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ORIGINAL RESEARCH ARTICLE

A comparative analysis of blockchain and Electronic Data Interchange (EDI) in supply chain: Identifying strengths, weaknesses, and synergies

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ABSTRACT

Supply chain management is crucial to modern commerce, improving operational efficiency, cost reduction, and customer satisfaction. Electronic Data Interchange (EDI) and blockchain are key technologies in this context. While EDI streamlines communication, blockchain ensures transparency. This study aims to address the lack of comprehensive comparisons in the existing literature, focusing on EDI and blockchain. Objectives include analysis of data security, speed, cost, scalability, and efficiency. Case studies reveal nuanced differences and similarities, highlighting the potential benefits of integration. The study conducts a comprehensive analysis of articles from diverse domains, examining the comparison between Electronic Data Interchange (EDI) and blockchain technologies to identify synergies. This research guides technology selection, providing decision-makers with essential information and promoting innovation in supply chain management by understanding the comparative advantages and challenges of EDI and blockchain, as well as their synergies in hybrid applications.

Keywords: supply chain management; electronic data interchange; blockchain technology; industry

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1. Introduction

The use of computerized enterprise resource planning (ERP) and supply chain management software has become a priority for almost all major companies worldwide[1], to ensure that the supply chain, at all levels, whether B2C or B2B, remains transparent, secure, and capable of real-time modification[2]. Indeed, the need to exchange and share information has become increasingly important in supply chains, and the rise of e-commerce has accentuated this even further: suppliers and consumers alike expect reliable, real-time order tracking information. So, the quest for rapid information transmission inevitably involves the dematerialization of order, delivery, and shipping documents. The dematerialization of information poses new problems, such as the conditions of authorization for data storage, the transmission of data to authorized persons, their secure access rights, and the prevention of fraud[3]. In addition, inefficient inventory management leads to errors and delays in the product supply chain, affecting delivery times. What's more, most companies use systems such as Electronic Data Interchange (EDI), which is the only way to ensure visibility[2] and maintain information continuity across system boundaries for companies, governments, and other relevant entities in the supply chain.

However, when using EDI, service providers do not provide a unified electronic data interchange format standard, leading to the complexity of current data formats and problems with information security and confidentiality[4].

EDI struggles with the complexities of modern supply-chain processes due to data transfer issues between different ERP systems, leading to critical situations[5]. To address this, a shared view of the supply situation and an automated early detection system is needed for customers and suppliers to collaboratively manage supply chains and avoid costly bottlenecks. Trust is crucial for global cross-organization collaboration, and transparent processes enabled by Distributed Ledger Technology (DLT) can support contract negotiation and performance alongside existing EDI systems[2].

We see that the application of blockchain technology in supply chains can play an active role in economic development. Many authors believe that blockchain has great potential to revolutionize the process of electronic data exchange due to the capabilities of smart contracts[6].

Blockchain technology has gained considerable scope following the many successes of its first use case in the Bitcoin cryptocurrency. It is now widely recognized as a revolution in information recording, and since 2018 its potential has been explored in a variety of industries, raising high expectations, particularly in supply chain management and the logistics industry[7].

Blockchain is a decentralized technology that operates as a distributed database, recording transactions in a network through encrypted data blocks[8]. While closely associated with Bitcoin, blockchain extends beyond cryptocurrency and provides a secure framework for various applications[9]. It combines cryptography, distributed system technology, and peer-to-peer networking to ensure secure and tamper-resistant data storage. The absence of a single "command center" makes it difficult for hackers to attack and manipulate data, as all participants in the blockchain network validate and store transaction data. Blockchain's potential lies in its ability to revolutionize electronic data interchange, particularly through the use of Smart Contracts[6]. Blockchain can securely store data for a variety of purposes, including financial transactions, commercial contracts, procurement, transfer of confidential information, insurance, property rights, personal data management, official document archiving, intellectual property protection, and supply chain logistics[10].

This study conducts a detailed comparison between blockchain and EDI in supply chain management, objectively assessing their strengths, weaknesses, and potential synergies based on solid empirical evidence. Utilizing a structured literature review from 2018 to 2023, the study analyzes selected articles through content analysis. The goal is to provide insights into the efficiency, data security, costs, and opportunities for hybrid integration between these technologies to enhance supply chain management.

In conclusion, this study contributes to a better understanding of the benefits, limitations, and practical implications of EDI and blockchain in supply chain management. It also highlights the need for future research to assess the performance, security, scalability, costs, and challenges of adopting these technologies in real supply chain management contexts. This knowledge can guide decision-makers in choosing the technology best suited to their specific supply chain needs, and foster innovation in this strategic area.

2. Literature review

The key concepts relating to this research will be presented in this section to provide the most relevant knowledge base on the subject of this research.

2.1. Supply chain management: A comprehensive overview

Supply chain management (SCM) is about supervising and controlling the movement of information, materials, and finances from the initial raw material phase to the final delivery to the customer. It covers every aspect of this operation and includes different participants like suppliers, manufacturers, wholesalers, retailers, and customers[11]. **Figure 1** below illustrates the interconnection of these entities within the supply chain.

