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Quality Management System Based Blockchain Applications

Hilal YILMAZ[a], Ozlem SENVAR*[b]

[a] *Marmara Üniversitesi, Mühendislik Fakültesi, Endüstri Mühendisliği Bölümü, İstanbul, 34854, TÜRKİYE*
[b*] *Marmara Üniversitesi, Mühendislik Fakültesi, Endüstri Mühendisliği Bölümü, İstanbul, 34854, TÜRKİYE*

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Corresponding Authors
e-mail: ozlemsenvarresearch@gmail.com

ABSTRACT

This study investigates blockchain technologies and blockchain related researches from various sectors considering sectoral applications including food, healthcare, automotive, supply chain, information security, banking and quality management issues associated with these sectors. This study provides contributions by comparing blockchain technology features in food, automotive, healthcare, supply chain, information security, and banking. Blockchain technology features performances considering various industries. The aim of this study is to establish a framework to intelligent quality management system based blockchain. This study examines standards for blockchain and distributed ledger technologies and discusses quality challenges for blockchain applications.

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Kalite Yönetim Sistemi Tabanlı Blok Zincir Uygulamaları

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Sorumlu Yazar
e-posta: ozlemsenvarresearch@gmail.com

ÖZET

Bu çalışma, gıda, sağlık, otomotiv, tedarik zinciri, bilgi güvenliği, bankacılık ve bu sektörlerle ilişkili kalite yönetimi sorunlarını sektörel uygulamaları göz önünde bulundurarak çeşitli sektörlerden blok zinciri teknolojilerini ve blok zinciriyle ilgili araştırmaları incelemektedir. Bu çalışma, gıda, otomotiv, sağlık, tedarik zinciri, bilgi güvenliği ve bankacılıkta blok zinciri teknolojisi özelliklerini karşılaştırarak katkılar sağlamaktadır. Blok zinciri teknolojisi, çeşitli endüstrileri göz önünde bulundurarak performanslar sunmaktadır. Bu çalışmanın amacı, blok zincirine dayalı zeki kalite yönetim sistemine genel bir bakış sunmaktır. Bu çalışma, blok zincir ve dağıtık defter teknolojileri için standartları incelemektedir ve blok zincir uygulamaları için kalite zorluklarını ele almaktadır.

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1. INTRODUCTION *(GİRİŞ)*

With the developing technologies in recent years, people's consumption habits and consumers' perceptions of quality are changing day by day. In the rapidly evolving digital environment, organizations across various industries are looking for innovative ways to improve their processes and increase overall efficiency, effectiveness and productivity. Traditional quality management systems are required to be adapted with new technologies. In recent years, the importance of data, data analysis and real-time data tracking have been increased.

Blockchain technology has the potential to streamline and optimize complex processes, removing intermediaries, reducing costs, and enhancing efficiency. Blockchain technologies have grabbed attention and continue to increase in the near future. Simultaneous traceability, transparency, immutability and reliability are important features of blockchain technology.

The integration of these advanced technologies into Quality Management System (QMS) with the promise of streamlining and enhancement of outranking by increasing transparency, traceability, reliability, immutability and real-time visibility, accountability. With the enrichment of product diversity, new consumption habits increase the supply-demand balance, which reveals the necessity of adaptations in supply chain management, which involves a wide range of operations such as production, transportation, storage and delivery. It has to be taken into account that supply chain management has many benefits, but there are also drawbacks and shortcomings to consider. With the use of new technology, these problems were resolved and the system was aimed to work more effectively.

This study aims to investigate the main advantages, disadvantages and weaknesses along with limitations of blockchain. Moreover, this study examines blockchain related research from different sectors. This study provides an overview to incorporating blockchain technologies into quality management. This article explores the key components of this technological convergence and its implications for the future of quality management. To the best of our knowledge, blockchain technology based quality management has not been handled, yet.

The rest of this study is organized as follows: Section 2 explains blockchain technology concepts. In section 3, blockchain sectoral applications including food, healthcare, automotive, supply chain, information security, banking and quality management issues associated with these sectors are reviewed. In section 4, an overview to intelligent quality management system based blockchain is given. In section 5, quality challenges for blockchain applications are discussed. The last section presents conclusions and recommendations for future directions.

2. BLOCKCHAIN TECHNOLOGY *(BLOK ZİNCİR TEKNOLOJİSİ)*

Blockchain is the technology used to build the cryptocurrency Bitcoin, which is called the next generation digital currency. Bitcoin was first introduced in an article by Satoshi Nakamoto in 2008 [1]. A blockchain is fundamentally a distributed, decentralized digital ledger that securely and openly records transactions and uses cryptography to ensure the security and transparency of transactions (Figure 1). Figure 1 shows blockchain technology architecture. Blockchain has various types depending on the intended use. Distributed ledger technology ensures that all transactions are securely tamper-proofed through a decentralized peer-to-peer network of users on the same network. Smart contracts allow transactions to be confirmed without intermediaries. Moreover, cryptocurrencies can be generated by mining according to different algorithm structures.

Blockchain consist of a series of blocks, each of which has a list of transactions on it. A block becomes a chain when all the transactions from the prior block linked to it. With its decentralized and transparent nature, combined with cryptographic security, opens up new possibilities for enhancing trust, efficiency, and security in various domains.

In 2014, Buterin [2] published a white paper proposing Ethereum, in which smart contracts are integrated into the blockchain system. The code written into the block can run on the network and these pieces of code are called smart contracts. Ethereum has paved the way for the development of decentralized applications (dapps) with its innovation [3].

