Blockchain Empowers Audit Innovation, Digital-Intelligent Transformation Enables High-Quality Development

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Abstract

The establishment of a comprehensive risk management framework and robust, effective internal control mechanisms constitutes an essential prerequisite for corporate survival and healthy development. This paper argues that digital transformation in auditing facilitates the achievement of internal audit objectives and enhances internal control efficacy; blockchain technology, distinguished by its inherent characteristics of distributed decentralization, genuine transparency, and immutability, will facilitate the transformation of accounting practices and audit supervision approaches; blockchain technology will serve as a catalyst for an auditing revolution, comprehensively "empowering" audit and risk management functions. This paper presents JD.com's standardized blockchain ABS solution and demonstrates how the industrial blockchain applications of Tencent and TCL Group enable low-cost, reliable transmission of trust and value, thereby confirming that the close integration of blockchain technology with corporate finance and audit functions can enhance internal control and plays a crucial role in risk prevention and control within enterprise operations. "Blockchain + Auditing" enables real-time online auditing, risk evaluation, and early warning, with data analytics becoming the core of audit content; "Blockchain + Auditing" will become a critical instrument for enterprise internal control and risk management.

Full Text

Blockchain Empowers Audit Innovation: Digitalization and Intelligence Enable High-Quality Development

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Abstract

Establishing a comprehensive risk management system and a sound internal control mechanism constitutes a vital prerequisite for enterprise survival and healthy development. This paper argues that digital transformation of auditing facilitates the achievement of internal audit objectives and enhances internal control effectiveness. Blockchain technology, characterized by distributed decentralization, authenticity, transparency, and immutability, will revolutionize financial accounting practices and audit supervision methods. As a catalyst for an audit revolution, blockchain comprehensively empowers audit and risk management functions. The paper examines JD.com's blockchain-based ABS standardization solution, as well as industrial blockchain initiatives by Tencent and TCL Group that enable low-cost, reliable transmission of trust and value. These cases demonstrate that integrating blockchain technology with corporate finance and auditing strengthens internal control and plays a critical role in operational risk prevention and control. Blockchain-enabled auditing achieves online real-time auditing, risk assessment, and early warning systems, with data analytics becoming central to audit content. "Blockchain + Audit" emerges as a powerful instrument for enterprise internal control and risk management.

Keywords: blockchain technology; blockchain+audit; supply chain finance; internal control; risk management

I. Introduction

Strengthening and standardizing enterprise internal control represents a crucial condition for improving management standards, enhancing risk prevention capabilities, and promoting sustainable development. Internal control comprises the methods, procedures, and measures established among functional departments to organize, constrain, evaluate, and regulate business activities to achieve management objectives. In the digital intelligence era, intensified market competition exposes enterprises to ubiquitous risks. To prevent risks before they materialize and resolve them at the opportune moment, enterprises must advance their internal control construction.

Through training and education, management at all levels and all employees must cognitively recognize and embrace the significance of internal control in corporate governance, comprehensively understanding its necessity and vital role in establishing appropriate organizational structures, systems, and processes that enable efficient operation, cost savings, profit generation, and risk control. These mechanisms must be effectively implemented across all business segments, departments, and positions. In October 2019, President Xi Jinping emphasized during a Central Politburo study session that blockchain technology plays a crucial role in technological innovation and industrial transformation, urging breakthroughs in key core technologies, enhanced independent innovation capacity, accelerated development of blockchain technology and industries, and greater contributions to building a cyber powerhouse, developing the digital

economy, and supporting economic and social development.

The 20th Party Congress Report states: "We must focus on developing the real economy, promote new industrialization, and accelerate the building of a manufacturing powerhouse, quality powerhouse, aerospace powerhouse, transportation powerhouse, cyber powerhouse, and digital China." The digital economy era represents a comprehensive process wherein next-generation information technologies—including 5G, cloud computing, big data, IoT, artificial intelligence, mobile internet, and blockchain—penetrate every aspect of our economy, society, and daily life. As a key tool for corporate governance, internal audit inevitably faces opportunities and challenges from digital transformation. Through digital transformation of auditing, enterprises continuously strengthen audit functions, enrich audit perspectives, and enhance audit effectiveness, making digital transformation an inevitable choice for internal audit to adapt to digital trends and support high-quality development. "Blockchain + Audit" enables online real-time auditing, risk evaluation, and early warning, representing a crucial measure for digital transformation of auditing.

