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Exploring the Adoption and Implications of Blockchain Technology across Industries: Drivers, Impacts, and Sector-Specific Dynamics

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Abstract

Blockchain technology, expected to be the next transforming force following the internet, has gradually evolved from its origins in cryptocurrency. It has become a framework for operational efficiencies and innovative business models across diverse industries. Blockchain technology's diverse value propositions fuel this transition. This includes immutability, decentralization, and transparency, which are skilled in revolutionizing transaction procedures and data management by eliminating the need for intermediaries. This has resulted in a new paradigm of business practices. Analyzing over 30 scholarly articles, this paper explores the factors that drive and block the adoption of blockchain technology in modern industries. This study also reviews the influence this tech has on industries and its sector-specific dynamics. The findings of this study are that blockchain shows substantial potential to generate operational efficiency benefits; however, its long-term success depends on overcoming legal, regulatory, and technical barriers while guaranteeing interoperable and scalable solutions. Through a literature review, this study highlighted the need for multi-stakeholder collaboration and continued research to fully harness blockchain's capabilities for decentralization and innovation in today's industries. This research provides substantial insights into developing a conducive environment for housing blockchain technology in modern industries.

Keywords

Blockchain Technology (BT), Blockchain Technology Adoption (BTA), Cryptocurrency

1. Introduction

1.1. Background on Blockchain Technology

According to Tripathi *et al.* [1], blockchain technology is initially the name given to the design that underpinned the operation of Bitcoin. It is a decentralized technology that helps myriad parties document transactions transparently and safely [2]. It utilizes a linked chain of blocks and cryptographic algorithms to guarantee the recorded data's consensus, integrity, and immutability [3]. This helps to discard the need for intermediaries and maximizes confidence in applications, not just cryptocurrencies. Following this, Younus *et al.* [4] termed blockchain technology the main driver to fuel the "Fourth Industrial Revolution".

The initiation of the blockchain roots can be traced back to 1976. During that time, it was just a form of paper detailing the likelihood of distributed ledgers in the world of cryptography. It was not till 2008 when Satoshi Nakamoto, famous as the inventor of blockchain, released a paper on the blockchain concept and its capacity to be decentralized. According to him, blockchain technology was a dispersed peer-to-peer linked framework that could resolve apprehensions about keeping the transaction order and eliminating issues such as double-spending. This paper stated all the issues experienced by modern banking at the time, and described ways blockchain could be used to fix them. This greatly affected how transactions could be made with zero third-party intermediaries [1]. Since then, blockchain has been a fundamental tool in developing multiple technologies and the world in general, and it is anticipated to do much more in the future [5].

Unlike traditional databases regulated by a central authority, blockchain operates on a peer-to-peer basis [5]. This decentralization minimizes the risk of single points of failure and data manipulation. In addition, each of the participants in the network is given access to a copy of the whole blockchain. This guarantees that all transactions are verifiable and transparent. [5] highlight that the distributed nature of the chain improves trust among those involved. In addition, once data is recorded in a blockchain network, deleting or altering it is almost impossible. This is because each block of the chain is cryptographically connected to the previous ones, creating a secure chain. This immutability feature guarantees historical accuracy and data integrity [6].

1.2. Relevance to Modern Industries

Blockchain technology goes beyond its initial roles as a tool for cryptocurrencies to revolutionize various sectors with its transparent and reliable ledger system.

For instance, in supply chain management, firms use this technology to trace their products' movement from source to destination, guaranteeing ethical practices, transparency, and authenticity [7]. According to Thakker *et al.* [8], the diamond industry, on the other hand, has deployed blockchain technology to verify the authenticity and origin of precious stones, eliminating the trade of conflict diamonds. Furthermore, healthcare systems now leverage blockchain tech to share and store patient records while ensuring privacy securely [3] [9]. Also, this technology has been used to minimize the computational and communication burden in data management. A secure transaction has attained this for a group of networks. Lump-sum amounts of healthcare data have also been managed using blockchain contract systems [10]. In addition, integrating a blockchain platform with medical services has helped connect healthcare providers, patients, and doctors to better comprehend who is complying with treatments and their impact [9].

In education, blockchain applications have been used to verify degrees and certificates, perform student assessments, transfer credits, manage data, and for admission purposes. Verifying academic credentials is crucial for employers and other authorities to confirm the validity of an academic degree. Via blockchain technology, students can now access their official academic documents under the protection and control of their universities.

2. Methodology

To comprehensively answer the research questions, this study performed a systematic literature review to single out the factors affecting the adoption of blockchain technology across different industries. It also did a content review to identify the effects of this technology on operational efficiency in these industries. The study also evaluated the risks and opportunities brought by this technology. Guided by the PRISMA framework, the review procedure was done in phases: search strategy, exclusion and inclusion criteria, screening and selection, and data extraction and analysis.

2.1. Search Strategy

At the start, an extensive search of electronic databases was conducted to extract resources published from 2019 to 2025. This study relied on widely used databases in information systems research. This included the ACM Digital Library, Google Scholar, Web of Science, ScienceDirect, Emerald, Springer, Scopus, and IEEE Xplore. This study utilized all these databases, given that searching multiple databases helps maximize available data and provides diversified data resources. According to Ewald and Klerings [11], this helped reduce the risk of missing relevant research. The search terms utilized to extract resources from the above databases combined relevant keywords revolving around blockchain technology. For instance, "blockchain", "distributed ledger technology", "diffusion", "elements", "determinants", "acceptance", and "adoption", utilizing Boolean operators such as OR and AND. The search was conducted on the articles' keywords, titles, and abstracts.

