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The Effects of Blockchain Technology on Traceability And Efficiency in Supply Chain Management: A Systematic Literature Review

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Abstract

Supply chain management has become a real challenge due to ever accelerating technological innovations and organizations must not only aim to optimize supply chain processes, but also to build trust in all links of the supply network due to increased competition and supply chain expansion. Organizations need to implement an appropriate system that will improve efficiency and customer service, meet business objectives, and increase profitability. The purpose of this article is to illustrate how blockchain technology can improve traceability and supply chain efficiency by impacting business productivity. The conceptual framework of this research work is developed through a systematic literature review on the impact of the application of blockchain technology in supply chains. The Prisma methodology was used, obtaining 78 articles as references. The results show that blockchain technology has the potential to improve traceability and efficiency throughout the supply chain through cost reduction and decentralization of information. Finally, it was concluded that this leads to improved productivity of companies and a higher level of reliability with their stakeholders. This article adds to the literature on blockchain in the supply chain by focusing the research on the impact on traceability and efficiency.

Keywords
Supply chain, Blockchain, traceability, efficiency, and industry 4.0.

1. Introduction
With the development of international trade and economic globalization, logistics has become increasingly important in global partnerships (Hackius and Petersen 2020). Along with the development, problems related to information exchange, coordination, communication, decision making, and time management arise. Technological changes and globalization are factors that make supply chain management more difficult (Saberi et al. 2021).

With the expansion and development of an organization, problems arise that become apparent in supply chain management, mainly because of the lack of trust between nodes or links, product traceability and process optimization (Liu et al. 2023). The methodological implementation of a new supply chain management system is necessary, if industrial companies want to maintain their market position, increase process efficiency and increase their profitability, they must adopt new strategies focused on changing or adapting the business ecosystem to a more agile, traceable, transparent and interoperable one (Heidary et al. 2020).

With the continuous expansion of the supply chain, Blockchain technology emerges as a disruptive alternative, it is a distributed database that hosts a continuously growing number of transactions, each transaction that is added is attached to a previous transaction creating a blockchain, this cannot be deleted or edited, creating an immutable system over time (Vasquez 2021). This technology facilitates the solution of the main problems related to supply chain management, such as efficiency, traceability, and security (Saberi et al. 2021). However, being a new technology, assessing the possibility of early adoption in industrial companies is an opportunity for organizations to consider benefits and risks. Therefore, its application in many industrial sectors is only a concept. According to Della and Oliver (2021), blockchain for supply chain is still an emerging technology that needs more research.

1.1 Objectives
The main objective of this paper is to conduct an analysis of the way that Blockchain impacts on traceability and efficiency in supply chain management based in the latest academic research and industry use cases. Therefore, the study aims to answer the following specific research questions (RQ) through a systematic literature review:

- RQ1: What are the resulting effects of applying blockchain technology on supply chain management costs.
- RQ2: How does blockchain technology affect trust and transparency in supply chain management?
- RQ3: What is the impact of blockchain technology on the decentralization of information in supply chain management?
- RQ4: How does the number of processes and intermediaries in supply chain management vary when blockchain technology is implemented?

2. Literature review
As an innovative application model, blockchain is becoming one of the main forces of change in various fields of the industrial sector (Liu et al. 2023).

Blockchain features offer potential opportunities to meet to supply chain management requirements (Wu et al. 2019). Companies are implementing it as they see the potential to decentralize their databases and minimize their transaction costs, while making them inherently more secure, transparent and, in certain cases, faster (Casino et al. 2018).

As pointed out by Saberi et al. (2021), the ability to guarantee the reliability, traceability, and authenticity of information, portends a major rethinking in the management of supply chains, thus eliminating the need to establish a central organization to verify and keep the system operational, facilitating the exchange of information. Furthermore, the adoption of blockchain will reduce transaction costs, eliminate bottlenecks, and establish a supply chain capable of adapting to changes in the current global economic environment (Liu et al. 2023).

In Figure 1, a traditional supply chain can be observed in which the process starts with material suppliers, followed by the producing company, distributors, wholesalers, retailers, and consumers. Flow information is transmitted sequentially in each block (Sivula et al. 2020).

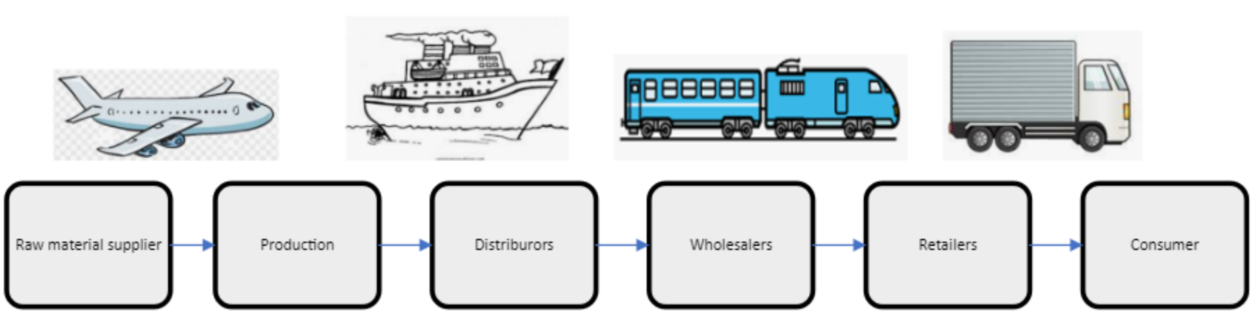

Figure 1. Traditional supply chain

In contrast, a blockchain-based supply chain is shown in Figure 2. It can detail the nature of the product, its quality, the actual quantity available, the exact location in real time, and the owner or holder of the product at any time interval. In this sense, blockchain eliminates the need for a central organization to keep the supply network operational by allowing the entire product journey from raw material acquisition to final sale to be inspected at any time (Saberi et al. 2019).