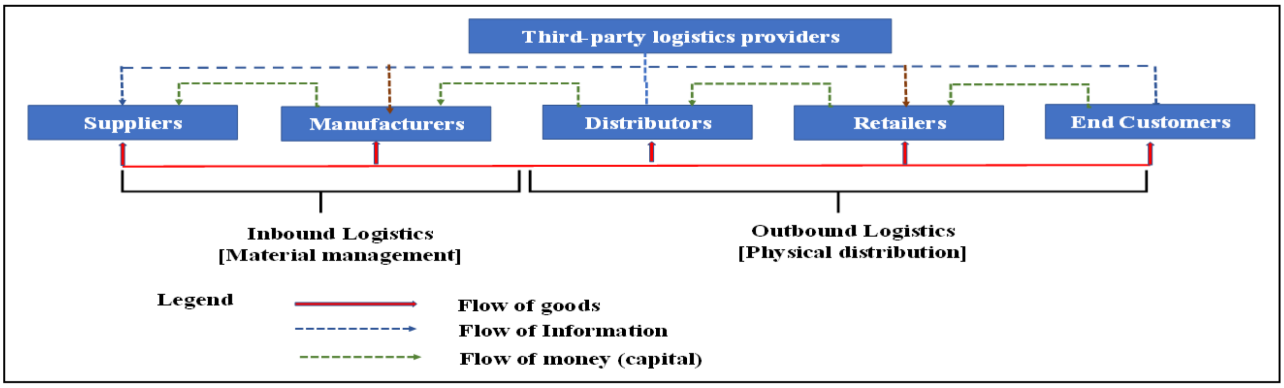

Figure 1. The supply chain process[12].

Common supply chain issues include a lack of visibility over the origin, manufacture, and use of products throughout their lifecycle. Even before reaching the end consumer, goods often pass through a network of actors such as retailers, distributors, transporters, warehouses, and suppliers, who are involved in design, production, delivery, and sale. However, these routes are often invisible to consumers[13].

In this context, the information flow becomes crucial for various management functions within the supply chain process. However, the current data management practices in supply chains are obstructive and inefficient. Some stakeholders store data in isolated, offline systems, and information exchange often relies on traditional postal systems. To enhance efficiency, Electronic Data Interchange (EDI) is recommended for automating information flow. However, centralized data management poses challenges, including data tampering, security risks, and slow data retrieval. To advance supply chain data management, the following guidelines are proposed: (1) enhance coordination and information sharing within the supply chain, (2) ensure data authenticity, and (3) expedite data retrieval processes[14].

Blockchain technology is seen as a promising solution to supply chain challenges. It offers increased visibility, product traceability, and transparent, secure transactions, even in a complex environment involving multiple stakeholders[15]. However, there are challenges associated with implementing blockchain in logistics and supply chain management[16]. Despite this, blockchain has great potential for improving supply chain transparency and efficiency.

2.2. Electronic Data Interchange (EDI): A comprehensive overview

EDI (Electronic Data Interchange) is a universal communication language that facilitates exchanges between companies (B2B) and between companies and consumers (B2C)[17]. It enables companies to share information efficiently, without human error. EDI is widely used to exchange files and data such as product activities, purchase orders, shipping and billing notices, etc Using EDI, computers communicate directly with each other, eliminating the need for faxes or e-mails for each event, ensuring greater accuracy and instant notifications[2]. Compliant with X12 and EDIFACT standards, EDI proves flexible across industries, offering benefits such as improved information flow, enhanced inventory management, accurate accounting, and a significant reduction in administrative costs[18].

EDI (Electronic Data Interchange) is an efficient solution for facilitating data exchanges between companies. Without EDI, processes become long and tedious, with problems of double entry and human error, consuming resources. Although some sectors have not yet adopted EDI, as in the case of freight operators who persist in using traditional operating methods[19], many ocean carriers have implemented it to simplify exchanges with external parties. EDI offers advantages such as cost reduction, elimination of delays, high processing speed, error avoidance, reduced manual input, and minimal human involvement while using less paper[20]. Documents exchanged via EDI are processed by computers and must comply with specific standards. Information extracted from a company's internal systems must be available in a standard format agreed with the partner. EDI documents are then processed by appropriate applications on the recipient's system to generate the desired results. Remarkably, the entire process takes place without human intervention, except for the execution of the necessary actions[21].

Electronic Data Interchange (EDI) is the established foundation of global supply chain operations, enabling real-time information exchange for critical logistics functions. However, EDI has flaws and inefficiencies in supply chain management. However, emerging technologies like blockchain offer revolutionary enhancements, providing secure, versatile data management for various industries, including supply chain and logistics. Blockchain's potential in Supply Chain Visibility and Intelligence (SCVI) surpasses traditional EDI-supported analytics by encompassing a wide range of essential data points, making it a superior choice for intelligent data integration in supply chain operations[22].

In the context of supply chain management, Electronic Data Interchange (EDI) has been the standard communication system in the logistics industry for over 30 years, but the global standardization of EDI messages still leaves much to be desired. Various technologies are already being used to define the field of application, so it is necessary to identify potential applications and modes of application, as well as to further categorize usage according to new developments and coordination efforts. In this way, new business opportunities can be realized in the logistics industry[23].

The EDI document transmission operation consists of three stages: identification of the data to be included, creation of the EDI document, and transmission. The company can collect the data from different systems using computer programs, or enter it manually using a digital form. After creation, the EDI document is sent either directly to the trading partner's internal system or via an EDI network service provider. Upon receipt of the document, the trading partner converts the data, integrating it into its internal system and transmitting an acknowledgment of receipt to the sender. Today, EDI Cloud enables companies to integrate using different protocols, formats, and systems, whether managed internally, by a third party, or on the cloud, offering seamless upgrades without interrupting business operations[21]. **Figure 2** below illustrates the steps involved in transmitting an EDI document between ERP systems.