Blockchain technology builds a secure structure and provides transparent, real-time monitoring and unchangeable properties of data records. Blockchain technology has various features, which are briefly explained below:

Decentralization is the division of power and authority among several actors in a network so that no one party controls the entire system. Thus, by eliminating a single point of control, security and trust between network users is increased. This feature operates on a peer-to-peer network where multiple computers or nodes are involved in recording and verifying transactions.

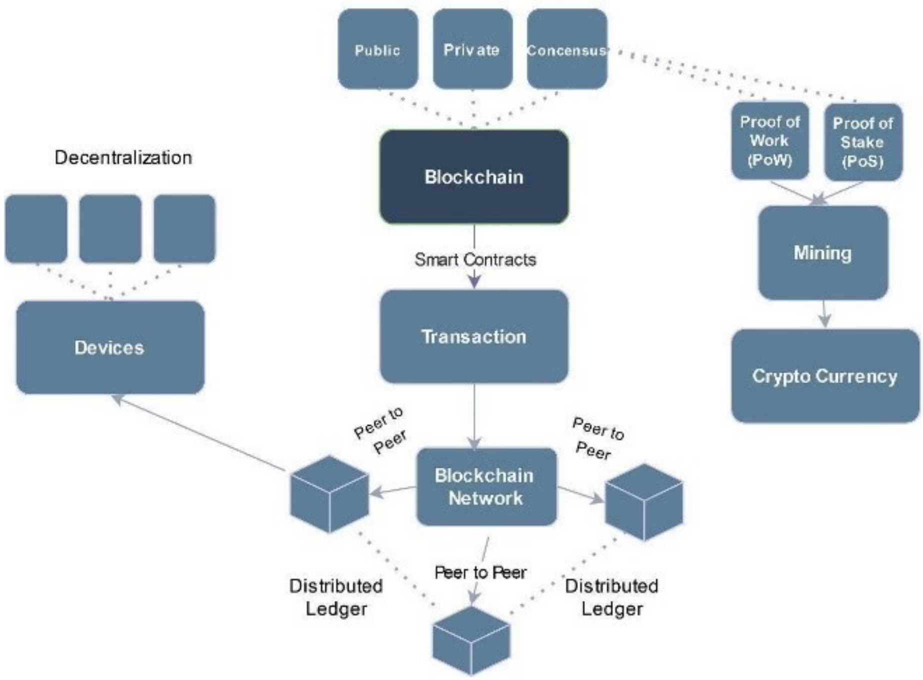

Figure 1. Blockchain technology architecture
(Blok zincir teknolojisi mimarisi)

•*Immutability* provides a tamper-proof ledger as it is nearly impossible to remove or alter data added to the blockchain. This feature is one of the most known and trusted features of blockchain technology.
•*Transparency* All network users can view the open and transparent ledger that the blockchain provides. When a user makes a transaction in the ledger, other users also have instant access to this information. This provides real-time visibility into blockchain technology.
•*Traceability* In a distributed ledger, a decentralized network of nodes keeps an unchangeable and transparent record of transactions. In a distributed ledger, a decentralized network of nodes keeps an immutable and transparent record of transactions. It is not possible to change previously made operations.
•*Anonymousness* A certain degree of anonymity is achieved in blockchain technology by providing users with cryptographic identifiers rather than revealing personal information.
•*Dis-intermediation* By eliminating the need for intermediaries in transactions, blockchain reduces costs and increases efficiency.
•*Security* Transactions on the blockchain are secured using cryptographic techniques, making them highly resistant to fraud and manipulation.
•*Reliance* The blockchain eliminates the need for users to put their faith in a central authority in order to execute and verify transactions.
•*Smart contracts*, which are digital agreements encoded by computer programs based on predetermined conditions, are automatically executed once the specified criteria are fulfilled, stored and signed on a blockchain network without requiring intermediaries, improving efficiency and transparency of contract execution.
•*Credibility* The transparency of blockchain improves transaction credibility and lowers the possibility of fraud.
•*Scrutiny* The blockchain makes all of its transactions publicly available, facilitating thorough examination and auditing.
•*Performance* Different blockchain networks have different performance capabilities; some are made for low latency and high throughput.
•*Execution* the quantity of transactions or operations that, at a given asset level, can be completed every second.
•*Scalable* is the capacity of blockchain technology to manage the increasing transaction volume, data storage and number of nodes working without compromising efficiency, decentralization, consensus and security.
•*Cryptography* is a technique that secures data, ensuring that transactions are tamper-resistant and identities are protected.

Nowadays, there are problems with mutual trust in collaborations due to fraud in records. When intermediaries are used in transactions, time delays and costs increase, which prevents the work from being completed efficiently and at low cost in a short time. With this technology, data is not stored in a single center, but is kept safe against possible data loss and malicious attacks by being kept on more than one server on the same network [4, 5].

Blockchain technology started to develop after the Bitcoin cryptocurrency [1]. Blockchain structure combined with distributed ledger technology is the simultaneous distribution of multiple copies of data to different servers. There are different structures in blockchain: public, private, hybrid and consensus mechanisms (Figure 1).

2.1. Distributed Ledger *(Dağıtık Defter)*

Blockchain processes transactions using distributed ledger technology (DLT). With this technology, unlike traditional databases, information and transactions are recorded in multiple sources instead of a single source. With distributed ledger technology, data is recorded securely, creating a transparent, traceable and unchangeable structure.

2.2. Public Blockchain *(Genel Blok Zincir)*

Public blockchain can make any user to access blockchain network. This is also known as permissionless blockchain. In a public blockchain, users verify transactions, which are then shared publicly through a timestamped consensus mechanism. Face challenges in scaling to handle a large number of transactions quickly. Public blockchains are truly decentralized, democratic and independent of authority. The most important disadvantage of public blockchains is that they require a lot of energy consumption.