2.2. Inclusion and Exclusion Criteria

2.2.1. Inclusion Criteria

Specific inclusion and exclusion criteria were utilized on the retrieved articles to guarantee that the articles were of high quality and relevance. Only articles that met the criteria below were saved to be used in this study:

1) ***Written in English***: Given that English is the core language of scientific communication, articles composed in English were considered for extensive analysis. They were saved to guarantee an in-depth analysis of the factors affecting blockchain adoption. However, articles that were not full-text and did not have complete content were discarded. Also, articles that had restricted access were made available. This included open-access articles, articles requiring a subscription, or access to academic libraries.

2) ***Empirical investigation***: An empirical investigation was conducted following the selection of articles based on the English language. For this study, only articles that empirically assessed the factors, opportunities, and challenges affecting the implementation of blockchain technology were included. This criterion aimed to redirect the study to research that offers insights and improvements.

3) ***Published in conference papers and journals***: Resourceful articles published in reputable scholarly journals and conference proceedings were also saved to capture diversified research outputs.

2.2.2. Exclusion Criteria

Articles were excluded only if they met any of the following descriptions

Non-English language: Articles written in languages other than English were discarded due to language limitations.

Focus of cryptocurrency with no apparent connection to blockchain technology: Articles that specifically talked about cryptocurrency without showing a connection to blockchain technology were excluded, since they could sway our study from its objectives.

Lack of specific address to research questions: Articles that did not particularly address the factors impacting blockchain implementation were discarded to guarantee relevance and focus of this research.

2.3. Screening and Selection

This study utilized a systematic process to identify and remove duplicates from the saved articles. At first, EndNote 20 software was utilized to get rid of exact duplicates based on author affiliation and title. This was followed by a manual review of the remaining articles to guarantee that no duplicates had been spared. The remaining articles were then selected for a full-text review depending on the inclusion and exclusion criteria. Any disagreements regarding inclusion were solved by detailed discussion among the authors till consensus was met.

2.4. Data Extraction and Analysis

Data extraction was performed from the saved articles to get key information, including the industry and key findings related to the blockchain technology deployment. The factors impacting the adoption of blockchain were singled out and grouped according to recurring themes. This was also done to assess the risks and opportunities following the adoption process across industries. Table 1 summarizes the findings.

Table 1. Summary of key findings on blockchain adoption across industries.

Industry	Key Findings on Deployment	Factors Influencing Adoption	Perceived Benefits/ Opportunities	Perceived Risks
Finance	• Enhances transaction speed, transparency, and fraud prevention	• Regulatory frameworks • Technological readiness • Cost-benefit considerations	• Improved trust and transparency • Faster settlements • Reduced fraud	• Integration with legacy banking systems • Cybersecurity threats • Uncertain regulations
Supply Chain	• Boosts traceability, authenticity verification, and efficiency	• Human factors (awareness, training) • Technological infrastructure • Cost implications	• Real-time tracking • Enhanced transparency • Fraud reduction	• Scalability challenges • Resistance to change • Complex integration
Healthcare	• Improves data sharing, patient record management, and security	• Network enhancement • Data privacy concerns • Legal compliance requirements	• Reduced errors • Secure patient data • Streamlined record management	• High implementation costs • Data breaches • Lack of interoperability
Cross-Industry (General)	• Adoption depends on organizational readiness and context	• Comparative industry pressures • Leadership and culture • Perceived value vs. cost	• Operational efficiency • Competitive advantage • Long-term sustainability	• Legal uncertainties • Volatility of technology • Skills gap

2.5. PRISMA Framework

To guarantee the rigor of this review, the PRISMA framework (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was incorporated in the review process. This framework advanced the validity and reliability of the study findings. In light of the PRISMA framework, Figure 1 below shows the number of articles gathered for this study, summarizing the whole process.

3. Factors Influencing Adoption

3.1. Technological Factors

3.1.1. Perceived Data Quality

Perceived data quality is a fundamental antecedent of technology implementation. According to Dehghani *et al.* [12], the recognized attractive features of the information systems output are timeliness, quality, completeness, accuracy, and availability [12]. Rahman *et al.* [6] hold that perceived data quality positively relates to organizational blockchain technology deployment in diverse industries. It is a substantial positive factor driving industries' intention to adopt blockchain technology. In today's world, industries are putting heavy focus on data quality, which indicates the essentiality of organizational data when working with today's data-controlled business landscape. Firms seek to ensure better utilization of their available data, and blockchain technology has been identified as supporting this goal [6] [12] and mention that blockchain technology bears several characteristics, such as the ability to improve audibility, minimize single points of failure, attain a single version of the truth, and offer tamper-evidence, which can improve the overall usability, quality, and completeness of an organization's data. Generally, firms are sensitive to these blockchain features, which have led to data quality being a substantial facilitator for organizational adoption.