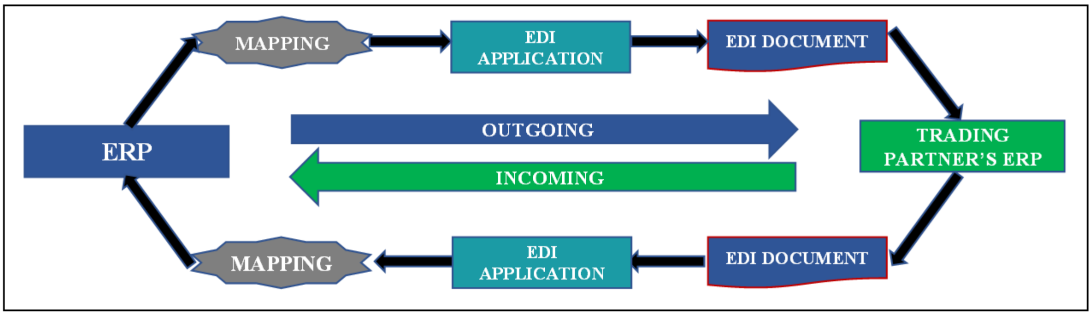

Figure 2. EDI process[21].

2.3. Blockchain technology: A comprehensive overview

Blockchain can be described as a decentralized database containing an organized list of records interconnected using links called chains[24]. Different types of blockchain can be distinguished, such as the public or "permissionless" blockchain, which allows anyone to participate and access data, and the private or "permissioned" blockchain, which requires specific authorization to participate and access data[25].

Blockchain technology is characterized by its immutability, where stored data is permanent and cannot be altered. It is also characterized by its decentralization, as there is no central authority and the network nodes maintain the blockchain. The persistence of validated transactions is another key aspect, ensuring a permanent record. In addition, anonymity is partially preserved for the parties involved in the transactions. Finally, thanks to algorithms, transactions can be traced, offering a secure, decentralized, and transparent solution for users[26].

To create a decentralized, transparent, and secure environment for diverse applications, two essential components work together: distributed ledger technology (DLT) and smart contracts:

- Distributed Ledger Technology (DLT): Distributed Ledger Technology (DLT) is a decentralized computing system that enables multiple parties to maintain a common, shared record of transactions[8]. In a DLT network, transactions are recorded in the form of data blocks, which are then added sequentially to a blockchain, forming an immutable and transparent history of all activity. DLT is characterized by its decentralization, immutability, transparency, and security. It offers a solid infrastructure for solving problems such as fraud, inventory management, and standards compliance[3].In a supply chain context, DLT can be used to track and record product movements, financial transactions, supplier information, quality certifications, and other relevant data. This enables all supply chain stakeholders, including manufacturers, suppliers, distributors, and consumers, to access a shared, secure, and transparent information system[8].
- Smart contracts: Smart contracts, and automated programs on blockchains, enhance transactional efficiency and security, particularly in the supply chain. They improve transparency, cut costs, and streamline contractual processes[27]. Operating as self-executing digital agreements, these contracts are coded into blockchain platforms, executing based on predefined conditions and consensus mechanisms. They leverage initial coin offerings for financing, incorporating business logic from multiple parties through distributed ledger technologies. By eliminating intermediaries, these contracts streamline processes and enhance transparency, ensuring execution across all network nodes. However, their transformative potential comes with the need for careful consideration of legal and security concerns[23]. Smart contracts are sophisticated cryptographic programs that run on the blockchain. They unlock value only when certain conditions are met. Unlike EDI, smart contracts can interact directly with companies' digital systems without the need for human intermediaries, making them more efficient and secure[6].

In the context of supply chain management, Blockchain is a decentralized technology based on the principle of peer-to-peer and cryptography, creating a shared register of verified, immutable, and secure transactions in a single database. When a customer orders goods, he sends the order as a hash to the supplier, who decrypts it with a private/public key). Alternatively, the customer and supplier can negotiate and create a smart contract that represents the terms of the contract and automates all subsequent steps in the process. The peer-to-peer nature reduces transaction costs and speeds up the process, and the immutability of the distributed ledger ensures trust and security. What's more, confidentiality is preserved by sharing only hashes and digital identities. Blockchain offers transparency, and automation and eliminates intermediaries, but its adoption requires technical expertise. The decision to adopt this technology depends on each company's needs and resources[21] . **Figure 3** below illustrates the process of Blockchain integration within the supply chain.

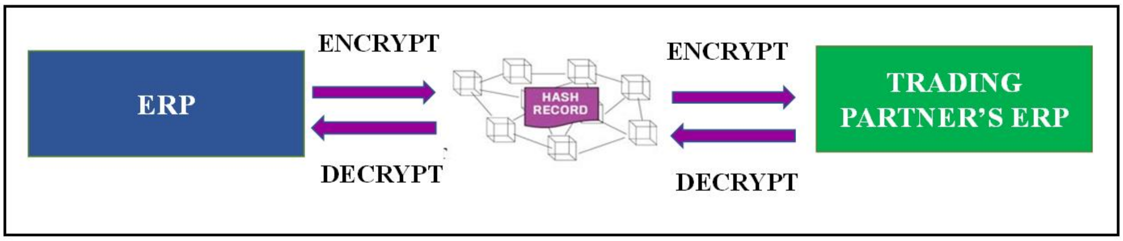

Figure 3. Blockchain process[21].