2.3. Private Blockchain *(Özel Blok Zincir)*

Private blockchains, which are not decentralized, are structures in which access to the system is given only to authorized users. Only those with permission can make transactions or verify changes on the blockchain. Private blockchains are specifically designed for enterprise applications. In private blockchain, data privacy is inevitable so that secure data sharing is ensured.

2.4. Hybrid Blockchain *(Hibrit Blok Zincir)*

Hybrid blockchain is an integrated structure that includes private and public blockchain features to get the best efficiency from the system This type of blockchain is used by private institutions due to its closed structure and providing a more secure environment for network activities.

2.5. Consensus Mechanism *(Konsensus Mekanizması)*

In a consensus mechanism, nodes in the network agree on the accuracy of the transactions made and ensure that these transactions are included in the blockchain. In this way, errors that may occur in the system are prevented and a safe environment is provided for transactions. Several consensus methods are used to confirm transactions and maintain the integrity of the blockchain, such as Proof of Work (PoW) and Proof of Stake (PoS).

•*Proof of Work (PoW)* Users (crypto miners) must solve complex cryptographic puzzle to add a new block to the system. The user who finds the solution, which needs to be verified, receive crypto coin as a reward. This system is the most decentralized and secure of all authentication mechanisms [6]. However, low transaction rates, excessive energy usage and expensive operating fees are the disadvantages of PoW. Cryptocurrency Bitcoin uses the POW mechanism.

•*Proof of Stake (PoS)* The authority for confirming transactions and creating new blocks is determined according to the amount of funds held by users (stakers). PoS is an alternative consensus mechanism with high speed, low cost and low energy consumption [6]. Cryptocurrency Ethereum has switched from PoW mechanism to PoS mechanism. The reason is that Ethereum switched to PoS due block confirmation speed in PoW is low.

The foundation of cryptocurrencies like Bitcoin and Ethereum, blockchain technology, has proven to be a transformative force that has the potential to completely transform a number of industries [3, 7]. Its special properties enable a decentralized, transparent and secure solution to long-standing problems in conventional systems.

2.6. Web 3.0 *(Web 3.0)*

Web 3.0, which represents the process that has been ongoing since 2010, is also called the Semantic Web. In this new era, computers imitate human analysis with the help of artificial intelligence or machine learning, use data in an autonomous structure and build user-specific results. Unlike traditional web servers, Web 3.0 applications use blockchain servers that communicate with each other in decentralized networks rather than a single server. The foundations of Web 3.0 protocols come from cryptocurrency systems. While transactions are made with tokens in crypto currencies, there is no such structure in Web 3.0.

2.7. Internet of Things (IoT) *(Nesnelerin İnterneti (IoT))*

The Internet of Things (IoT) refers to a set of devices that are connected to the internet connected devices through a network or other communication networks and exchange data among themselves. With blockchain, manufacturers can make agreements with secure transactions in production and sales processes through smart contracts whose content cannot be changed [8, 9]. In this way, transactions are confirmed quickly and it can be easily monitored whether the content of the contract is complied with. To record data, IoT devices collect data at every stage of production and this data is securely stored with DLT. Since the data is not stored in a single center, real-time traceability of the data is ensured by all users in the network.

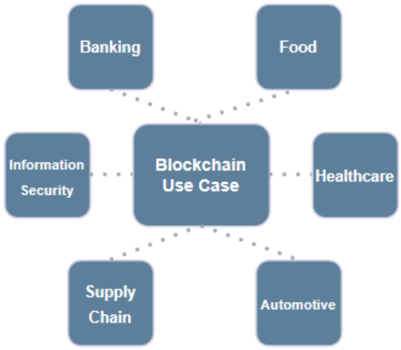

Figure 2. Sectoral application fields via blockchain based systems
(Blok zincir tabanlı sistemler üzerinden sektörel uygulama alanları)

3. Sectoral Applications via Blockchain *(Blok Zincir Sektör Uygulamaları)*

Blockchain technology is becoming increasingly widespread in a wide variety of sectors due to its accessibility, useful structure, and effective and efficient solutions. In this study, various sectors, given in Figure 2 were examined. Figure 2 shows sectoral application fields via blockchain based systems. Table 1 shows blockchain technology related literature review considering various sectors involving more specifically food, healthcare, automotive, supply chain, information security and banking.

3.1. Food Industry *(Gıda Endüstrisi)*

3.1.1 Blockchain Technology in Food Industry (Gıda Endüstrisinde Blok Zincir Teknolojisi)

It's known that there are inefficiencies, data discrepancies, and a lack of transparency within traditional food traceability systems. There are various problems in the food industry supply chain, such as food fraud and food spoilage due to improper storage. Thus, economic costs increase, delivery of the product at the desired time is delayed, and productivity decreases [10, 11]. Blockchain technology offers many features such as simultaneous data tracking throughout the entire supply chain from producer to consumer, ability to monitor data by users on the same network, and immutability of data. Blockchain technology produces innovative solutions for the food industry and provides a safe, transparent and immutable system structure. To prevent food from spoiling, it must be stored in appropriate environmental conditions. By controlling the ambient temperature and humidity with the help of IoT devices, it can be checked whether the food is stored properly or not, and problems can be solved immediately. Blockchain technology, with its many features, meets the needs of the food sector and allows the establishment of a more efficient system [11].

The process from the production of the products to their delivery to the consumer can be followed in real time by all participants involved in the process With its transparency and traceability feature. In this way, it can be easily checked whether the requirements such as storing and transporting food in appropriate environments are met and whether the necessary precautions are taken [11]. The immutability feature provides a safer environment by preventing the recorded data from being changed, thus preventing possible fraud in food products [12]. Product data records can be viewed by all people on the network, and operations can be carried out more efficiently and quickly with simultaneous data recording and monitoring features [12, 13].