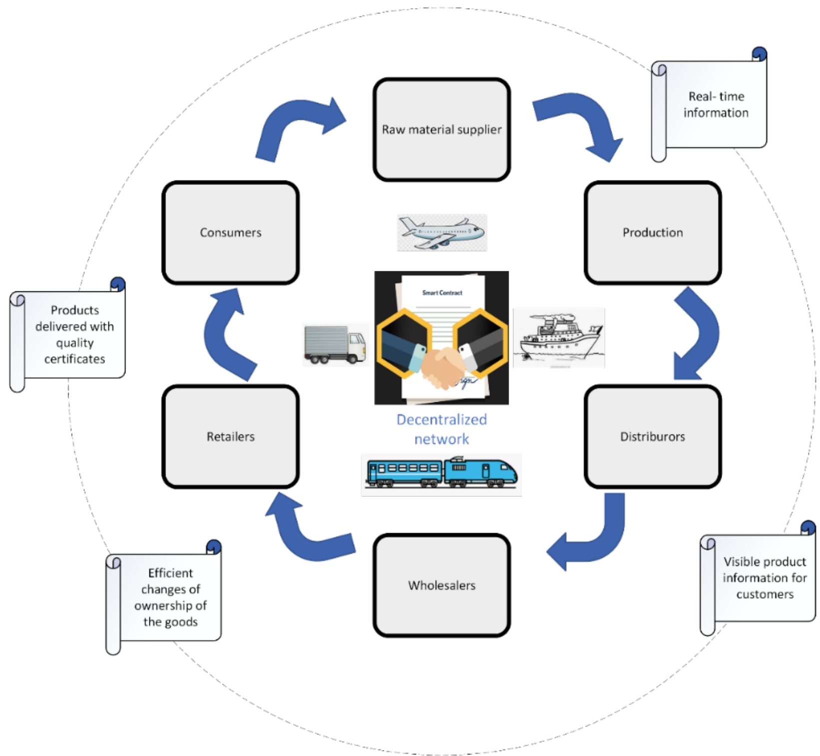

Figure 2. Supply Chain with blockchain

Furthermore, the impact on supply chain performance can be measured by any of the five generic indicators that have been discussed in previous work (Markus and Buijs 2022):

- Speed: refers to running things faster. It can be measured as the time elapsed between the start and end of one or more processes.
- Quality: refers to doing things right. It is measured by how well a process can produce products or services that meet established specifications.
- Cost: refers to making things cheaper.
- Reliability: refers to the fulfillment of promises related to the right quantity at the right place at the right time. It may include the delivery of products or services, as well as information or intermediate steps in the creation of the product or service.
- Flexibility: refers to the ability to change or adapt. This indicator can be divided into the flexibility range that indicates how much a process can be changed and responsiveness flexibility that tells us how fast a process can be changed (Markus and Buijs 2022).

Traceability can be measured through the amount of information companies can collect of the processes that a finished product has gone through from the purchase of raw materials to the final consumer. On the other hand, efficiency is linked to the indicator of cost reduction and speed by reducing processes and intermediaries, but with the same or better performance.

2.1 Supply Chain Traceability

Companies are trying to improve the traceability of their supply chains to ensure responsible sourcing with quality and safety standards due to pressures from governments, consumers, non-governmental organizations, and investors who consider traceability an urgent and differentiating requirement (Bateman and Bonanni 2019; Costa et al. 2013). However, according to a recent Deloitte survey of purchasing managers, only half of companies report high transparency in their first tier of suppliers, while 90% responded with moderate to very low transparency after the first tier of their supply chains (Sodhi and Tang 2019). An example of this occurred in 2014, when 1262 public companies, from the United States, disbursed approximately $709 million and 6 million man-hours to disclose whether their supply chains are linked to violence in Africa. but 90% of companies reported that it remains undetermined whether their products are conflict-free (Chasan 2015).

Traceability can be defined as the ability to track all information in real time. In addition, all information can be shared and visualized in real time by key participants in the supply chain. Consequently, blockchain enables improved transparency and visibility in supply chain management (Park and Li 2021).
This tool is useful not only for emergency management as it can replace any information authentication process (which would be slow and not completely reliable) by providing traceability that guarantees the origin and immutability of the information at the very moment it is adopted. Instant confirmations of origin and authentication have the potential to become a fundamental capability for the guaranteed and transparent use of information in the supply chain (Cozzini et al. 2022).