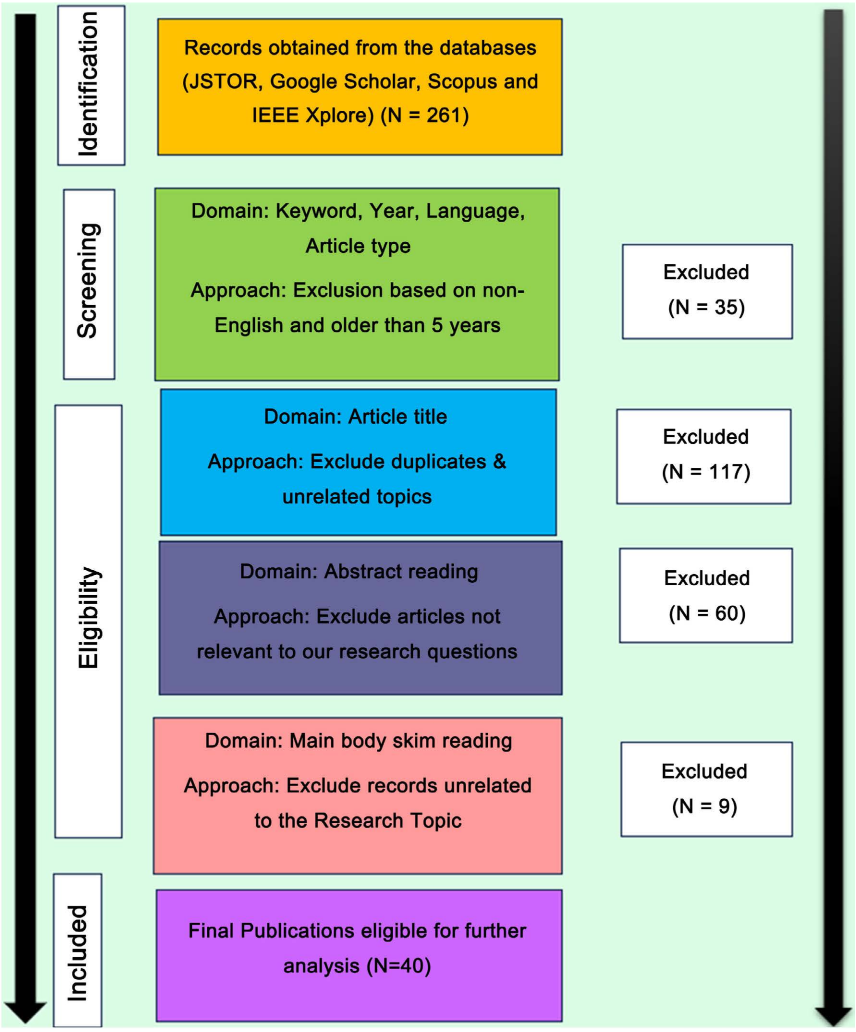

Figure 1. PRISMA framework.

3.1.2. Perceived Interoperability

Perceived interoperability refers to how easily a firm believes a new technology can be integrated into their existing system and smoothly work with existing platforms and partners. Scholars such as Dehghani *et al.* [12] have found perceived interoperability to be a substantial positive factor influencing organizations' adoption of blockchain technology. This confirms the usefulness of interoperability in technology adoption, spotlighted by research conducted by the UK Department for Science, Innovation, and Technology in 2025. According to their report, the more quickly a technology system can be assimilated into a firm's existing technology infrastructure, the more the firm can adopt it. Regarding blockchain technology, mainly small firms view blockchain as a trigger if it is highly interactive with their current technology infrastructure, including technological procedures, servers, enterprise information systems, and databases. This shows that small firms have the highest possibility of adopting blockchain technology, given that the adoption process would lead to minimal or no changes to their enterprise information systems and legacy infrastructure. This reduces the time and cost to adopt and integrate or implement blockchain technology. Bigger firms have a much more intricate technology infrastructure, making it hard for them to integrate new technologies such as blockchain into their systems.

3.1.3. Perceived Technological Volatility

Perceived technological volatility is the belief that a technology is unstable, rapidly changing, or uncertain in the long term. Regarding barriers for blockchain adoption, perceived technological volatility has been shown to have a negative relationship with intention to adopt blockchain systems [12]. It is characterized by uncertainty regarding the technology's rate of change in improvements and specifications. Firms view blockchain as consistently evolving and recurrently changing, which minimizes their intentions to implement it.

In this case, within the organizational context, a discerned lack of technological knowledge has been shown to influence blockchain adoption negatively. This supports Ko & Chang's [13] findings that firms with no intentions of adopting blockchain technology hold that they do not possess the required technical competence, referring to knowledge, for adoption. A possible explanation is that BT is more intricate than other technologies. This makes it hard for individuals to learn and fully comprehend it.

Effective adoption calls for expertise for diverse technologies, including a programming language, a network of nodes, transactions, chains of blocks (the ledger), blocks of hashed data, and cryptographic hash functions. Many firms have some degree of technological knowledge in one or even several areas. However, blockchain technology calls for a certain degree of specialization. With this lack of technological knowledge, firms will not know how to properly develop or adopt a blockchain solution. Hence, they will have a low adoption intention, making a lack of tech knowledge a substantial barrier to adopting blockchain technology.

There is a positive correlation between a firm's organizational culture and readiness and its intentions of adopting innovative technologies, and in our case, blockchain technology [6]. Adoption is only successful when blockchain technology improves the organization's targeted strategies, for example, auditability and coordination, and when the firm is structurally ready to deploy the tech. Firms with harmonized data systems, laid out change control processes, and mapped processes can easily consider adopting blockchain tech, compared to those without such clear structures. According to Rahman *et al.* [6], organizational readiness substantially blocks blockchain implementation because many companies lack the governance mechanisms, structure, or culture to support such huge technologies. When leadership fails to prioritize digital transformation, employees are left without clear direction or necessary training, building resistance and confusion. Weak IT infrastructure and insufficient data standardization further slow implementation, since integrating blockchain systems into outdated models becomes costly and complex. Without apparent readiness, including smoothened procedures, change management strategies, and technical expertise, organizations tend to avoid adopting or postponing it, in fear of wasting investment or causing operational disruption.