China's Ministry of Finance issued the "Accounting Informationization Development Plan (2021-2025)" (Caikuai [2021] No. 36) in December 2021, stating: "Improve the information-based supporting construction of internal control systems to promote effective implementation of internal control systems" [1]. Enterprises should timely identify and assess internal and external risks related to control objectives and determine appropriate risk response strategies. Based on risk assessment results, enterprises should conduct corresponding control activities to keep risks within acceptable limits. Countless facts and lessons repeatedly prove that establishing a comprehensive risk management system and a sound internal control mechanism constitutes a vital condition for enterprise survival and healthy development.

To fulfill its responsibility for evaluating and improving organizational risk management, control, and governance processes—transforming from compliance-based, single-type audits to consultative, continuous audits—internal audit must fully apply cutting-edge information technology to expand coverage, extending its temporal focus from ex-post to in-process and ex-ante, its spatial scope from accounting to business operations and governance, and its information range from offline, scattered data to online, integrated data. "Audit digitalization focuses on comprehensive, multi-angle, and in-depth big data analysis. Enterprises strive to use audit digitalization to assist in precisely responding to external supervision, deeply exploring internal risks, timely identifying development opportunities, and providing greater value for enterprise development in the digital intelligence era" (Ernst & Young, 2022) [2].

In recent years, deep integration of industrial digitalization and digital industrialization has made production and operation activities across all industries increasingly dependent on digital technologies such as big data, artificial intelligence, blockchain, and cloud computing. Data has become an important produc-

tion factor alongside land, capital, labor, and technology. As corporate strategic decision-making, production operations, and management methods achieve digitalization, internal audit objects, methods, and tools develop synchronously. Faced with real-time, massive, and diverse data, to fully perform internal audit functions requires rapid audit responses, efficient information processing, and centralized multi-dimensional analysis. Audit digitalization integrates enterprise data, builds scientific analysis platforms, embeds closed-loop rectification processes, and outputs process optimization recommendations, achieving full-lifecycle digital management of internal audit and supporting organizations in fully leveraging internal audit functions.

As an important governance tool, internal audit provides significant support for ensuring compliant and robust operations and efficient, stable functioning. Faced with rapidly changing market environments, fast-evolving science and technology, and continuously improving regulatory policies, internal audit must innovate audit methods, optimize audit strategies, and enhance audit effectiveness. Audit digitalization supports the orderly integration of multiple steps including data processing, data analysis, and data application; flexible utilization of various methods such as remote auditing, continuous auditing, and agile auditing; and comprehensive implementation of multiple functions including customized model development, industry best practice benchmarking, and real-time monitoring alerts. This reduces audit implementation costs, improves audit efficiency, and promotes audit result transformation, providing support for enhancing internal audit effectiveness. In the digital economy era, increasingly mature blockchain technology will make significant contributions to the audit field. With its unique advantages of distributed decentralization, public ledgers, and transparency, blockchain will enable enterprise-wide coverage auditing, automated tax filing, and real-time operational monitoring, improving audit data quality and authenticity and facilitating the transformation and upgrading of audit models. Blockchain technology offers unparalleled advantages in improving audit quality and efficiency, expanding the breadth and depth of audit supervision, and enabling real-time auditing.

II. Characteristics and Technical Architecture of Blockchain Technology

(1) Concepts of Blockchain and Blockchain Technology

Blockchain refers to a technical solution for collectively maintaining a distributed trusted database through decentralized (or multi-central) and trustless approaches. Any number of nodes in the system process and record information exchange data from a period into a data block through cryptographic algorithms, generating the block's fingerprint for linking to the next block and verification. All participating nodes collectively determine the authenticity of records. "Blockchain is a collective term for technical solutions similar to non-relational databases, which developers can implement through various

programming languages and architectures" (Li Liwei, 2021) [3].