3. Methodology

This study aims to compare blockchain and Electronic Data Interchange (EDI) in supply chain management. The research questions guiding this study are:

- Are EDI and blockchain competitors?
- Will blockchain replace EDI ?
- Are EDI and blockchain complementary?
- How are blockchain and EDI converging?

Data Collection: A structured literature review is conducted to gather relevant articles published between 2018 and 2023 from various databases, including conference papers, journal articles, chapters from relevant journals and books, theses, and pertinent publications. The selected databases include Web of Science, Scopus, IEEE Xplore, ACM Digital Library, as well as relevant academic journals. In total, 20 relevant articles were identified that investigate the collaboration between blockchain and electronic data interchange (EDI) in the context of the supply chain.

Inclusion Criteria and Search Query: Articles meeting our criteria focus on the application and comparison of blockchain and Electronic Data Interchange (EDI) in supply chain management. The search query is (NOT (blockchain AND EDI) AND ("supply chain" OR "logistics" OR "SCM"), ensuring comprehensive coverage, including articles addressing these technologies in the context of supply chain management. The use of the OR operator broadens the search to include related terms like "logistics" and "SCM."

Exclusion Criteria: articles not directly related to blockchain or EDI or those published before 2018.

Data Extraction: data is extracted from selected articles using a predefined data extraction form. The form captures information such as title, authors, year of publication, research objectives, methodology, results, and limitations. Key data points related to blockchain and EDI, including their strengths, weaknesses, applications, challenges, and potential synergies, are extracted for analysis.

Data Analysis: a content analysis approach is used to categorize and compare literature findings. The data is organized into themes and sub-themes related to blockchain and EDI in supply chain management. Similarities and differences between these two technologies are identified to understand their respective advantages and limitations. Potential synergies and areas of convergence between blockchain and EDI are explored through a qualitative analysis of literature findings.

Integration and Interpretation of Data: the results of this literature review are integrated to provide a comprehensive understanding of the strengths, weaknesses, and synergies between blockchain and EDI in supply chain management. Data is interpreted to answer research questions, identify trends, and draw meaningful conclusions.

Limitations: the availability and representativeness of the selected articles, as well as the generalizability of the findings to different industries.

The conceptual research model, depicted in **Figure 4** below, describes the theoretical framework used in this study. This model serves as a visual representation of the relationships between the various concepts and variables studied.

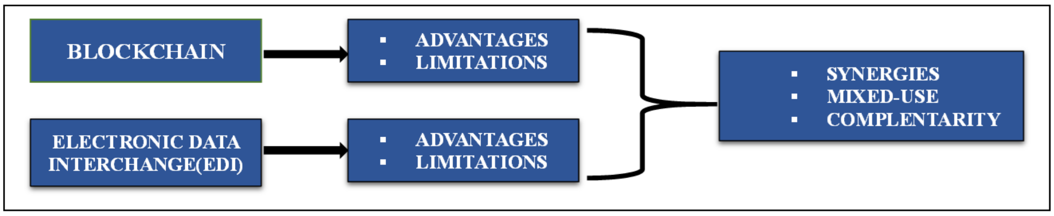

Figure 4. Conceptual Research model (source: Authors).

4. Research findings

4.1. Studies comparing EDI and Blockchain in supply chain management

After an extensive selection process, we have identified 20 relevant articles that investigate the collaboration between blockchain and electronic data interchange (EDI) in the context of the supply chain. The chosen collection encompasses various sectors such as healthcare, logistics and governance. **Table 1** will present an in-depth comparison of EDI and blockchain functionalities in these sectors, offering valuable insight into their specific applications. This comparative analysis not only enhances our overall understanding, but also highlights how the integration of EDI and blockchain skilfully addresses the challenges specific to each sector, resulting in advances in efficiency, security and transparency.

Table 1. Comparative analysis of technological synergies: EDI, blockchain, and their integration in diverse sectors.

Context	Advantages of EDI	Limitations of EDI	Advantages of blockchain	Limitations of blockchain	Advantages of combining EDI and blockchain
Supply chain logistics[28]	Efficient exchange of information.	Lack of unified data format standard.	Standardized format, security, integrity, authenticity.	Not specified.	Simplified data formats, enhanced security, transparency, efficiency, economic development.
Healthcare industry[18]	Improved information flow, accurate accounting, reduced administrative costs, compliance.	Disjointed data, and limited availability during provider changes.	Security, access, integrity, medical data management.	High costs, technical complexity, scalability, and speed issues.	Effective data connection, secure transmission, improved efficiency, accuracy, and security.
Healthcare supply chain management[2]	Communication between computers, accuracy, instant notification.	Lack of standardization, complexity, slow evolution.	Transparency, collaboration, medical data management, scalability, security, contracts.	Not specified.	Transparency, collaboration, medical data security, scalability, efficiency.
Supply chain logistics for a retailer[23]	Rapid and accurate communication, reduced errors.	Communication errors, redundancy, validation complexity.	Fast, accurate data exchange, visibility, authenticity.	not specified.	Simplified document distribution, and improved efficiency, trust, and security.
Logistics and transportation of goods[6]	Automated communication, efficiency.	Dependence on intermediaries, scalability, reliability.	Decentralization, security, automation, transparency.	Lack of understanding, decreasing interest in cryptocurrencies, and research gaps.	Secure data exchange, automation with smart contracts, and reliable transactions.
Multinational industrial waste management in automotive and railway manufacturing[29]	Cost reduction, processing speed, accuracy.	Data manipulation, lack of transparency, synchronization issues.	Transparency, cost reduction, security, automation.	Data privacy, bureaucratic obstacles.	Improved data security, documentation, intellectual property protection
Businesses aiming to facilitate transactions and manage supply chains[21]	Cost reduction, efficiency, strategic benefits, data security.	Longer integration time, technical resources, modifications difficulty.	Decentralization, shared ledger, automation, transparency.	Technical expertise, transaction speed, and development costs.	Secure and efficient data exchange.