2.2 Supply Chain Efficiency

Supply chain performance is examined in terms of efficiency and effectiveness, based on indicators such as cost, speed, reliability, quality, and flexibility. Efficiency is referred to as the internal performance standard and measures how well supply chain processes leverage resources, with the goal of cost savings (Pankaj 2021).

Blockchain technology due to features such as decentralization, consensus mechanism, traceability, and trust, allows the development of efficient workflows by simplifying processes, properly managing data and processing transactions in less time such as: trading goods, eliminating intermediaries, and creating new data management tools (Casino et al. 2018; Karaszewski et al. 2021). On the other hand, by excluding intermediaries, such technology allows eliminating or minimizing risks, as well as reducing overall costs, time, and fees, since the parties that make up the supply chain will have full control over the workflow in real time, allowing them to make better decisions (Chandra et al. 2019).

For instance, Barclays, a British financial company, in 2017, implemented a full Blockchain system for financial exchanges for one hundred thousand dollars (McDaniel and Norberg 2019). This was followed by a financial deal with the Irish cooperative Ornua, the financial deal was done simultaneously with the Blockchain and was completed in 4 hours, compared to an average of 10 days.

2.3 Supply Chain Productivity

The blockchain is distinguished by decoupling, disintermediation, addressability, and memory. These features help to reduce dependence on intermediary and proprietary elements of the value chain in the production process, thus significantly reducing transaction costs, management costs, operational costs and greatly improving productivity. The higher the level of blockchain development, the higher the level of productivity of enterprises (Autio 2018; Cao et al. 2022).

Finally, Radmanesh et al. (2023) conclude that blockchain technology has the potential to improve productivity as the results of the study highlight the superiority of blockchain decentralization over the centralized mode in terms of speed and quality of solutions. In particular, the quality of the final solutions obtained is up to 45% higher than the centralized mode. In addition, there was a substantial improvement of approximately 87% in solution speed in the optimistic state, and a 51% improvement was observed in the pessimistic state. These improvements in solution time reduce costs and time spent.

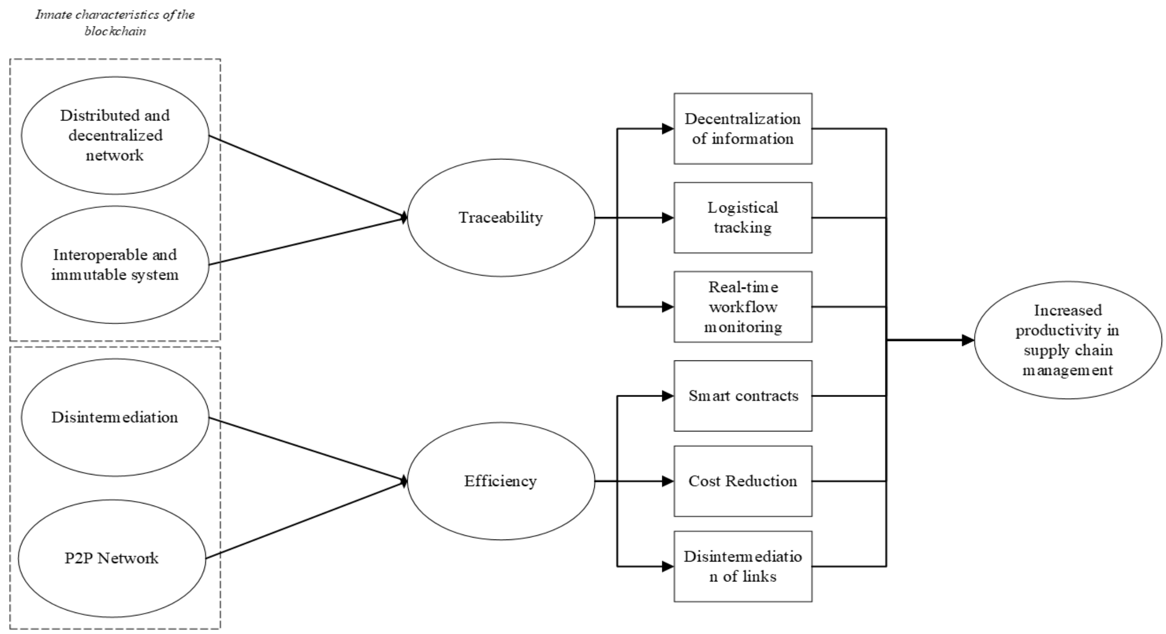

Figure 3. Impact of blockchain technology on supply chain management.

In Figure 3, the fact that blockchain technology is a decentralized network directly affects traceability in supply chain management, since its application enables logistics tracking and workflow monitoring in real time. On the other hand, the reduction of intermediaries affects efficiency in the supply chain, due to the reduction in the number of links and, therefore, in logistics costs, as well as in communication errors and information exchange. All this leads to sustainable supply chain management. Furthermore, the reliability of the model is demonstrated in the results chapter to show how blockchain affects traceability and efficiency in supply chain management.

3. Methods

The following study was designed by adopting the characteristics of the PRISMA 2020 guidelines for conducting systematic literature reviews, as it is shown in Figure 4, with the objective of conducting quality, complete, transparent and accurate research.

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The research was carried out in three different stages: First, the identification of the existing need in the literature and the preparation of the proposal. Second, the review, analysis, selection and synthesis of the research found. Finally, the preparation of the results, discussion and conclusions (Tranfield et al. 2003).