A blockchain consists of a chain of blocks. Each block stores certain information, connected chronologically. This chain is stored on all servers; as long as one server in the entire system remains operational, the entire blockchain remains secure. These servers, called nodes in blockchain systems, provide storage space and computing power support for the entire blockchain system. Modifying blockchain information requires consent from more than half of the nodes and altering information across all nodes. Since these nodes are typically controlled by different entities, tampering with blockchain information is extremely difficult. Compared to traditional networks, "blockchain has two core characteristics: first, data is difficult to tamper with; second, decentralization. Based on these characteristics, information recorded on blockchain is more authentic and reliable, helping solve mutual distrust problems" (Lin Yalong, 2021) [4].

Blocks contain transaction information for specific transactions, block root hash (Hash, generally translated as hash or digest; transforming input of any length into fixed-length output through hash algorithms, where the output is the hash value), timestamp (Unix timestamp, a sequence of characters or encoded information identifying when a specific event occurred, usually providing date and time, sometimes precise to fractions of a second), and other data. The timestamp includes time information for block generation and linking to the main chain, while other data mainly comprises block signature information, random values, etc. Overall, blockchain technology is a new technology formed by cross-integrating different disciplines including cryptography, mathematics, computer science, network science, economics, and logic.

(2) Characteristics of Blockchain Technology

Blockchain is the cornerstone of trust-building, enabling trusted networks for credit transmission and value transfer. "Blockchain focuses on building secure and reliable blockchain infrastructure, enabling enterprises and governments to quickly and efficiently build blockchain networks and industry applications, achieving credible and rapid flow of capital, logistics, and information, and efficient and credible collaboration, helping reduce cooperation costs and improve efficiency" (Huawei Cloud, 2023) [5]. A system with the following three properties constitutes blockchain: first, blockchain is a distributed database (system) placed in an insecure environment; second, blockchain uses cryptographic methods to ensure existing data cannot be tampered with; third, blockchain uses consensus algorithms to reach consensus on new data (Technology Bian, 2023) [6].

1. Distributed Decentralization Distributed decentralization is blockchain's most significant characteristic; each node on the blockchain can achieve self-management without relying on central nodes. Blockchain data transmission adopts a "peer-to-peer" model. Regardless of which node inputs data, data propagates to the blockchain cloud, and other nodes automatically record transaction

information, thereby achieving distributed recording, storage, and updating of data. Since blockchain systems store data information in the cloud, any node on the blockchain system can become a host or temporary center. Each block is a data unit and record, with multiple parties participating in bookkeeping, information writing, and maintenance. Advantages of distributed decentralization systems mainly include improved efficiency, avoidance of system paralysis caused by central node failures, public transparency and immutability of information, reduced transaction costs, saved human resources, risk control, and guaranteed universal bookkeeping and public ledger realization.

2. Data Authenticity and Transparency Through technological innovation, blockchain relies on common algorithms and trust networks established between machines to eliminate third-party authentication, credit endorsement, and guarantees, forming a new credit mechanism that fundamentally changes centralized credit mechanisms. Before data is recorded on blockchain, it is reviewed according to publicly standardized algorithmic criteria to promptly identify abnormal data and enable real-time transaction verification. After data is recorded, all relevant nodes on the blockchain jointly determine record accuracy, greatly reducing room for fraud and effectively preventing falsification while enabling real-time audit tracking. Since blockchain data is timestamped (time-stamped), data cannot be arbitrarily tampered with, possessing irreversibility that ensures data authenticity and effectiveness. Because blockchain system data information can be reviewed, traced, and restored to original transaction records by all relevant nodes, data transparency is ensured.

3. Data Immutability Blockchain systems use cryptographic technology to encrypt identity proof information, ensuring online transactions between parties and preventing data tampering during transmission. Since blockchain systems adopt distributed decentralized databases, each node on the blockchain can obtain a complete copy of data information. Once verified information is added to the blockchain, it is permanently stored. Unless more than half of the nodes can be simultaneously controlled, modifications to a single node's database are invalid. Data cannot be arbitrarily altered, ensuring extremely high data reliability and security.