3.1.2. Blockchain Based Intelligent Food Quality Management System *(Blok Zincir Tabanlı Zeki Gıda Kalite Yönetim Sistemi)*

Nowadays, food and agricultural implementations Information and Communications Technologies are incorporated with blockchain technology.

Blockchain unique digital identifiers to food products provide traceability within the food supply chain including information such as agri-food growth conditions, lot numbers, and expiry dates preventing food waste and fraud, monitoring ecological footprint along with registering transactions of immutable food enabling source identification of foodborne illness. Digital nature of blockchain technologies can track on-farm data sharing [14].

According to Antonucci et al. [15], real time quality management and control systems with IoTs in the food supply chain increase security. Radio frequency identification (RFID) and blockchain technology in the agri-food supply chain traceability system ensures the authenticity of the food safety and quality [10]. Burgess et al. [16] presented blockchain based quality management architecture developed for short food supply chains providing unique ability to store specific quality related data and supporting non repudiation.

Table 1. Blockchain technology related literature review considering various sectors
(Farklı sektörleri göz önünde bulundurarak blok zincir teknolojisi ile ilgili literatür taraması)

Sector	Author (Year)	Title
Food	Torky & Hassanein (2020)	Integrating blockchain and the internet of things in precision agriculture: Analysis, opportunities, and challenges
Food	Stranieri et al. (2021)	Exploring the impact of blockchain on the performance of agri-food supply chains
Food	Burgess et al. (2022)	Blockchain Enabled Quality Management in Short Food Supply Chains,
Food	Pelé et al. (2023)	IoT and Blockchain Based Framework for Logistics in Food Supply Chains
Food	Vanany, et al. (2024)	Assessment of halal blockchain in the Indonesian Food Industry
Food	Duan et al. (2024)	Leveraging blockchain to tackle food fraud: Innovations and obstacles
Healthcare	Jamil et al. (2019)	A Novel Medical Blockchain Model for Drug Supply Chain Integrity Management in a Smart Hospital
Healthcare	Araújo et al. (2022)	A systematic review of the literature on the application of blockchain in the health supply chain
Healthcare	Abdallah & Nizamuddin (2023)	Blockchain-based solution for Pharma Supply Chain Industry
Healthcare	Fiore et al. (2023)	Blockchain for the Healthcare Supply Chain: A Systematic Literature Review
Healthcare	Rizzardi et al. (2024)	IOT-driven blockchain to manage the healthcare supply chain and protect medical records
Supply Chain	Tönnissen & Teuteberg, 2020	Analysing the impact of blockchain-technology for operations and supply chain management: An explanatory model drawn from multiple case studies
Supply Chain	Musigmann et al, 2020	Blockchain Technology in Logistics and Supply Chain Management—A Bibliometric Literature Review
Supply Chain	Liu et al. (2023)	Improving supply chain transparency with blockchain technology when considering product returns
Automotive	Xu et al., (2022)	Blockchain applications in the supply chain management in German automotive industry
Automotive	Yasmin & Devi (2023)	Blockchain and Cloud-based Technology in Automotive Supply Chain
Automotive	Kamble et al. (2023)	Blockchain technology's impact on supply chain integration and sustainable supply chain performance: evidence from the automotive industry
Banking	Cucari (2022)	The impact of blockchain in banking processes: the Interbank Spunta case study," Technology Analysis & Strategic Management
Banking	Hashem (2023)	The Impact of Blockchain Technology on Audit Process Quality: An Empirical Study on the Banking Sector
Banking	Al-Dmour et al. (2024)	Blockchain applications and commercial bank performance: The mediating role of AIS quality
Banking	Leitão (2024)	Cross-border Payments and Remittances on Blockchain: Exploring the use of blockchain for facilitating cross-border payments and remittances, reducing costs and improving transaction speed
Quality management	Muruganandham et al. (2023)	TQM through the integration of blockchain with ISO 9001:2015 standard based quality management system

3.2. Healthcare System *(Sağlık Sistemi)*

3.2.1. Blockchain Technology in Healthcare Sector
(Sağlık Sektöründe Blok Zincir Teknolojisi)

Health services are of vital importance, and the medicines and materials used in the treatment processes and the duration of the treatment must be used in favor of the patient. In parallel with this situation, the healthcare supply chain also has a wide network, and there are many providers, from manufacturers to hospitals, who will ensure the supply of the requested materials within the specified period. Due to various negativities that may occur in this process, supply processes may be disrupted and negative effects may occur for patients.

Blockchain technology offers innovative solutions to various problems in the healthcare industry. Patient data should be stored in a secure environment and access by unauthorized persons should be prevented. The supply of medicines and other equipment should be carried out under appropriate environmental conditions. The use of blockchain technology in supply chain management is a structure that can be used to solve problems in the health sector by storing health data in a secure environment with immutability feature, preventing access by unauthorized persons and at the same time preventing it from being changed [17, 18].

Medicines and other medical supplies must be original and imitation products must not be used. However, due to fraud in some drugs, different products are put on the market instead of real products, and this causes various problems in terms of treatment. Since the process from the production to the purchase of the products produced with Blockchain technology is recorded simultaneously and with tamper-proof, any counterfeiting of the products is prevented [18, 19].