3.2. Regulatory and Legal Frameworks

Perceived standardization uncertainty and perceived regulatory uncertainty have a substantial negative correlation with a firm's intention to integrate blockchain tech into its existing systems. Dehghani *et al.* [12] mention that the bigger the level of uncertainty a firm has regarding the standards and regulations revolving around blockchain, the lower the probability of the firm using it. Small organizations may be less skilled at handling the intricacies of standardization or regulatory uncertainty due to a lack of the required knowledge or inadequate funds to cover compliance costs.

On the other hand, larger firms may be more proficient at handling regulations or standards. Nonetheless, they may be more flexible in aligning with the regulations and standards than bigger firms due to influences such as cloud computing (rather than possessing legacy infrastructure). Despite this, firms do not want to risk their scarce resources to develop a blockchain solution just for a regulation or standard to be developed that negatively affects their production deployment. As it looks, firms prefer the regulations and the standards to be developed and finalized before they take a step.

3.3. Cost-Benefit Considerations

High costs are among the most substantial challenges hindering companies from deploying blockchain technology [6] [14]. The necessity for continuous staff licensing fees, compliance measures, and infrastructure upgrades builds substantial financial strain, mainly for medium and small-sized enterprises. Many companies view blockchain as a technology that needs heavy upfront investments with delayed or uncertain returns. This makes it difficult to justify its implementation, especially when profit margins are already tight [14]. In addition, companies are scared of being the first movers, shouldering considerable integration costs while waiting for partners to join the ecosystem. This cost burden mostly makes firms reject or delay blockchain adoption entirely and stick with the cheaper legacy models they find predictable.

3.4. Network Enhancement

Network enhancement is one factor that shows an insubstantial influence on blockchain adoption intention [12]. This is partially due to the challenges in engaging in blockchain consortia [15]. Challenges include recruiting new members, specifying governance rules, assigning responsibilities, defining members' roles, and funding issues. Hence, Kouhizadeh *et al.* [16] spotlight the essentiality of encouraging and recruiting partners. Moreover, the network-advancing features of blockchain may also be due to several low-degree factors, which make the benefits less visible when weighed against data quality. Firms may only recognize the network-improving benefits once they have adopted and utilized blockchain.

4. Blockchain and Operational Efficiency

Blockchain technology is gaining popularity as a transformative tool that can improve operational efficiency across various sectors. Its key features, smart contracts, transparency, immutability, and decentralization, assist industries in smoothing processes, maximizing trust in data handling, and minimizing fraud rates. This section analyzes the application of this technology in the supply chain sectors, the finance sector, and the healthcare sector.

4.1. Finance Sector

4.1.1. Use Cases

According to Regmi *et al.* [17], the financial industry was among the first adopters of BT, mainly due to its capabilities to change financial operations. Substantial use cases include smart contracts, clearing and settlement, cross-border payments, and digital identity [18].

Blockchain technology in the finance field permits real-time international transactions. This is made possible by removing intermediaries, which reduces processing times and costs. Platforms such as Stellar and Ripple are clear examples that promote decentralized international transfers. In addition, smart contracts automate financial agreements, including insurance payouts or loan disbursements, without third-party verification.

4.1.2. Cost Reduction, Speed, and Transparency

According to Trivedi *et al.* [18], removing intermediaries such as legal services, brokers, and banks minimizes the operational expenses and transaction fees. Additionally, automated smart contracts replace paperwork and manual checks. This saves administrative costs and simplifies the investment processes. Also, Trivedi *et al.* [18] mention that smart contracts facilitated by BT automate contracts, resulting in the minimization of the time needed for asset settlement and transfer. Opposite to conventional systems that involve manual authentication, these procedures guarantee instant execution and minimal delay, improving market efficiency.

Furthermore, transparency is improved as all transactions are immutable and timestamped. This reduces the possibilities of fraud and allows for real-time auditing. Financial organizations have started building their own blockchain-based platforms, such as Onyx, to smooth interbank transfer and make 24/7 settlement of digital assets possible. These advancements have enhanced operational efficiency and contributed to regulated compliance by enabling better data traceability and reporting.

4.2. Healthcare Sector

4.2.1. Medical Record Management

In the healthcare sector, blockchain technology is utilized for almost everything, from securing patient data to managing the pharmaceutical supply chain [9]. According to the data, America is anticipated to spend approximately 20% of its GDP on healthcare by 2032 as constant data breaches, high hospital costs, and inefficient practices continue to trouble the industry ("NHE Fact Sheet," 2023). These expensive risks are triggering a journey for greater innovation and efficiency [10]. Looking at its capability to minimize spending, enhance the overall healthcare experience, and safeguard patient data, blockchain tech may help relieve the pain in the healthcare sector [9]. Technology is already being utilized to manage the outbreak of harmful diseases.

According to Shrank & Parekh [19], 25% of US healthcare expenditure is seen as a waste because of harmful services that could be replaced with cheaper options or do not have clear benefits. Accessing a patient's healthcare record delays patient care and exhausts staff resources [10]. Medical records utilizing blockchain tech build one ecosystem of patient data that can be referenced efficiently by healthcare institutions and professionals [9]. This way, the blockchain technology can result in personalized care plans and diagnoses. Examples of companies that embrace this concept to create personalized health plans and shared databases are Avaneer Health, Professional Credentials Exchange (ProCredEx), and Patientory.