Table 1. (*Continued*).

Context	Advantages of EDI	Limitations of EDI	Advantages of blockchain	Limitations of blockchain	Advantages of combining EDI and blockchain
Inter-organizational information systems (IOIS)[30]	Efficiency, cost reduction, connectivity.	Point-to-point messaging, lack of synchronization, limited accessibility.	Efficient transactions, reliability, transparency.	Technical and organizational challenges, legal constraints.	Efficient data exchange, cost reduction, secure collaboration.
Logistics and Goods Transport[7]	Reduces costs, enhances efficiency, improves accuracy, and Promotes sustainability.	technical complexity, high costs, limited interoperability, implementation difficulties, reliance on point-to-point transmission, Face challenges in widespread adoption, and accessibility limitations.	Automating processes ensures data security, reduces fraud risks, facilitates document exchange, builds trust, allows for customizable solutions, opens up new opportunities, promotes efficient transactions, offers reliability, and enhances transparency.	Requires technology understanding, adoption challenges, centralization vs. decentralization balance, data validation needs, integration with existing systems, legal constraints, investment and maintenance costs, and shortage of qualified developers.	Integrates EDI with blockchain security enhances process automation, boosts transparency and trust, lowers administrative costs, enables solution customization, and opens new business opportunities.
The automotive sector[31]	Supply Chain Integration, Enhancement of stability and efficiency, Reduction of errors, Process optimization, and Improvement of compliance.	Dependency on centralized networks and obsolete protocols.	Authenticity and transparency of transactions, Reduction of counterfeits. Real-time validation and increased traceability.	Scaling and implementation complexity.	Enhanced security. Increased traceability and transparency. Reduction of fraud and counterfeit risks. More efficient supply chain management.
Sharing health data in the healthcare sector focusing on B2B and B2C scenarios[32]	Automation of business processes.	Man-in-the-middle attacks, Vulnerability to supply chain attacks, Use of cryptographic protocols, Single Point of Failure (SPOF), Insufficient access controls.	Secure and verifiable data sharing, Granular access control, Protection against data manipulation, avoiding vulnerable protocols, reduced cyberattack risks, Verifiability, and fault resistance	Cyberattack risks (51% attacks), Vulnerabilities in smart contracts, technical complexity	Enhanced security and data privacy, Protection against manipulation and SPOFs, Precise access control, Reduction of Man-in-the-Middle attacks, Elimination of vulnerable protocols.
Supply chain management[33]	Faster and consistent information flow, Improved communication infrastructure, reduced order processing time, Enhanced customer service quality.	Not specified.	Traceability, Process automation, Cost reduction, Data security, Support for Industry 4.0.	Implementation challenges in existing supply chains, Integration limitations, Early-stage knowledge, and applications	Improved traceability, process automation, data security, Cost reduction, and support for Industry 4.0.
Supply chain management[12]	Synchronized information, Efficiency improvement, Cost reduction, Enhanced traceability.	Centralization, High costs, technical complexity, Lack of flexibility Dependency on intermediaries Security limitations.	Transparency, Traceability, Reduced, maintenance costs Process automation.	Scalability, Energy costs, Data privacy, Legal and regulatory challenges, Interoperability.	Enhanced supply chain management efficiency, Transparency and data security, Automated execution of agreements
Automotive supply chain[34]	Rapid and accurate data communication. Information exchange automation. System integration and reduced transmission errors. Enhanced coordination and collaboration in the supply chain.	Not specified.	Transparency, Traceability, Security and reliability, Paperless processes, smart contracts, and efficient delivery management	Rapid evolution challenges, Lack of specific blockchain knowledge in the automotive industry.	Simplified information flows, enhanced transparency, security, and supply chain management.

Table 1. (*Continued*).