4. Anonymous, Open, and Autonomous Based on trustless mechanisms, each participating node on the blockchain is anonymous; nodes do not require public identity information or mutual trust. Transaction parties transmit information through specific network addresses, and only those with private keys can open corresponding "wallets." Blockchain systems are externally open; anyone can query and use relevant data except private information through public blockchain nodes, making the entire system highly transparent and open. All nodes on blockchain systems adopt the same protocols and standard requirements. Based on a mutually trusted environment, any node can freely and efficiently record, update, and store data, with each node successfully achieving self-query, browsing, and maintenance of its own database.

(3) Technical Architecture of Blockchain

Blockchain technical architecture mainly comprises the physical layer, data layer, network layer, consensus layer, and application layer.

1. Physical Layer: Network, Storage, and Computing Resources Blockchain nodes typically consist of servers, edge nodes, and IoT devices, with server scheduling and allocation of network and storage resources being essential elements of the blockchain foundation. Cloud computing technology can perfectly integrate with blockchain infrastructure, bringing advantages in availability, trust, security, scalability, and data management. Cloud computing infrastructure can provide network, storage, and computing resources for the blockchain physical layer, with their combination used to ensure enterprise security architecture. Blockchain-as-a-Service (BaaS) realized through cloud computing platforms is an indispensable part of blockchain infrastructure. "Major cloud service companies including IBM and Microsoft Azure have developed and deployed BaaS platforms, providing development, usage, and hosting of blockchain applications, functions, and smart contracts based on cloud computing services" (Li Zhengmao et al., 2022) [7] (P. 280).

2. Data Layer: Account Models and Blockchain Data Structures Current blockchain widely adopts the UTXO (Unspent Transaction Output) model and Account model. UTXO records based on spent inputs and outputs in transaction records offer advantages of being stateless, having good concurrency performance, and reducing computing resource consumption, but suffer from poor state space utilization. The Account model, similar to real life where each address is an account and each transaction updates account balance and other information, offers high programmability suitable for providing complex services like smart contracts. Therefore, the Account model is more suitable for infrastructure account model technology. Blockchain storage data structures mainly have two mature solutions: chain-of-blocks structure and Directed Acyclic Graph (DAG). The chain-of-blocks data structure is a widely adopted solution where blocks connect to form a "blockchain," with each block containing transaction data, random numbers, timestamps, etc. DAG's advantages include concurrent transaction execution, no transaction throughput bottlenecks, horizontal scalability through increasing node numbers, and fast transaction confirmation speed, but it has not been widely adopted. Currently, blockchains using this technology mainly include Hedera Hashgraph and Fantom.

3. Network Layer: Distributed Network Mechanisms The network layer focuses on distributed network mechanisms, including P2P (peer-to-peer) networking, data propagation, and message verification. Also known as the P2P layer or propagation layer, it is responsible for inter-node communication and world state propagation. The network layer ensures nodes can discover each other, communicate, propagate, and synchronize to maintain the blockchain network's effective current state. P2P networks are computer networks where computers (nodes) are distributed and share network workload to achieve ulti-

mate goals. “Nodes executing transactions on blockchain are divided into two types—full nodes and light nodes. Full nodes ensure transaction verification and confirmation, mining, and enforcement of consensus rules; they are responsible for maintaining trust in the network. Light nodes only retain blockchain headers and can send transactions” (Li Zhengmao et al., 2022) [7] (P. 281). Blockchain utilizes distributed networks where everyone can download all information on the blockchain and interact with it. Blockchain platforms mainly use decentralized networks and distributed networks. In distributed networks, nodes are geographically distributed, completely avoiding disadvantages of centralized networks and ensuring network robustness and stability. The main idea of distributed networks is that each node can access and obtain equal access rights, making it more suitable as underlying network technology for infrastructure construction.