According to the method of Casino et al. (2018), the methodology starts with the information search process considering scientific articles published between 2013 and 2023. Subsequently, keywords such as "Blockchain", "supply chain", "efficiency", "traceability", "supply chain management" were selected. Based on these keywords, search strategies such as ("Blockchain" AND "supply chain" AND ("traceability" OR "efficiency")) were formulated. In addition, in order to collect reliable information, Scopus, Web of Science, Ebsco and Proquest databases were used.

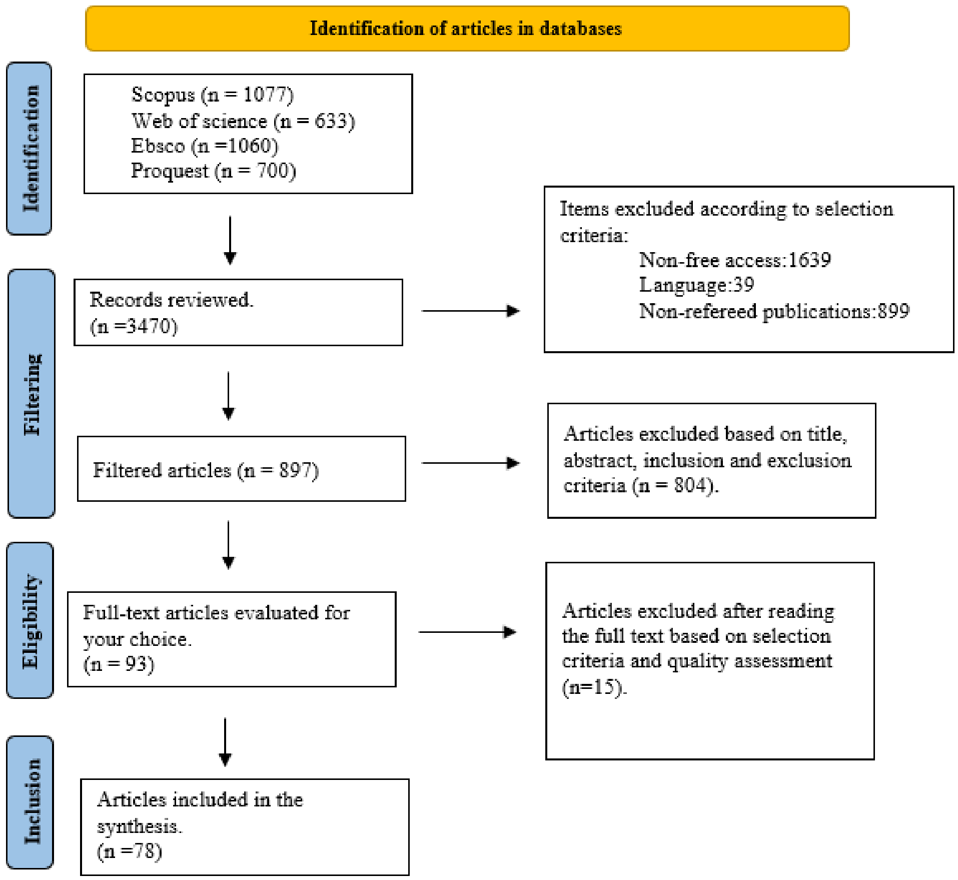

Figure 4. PRISMA review process

4. Data Collection

The VOSviewer software is a tool that allows the identification of bibliometric indicators of a group of selected articles, such as: nationality of authors and co-authors, country of origin, journal or the relationship between articles and word count.

In this work, the software was used to map the co-occurrence of keywords in order to map the research field and thus determine the most relevant topics. For this purpose, a search was performed in the Scopus database using the search strategy TITLE-ABS-KEY (blockchain) AND TITLE-ABS-KEY (supply AND chain) AND TITLE-ABS-KEY (traceability OR efficiency), then the search was limited to a time interval from 2013 to 2023 and to open access articles in English, obtaining 356 results. From the set obtained, the information related to citations, bibliography, abstract and keywords was exported in CSV format, then, with the information collected, an analysis was performed using a bibliographic data map in VOSviewer. This analysis is shown in figure 5.