Avaneer is a firm backed by healthcare leaders such as the Cleveland Clinic, Aetna, and CVS Health, among others [20]. This company is committed to utilizing blockchain tech to enhance efficiency in healthcare. This firm utilizes a public ledger to update provider directories, support better claims processing, and secure healthcare data exchanges.

ProCredEx, on the other hand, has established a distributed ledger of healthcare credentials data that strengthens the efficiency of the intricate dataset by rendering the data permanently traceable and immutable [21]. This permits data to be manipulated to align with unique organizational needs and shared with authorized partners. The platform utilizes proprietary validation engines. It also limits memberships to approved and vetted organizations so that medical systems can efficiently attain verified credentials, enhance care quality, and patient safety.

Patientory's end-to-end encryption system guarantees patient data is shared efficiently and safely [22]. The firm's platform helps clinicians, patients, and healthcare providers to access, store, and transfer all essential info through blockchain. Patientory helps the healthcare sector move more quickly by having all patient information under one roof.

According to Attaran [9], patient consent is crucial in the healthcare industry. Blockchain technology permits patients to control access to their records using a cryptographic key, revoking or granting permission as required. Solutions such as Healthereum and MedRec are flourishing platforms that have deployed BT. Patients can manage their health records with them while guaranteeing they stay accessible to caregivers when appropriate.

4.2.2. Data Integrity, Privacy, and Interoperability

The immutability of blockchain technology guarantees that once medical data is recorded, it cannot be changed without having to be deleted. This ensures a trustworthy audit trail, regulatory audits, and insurance claims, and is crucial in malpractice disputes. Additionally, blockchain tech in healthcare promotes compliance with regulatory policies such as HIPAA in the US and GDPR requirements in Europe. This is done by restricting unauthorized data access while permitting interoperability across systems [23]. For instance, the Estonian eHealth Foundation has adopted blockchain tech to secure over a million patient records, helping authorized providers access patients' medical records smoothly. The efficiency gains in this case are twofold: minimizing administrative overhead and improving care coordination. According to Saeed *et al.* [23], healthcare blockchain technology helps eliminate manual verification and recurring paperwork. It also ensures that clinicians can quickly access updated and accurate patient records.

According to Attaran [9], blockchain technology systems in healthcare allow for interoperability by offering a decentralized ledger of accepted facts in medical records to which all healthcare service providers have access. This insinuates that while the user interface may differ, the central ledge stays the same across all service suppliers.

Applications of blockchain technology in healthcare deal with crucial issues, such as safe sharing of medical records, authentication, and interoperability. Despite the rising focus on the BT, recognizing such concerns is a remarkable barrier to its extensive implementation [23]. More emphasis must be put on ethical recommendations and regulatory compliance for problems such as access to patient data and ownership control.

4.3. Supply Chain Sector

4.3.1. Traceability, Anti-Counterfeiting, Automation

The supply chain sector is flooded by intricate systems that involve multiple stakeholders, including retailers, wholesalers, customs agencies, suppliers, manufacturers, and transporters, spread across numerous regions [7] [24]. This intricacy makes this industry vulnerable to a lack of transparency, inefficiencies, counterfeiting, and fraud. For a long time, tracking goods across such networks has traditionally depended on trust-based verification, siloed databases, and paper-based documentation. Moreover, this has always resulted in disputes, errors, and delays.

To address these issues, blockchain technology has created an immutable and shared chain of custody for goods, guaranteeing that every step, from sourcing raw materials to production, storage, shipping, and transportation, is timestamped and securely recorded. Every participant in this industry is given access to a single truth version, reducing the necessity for reconciliation between several records.

The food industry is a perfect compelling illustration of the value of blockchain technology. Food safety scandals, such as contamination outbreaks, need urgent investigation to avoid exposing consumers to harm and minimize reputational damage. Before blockchain technology, tracing the source of contaminated meat or lettuce could take a week, and during this time, the affected products could still be consumed or sold. Walmart's collaboration with IBM's Food Trust platform changed this procedure, minimizing trace times to seconds. This quick or instant identification lets retailers eliminate only the affected batches from shelves. This reduces waste while simultaneously safeguarding public health.

Blockchain technology goes beyond food safety. It also plays a crucial role in fighting counterfeiting in the pharmaceuticals, luxury goods, and electronics sectors. The World Health Organization mentions that for every one in ten medical products in middle- and low-income nations is falsified or substandard, eroding public trust and contributing to health crises. By giving blockchain ledger product serial numbers, firms can verify authenticity at every distribution stage. Also, consumers can scan NFC tags or QR codes to check a product's originality, production dates, and journey via the supply chain.

4.3.2. Real-Time Visibility and Efficiency Gains

Traditionally, supply chains primarily operate with incomplete or delayed visibility due to limited information sharing and fragmented data systems—solutions founded using blockchain technology deal with this by providing end-to-end and real-time transparency across all network participants [7]. For instance, global logistics giant IBM and Maersk launched Trade Lens in the shipping industry. This platform utilizes blockchain technology to allow shippers, customs authorities, ports, and freight forwarders to share real-time shipment info. This has reduced costs linked to documentation errors, enhanced alignment with customs regulations, and reduced administrative delays.