3.2.2. Healthcare Quality Management *(Sağlık Kalite Yönetim Sistemi)*

The health sector is a comprehensive system and there are many factors in the functioning of the health quality management system; Corporate management, accurate diagnosis and treatment of diseases, patient satisfaction and supply management constitute the system as a whole [20]. Implementation of a quality management system in healthcare improves the efficient use of resources by increasing the reliability and trustworthiness of all personnel. Institutions adopt quality management criteria in a competitive environment and ensure continuity with systems with new technologies in line with the principle of continuous improvement. There are various studies [21, 22] in the literature to make a better structure in the quality management system in health.

3.3. Automotive Industry *(Otomotiv Endüstrisi)*

3.3.1. Blockchain Technology in Automotive Industry *(Otomotiv Endüstrisinde Blok Zincir Teknolojisi)*

The production processes of automobiles are detailed and costly, and product quality must meet customer expectations. Globalization will lead to an even greater increase in the volume of the automotive supply chain. Since materials in automotive production are supplied by many suppliers, they may also be from different countries, and therefore the scope of the sector's supply chain is wide. In order for production to be carried out efficiently and on time, the system is expected to operate effectively, traceably, and securely. There may be disruptions in production processes as a result of problems with suppliers or raw materials, and this will affect the entire production [23, 24].

With blockchain technology, all processes in the automotive sector from supplier to manufacturer are recorded in an immutable manner and authorized users on the same network can access data accurately and securely with a decentralized structure [25]. In this way, possible delays and interruptions are detected and a faster and more effective process is carried out. Recording product stock, price and delivery information completely and unchangeably, preventing possible fraud, preventing cost and time loss and providing users with a traceable, transparent, low-cost and fast infrastructure [26, 27].

3.3.2. Automotive Quality Management System *(Otomotiv Kalite Yönetim Sistemi)*

The automotive industry is competitive and complex, and materials for production are sourced from many different global suppliers. Any delay, damage, or disruption of planned production in products supplied due to reasons such as a global crisis or epidemic can cause great losses for companies. In these processes, with the existence of an effective quality management system, timely solutions can be provided to problems that may arise. IATF 16949:2016 [28] is a standard specific to the automotive industry. This standard is intended for organizations that manufacture automobiles and related parts and contains certain additional requirements, and is based on ISO 9001:2015 [29] quality management system.

3.4. Supply Chain Management *(Tedarik Zinciri Yönetimi)*

3.4.1. Blockchain Technology in Supply Chain Management *(Tedarik Zinciri Yönetiminde Blok Zincir Teknolojisi)*

The importance of supply chain management continues to increase due to increasing production types and consumption habits with new technologies. The production supply shortage experienced worldwide due to sudden events (such as the pandemic period of Covid-19, chip crisis in Taiwan) has necessitated improvements in supply chain management. Features of blockchain technology eliminate the problems experienced in the supply chain due to the transparent, reliable, real-time traceable and unchangeable [30]. The processes of the products from the supplier to the manufacturer are seamlessly tracked via blockchain. In this way, it ensures that the products are delivered on time and under favorable conditions. Using blockchain smart contract technology, a secure trading environment is provided with agreements made by all participants in the process [31]. As a matter of fact, there can be conflicts between supply chain individuals, specifically in coordination of forecasting demand. If forecasting demand is uncoordinated, distorted demand forecasts result in bullwhip having forecast error and variance. Blockchain technology provides an information system and consensus formation mechanism that can intermediate supply chain network behavior.

3.4.2. Supply Chain Quality Management *(Tedarik Zinciri Kalite Yönetimi)*

Supply chain quality management (SCQM) operationalize and understand the impact of supply chain management on quality management [32]. Blockchain based Supply Chain Quality Management, which involves management mechanisms along with new Information Technologies (IT) systems used in supply chain quality management, solves the issues of distrust on the basis of unchanged information and traceable records through standardized norms and agreements. In blockchain based SCQM, blockchain technology, is integrated to new supply chain system in which information sharing and quality control are assured. Framework of blockchain based SCQM covers enterprises on the supply chain, blockchain, smart contracts and various IoT sensors [33,34]. Blockchain technology adopts the governance model of human society in IT systems, and further develops the decentralized system that provides different interest groups to share power in the same IT system, which improves the qualities of products and services in supply chains by contracts. Establishing automated executions of quality management contracts, it is possible to develop an auto-run intelligent system. Blockchain and smart contract establish more reliable quality track and control system, more agile ultimate customer.

3.5. Information Security Systems *(Bilgi Yönetim Sistemleri)*

3.5.1. Blockchain Technology in Information Security Systems *(Bilgi Yönetim Sisteminde Blok Zincir Teknolojisi)*

The use of developing technologies also increases the amount of data obtained. Adequate technologies and storage centers are needed to store huge amount of data, protect integrity and confidentiality. Compared to traditional databases, blockchain technology offers a more secure and robust platform for storing and accessing data than other platforms. While data is kept in a single center in traditional databases, through blockchain's distributed ledger technology, copies of the data are stored in the relevant network. Whenever a new file is saved or any update is made to the file, it is instantly copied to the storage. With this and the automatic data backup feature, data loss is prevented. Data are stored securely through smart contracts allowing users to carry out their transactions without sharing important personal information.

Applications of blockchain technology to strengthen cybersecurity include: Blockchain technology ensures the security of the systems it operates on and the devices connected to it. It prevents unauthorized persons from accessing the data with end-to-end encryption methods used on the data [35]. By storing data in a decentralized structure, it minimizes malicious attacks and data loss that may occur in possible attacks.

3.5.2. Information Security System Quality Management *(Bilgi Güvenliği Sistemi Kalite Yönetimi)*

Protection of information and data breaches are important. There are various regulations regarding this issue. These regulations provide benefits for organizations in ensuring the security and continuity of their information assets. As an international standard, ISO/IEC 27001 [36] is one of them. The features that form the basis of information security systems are included in the ISO/IEC 27001 standard as follows: confidentiality, availability and integrity. Confidentiality refers to protection of information against unauthorized access. Integrity refers to prevention of information from being modified by unauthorized persons. Accessibility refers to availability and usability of information by authorized persons.