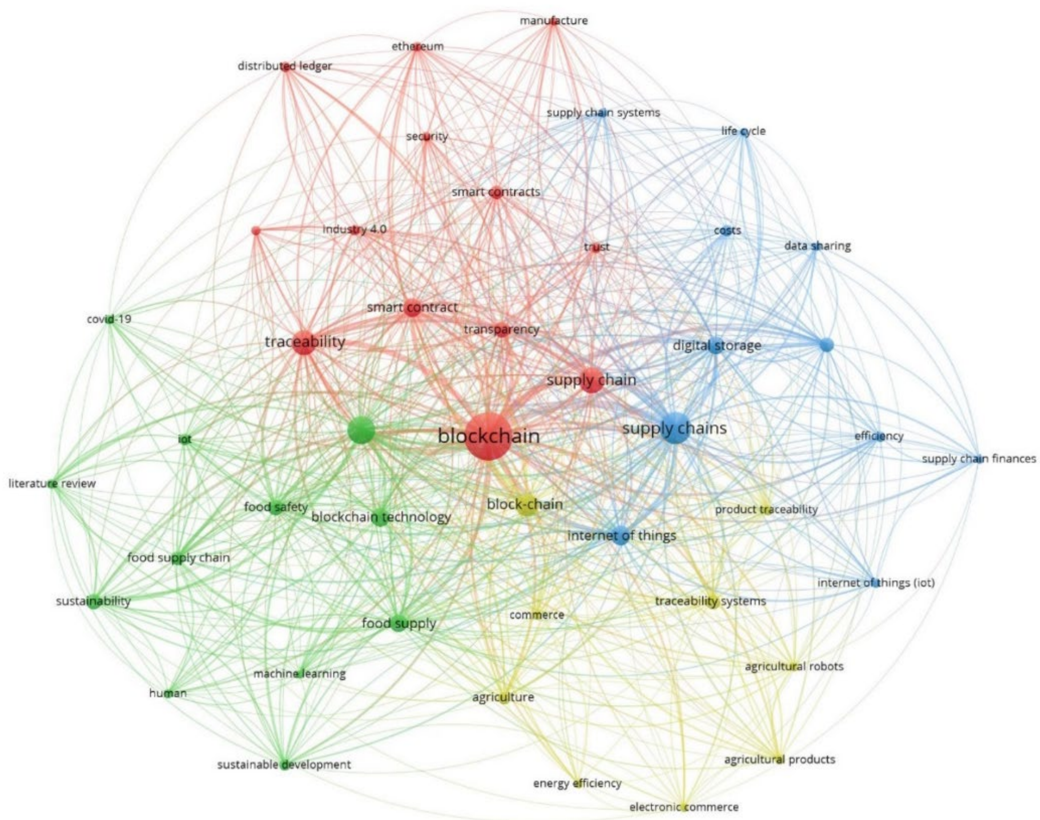

Figure 5. VOSviewer output

The term co-occurrence in the software refers to the number of documents in which a keyword appears. Thus, to facilitate the analysis the minimum number of occurrences of a keyword considered was 15. In the map the size of the nodes is directly related to the frequency of the keywords, in the analyzed sample the keywords with the highest frequency are "blockchain", "supply chain", "traceability", "Smart contracts", "food supply", "costs". In this way we can identify that those fields on which blockchain research in the supply chain is focused are related to traceability and efficiency.

Subsequently, after the search and selection of articles, the included research was evaluated and analyzed through Excel tables where the information could be distributed in terms of results, methodological aspects, variables, journal, authors' affiliation, among others.

5. Results and discussion

5.1 Numerical results

It is important to understand the attributes that will enhance traceability and efficiency in supply chain performance. First, previous studies were reviewed to identify the key attributes of traceability and efficiency in order to explain the relationship between the two variables and supply chain performance.

It is necessary to clarify that, although the previous studies have different names for an attribute, some of them have been synthesized with similar names, as presented in Table 1, considering that a total of 78 articles have been used. Also, the relationship between supply chain and the attributes is explained in Table 2.

Table 1. Blockchain dimensions identified in the articles.

Advantages of Blockchain	**Number of elements considered as an attribute**	**Percentage of total items**
Transparency and visibility	48	83%
Decentralization	30	52%
Immutability	31	53%
Cost reduction	31	53%
Process reduction	32	55%

Table 2. Characterization of Attributes

Attributes	Relationship with the supply chain
Immutability	Blockchain has the feature of immutability once a transaction is written to the decentralized ledger, anyone can delete or modify the transaction. If something changes, all participants in the supply chain will be able to see the changes (Nandi et al. 2021; Kim and Shin 2019).
Decentralization	Blockchain technology allows people to share all information securely. In other words, all participants can access transaction details one after another through networks without relying on anyone (Park and Li 2021; Kim and Shin 2019).
Transparency and visibility	Due to the fact that blockchain is a highly decentralized network compared to the traditional centralized database, all participants in the supply chain can simultaneously receive up-to-date information about what is happening in the network. In supply chains, many business problems can be solved by sharing in real time information (Wang 2018; Kim and Shin 2019).
Cost and process reduction	Blockchain helps to reduce costs because it favors real-time visibility and reduces complexity by eliminating intermediaries or processes (Sivula et al., 2020). The cost reduction due to the implementation of blockchain technology can be divided into verification costs and communication network costs (Catalini and Gans 2016).

5.2 Graphical results

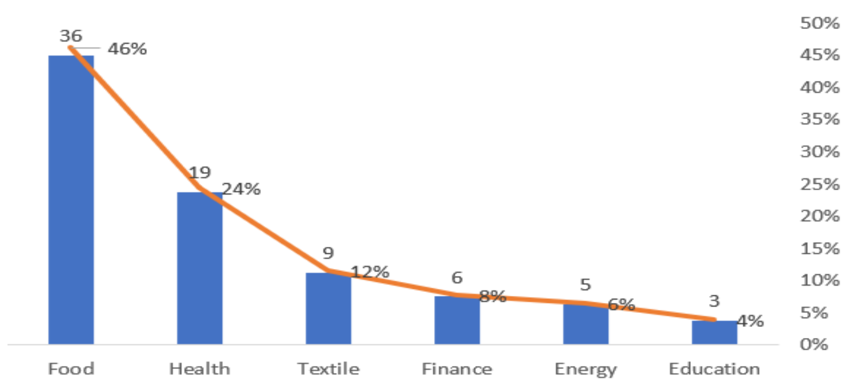

Figure 6. Industry-related items

Figure 6 is interpreted as the number of articles where it is argued that the blockchain impacts the traceability and efficiency of the supply chain in different industries. For example, of the 78 articles analyzed, 36 of them relate the benefits of blockchain to the food sector.