4. Consensus Layer: Consensus Mechanisms The consensus layer's core is the consensus mechanism, which is the most critical and important layer of any blockchain. Consensus is responsible for verifying blocks, ordering blocks, and ensuring agreement among all nodes. “Currently mature technologies include PoW (Proof of Work), PoS (Proof of Stake), DPoS (Delegated Proof of Stake), PBFT (Practical Byzantine Fault Tolerance), and RAFT (Replicated and Fault Tolerant), etc.” (Li Zhengmao et al., 2022) [7] (PP. 281-282). As the most classic consensus algorithm, PoW achieves node consensus through block hash calculation, offering advantages of simplicity and efficiency, allowing anyone to participate, but wasting computing resources and unsuitable for infrastructure technology selection. PoS consensus obtains block writing rights by staking tokens in the blockchain, offering low energy consumption and fast consensus speed, but requiring a token system. DPoS is a consensus algorithm based on shareholder elections that can significantly reduce participating consensus nodes for fast consensus verification, but also relies on blockchain network token incentives. The PBFT consensus protocol is a Byzantine fault-tolerant replication algorithm suitable for private and consortium chain scenarios requiring strong consistency, while RAFT is a voting-based consensus solution aiming to make the Paxos algorithm easier to implement and understand in practical scenarios. RAFT achieves low latency and high throughput, but overall performance depends on the leader node's working state with low fault tolerance. Hybrid consensus combines advantages of the above mechanisms to form layered consensus mechanisms that balance decentralization and efficiency, meeting efficiency requirements for building blockchain infrastructure.

5. Application Layer: Smart Contract Capabilities The application layer relies on blockchain to provide smart contract capabilities. The contract layer focuses on using smart contracts, algorithms, and various scripts to implement complex programmable transactions in blockchain. A set of state response rules called smart contracts expresses business logic, controls digital assets, and determines participants' rights and obligations. If two or more participants agree to all terms in a smart contract, the contract will be cryptographically signed and broadcast to the entire network. Once conditions are met, smart contracts will

automatically and independently execute according to predefined rules. Similar to transactions in blockchain, smart contracts are self-executing programs whose inputs, outputs, and states are verified by each node in the network. Each blockchain system uses its own programming language to implement transaction logic. The application layer is where clients or end-users reside. Client applications initiate transactions to start business workflows. This layer constitutes the central user interface for distributed ledger technology providing products and services, including various business applications such as digital identity, market security, intellectual property, and IoT. Applications can communicate with network nodes using software development kits (SDKs) for specific languages or command-line interface tools provided by blockchain implementations. These applications help optimize business management and provide new services. The application layer includes frameworks, user interfaces, APIs, and scripts that end-users can utilize to interact with blockchain networks. It has a sublayer called the execution layer, which contains the actual executed code and rules.

III. Blockchain's Multi-Party Consensus Characteristics Facilitate Credit Risk Management

Blockchain is a distributed ledger technology that is essentially a shared database. Data or information stored in it possesses characteristics of being unforgeable, fully traceable, publicly transparent, collectively maintained, and multi-party shared. These features establish a solid trust foundation and create reliable cooperation mechanisms. The new paradigm it creates is a protocol about trust, based on which an Internet for transferring value—a value Internet—can be built. At the most basic level, ledgers depict economic and social relationships. Consensus about ledgers and precise trust constitute one of the cornerstones of market economy. Encrypted global distributed independent ledger networks provide an operational model beyond management by governments, central banks, or any monopolistic central institution, shaking traditional trust mechanisms at the core of finance and creating a technology-based social trust system. For existing financial ecosystems designed around centralized institutions, blockchain's emergence brings tremendous disruption. Blockchain evolves social systems from bilateral mutual trust or central trust mechanisms to multi-party consensus and social consensus, enabling people to build credit beyond time and power constraints.

To standardize blockchain technology services, on January 10, 2019, China's Cyberspace Administration issued the "Blockchain Information Service Management Regulations." On May 23, 2023, the national standard "Blockchain and Distributed Ledger Technology—Reference Architecture" (GB/T 42752-2023) [8] was officially released and implemented on December 1, 2023, representing China's first national standard in the blockchain technology field. Beyond digital currency applications, blockchain technology is applied in numerous scenarios.