In dairy, vaccines, and seafood, among other temperature-sensitive supply chains, blockchain technology can be blended with Internet of Things sensors to document environmental conditions such as light exposure, temperature, and humidity. If a shipment does not match the needed temperature range, the system can alert stakeholders immediately, ensuring corrective actions can be taken before any damage occurs. This reduces waste, ensures quick dispute resolution, and improves customer trust.

5. Industry Context and Perceived Risks/Value

Blockchain's adoption is not uniform across industries. Stakeholder trust dynamics, regulatory environments, technological maturity, and market pressure shape it. This section explores how these contextual influences impact the view of risks and benefits.

5.1. Contextual Influences

5.1.1. Regulatory Frameworks

In the finance industry, regulatory oversight is thorough. Conformity with regulations such as the Basel III, the US Bank Secrecy Act, and the European Union's PSD2 directive banking standards calls for blockchain solutions to integrate Anti-Money Laundering (AML) and Know Your Customer (KYC) mechanisms. These regulations slow implementation while pushing innovation toward permissioned blockchains, where stakeholders are vetted, and access is reserved for only approved entities [18]. Simultaneously, in healthcare, laws such as GDPR in the EU and HIPAA in America provide strict privacy protection for patient records. Blockchain models for healthcare must then prioritize compliance audits, encryption, and access control to make the deployment process more secure, though slower [10].

Conversely, the supply chain sector experiences less uniform regulation [24]. Although sectors such as pharmaceuticals, overseen by the US Drug Supply Chain Security Act, and food, overseen by the US Food Safety Modernization Act, are regulated, other areas are lightly regulated. This flexibility in regulation can speed experimentation with BT, but also raise concerns about legal accountability in global trade contexts.

5.1.2. Industry Size and Market Dynamics

Big international companies with intricate global operations are more willing to invest in BT due to the perceived gains that scale with size [25]. For instance, international retailers benefit more from tracking thousands of suppliers than local small businesses with limited product lines. Small and Medium Enterprises mostly experience slow deployment unless fueled by a dominant trading partner or presented with affordable Blockchain-as-a-Service (BaaS) alternatives from Microsoft Azure or AWS, among other cloud providers.

5.1.3. Infrastructure and Technology Readiness

Industries with advanced IT infrastructure, such as banking, can integrate BT. On the other hand, industries such as healthcare in lower-income nations may experience challenges from outdated legacy systems, low digital literacy among staff, and fragmented databases. Simultaneously, supply chains in marginalized regions may lack the IoT infrastructure and connectivity for BT tracking to be successful [7].

5.2. Perceived Risks

5.2.1. Cybersecurity and Data Breaches

Although the blockchain's cryptographic security is robust, regular vulnerabilities exist in adjacent systems, such as digital wallets and smart contract code. The infamous 2016 DAO hack that exploited a deficiency in smart contract logic led to a loss of over $60 million. In the supply chain sector, a deficient IoT device generating falsified data in blockchain systems can compromise the reliability of the entire model.

5.2.2. Lack of Standardization

Dehghani *et al.* [12] state that the lack of universally accepted blockchain frameworks builds interoperability hardships, mainly when several firms utilize different models. This is mainly an issue in supply chains that involve multiple international partners, whereby integration costs surpass the efficiency gains.

5.2.3. Legal Uncertainty

Rahman *et al.* [6] mention that although they are technically binding, smart contracts experience uncertainty in courts because of jurisdictional differences in identifying automated agreements and digital signatures. Industries such as healthcare and finance, highly bound by legal compliance, may hesitate to rely on blockchain systems unless clearer precedents emerge.

5.3. Perceived Benefits

5.3.1. Market Differentiation and Competitive Advantage

Trivedi *et al.* [18] state that blockchain technology can be a strategic differentiator. In finance, firms that adopt blockchain tech earlier can attract clients looking for faster and lower-cost transactions [18] [26]. Conversely, providing patient-controlled medical records in healthcare can improve brand reputation and trust. In supply chains, sourcing transparency backed by blockchain technology can appeal to ethically minded customers willing to pay a premium for sustainable products and services [24].

5.3.2. Audibility and Regulatory Compliance

Ko & Chang [13] mention that the immutable ledgers by blockchain tech smoothens compliance audits by offering regulations with secure and read-only access to relevant transaction histories. This minimizes both the cost and time of fulfilling regulatory obligations.

5.3.3. Increased Trust among Stakeholders

By having decentralized control, blockchain technology builds a shared environment of trust where no single participant can compromise any records for personal benefits. This is valuable in multi-firm collaborations such as global logistics networks and healthcare data exchanges.

5.4. Comparative Analysis across the Three Industries

As shown in the table below, **Table 2**, the comparative analysis across the three primary industries addressed in this study shows that although the operational efficiency gains generated by blockchain technology are evident across these three sectors, adoption decisions are mainly influenced by internal capability and external context. The healthcare and Finance industries experience slower adoption cycles mainly because of the higher data sensitivity and heavier regulations that bind these industries. On the other hand, the supply chains facing pressing needs for traceability and transparency are facing rapid pilot and experimentation deployments.

Table 2. Comparative analysis.