5.3 Proposed improvements

RQ1: What are the resulting effects of the application of blockchain technology on supply chain management costs?

Blockchain technology contributes to the automation of processes so costs can be reduced through greater efficiency and better access to reliable information (Rejeb 2020). Blockchain provides advantages by reducing auditing costs, transaction verification and exchange costs because of not relying on intermediaries with high fees to perform commercial transactions between the different links of a supply chain (Michelman 2017). In this regard, Raj et al. (2022) argue that smart contracts improve the benefits of such members and reduces supply chain costs as it drastically reduces the costs of logistics providers by avoiding paperwork, credit payment, product tracking cost and software purchases.

In addition, an implementation of blockchain technology could give benefits such as improved efficiency in terms of labor and its capacity through the optimization of operations. In addition, it helps to reduce the waste of goods thanks to better information management and greater accuracy in tracking products along the supply chain. An analysis of the monetary benefits to be gained by investing in blockchain is detailed in Table 3 (Perboli 2018).

Table 3. Cost-benefit analysis

Cost details	Value (in thousands of euros)	Benefits	Value (in thousands of euros)
IT (information technology) team	130	Increased efficiency	45
Blockchain Platform	240	Reduction of merchandise wastage	450
Total	370	Total	495

PE2: How does blockchain technology affect trust and transparency in supply chain management?

In previous research, Aslam et al. (2021) mention that blockchain improves transparency, visibility, trust, cybersecurity, inventory management and real-time information sharing (Aslam et al. 2021; Madhwal and Panfilov 2017; Dorri et al. 2017). This new technology helps to improve immutability, decentralization, trust, transparency, security and visibility by providing traceability at all levels of the supply chain (Wang et al. 2021; Adams et al. 2018). Aslan et al. (2021) indicate that blockchain provides information reliably and faster between supply chain links in times of COVID-19 pandemic. Pournader et al. (2019) state that there is a relationship between trust and transparency, and supply chain. Nabipour et al. (2021) classify the utility of blockchain into four groups: visibility, digitization, transparency, and smart contracts. Casino et al. (2019) report that blockchain has the potential to improve 3 areas in the supply chain: visibility, optimization, and demand. Sevda et al. (2021) found that traceability ensures product quality and safety, increasing transparency and visibility.

According to Francisco and Swanson (2018), Blockchain potentially offer the visibility, which consumers are increasingly demanding, of supply chains. For example, recording data on whether fish have been legally caught or whether diamonds have been legally mined. This is largely due to decentralization, which enables a consensus-based trust mechanism underpinning the technology (Hackius and Petersen 2017), which aids the performance of key processes in supply chain management through simultaneous immutability and transparency (Kshetri 2018). According to Aslan (2021), transparency exists from the moment the information of the entire blockchain is stored in an open archive for all members to access and analyze all transactions.

PE3: What is the impact of blockchain technology on the decentralization of information in supply chain management?
The main advantage of blockchain technology is, in theory, the decentralization of control in the supply chain system optimizing processes by reducing intermediaries, allowing other parties in the chain to manage their transactions directly (Dickson 2016; Kharmalov and Parry 2018). In a decentralized system, information is immutable and transparent to all members in the blockchain. There are no third parties to validate transactions. In the supply chain, a decentralized network promotes visibility among all parties in the chain who have access to the information without the need for some kind of permission (Tapscott 2016). Blockchain technology enables a digital transition from centralized platform control to a decentralized platforms in the Industry 4.0 era (Wang et al. 2020).

Hald and Kinra (2019) address the enabling aspects of blockchain features, where a decentralized database provides availability, cryptography promises immutability, and enables real-time traceability. Decentralization for transactional history is created as all members of the blockchain network have copies of the files. In addition, the blockchain maintains the transaction history, any edits or alterations can be seen by the members of the supply chain and discarded if there is no mutual consensus among the members (Aslan 2021).

PE4: How does the number of processes and intermediaries in supply chain management change when implementing blockchain technology?
In relation to efficiency, the creation of blockchain-based systems will eliminate or reduce the need for centralization, intermediaries and information transfers, thus increasing throughput, likewise, through real-time monitoring it will be possible to track and identify problems and emerging situations for preventive management purposes, this could be seen during the pandemic with the unexpected increase in demand due to panic buying (Sevda et al. 2021; Nabipour and Ulku 2021).