(1) Blockchain Technology Shows Great Potential in Corporate Finance and Audit Systems

Financial fraud incidents in listed companies occur frequently. According to China Securities Regulatory Commission reports, in 2020, the CSRC investigated 59 cases of financial fraud and other violations among listed companies, accounting for 23% of information disclosure cases. Financial fraud in listed companies exhibits the following characteristics: First, fraud cases display full-chain patterns with complexity and systematicity, primarily manifested as 虚构 entire business chains and implementing systematic financial fraud. Second, fraud methods are endlessly evolving and hybridizing with certain concealment. Beyond traditional methods such as falsifying bank and logistics documents, fabricating contracts, and issuing fake invoices, fraudsters also employ concealed new methods using overseas businesses or innovative financial instruments. Third, fraud motivations are diverse, commonly including performance commitment pressures, market value management, and covering up embezzlement. This indicates that accounting processing in listed companies' financial systems still faces many unresolved pain points (Hu Cuihua et al., 2022) [9] (P. 75).

1. Real-Time On-Chain Auditing Facilitates Timely Risk Identification and Control Measures Developing financial systems based on blockchain technology requires substantial human, material, and financial resources. Considering technical capabilities and input-output ratios, most listed companies struggle to invest heavily in updating blockchain-based financial systems. Moreover, if listed companies develop independently, their financial systems' standardization would be difficult to unify. Blockchain technology companies specializing in underlying technology possess superior core technologies, technical talents, and R&D costs compared to self-developed financial systems by listed companies. If blockchain technology companies could provide listed companies with financial platforms similar to those offered by UFIDA and Kingdee, the following advantages would emerge: First, listed companies' financial business processes would become more efficient, with distributed workflows developed through smart contract technology achieving electronic financial processes and improving collaborative efficiency. Second, financial costs would be lower, with blockchain's distributed ledger characteristics significantly shortening financial approval process cycles. Third, blockchain's transparent, shared, and tamper-proof characteristics would ensure financial authenticity in listed companies, promoting a virtuous cycle of financial information disclosure and enhancing standardization. Fourth, business supervision and enterprise risk management would become more convenient, enabling regulatory and audit institutions to conduct real-time on-chain auditing of listed companies and helping enterprises identify risks timely and implement corresponding control measures.

2. Blockchain Contract Functions Ensure Traceable and Tamper-Proof Contract Information Ant Technology Group's blockchain smart contract platform includes identity management, compliance management, and regulatory modules. The identity management module primarily confirms transac-

tion authenticity from enterprise business registration information and IP addresses. Compliance management manages supplier and seller information, cooperating with electronic signatures and contract abstracts in financial systems to confirm contract signing compliance. The regulatory module can set signing personnel permissions and monitor and audit contract transactions. Ant Technology Group's blockchain platform guarantees third-party evidence preservation for contracts and ensures storage security. Digital signatures based on asymmetric encryption technology can ensure contract integrity and compliance while determining contract sources, making them tamper-proof and non-repudiable. Blockchain contract drafting, signing, sending, electronic signatures, custody, querying, and modification all occur on Ant Technology Group's blockchain platform. Once a contract is successfully signed, it sends requests to proxy nodes. Once most proxy nodes confirm consensus, the node chain updates blocks with contract information to ensure traceability and tamper-proof contract information.

Ant Technology Group's blockchain platform features blockchain electronic bills/invoices. During audits of financial companies, construction companies, and other listed companies, internal and external auditors often can only obtain copies of invoices or bank receipts, making authenticity difficult to guarantee. Large companies processing travel expense reimbursements frequently complain about slow processing, cumbersome procedures, and inaccurate amounts. Audit personnel struggle to review thousands of invoices and bills in listed companies within short timeframes. Effectively handling bill circulation issues during internal and external audits helps enterprises prevent financial fraud. Additionally, in annual audits, high confirmation inquiry and mailing costs and untimely responses trouble external auditors and company financial personnel. The bill circulation process involves numerous participants, leading to inefficient circulation and opaque information; increased supervision costs for underlying invoices and bills, low audit efficiency, and high susceptibility to material falsification (Hu Cuihua et al., 2022) [9] (PP. 76-77).