3.6. Banking *(Bankacılık)*

3.6.1. Blockchain Technology in Banking *(Bankacılıkta Blok Zincir Teknolojisi)*

The banking sector, like other sectors, has to adapt its systems to new technologies in order to remain strong in the face of rapidly developing technologies. Various limitations of the current system cause various disruptions in transactions. Blockchain technology has emerged as a robust, reliable and versatile new technology that brings a different perspective to existing systems. Banking also started to integrate its systems with this technology to benefit from this [37]. The contributions of blockchain technology to the banking sector are as follows: Features that distinguish blockchain technology from the currently used bank payment system: While banks carry out their transactions through a central system, blockchain works in a decentralized network system. Unlike the banking system, Ledgers and banking transactions in blockchain are open to the public and data can be accessed in real time and transparently [38].

International money transfer transactions are made by using an intermediary and paying a transaction fee, and these transactions are slower. In blockchain technology, transactions can be made faster, transparently and with lower transaction fees. Various authentication methods are used to ensure security in banking transactions. In blockchain-based systems, verification processes can be carried out more securely.

Smart contracts are increasingly executed in applications fulfilling trustworthy and strong certifications in transactions between parties, whereas can be carried with immutable, transparent, traceable, and secure infrastructure. Recording transactions with blockchain's distributed ledger technology with blockchain decentralized consensus, allows accounting, bookkeeping and auditing in banking transactions to be carried out in a more functional, transparent, fast and secure way.

3.6.2. Banking Quality Management System *(Bankacılıkta Kalite Yönetim Sistemi)*

Banking sector should improve the quality, efficiency, effectiveness, productivity and resilience. Cucari et al. [39] focused on the efficiency of processes, security and information network as types of banking applications. Customer portfolio is important in banking transactions in the banking sector. Credit operations are also based on customer reliability. Blockchain-based know your customer (KYC) system was developed to ensure that transactions that are reliable for both the customer and the institution. Blockchain strengthens identity verification and Know Your Customer (KYC) processes, for enhancing accurate customer data and supporting personal investment along with financial operations and customer relationship management (CRM) [40, 41].
Banks should innovate through the implementation of blockchain. In this regard integration of new quality management systems along with new standards for blockchain technologies into banking sector. Integration of new generation technologies such as cloud data, artificial intelligence and IoT, blockchain technology into the banking sector is considered mandatory to increase efficiency, security and transparency [42].

CPA&AICPA [43] examined the impact of digital blockchain technology on auditing process of financial reports and services of quality assurance. Due to digitalization, utilization of digital tools is required for auditing process. Hashem et al. [44] recommend features (such as strategic, less time consuming, continuity, review, scope expansion consultancy) for more efficient audit processes of blockchain.

In the banking sector, integration of Accounting Information Systems (AIS) with Blockchain technology, features such as security, transparency and immutability come to the fore [45]. Al-Dmour et al. [46] revealed that there is a robust positive effect of Blockchain on AIS quality, significantly enhancing business performance.

The decentralized nature of Blockchain is used in cross-border payments and remittances by decreasing costs, increasing transaction speed, and transparency. As blockchain technology continues to develop, innovation and collaboration between industry stakeholders and regulators continue to transform the global financial system, making cross-border transactions more efficient, affordable, and accessible for individuals and businesses around the world [47].

4. QUALITY MANAGEMENT SYSTEM BASED BLOCKCHAIN TECHNOLOGY (*KALİTE YÖNETİM SİSTEMİ TABANLI BLOK ZİNCİR TEKNOLOJİSİ*)

There are eight quality management principles, which are kaizen (continuous improvement), customer focus, leadership, involvement of people, processes, approach, system approach to management, factual approach to decision-making, and mutual beneficial supplier relationship. As a matter of fact, kaizen should be taken into account within the quality management system. For this reason, continuous quality improvement should be concerned for all quality management based blockchain applications to improve performance along with effectiveness [48]. According to Muruganandham et al. [48] there are limited applications for continuous quality improvement research. Apart from kaizen, other seven quality management principles should be broadly incorporated with blockchain systems.

Blockchain technology relies on cryptography which provides data compilation in blocks. Inevitably, validation should be performed considering kaizen technique via plan-do-check-act (PDCA cycle). After performing validation, block is formed and can be accessed by stakeholders. Afterwards, each block is incorporated with input and output hash values making blocks immutable for modification and having no variability. IoT technology is a system that has the ability to collect data by connecting devices to IoT based systems, and when integrated with blockchain technology, it enables the data to be stored in a database and shared with other relevant systems. At the same time, various options can be made within the quality management systems incorporated information obtained through IoT systems. Figure 3 shows the principal working logic of the intelligent quality management based blockchain system in terms of the PDCA cycle. There is a need for a quality management based blockchain system. In this regard, Blockchain technologies can solve mutability problems and enhance traceability considering kaizen.

There are studes in the literature on the integration of blockchain tehnology with the ISO 9001:2015 [49] standard. Muruganandham et al. [48] stated that the isruptions experienced in the operation and control of

ISO 9001:2015-based Quality management system processes can be overcome by using blockchain technology infrastructure with the considered scenarios.