The Blockchain has an important role to play in eliminating intermediaries, disruptions in the flow of business and allowing, for example, small farmers to communicate directly with consumers and end users, thus reducing corruption (Aiken 2020). This tool would provide agility in the supply chain because it can enable smart contracts for automated delivery. The automation-based smart contract can replace paper-based and long-term agreements with a digital marketplace, where transactions can be completed quickly without compromising ownership. Since blockchain makes it possible for two parties to transact directly, producers can buy raw materials from farmers. That will help farmers get better prices for their products and reduce food prices (Kalla et al. 2020). In the same line of efficiency, smart contract integrates the whole flow and makes it simple and reliable for all stakeholders in the supply chain, reducing the number of intermediaries and transaction cost by almost 37% (Ahmadisheykhsarmast and Sonmez 2020; Hasan et al. 2019; Omar et al. 2020; Tapscott and Tapscott 2016).

5.4 Application of Blockchain in the supply chain of industries

Food industry

Traditional supply chains rely on manual processes, which are time-consuming to find information about the sources and routes of food with safety concerns (Park and Li 2021). However, blockchain technology allows consumers to trace their food back to the supply chain. This is possible through radio frequency identification tags or quick response codes that the consumer can scan. With an application programming interface (API) connection to the blockchain, consumers can see where their product originated and what steps in the process it has undergone (Azzi et al. 2019). The depth of information consumers can see depends on the permissions they are granted (Stranieri et al. 2021). In the case of food safety issues, companies can quickly and efficiently trace back through the supply chain to recall a specific batch of contaminated food rather than recalling the entire inventory (Dos Santos et al. 2019). Food companies can avoid distributing unsafe and defective products, mitigating potential economic losses and reputational damage (Mondal et al. 2019). For these reasons, velocity is an indicator that can measure the amount of time a company takes to trace the origin of products (Markus and Buijs 2022).

Additionally, Walmart, in collaboration with IBM, used Blockchain to improve traceability in its supply chain (Kamath 2018). In a mock recall, Walmart tried to assess with Blockchain technology, on average, how long it can take to track the origin of a product and get it from the table to the warehouse. Walmart found that while it took an average of 6 days, 18 hours and 26 minutes to track a batch of products with the standard track and trace method, with the blockchain, mangoes and pork were tracked through the blockchain could be accurately identified in just 2.2 seconds (McDaniel and Norberg 2019).

Blockchain can potentially eliminate middlemen in a certain part of the food supply chain, reducing the cost overrun of goods sold (Wong et al. 2019; Chen et al. 2020). A smart contract, a computer program with the ability to self-execute based on predetermined conditions, can be executed on Blockchain to further reduce costs (Creydt and Fischer 2019; Liu et al. 2023). For example, the smart contract has the ability to automatically authorize payment to suppliers once buyers provide proof of delivery and confirmation of product status, which minimizes human intervention to save time and effort (Vu et al. 2023).

Textile industry

The fashion industry, specifically clothing and footwear, affects more than 100 million children worldwide (UNICEF, 2020). In addition, the textile industry is already the second most polluting industry due to manufacturing processes. These processes involve the use of an excessive amount of chemicals that generate hazardous waste (Nimkar 2018). This industry is known for selective information sharing related to its supply chain. Selective sharing is used as a technique to avoid accountability or to gain competitive advantages over other companies and hide corrupt practices (Cho et al. 2015). In the textile industry, blockchain technology has two main applications, the first is to ensure product authenticity and the second is to ensure product sustainability (Ahmed and MacCarthy 2021). This technology offers significant benefits in terms of fair policies, reward systems, product flow systems, compliance, transparency, error identification and payment procedures (Nazam et al. 2022). In addition, blockchain can be used to ensure the legitimacy of products and track them throughout the product lifecycle, from raw materials to finished products. Therefore, it provides the customer with the history of the finished product to inform them where the raw material is sourced from, what the product life cycle is, what procedure is followed to manufacture the finished products, among other things, in order to fight counterfeiting (Ahmed and MacCarthy 2021; Tripathi et al. 2021).

Sanitary industry

Medication errors are one of the gaps that cause the most deaths each year. They can be due to inadequate intake of medications or ingestion of counterfeit drugs that can have dangerous side effects. Without adequate background knowledge of medical products or patient history, it is quite complex for healthcare experts to initiate any treatment option. Diagnostic errors account for 60% of all clinical errors and between 40,000 and 80,000 deaths per year. Consequently, the magnitude of this problem is staggering, as the counterfeit drug business has become a $75 billion industry.

In healthcare systems, blockchain can be applied for a variety of benefits. They are detailed in Table 4.

Table 4. Benefits of the Blockchain in the healthcare industry.

Application	Detail
Electronic medical records	Using blockchain, a single and secure record is created in a decentralized database. It will contain all test results, the list of medications used, prescription details and all kinds of information related to each person's health. It can be accessed at any time and from anywhere (Angraal et al. 2017).
Distribution of medicines	With blockchain, when people buy a drug, they can confidently examine the source and production history. Detecting counterfeit drugs or prescriptions not only helps drug manufacturers and sellers financially, but can also save lives (Sarkar et al., 2021). In addition, the supply of erroneous drugs will be reduced when the same drugs are in demand again, as previous transactions are recorded for each patient (Barredo Arrieta et al. 2020).
Clinical trial	The clinical trial is performed on a patient with the goal of curing the person. With blockchain, after each trial, the results can be stored along with the patient's statistics. This will reduce the time needed to cure another patient suffering from the same disease (Panigrahi et al. 2021). It will also invalidate manufacturers' claims about the potency and effects of any drug or product on the individual organism, as all information is easily accessible and can be consulted by all interested parties (Barredo Arrieta et al. 2020).