Context	Advantages of EDI	Limitations of EDI	Advantages of blockchain	Limitations of blockchain	Advantages of combining EDI and blockchain
Governance and organization of companies, with a focus on Equality, Diversity, and Inclusion (EDI) in decision-making and resource allocation[35]	Boosting democracy participation and trust, promoting equitable resource redistribution, combating social exclusion and oppression, supporting developing countries with advanced tech, advancing equality, diversity, and inclusion, and enhancing government interfaces for efficiency.	Addressing social exclusion and oppression, challenges in EDI policy delivery and adoption, shifting governance and freedom perspectives, fostering trust in democracy, reducing social exclusion, improving data security, and promoting EDI support in economically disadvantaged countries.	Promoting inclusive governance, automating transparency with smart contracts, and supporting EDI through self-sovereign digital identity and blockchain technologies.	Need to restore public trust in social networks and government, Perceived pyramid-like organizational structure in blockchain, Lack of assessment of social diversity and exclusion issues.	Enhanced transparency, security, and coordination, Improved governance and trust in democracy, Active participation and support for EDI in various contexts.
Cold chain management in Indonesia[36]	Speed, automation, integration, and inventory visibility.	Complexity, initial financial costs, lack of required security for some businesses.	Enhanced product security and safety, efficient supply chain management, real-time transparency and tracking, and reduced transaction and contamination traceability time.	Implementation complexity, costly usage, privacy concerns, scalability issues.	Enhanced traceability of the cold chain, Rapid information transmission and coordination, Improved safety, quality, and reduced counterfeiting.
Maritime transport industry[37]	Quick and easy transfer of electronic bills of lading. Streamlined business operations and data transmission.	Paid subscription-based systems, centralization risks, lack of legal support.	Resilience, security, streamlined processes, cost reduction	High energy consumption, risk of 51% attacks, regulatory compliance	Decentralized and secure data management, Improved visibility and efficiency in maritime supply.
River transport[38]	Real-time interaction and information exchange, Message traceability.	Lock-in, system incompatibility, rigidity, high implementation costs, risk of dependence.	Accelerated real-time transportation processes, precise product information management, cost reduction in port operations, improved visibility and efficiency in logistics networks, and streamlined administrative processes.	Scalability challenge, high implementation costs, privacy concerns.	Improved information exchange, transparency, and efficiency, Facilitation of data interpretation and exchange, Strengthened management of manufacturing and logistics operations
Supply chain management in the fashion and logistics industry[39]	Effective communication, Data management, Interoperability, Cost and time reduction, Minimization of negative externalities.	Technical specifications, lack of data synchronization, compatibility issues, quality of goods, delivery time management.	Secure information exchange, Process efficiency improvement, Transparency and traceability, Autonomous smart contract execution.	Scalability issues, high implementation costs, and data privacy concerns.	Improved data exchange, transparency, efficiency, traceability, Record-keeping, and secure data sharing, enhancing supply chain management processes.
Inventory management in supply chain operations[40]	Commonly used for demand information capture and sharing, and enhances information exchange in supply chain operations.	Technical specifications, lack of error detection and correction, inability to handle all types of information.	Transparency, traceability, error reduction, shared "single version of the truth," quick issue detection and resolution through smart contracts.	Not specified.	Enhanced information exchange, transparency, and efficiency; bridging EDI gaps with blockchain technology; and improving information flow and operations management in manufacturing and logistics.

4.2. Real-world applications and case studies

In the ever-changing landscape of modern business, the integration of blockchain and electronic data interchange (EDI) has emerged as a transformative force, offering versatile solutions to the challenges of supply chain management in various sectors. Our exploration primarily focuses on the healthcare, food, and automotive industries; however, **Table 1** provides an overview of several other domains where the applications and innovations discussed here contain valuable insights. It's essential to recognize that the principles elucidated are applicable across a broad spectrum of industries, and by examining practical examples from these three sectors we aim to gain a nuanced understanding of how the synergistic application of blockchain and EDI technologies can act as catalysts for efficiency, transparency, and innovation. Now, we will delve into real-life case studies that highlight the impact of the intersection of these technologies with supply chain management.

4.2.1. Healthcare sector

At the heart of a thriving healthcare ecosystem, where seamless supply chain management is not simply a commodity but a critical necessity, the integration of blockchain and electronic data interchange (EDI) is emerging as a beacon of efficiency. Imagine a scenario in which a patient's journey, traditionally marked by pockets of disconnected data, is transformed into a coherent narrative. The blockchain, which functions as a secure distributed ledger, not only protects sensitive information but also enables the integration of new data from wearable devices. A compelling case study of the Croatian health landscape during the COVID-19 pandemic is a poignant example. A local retailer rapidly distributed disinfectant gel, demonstrating how the integration of EDI translators and blockchain streamlined logistics, eliminated intermediaries, and ensured the security of critical inventory data[23].

The integration of blockchain and EDI in healthcare offers a comprehensive solution to the challenges faced in supply chain management[18]. EDI, a long-standing tool for data exchange, has faced limitations in connectivity and leveraging data to improve patient care. Integrating blockchain technology enables disparate data sources within the healthcare network to be connected more efficiently and securely. Operating like a distributed ledger, blockchain guarantees the security, confidentiality, and integrity of exchanged data. Unlike traditional EDI, which creates "pockets" of disconnected data, blockchain provides a coherent framework for connecting dispersed data fragments.

In particular, blockchain enables the inclusion of new data from wearable devices and applications, contributing to a better understanding of a patient's overall health status. The use of blockchain as a communication medium for existing EDI addresses the shortcomings of current EDI systems. This integration secures patient medical records, offering authorized healthcare providers coordinated access to relevant medical information. Combining blockchain and EDI with metadata analysis has many benefits, including increased accuracy through megadata analysis, identification of potential inefficiencies, and cost reduction. In healthcare, this technological integration offers a more comprehensive view of patient records, facilitating informed decision-making and improving care coordination[18]. These two examples highlight the transformative potential of combining blockchain and EDI technologies in real-world applications[23].

4.2.2. Food sector

Moving from one sector to another, imagine the fusion of blockchain and electronic data interchange (EDI) within the food supply chain. Imagine a system where transparency, speed, and reliability are fundamental to food safety. Hyperledger Fabric technology establishes a traceability system, guaranteeing controlled access and streamlined data submission[41]. Case studies highlight the speed of data exchange and improved product traceability, particularly during disruptive events such as the COVID-19 pandemic[36]. The seamless integration of EDI and blockchain not only improves information management in the food sector but also enhances trust between stakeholders.