Factor	Healthcare	Supply Chain	Finance
Barriers	Legacy systems, Date sensitivity	Lack of standards, Fragmented systems	Resistance to change
Main Risks	Integration challenges, Privacy breaches	Scalability, Interoperability	Hacking, Legal compliance
Regulatory Impact	High	Moderate	High
Key Benefits	Interoperability, Data integrity, Privacy	Transparency, Traceability, Automation	Transparency, Speed, Cost reduction
Adoption Level	Moderate	Growing	High

6. Challenges and Barriers

6.1. Technical Challenges

6.1.1. Energy Consumption

Blockchain technology intrinsically needs augmented amounts of energy consumption to ensure the users' honesty and to validate transactions through mining. This energy usage exponentially multiplies over time with the growth of the network of adopters. The energy consumption for mining is growing nonstop. However, the expense and waste of this energy make the network secure, and a malicious entity has to expend even more energy to attack the network. This energy consumption is core to the blockchain technology to guarantee security, although multiple alternatives have been suggested to reduce it. Since climate change has become a global issue, emerging and existing businesses must comply with the regulations to guarantee that they comply with climate conservation policies. Due to all these factors, many prospective adopters see the need for large amounts of energy consumption as a barrier.

6.1.2. Scalability

In their 2024 work, Morar & Popescu [27] mention that scalability still presents a big issue when blockchain networks grow, resulting in a rise in the need for big storage and transaction processing time. This practically affects the utilization and adoption of the technology in several domains [28]. For instance, the limited block size leads to a reduced number of transactions and the duplication of data across different nodes, which may sometimes increase the costs with zero benefits [29]. Simultaneously, they are highly resource-based, plaguing those blockchain applications implemented in frameworks of the IoT and energy-sensitive environments, bringing about high computational bounds and costs of transactions. The issues of slower transaction verifications and network spamming further increase the scalability problems.

To address these performance and scalability challenges, off-chain storage solutions such as InterPlanetary File System (IPFS) manage data scalability without interrupting performance, which is more suitable in cases of lumping some data management. Farooq *et al.* [30] state that IPFS is a peer-to-peer decentralized file system built to share and store data in a distributed network. It utilizes content-addressed storage. In other words, rather than using location on a specific server for identification, each file is assigned a unique cryptographic hash. Although it has decentralized advantages, the network may experience times of slower content retrieval than traditional CDNs.

6.2. Human Factors

Lack of Awareness

The available literature highlights that the adoption and deployment of blockchain tech experiences massive hardships because of a lack of general awareness about its functionalities and potential. This barrier is more evident for stakeholders with little or no tech knowledge. Also, they refuse to accept this technology due to skepticism around cryptocurrency, which is mainly related to Bitcoin. This skepticism continues to be the reason for outright prohibition and regulatory hindrance, hindering its broad adoption.

Focusing on the adoption of BT in education, the low adoption rate of blockchain technology in education is severely affected by a lack of experts and human resources whose competencies permit dealing with complex data systems. Morar & Popescu [27] mention that this adds to the shortage of blockchain technology in education since most institutions do not seek to venture into this tech with insufficient knowledge and information on how best it should be deployed and managed. Moreover, BT is still immature. This is evident through the poor usability of applications with an extended concentration on Privacy and security at the expense of adequate training and user-friendly interfaces. Furthermore, the intricacy of blending blockchain technology with today's educational systems triggers these issues.

The successful handling of challenges linked to the implementation of blockchain technology calls for a cohesive strategy, involving integration and multiple aspects of education. Awareness and education require a prime focus area. In this case, the key is the establishment of complete awareness programs and educational materials. This will ensure that all those related know how the technology functions and the potential the technology holds [26]. This will also assist in minimizing skepticism about problems related to cryptocurrencies by focusing on the big applications that the technology has, such as past financial transactions.

With increased development and training investment linked to education, professionals will be provided with the needed skills for proper use and management of BT systems. Hence, this is one way by which the skilled BT professional shortage can be addressed.

6.3. Legal and Regulatory Compliance

Drawing from the existing literature, legal and regulatory compliance is a serious stumbling block to the broad adoption of blockchain technology across various industries. It is complex and important for the stakeholders to classify and identify token types that pose regulatory implications against blockchain, basing such qualifications on their use cases and design. The GDPR (General Data Protection Regulation) introduces strict requirements regarding data protection and safety, which are challenging to fulfill because of the transparent and decentralized nature of the blockchain.

In addition, the absence of universal standards interferes with the reliability and security of blockchain systems. This complicates the merger with diverse regulations like the GDPR and the California Consumer Privacy Act (CCPA). It even touches the education field to a point where the regulatory educational authorities manage crucial aspects such as verification standards, the candidate certificate integrity, and degree attestation.

To navigate the intricate regulatory landscape effectively, extensive studies are needed to guarantee that the blockchain technology solutions align with the regulatory requirements. It also calls for clear communication with the stakeholders.

Furthermore, the interplay between government support and stakeholders is crucial in cases of challenging regulations. For example, in the education sector, there is a need for compliance with data protection laws, such as GDPR. Moreover, one practical solution could be establishing clear regulatory systems in a field as delicate as healthcare, which is experiencing legal challenges. This may permit the decentralized features of the blockchain to align with particular regulations, e.g., HIPAA.

6.4. Integration with Legacy Systems

The confidentiality and privacy concerns linked to blockchain technology are primarily due to the loss of the private key and blockchain transparency. This may lead to the leaking of sensitive data, such as sensitive health records.

According to Zhan *et al.* [31], Delegated Byzantine Fault Tolerance (DBFT) and Proof of Trust (PoT), among other safety and better consensus mechanisms, can be used to maximize transaction speed, enhance security, and minimize energy consumption. PoT chooses the validators based on a trust score derived from transaction history and historical behavior. On the other hand, DBFT blends Delegated Proof of Stake and BFT algorithms, where participants are required to vote to elect delegates who attain consensus on a new block. However, issues such as potential security and centralization risk are still open to these applications. These approaches improve privacy, efficiently utilize resources, and maximize integration intricacy.