(2) Blockchain Applied to Asset Securitization: Using Modern Digital Technology to Prevent Credit Risk

1. JD.com Launches First Blockchain ABS Standardization Solution
In recent years, based on continuous integration and innovation of blockchain technology with financial scenarios, JD Digits has focused on trustworthy enterprise-level blockchain services, conducting industrial innovation and integration in supply chain management and digital finance, and building an independently innovative blockchain open-source underlying technology engine. Previously, due to information security and transparency concerns, asset securitization processes involving plan managers, law firms, rating agencies, accounting firms, and custodian banks featured numerous business communication procedures, time-consuming data verification, high communication and trust costs, and relatively slow securitization processes. Through blockchain's

distributed architecture building a multi-party collaborative network system, on one hand, multi-party information authorization visibility improves information acquisition efficiency in business execution and enables 穿透式监管 of underlying assets; on the other hand, relying on smart contract technology, originally offline-executed business processes are brought on-chain, improving multi-party business collaboration efficiency and reducing execution costs.

JD Digits has connected multi-party institution authorized information visibility, enhanced efficiency, 穿透底层资产, monitored smart asset quality, and automated auxiliary reconciliation. In June 2019, JD Digits launched the market's first blockchain ABS standardization solution, becoming one of the most representative technology output directions in the financial field. Through JD Digits' independently developed JD.BaaS (Blockchain-as-a-Service) platform, it helps ABS (Asset-Backed Securities) business participants including asset parties, plan managers, law firms, rating agencies, accounting firms, and custodian banks optimize business processes and improve ABS issuance efficiency. After completing the blockchain network solution, a new ABS business node can be connected within two days. Compared with original technical solutions, deployment time is reduced by 85%, with annual operational cost savings exceeding one million yuan per business node, while effectively improving system transparency and accountability among business participants and better ensuring secure use of financial-related data (Huanqiu.com, 2020) [10].

From "trusted supply chain" builder to "digital finance innovation" practitioner, JD Digits has always regarded blockchain as a core enterprise technology, deeply participating in China's financial industry technological transformation wave. Since formally establishing a blockchain technology team in 2016, launching the "Zhizhen Chain Anti-Counterfeiting Traceability Platform" the following year, releasing JD.Chain (a blockchain framework system designed specifically for enterprise applications) and JD.BaaS, and launching the ABS standardization technology solution, JD Digits has forged a complete blockchain technology and service architecture through rich scenario practices.

2. Baidu Finance and Other Institutions Jointly Issue Blockchain-Backed ABS In June 2016, Baidu invested in Circle, a US blockchain technology payment company established in 2013 that mainly provides payment and transfer services based on blockchain underlying core technology. In May 2017, Baidu Finance jointly issued a blockchain-backed ABS project with other financial institutions.

Don Tapscott, father of the digital economy, once said: "Blockchain technology will have extensive and profound impacts on future society, becoming the most influential black technology in the coming decades" (Fang Lifei & Liu Guiying, 2020) [11] (PP. 6-7). Tapscott's words reveal blockchain's enormous driving role across all aspects of social production and life. The blockchain wave has spread across global fields, forming an unstoppable momentum worldwide.

