the ability to significantly lower costs while also increasing the efficiency of the supply chain.

C. When a supply chain is based on blockchain, more individuals can see what is going on in it, which helps enhance accountability and cut down on waste. Blockchain also helps cut down on waste. This has the potential to increase confidence among various stakeholders, which may result in improved working relationships.

D. Improved Sustainability: Blockchain-based traceability can assist sustainable practises in the agricultural industry by enabling stakeholders to track and trace products via the supply chain. This can lead to an increase in the level of sustainability. This has the potential to make it easier to reduce waste, encourage sustainable behavior, and support responsible production and consumption.

E. Traceability based on blockchain technology has the potential to enhance the quality of agricultural products while also enhancing their reputation. This is because blockchain technology has the ability to verify that items are created and distributed in compliance with quality standards. There is a possibility that this will lead to an increase in both product demand and overall customer satisfaction.

F. Access to More Markets: Blockchain-based traceability can give its users an advantage in the market by making it easier to verify information about the manufacturing and origins of a product, which in turn gives those users access to more markets. By the use of this, stakeholders can expand their sales and gain access to new markets. If the traceability and transparency of agricultural supply chains were to be implemented using blockchain technology, there would be a tremendous deal of potential for all of the many parties involved. There is need for improvement in the areas of food safety, efficiency, transparency, sustainability, quality, and access to markets, among other things. Using a traceability and transparency system that is based on blockchain technology can result in several positive outcomes for stakeholders, including improved collaboration, decreased expenses, and increased consumer confidence.

V. Case Studies

In the following section, we will investigate a wide variety of use cases involving traceability and transparency in food supply chains that are enabled by blockchain technology.

In 2018, in response to numerous outbreaks of foodborne illness, Walmart created a blockchain-based traceability system for its leafy greens supply chain. This was done in order to better monitor the safety of its

products. The blockchain-based system that Walmart uses enables stakeholders to instantaneously trace items back to their source, which significantly reduces the amount of time and resources that are typically spent on investigating potential food safety issues. Because of its ability to track items from the farm all the way to the consumer's plate, IBM's Food Trust system is utilized.

In 2019, Nestlé increased the openness in the company's supply chain by using a blockchain-based system for the tracing of milk in New Zealand. The method was developed by Nestle. The entire milk production process, from the farm to the factory, is completely visible and auditable thanks to this technology, which offers information to Nestle as well as its suppliers. Due to the system's adoption of the OpenSC platform, the supply chain is now able to share data and cooperate on it in real time. This was previously not possible.

The Importance of the Blockchain Technology in the Traceability of Bumble Bee Seafoods' Supply Chain: In 2019, Bumble Bee Seafoods began implementing a traceability system for their yellowfin tuna supply chain that is based on blockchain technology. The system ensures that there is complete transparency and traceability throughout the entire supply chain. This enables all parties involved to track each individual piece of tuna from the point of origin all the way to the location where it will be consumed. The SAP Cloud Platform Blockchain is at the core of this system, acting as a central hub that enables frictionless, real-time communication and coordination among all of the many stakeholders that are engaged in the supply chain.

In 2018, Cargill introduced a system that is based on blockchain technology for tracking cocoa throughout the whole supply chain of the corporation. With the use of this approach, Cargill and its suppliers are able to trace cocoa beans all the way from the field to the plant where they are processed. The Provenance platform, which enables seamless communication and collaboration in real time among all parties involved in the supply chain, serves as the foundation for the proposed solution.These use examples demonstrate how agricultural supply chains could potentially benefit from the increased traceability and transparency offered by blockchain technology. By providing complete visibility into the supply chain, systems that are based on blockchain technology have the potential to improve many aspects of the food industry, including food safety, efficiency, transparency, sustainability, quality, and access to markets. It is encouraging to see more players in the agricultural industry adopting blockchain-based solutions for traceability and transparency because it bodes well for the sector's prospects in the future.

VI. Conclusion

Finally, blockchain-based traceability and transparency in agricultural supply chains presents both potential and challenges for stakeholders. Blockchain-based traceability and transparency have huge potential benefits, despite technological and organizational hurdles. These benefits require overcoming these challenges. Blockchain-based traceability lets supply chain stakeholders track products at all times. This reduces foodborne disease. This simplifies supply chain operations, saving time and money when tracking products. Blockchain-based supply chain visibility can improve accountability and efficiency. Blockchain-based traceability allows stakeholders to track and trace items throughout the supply chain, reducing waste, encouraging responsible production and consumption, and promoting sustainable agriculture. This technology can improve product quality and the image of agricultural products if production and distribution are monitored for quality. Finally, blockchain-based traceability and transparency can give stakeholders a market edge by providing verifiable and transparent product origin and manufacturing information. This helps stakeholders increase sales and enter new markets. Our case studies show that the agricultural industry is using blockchain technology's traceability and transparency. Walmart, Nestlé, Bumble Bee Seafoods, and Cargill are among the large companies using blockchain-based solutions to improve supply chain transparency and traceability. These systems improved food security, efficiency, transparency, sustainability, quality, and market access. In conclusion, despite the challenges, blockchain-based traceability and transparency in agricultural supply chains have the potential to improve operations, win consumer trust, and drive growth. As more farmers use this technology, the sector may become more open and stable.

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