7. Future Trends and Opportunities

Several future directions are being explored to combat the challenges and discover the full potential of blockchain technology [5]. The scalability issues are being solved via research and development into solutions built to maximize transaction throughput and minimize network congestion. Techniques such as state channels, off-chain scaling, sidechains, and sharding enhance scalability while maintaining the key frameworks of security and decentralization. Interoperability is an additional area of focus, with advancements of foundations such as the Blockchain Interoperability Alliance (BIA) and Interledger Protocol (ILP) that fuel asset transfer and cross-chain communication. These efforts aim to destroy the silos between blockchain networks. This will enable a more flexible and connected ecosystem [5]. In addition, privacy-conserving technologies are being built to address data confidentiality and Privacy concerns. Platforms such as Monero and Z-cash utilize cryptographic techniques to guarantee that users can ensure more Privacy on blockchain networks. These privacy-based platforms are getting popular since they offer improved security with zero compromises on the fundamental aspects of BT. Another crucial consideration for blockchain networks is energy efficiency. This has received much criticism due to its impact on the environment. Researchers and scholars are exploring blended consensus energy-efficient protocols and mechanisms to minimize energy usage without interfering with decentralization and security aspects of BT. These energy-saving approaches aim to make blockchain technology more sustainable in the future.

Compliance and regulation have been a key concern. According to Javaid *et al.* [26], collaboration between regulators, industry stakeholders, and policymakers is important to build clear compliance standards and regulatory frameworks. Clear guidance from authorities, regulatory sandboxes, and pilot projects is vital for promoting innovation while guaranteeing investor confidence and consumer protection. Blending with emerging technologies such as Internet of Things (IoT) and Artificial Intelligence (AI) is a promising route for maximizing blockchain's potential. Also, integration with AI enables automated decision-making, predictive analytics, and fraud detection, while convergence with IoT fuels decentralized and secure data management and exchange.

These future directives show that blockchain technology constantly evolves and can remodel industries worldwide. With continued collaboration, research, and development, the future will realize blockchain's full revolutionary influence on digital technology.

8. Recommendations

The findings of this research indicate that firms currently believe that their employees lack or have insufficient technological knowledge required for BTA. The clear implication for this is establishing awareness and training programs that guarantee that employees acquire knowledge for blockchain adoption and can efficiently use it. Dehghani *et al.* [12] spotlights that the weight of employee training bears a direct positive correlation to IT adoption, indicating the effectiveness of such training programs. Moreover, firms building blockchain solutions for other firms to implement must know that their capable clients may lack the knowledge to adopt and effectively utilize the solution. To kill the knowledge gap, they need to provide accompanying education materials, support services, and training with the sale of their blockchain solution.

As an alternative, the firms building blockchain technology solutions for other firms could reduce some of the intricacy within a layer of user interface to improve the likelihood of adoption, or, from their view, improve sales.

A similar implication goes to the BT consulting organization [12]. These firms need to consider developing a training program or method and education designed to ease the intricacy and provide it to the firms utilizing their services. An adequately structured and formally developed BT education curriculum could become a transforming avenue of consultation services. Whether the firm provides BT solutions or a BT consulting firm or organization deploying it, training and education materials will help narrow the knowledge gap. The more tech knowledge a firm possesses, the more likely it is to adopt.

A final avenue for future studies could be performing a longitudinal study on how the adoption landscape changes. Blockchain tech is rapidly advancing, insinuating that the environmental, technological, and organizational factors can change anytime. A longitudinal study could be designed to capture these changes. Moreover, research on a firm's blockchain continuance intention would throw some new insights on post-implementation behavior and offer a more holistic picture of the adoption landscape.

9. Conclusions

This study has analyzed various aspects of blockchain technology and its application in different industries. The study investigates blockchain tech's opportunities, challenges, and future directions in several domains, including blockchain and Internet of Things, as well as hybrid blockchain architectures.

Throughout this study, three findings stand out. First, adoption is not just a technical decision but an ecosystem and organizational decision. Things such as partner enablement, executing sponsorship, and change readiness determine whether projects go past pilot phases. Secondly, economics govern the adoption momentum. Total ownership cost (onboarding, security, integration, and compliance) must be weighted by near-term and clear risk reductions or savings, mainly in thin-margin cases. Lastly, perception is a crucial factor. High perceived technical volatility and low perceived interoperability depress blockchain adoption by inflating obsolescence risk and expected switching costs; conversely, proof points, visible standards, and credible vendor roadmaps enhance adoption confidence.

This study's findings also spotlight blockchain tech's immense capability to revolutionize sectors and industries by dealing with crucial issues such as accountability, transparency, privacy, security, and trust. The findings shed light on the practical benefits and implications of using blockchain technology in particular cases. Furthermore, this study has contributed to increasing the adoption of blockchain tech and enriching the technological adoption literature. Firms intending or participating in blockchain advancement, blockchain researchers, and blockchain consulting firms now have a deeper understanding of the adoption landscape. This can be utilized to further organizational adoption, development, and deployment.

In summary, blockchain technology is neither a fad nor a panacea. Its value emerges when ecosystem design, strategy, and economics align. Blockchain technology can generate durable trust at scale and efficiency gains when businesses blend disciplined adoption with clear incentives and reliable networks.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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