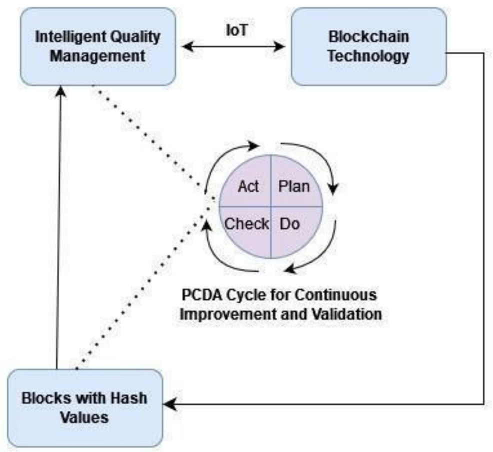

Figure 3. Intelligent quality management system based blockchain

(Zeki kalite yönetimi sistemi tabanlı blok zincir)

ISO has released standards in the field of blockchain and distributed ledger technologies. Table 2 shows information on 12 ISO standards published since 2019 in this area. Since blockchain technology is still evolving, more standards will be developed as applications for the technology improve.

5. QUALITY CHALLENGES FOR BLOCKCHAIN APPLICATIONS *(BLOK ZİNCİR UYGULAMALARI İÇİN KALITE ZORLUKLARI)*

5.1. Quality Issues and Requirements *(Kalite İşleri ve Gereksinimleri)*

According to McCall's Software Quality Model [50] factors and related criteria are used to determine the quality of software. Blockchain structures consist of hardware and software systems and the quality criteria that should be considered for software and hardware systems are also valid for blockchain technologies. The factors of this model can be evaluated with establishing quality requirements for blockchain technology. These factors can be considered as follows: Efficiency, Reliability, Integrity, and Accuracy.

Efficiency factor is achieved by having appropriate and sufficient hardware and software for the system to operate as desired. Examples include having good storage capacity, high network speed, and using software with high processing capacity.

Accuracy factor can fulfill the required task completely when traceability and consistency criteria are ensured. In the blockchain system, traceability of transactions is ensured with decentralized structures, while consistency of transactions is ensured by using smart contracts. In this way, the accuracy of the transactions is ensured and the requirements of the reliability factor are met.

Table 2. Published ISO standards for blockchain and distributed ledger technologies

(Blok zincir ve dağıtık defter teknolojileri için yayınlanmış ISO standartları)

Standards	Type	Published	Stage
ISO/TR 3242:2022	Use cases	2022-10	International
ISO/TR 6039:2023	Identifiers of subjects and objects for the design of blockchain systems	2023-06	International
ISO/TR 6277:2024	Data flow models for blockchain and DLT use cases	2024-02	International
ISO 22739:2024	Vocabulary	2024-01	International
ISO/TR 23244:2020	Privacy and personally identifiable information protection considerations	2020-05	International
ISO/TR 23249:2022	Overview of existing DLT systems for identity management	2022-05	International
ISO 23257:2022	Reference architecture	2022-02	International
ISO/TS 23258:2021	Taxonomy and ontology	2021-11	International
ISO/TR 23455:2019	Overview of and interactions between smart contracts in blockchain and distributed ledger technology systems	2019-09	International
ISO/TR 23576:2020	Security management of digital asset custodians	2020-12	International
ISO/TS 23635:2022	Guidelines for governance	2022-02	International
ISO/TR 23644:2023	Overview of trust anchors for DLT-based identity management	2023-05	International

Integrity factor ensures that access to the system which is permitted to limited users and system control is performed by authorized users while unauthorized access is prevented in the blockchain system, possible fraud in transactions is not allowed. Blockchain is known as a transparent system in which users with authorized access can control.

In addition to McCall factors [50], the following factors can also be considered as blockchain system quality requirements.
Installation cost: Since blockchain is a costly system, a less costly system can be established by reducing costs.
Network speed and capacity: In order to carry out transactions quickly and accurately in the system, there must be a strong software and hardware infrastructure that can adapt to the network speed so that the users in the network can make fast transactions.
Energy sustainability: Blockchain mining requires high energy consumption. For this reason, systems that consume less energy are needed to be developed.
Security: Although blockchain has smart contracts and a decentralized structure, it is necessary to prevent attacks and fraud on the systems by ensuring the reliability of users and transaction information.

5.2. Blockchain Performance Measurement Metrics

(Blok Zincir Performans Ölçüm Metrikleri)

They are quantitative indicators that measure how the system works and how it achieves its goals. The system is examined and evaluations are made in terms of quality, performance and scalability. Blockchain performance evaluation metrics are provided in Table 3.

Although the performance evaluation metrics are presented in Table 3, the priorities for each system and user may be different. Therefore, it is not always possible to accurately and reliably measure the performance of the blockchain system. Performance tests of blockchain systems can be done using some special software. It is difficult to make a fair evaluation according to various criteria such as blockchain structures (public, private), network capacity, network speed, number of users, number of transactions made, hardware structure.

Awareness and usage rate of blockchain systems is increasing. Although the blockchain system is and advanced and complex structure for cryptocurrencies and integrated systems, the consumed energy is also quite high. There are concerns to reduce energy consumption to enhance ecological sustainability. Some blockchain systems are trying to build less energy consuming structures. In countries where usage of energy is widespread, and there are initiatives in which the energy is consumed for mining of cryptocurrencies obtained from renewable energy sources [51].

5.3. Blockchain Performance Measurement Methods

(Blok Zincir Performans Ölçüm Yöntemleri)

Blockchain performance evaluation methods are empirical and analytical methods. Empirical methods include benchmarking, testing, and checking.
Benchmarking compares the performance of a blockchain system with other systems. Testing performs experiments or simulations to test the functionality and reliability of a blockchain system. An audit examines and verifies the code, design, and architecture of a blockchain system for compliance with requirements.