In the food industry, the convergence of blockchain and EDI is bringing substantial improvements to the supply chain[41]. Blockchain addresses the challenges of information sharing, data retrieval, and product traceability thanks to its immutable, transparent, and decentralized nature. By leveraging Hyperledger Fabric technology, a robust food traceability system is established, enabling controlled access and efficient data processing. In addition, EDI facilitates communication between supply chain actors, minimizing delays and errors in order processing and deliveries. Thanks to the integration of EDI and blockchain, the food supply chain benefits from increased transparency, speed, and reliability, guaranteeing food safety and boosting consumer confidence[41].

This comprehensive solution meets the challenges of information sharing thanks to the transparency and decentralization of blockchain. It speeds up data retrieval and strengthens product traceability thanks to the immutability of blockchain. Essentially, the integration of EDI and blockchain improves information management, speeds up data retrieval, and strengthens product traceability in the food supply chain[41].

In another use case[36], the solution proposed to advance the food supply chain involves the harmonious integration of EDI and blockchain technologies. EDI's role in facilitating fast, accurate data exchange helps to improve product traceability and strengthen relationships between customers and suppliers, particularly during disruptions such as the COVID-19 pandemic. The integration of blockchain ensures product safety, reduces counterfeiting, and promotes sustainable supply chain management. This technology enables rapid traceability of information in the event of contamination, from days to seconds, guaranteeing food safety. This integrated approach not only improves product traceability, safety, and quality but also enhances supply chain management, offering greater flexibility, particularly in times of crisis[36].

4.2.3. Automotive sector

The automotive sector, renowned for its complex supply chain processes, is undergoing a paradigm shift with the symbiosis of electronic data interchange (EDI) and blockchain. Imagine a scenario in which manufacturers and suppliers seamlessly share operational information, guaranteeing both security and transparency thanks to the capabilities of blockchain beyond EDI. The initial use case proposes integration, recognizing the growing importance of EDI and the Internet in supply chain automation and efficiency. Blockchain, extending its benefits beyond EDI, simplifies information flows by ensuring secure and transparent sharing of operational data between manufacturers and suppliers. This strategic combination improves supply chain management, using EDI for internal processes and blockchain for extended integration with trading partners. The result is improved efficiency, transparency, and trust throughout the automotive supply chain[34].

In a second distinctive use case[37], the proposed solution involves the creation of a blockchain-based EDI system, introducing a crypto-currency called AUTOCOIN, a crypto-currency exchange platform called AUTOCOIN-XCHANGE and a crypto-currency wallet called AUTOWALLET. This holistic system establishes a transparent, authenticated relationship between carmakers, original equipment manufacturers (OEMs), and automotive dealers, guaranteeing a secure flow of data upstream and downstream. AUTOCOIN plays a crucial role in tracking and authenticating transactions throughout the supply chain, preventing data falsification. The blockchain-based protocol verifies the authenticity of transactions in real-time, enhancing the traceability of automotive components. This global approach, which integrates smart contracts on AUTOCOIN-XCHANGE, mitigates counterfeiting by requiring suppliers to register components for proper approval and categorization[31].

In summary, the integration of EDI and blockchain technology within the automotive sector illustrates the capability to enhance both supply chain efficiency and transparency. This combined strategy ensures precise transaction tracking, mitigates the risk of data falsification, and fosters increased trust among diverse stakeholders in the automotive industry.

5. Discussion

Building on the detailed findings from our comprehensive analysis in **Table 1**, the forthcoming discussion aims to explore the complex dynamics that shape the interaction between Electronic Data Interchange (EDI) and Blockchain within the domain of supply chain management.

In today's fast-paced digital world, the integration of advanced technologies is crucial for enhancing the efficiency and security of data exchange and business operations. Electronic Data Interchange (EDI) and Blockchain have emerged as prominent players in this realm, each possessing its unique strengths and weaknesses. This discussion aims to explore their roles in supply chain management and how they can work together to improve various aspects of this critical business function.

- EDI and Blockchain as Complementary Technologies: The majority of articles agree that blockchain won't replace EDI; instead, these technologies are considered complementary. EDI offers advantages such as speedy and automated information transfers, enhanced integration and coordination within the supply chain, and increased inventory visibility. Conversely, blockchain offers potential benefits in terms of transparency, security, and transaction traceability. Combining EDI and blockchain can eliminate disputes through transparent and immutable records, optimizing data exchange processes and reducing associated costs.
- Blockchain's Advantages in Supply Chain Management: Blockchain offers several potential advantages over traditional EDI systems in supply chain management. Firstly, it provides a standardized data exchange format, ensuring better data integrity and authenticity, thus enhancing data security. Moreover, blockchain facilitates transaction automation through smart contracts, promoting faster and more efficient supply chain management. Its increased security, stemming from its decentralized and tamper-proof nature, addresses privacy and information protection issues, thereby strengthening trust among business partners. Finally, blockchain enables quicker payments within the supply chain, improving overall efficiency and reducing collaboration costs.
- Drawbacks of Blockchain in Supply Chain Management: it becomes clear that blockchain while offering notable advantages in supply chain management, is not without its drawbacks. Challenges identified include scalability issues, high implementation costs, technical complexity, dependencies on intermediaries, security issues such as the 51% risk of attacks, as well as potential regulatory compliance and privacy hurdles. These limitations underscore the importance of a nuanced approach and careful consideration of the pros and cons before adopting blockchain technology in supply chain management.
- Commonalities between EDI and Blockchain: EDI and blockchain share common goals in enhancing goods and information flow within businesses. Both technologies bolster data security, transaction traceability, and product visibility. Additionally, they promote transparency and trust among supply chain actors. Blockchain's immutable record-keeping plays a significant role in creating a secure environment for data exchange.
- Comparison of EDI and Blockchain: **Table 2**, based on research findings, compares Electronic Data Interchange (EDI) and Blockchain across key aspects: Technology, Data Format, Security, Transparency, Automation, Integration Challenges, Scalability, and Energy Consumption. This comparison provides valuable insights into their respective roles in modern data exchange.