Energy industry

The potential applications of blockchain in the energy sector have a huge impact on both processes and platforms (Bilal et al. 2014). This technology could increase transparency because customers energy savings data, financial institutions information or information related to any stakeholder in the energy sector will be encrypted and can only be viewed by people who are authorized to enter. In addition, the transaction cost is lower with blockchain because it does not need intermediaries and transactions can be executed directly between stakeholders. Thus, it reduces the complexity of the process and the cost. Without intermediaries, the transaction cost of energy-related contract management decreases significantly (Khatoon et al. 2019).

Blockchain technology can also be used to issue certificates of origin, specifically for green energy production and renewable energy sources (Park et al. 2018; Tanaka et al. 2017), to develop peer-to-peer energy transaction schemes (Pop et al. 2018) providing the opportunity that data related to energy savings can be stored through the blockchain platform in order to balance the energy bill or purchase additional energy services (Khatoon et al. 2019).

5.5 Validation

According to the research conducted by Nandi et al. (2020), among the 126 sample cases that applied Blockchain technology, 99% of them are aimed at resolving information gaps across supply chain links and enabling information sharing capabilities of supply chain companies. In addition, information sharing issues in the sample cases are solved by addressing the following problems: interoperability of enterprise resource planning (ERP) systems; IoT interoperability issues; information security; and non-inclusion of upstream and downstream supply chain entities. The percentage of the details explained above are shown in Table 5.

Table 5. Blockchain effectiveness

Capabilities	Number of cases	Percentage
Exchange of information	125	99%
Coordination	102	81%
Integration	26	21%
Collaboration	11	8.7%

5.6 Discussion

Most studies do not cover the technical and implementation details of blockchain-based supply chain systems, so a point of maturity has not been reached and the return on investment is unclear (Dasaklis et al. 2022). Sevda et al. (2021) point out that the adoption of blockchain technology poses significant challenges, as there are no laws to ensure the security of companies when using this new technology; in terms of data scalability, most supply chain users would also have to implement blockchain to take advantage of its benefits; and full transparency is not always desired by all companies (Dasaklis et al. 2022). Supply chain blockchain is an emerging technology that needs more research on applications across industries (Della and Oliver 2021).

Decentralization of information is one of the most important features offered by the blockchain (Hald and Kinra 2019). However, Della and Oliver (2021), to some extent, claim that this decentralization along the supply chain does not seem to be a very attractive feature for certain companies. Beck et al. (2018) argue that blockchain technology allows limiting the accessibility of information for special cases where there is a mutual agreement of the parties involved. As an example, a certain organization might have greater availability of information to track sources than other participants in the supply chain but would not be allowed access to all data (e.g., prices from other suppliers further down the supply chain). The ability to access information and execute transactions could be limited to some blocks called "private blockchains." In this mode, only authorized nodes can access information, so data is kept between authorized parties in a supply chain, unlike "Public Blockchains", which allow all participants to access information and execute transactions. On the other hand, without blockchain technology, an intermediary is left with control of the information and management of the transactions between the various parties receiving payment for their services. With blockchain technology, the various parties in a supply chain can communicate directly. Being able to conduct transactions without an intermediary is beneficial, and not only because it allows companies to eliminate costs, but also because it avoids failures and delays in communication that can be committed by the intermediary agent (Kharmalov and Parry 2018).

6. Conclusion

This study contributes to the research of blockchain in relation to the supply chain, although the objective of any organization when applying new management systems is to obtain benefits, it is necessary to perform a complete analysis and know the implications of applying a new technology, and even more so if there is no solid base of studies that indicate the effects that this will have in terms of its application. The research conducted indicates that the effects of blockchain on traceability and efficiency in supply chain management are positive from a conceptual point of view, relating the innate characteristics of blockchain with a possible behavior in the supply chain. This technology would allow reducing costs and execution time of transactions in the supply chain increasing efficiency in the supply chain since having all the decentralized and immutable information within reach of all parties would no longer require intermediate agents to manage and approve the companies' own processes. It also makes it possible to increase the traceability of both the company's own products and those of its suppliers by verifying and accessing updated information in real time. However, until latent issues such as scalability, standardization and organizational challenges are addressed, it will not be possible to state clearly what the potential impact will be.

6.1 Limitations of the study

The study aimed to identify the effects of blockchain on traceability and efficiency leaving aside the theoretical and practical implications, as well as possible implementation issues since there was no access to information on actual results from companies that have applied or implemented Blockchain technology in their respective supply chains to validate the possible effects detailed in this article.

6.2 Future research

There is a need for parallel growth between conceptual research and practice that will allow us to obtain accurate results and proposals that can be translated into a real scenario. With future research and as the blockchain consolidates, it will be possible to predict more accurately the effects this technology will have on traceability and efficiency. For the time being, companies should focus on determining which specific feature of blockchain fits their organization; for example, in the food sector the most important feature will be traceability, while in the manufacturing sector it will tend towards process efficiency. Organizations will need to conduct a thorough analysis and determine the benefits while considering the risks and implications of implementation.

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