Table 3. Blockchain performance evaluation metrics
(Blok zincir performans değerlendirme metrikleri)

Metrics	Definition
Latency	The time required for a transaction to be confirmed and recorded on the blockchain
Throughput	The number of transactions performed per second
Scalability	The capacity of the network, including the number of nodes it has and how many transactions it can process
Block Size	Refers to the maximum amount of data, such as transaction details, timestamps, and cryptographic hashes that a single block can store. The block size determines how many transactions can be included and processed within the block.
Resource	Blockchain systems require high hardware capacity and consume a high amount of energy.
Security	Ensuring the blockchain is protected against malicious attacks and fraud
Storage	It requires more capacity due to the size of the data stored in the blockchain system
Network Size	It refers to the total number of nodes actively participating in a blockchain network.

Benchmarking compares the performance of a blockchain system with other systems. Testing performs experiments or simulations to test the functionality and reliability of a blockchain system. An audit examines and verifies the code, design, and architecture of a blockchain system for compliance with requirements.
Analytical methods include Stochastic Models, Queuing Models, Markov Chains, Emulation, Markov Decision Processes, Random Walks, Stochastic Petri Nets, Data Mining, Machine Learning.

6. DISCUSSION AND CONCLUSION *(TARTIŞMA VE SONUÇ)*

Blockchain technology provides more transparent, secure, traceable and decentralized structure compared to traditional systems. Since records are not stored in a single center, it builds a trustful environment preventing possible data loss and security breaches and allowing simultaneous tracking of information and elimination of disruptions in processes. It designs a reliable environment in agreements between parties with smart contracts. Table 4 provides a sector-by-sector comparison of blockchain technology features in food, automotive, healthcare, supply chain, information security, and banking.

Table 4 compares blockchain features by sector based on their full availability to all users sharing the blockchain network from supplier to end user: In terms of the operation of the sectors, the anonymousness feature is only available in information security, while in other sectors, information visibility is desired on transaction basis rather than anonymity of users. The execution feature in terms of transaction or transaction amount cannot provide full performance any sector in sectoral applications, depending on the network structure and user density. The scalability feature is related to the users using the network. The large number of users affect the transaction volume and the data storage load. Since scalability depends on the block size, cannot be completely fulfilled in any sector in industrial applications.

In contrast to the benefits of blockchain technology, there are complexities along with difficulties of blockchain technology in terms of installation and use. The use of blockchain technology also presents several challenges: The lack of standardization makes it difficult to implement a standardized platform for managing the supply chain. Integrating platform for managing the supply chain. Integrating blockchain technology with existing systems can be challenging, as it requires significant changes in the existing processes and infrastructure. Complexity, due to the complex structure of blockchain, users may resist the adoption of this technology. Cost, implementing blockchain technology can be costly, requiring significant investment in technology and infrastructure. Security, blockchain security has advantages and disadvantages.

Table 4. Comparing blockchain technology features in food, automotive, healthcare, supply chain, information security, and banking.
(Gıda, otomotiv, sağlık, tedarik zinciri, bilgi güvenliği ve bankacılık alanlarındaki blockchain teknolojisinin özelliklerinin karşılaştırılması)

	Food	**Automotive**	**Healthcare**	**Supply Chain**	**Information Security**	**Banking**
Traceability	✓	✓	✓	✓	✓	✓
Transparency	✓	✓	✓	✓	✓	✓
Immutability	✓	✓	✓	✓	✓	✓
Anonymousness	×	×	×	×	✓	×
Dis-intermediation	✓	✓	✓	✓	✓	✓
Security	✓	✓	✓	✓	✓	✓
Reliance	✓	✓	✓	✓	✓	✓
Smart contracts	✓	✓	✓	✓	✓	✓
Credibility	✓	✓	✓	✓	✓	✓
Scrutiny	✓	✓	✓	✓	✓	✓
Performance	✓	✓	✓	✓	✓	✓
Execution	×	×	×	×	×	×
Scalable	×	×	×	×	×	×
Cryptography	✓	✓	✓	✓	✓	✓

Security breaches and malicious attacks are among the problems encountered in blockchain networks. One of the challenges facing blockchain is energy consumption. The PoW mechanism requires high energy consumption. The high energy consumed is also a feature that has been criticised regarding sustainability. Despite the challenges, the use of blockchain technology holds significant promise for the future.

Personal data are required for identification of patterns in delicate situations. Blockchain technologies are needed to be used for security and immutability considering storage of the highly sensitive data. The further directions of blockchain technologies will include a variety of implementations of decentralized blockchains along with super secured networks to enhance minimization of inherent vulnerability of centralized databases.

Artificial intelligence based blockchain technologies can contribute to tracing how algorithms work and how their input affects the output of machine learning. For further directions, new technological advancements are required with the integration of artificial intelligence and blockchain technologies considering cybersecurity challenges and having double shield against cyberattacks by training machine learning algorithms to automate real time threat detection and to continuously learn about the behavior of attackers arisen in dynamic and uncertain environments.

For further directions, sustainability related researches should be considered within blockchain technology-based systems. Sectoral applications should consider three sustainability dimensions in terms of social, environmental, and economic aspects.

There are limitations in theory which need to be improved via empirical studies. As blockchain applications proliferate, data volume, volatilities, complexities, scales, diversities will be getting increased with the growth rate of blockchain technologies. Rapid development of data applications have placed extremely high demands on the user amount, concurrency, and energy efficiency optimization of privacy protection service requests. Rapid development of blockchain applications will require analyzing data of blockchain technologies emerging methodological advancements in data science. As a matter of fact, there are still issues for standardization of blockchain technologies within quality management involving especially considering new auditing developments and approaches via intelligent monitoring technologies, and dynamically exploring regulatory methods to improve quality assurance.

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