Table 2. Comparison of Electronic Data Interchange (EDI) and blockchain: Key aspects.

Aspect	Electronic Data Interchange (EDI)	Blockchain	Combining Blockchain with EDI	Challenges and Considerations
Technology and Architecture	+ Mature technology	+ Decentralized and distributed ledger system	+ Synergizing mature EDI with blockchain security features	- Blockchain is in its infancy, with diverse consensus mechanisms; private blockchains may limit transactions.
Data Format and Standards	- Relies on standardized data formats, but lacks unified standards	+ No reliance on predefined data formats, data structures defined within smart contracts	+ Improved flexibility with smart contracts	- Lack of unified standards in EDI may hinder interoperability with blockchains.
Security	- May not offer the same level of security as blockchain	+ Known for high security due to its decentralized and tamper-evident nature	+ Enhanced security through decentralization and tamper-evident features	- Blockchain's security benefits may be offset by vulnerabilities in specific mechanisms or smart contracts.
Transparency and Traceability	- Offers limited transparency and traceability	+ Provides enhanced transparency and traceability	+ Improved traceability with transparent, immutable records	- Implementing traceability in blockchain-EDI systems may face challenges such as accurate data entry and fraud prevention.
Automation of Business Processes	- Automation is possible but may require additional integration	+ Includes smart contract capabilities for advanced automation	+ Advanced automation potential through smart contracts	- Integrating smart contracts may lead to complex business logic, requiring careful consideration.
Integration Challenges	- Integration with existing infrastructure can be challenging	+/- Integration challenges exist, but offers a more standardized platform once integrated	+ Potential for standardized integration, challenges in legacy systems	- Successful integration may depend on compatibility with existing EDI systems and blockchain technologies.
Scalability	- May face scalability issues, especially when expanding across industries	+/- Varies in scalability, with solutions being actively developed	+ Potential for scalability improvements with ongoing developments	- Scalability improvements may require continuous refinement and adaptation to industry needs.
Energy Consumption	+ Consumes less energy compared to blockchain	+/- Can consume significant energy, depending on the consensus mechanism	+/- Energy consumption varies based on specific blockchain implementations	The environmental impact of increased energy consumption in certain blockchain configurations should be considered.

- Convergence of EDI and Blockchain: The convergence of EDI and blockchain in supply chain management presents a compelling case. This integration eliminates potential disputes through transparent and immutable records. Smart contracts streamline transaction execution and enhance data exchange efficiency, reducing friction and associated costs. This synergy offers clear records, efficient automation, and cost savings. It also improves product traceability and security, ultimately reducing transaction and traceability time, especially in cases of contamination.
- Synergies between Blockchain and EDI: The synergy between blockchain and EDI in supply chain management is evident. Their combination enhances transparency, security, and coordination. The decentralized and shared data recording of blockchain fosters trust and cooperation among supply chain partners. This combination optimizes supply chain processes by improving information flows, reducing errors, and automating procedures, thus ensuring fair compensation for all stakeholders.

In summary, the combination of blockchain and EDI offers significant advantages in the management of the supply chain. While both technologies have their merits, they are not mutually exclusive; they can complement each other to create a robust and efficient supply chain ecosystem. The choice between EDI and blockchain should be based on the specific needs and requirements of each business. It is crucial for organizations to carefully evaluate the advantages and disadvantages of each technology to make an informed decision tailored to their unique circumstances.

6. Conclusion

The convergence of Electronic Data Interchange (EDI) and blockchain technology represents a significant advancement across various industrial sectors, offering notable advantages in transparency, security, and operational efficiency. Smart contracts play a crucial role in enhancing trust and reducing errors associated with EDI, with blockchain positioned to complement rather than entirely replace EDI in the short term. This combination addresses the limitations of EDI by simplifying data formats, strengthening security, and fostering collaboration, leading to improved traceability, and cost reduction, and ensuring data integrity while facilitating automation. The transformative potential of this integration is highlighted through case studies in healthcare, automotive, logistics, and governance. However, persistent challenges, particularly in scalability, confidentiality, and regulation, necessitate solutions for the complete realization of this integration's potential. Ultimately, the synergy between EDI and blockchain drives industries towards a future characterized by secure, transparent, and efficient data exchange, prompting companies to thoroughly assess their specific needs. Amid the evolving landscape of business technologies, the integration of EDI and blockchain emerges as a symbol of innovation, offering not only current solutions but also proactive readiness for future challenges. Companies embracing this integration journey position themselves in a supply chain characterized not only by efficiency and security but also by adaptability and future readiness.

Author contributions

Conceptualization, KEF; methodology, KEF and IEA; software, KEF; validation, KEF, IEA and AEM; formal analysis, KEF, IEA and AEM; investigation, KEF; resources, KEF and IEA; data curation, KEF, IEA and IEA; writing—original draft preparation, KEF; writing—review and editing, KEF and IEA; visualization, KEF, IEA and AEM; supervision, IEA and AEM; project administration, IEA and AEM; funding acquisition, KEF. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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