IV. Industrial Blockchain Reduces Financial and Legal Compliance Risks While Facilitating Financing

(1) Blockchain Applied to Supply Chain Finance: Efficient Risk Control Management and Convenient Financing

After all nodes in the industrial supply chain are on-chain, blockchain's private key signature technology ensures data reliability of core enterprises and others; putting contracts and bills on-chain digitizes assets, facilitating circulation and achieving value transfer. Blockchain accurately grasps pain points of small and micro enterprises and financial institutions in the supply chain system. In most supply chains, core enterprises (or chain masters) typically do not use cash transactions but adopt credit term transactions when facing suppliers, issuing payment certificates to upstream SMEs with payment due at maturity. In this process, trust cannot be transmitted. Actual participants are only "close relatives" of core enterprises—first-tier suppliers and distributors. Second-tier, third-tier, and multi-tier suppliers and distributors receive increasingly shorter credit terms. Additionally, since core enterprises' credit bills cannot be split and circulated, the supply chain's credit transmission mechanism is not smooth, with most "distant relatives" frequently facing capital shortages and needing to seek financing from financial institutions. However, small and micro enterprises often cannot obtain financing due to their own limitations.

After receiving orders, suppliers typically need to increase working capital to organize production. However, banks' avoidance of "one-thing-multiple-pledges" prevents multi-tier suppliers from using orders as loan collateral. Can existing assets be used as alternative collateral? Small and micro enterprises have low asset utilization rates for collateral, and due to small size, immature governance structures, and low financial transparency, they struggle to obtain effective collateral resources from other channels, hindering credit enhancement again. Furthermore, "distant relatives" lack direct trade relationships with core enterprises, resulting in insufficient trust data, while lacking practical platform-based and systematic management tools to activate upstream and downstream cooperation in the industrial chain.

Before lending, traditional financial institutions' risk control review requires three processes: pre-loan due diligence, mid-loan approval department information deepening, and information incorporation, with limited reference basis. Information collection and risk perception decisions rely on multiple business personnel, creating high human dependency, moral hazard, and difficulty in scaling. Combined, these three processes take about three weeks in traditional financial institutions' risk control, with settlement not completed automatically, keeping customer acquisition and credit enhancement costs high. On the basis of traditional credit models, all nodes in supply chain finance constitute a blockchain platform, crossing interest boundaries to cover upstream and downstream enterprises in the supply chain, including logistics, warehousing, quality inspection, finance companies, and financial institutions, enriching contract choice spaces

for all participants. Upper-layer business systems use the underlying blockchain platform to register and store comprehensive trade information of small and micro enterprises on-chain, including asset ownership, quantity, quality, warehouse receipts, guarantees, accounts receivable, inventory, and prepayments, thereby standardizing, digitizing, and tokenizing small and micro enterprise assets to generate bond certificates for enterprise payment, financing, and circulation.

Based on complete and authentic recording and traceability of issuance, circulation, splitting, and redemption of assets such as suppliers' accounts receivable to core enterprises, this significantly expands financial institutions' information reference scope. Consequently, the difficult problem of trust and value transmission can be solved at extremely low cost (Tang Daosheng et al., 2020) [12] (PP. 89-94).

Tencent established a financial blockchain cooperation alliance in May 2016. In April 2017, Tencent released the "Blockchain Solution White Paper," aiming to build a blockchain ecosystem. In December 2017, jointly with Guangdong Youbei and Huaxia Bank, it released "Xingbei Cloud Chain," a supply chain financial service platform based on blockchain technology. Based on the alliance chain's inherent immutability and distributed cross-verification mechanism, the credibility of business data at each node is ensured, solving identity trust problems that have long existed in warehouse receipt pledge financing, greatly enhancing operability of financial institutions' credit evaluation while significantly reducing risk control difficulty. Notably, electronic certificates on-chain are splittable, improving asset liquidity, substantially increasing financing availability, and effectively alleviating financing difficulties and capital shortages for multi-tier suppliers. Banks taking corresponding actions based on on-chain assets and trade information helps reduce lending service costs while obtaining low-risk, high-return assets. With insurance company participation, financial institutions have insurance compensation guarantees even when encountering abnormal risks. Core enterprises also benefit significantly; reduced overall supply chain costs optimize their payment term arrangements, solidifying long-term strategic cooperative relationships with suppliers and ensuring their industry leadership.

(2) Industrial Blockchain Reduces Financial Costs and Performance Risks

In TCL Group's industrial blockchain project, TCL Group incorporates customers of comparable scale into a fund settlement chain, using blockchain + industry upstream and downstream purchase and sale for on-chain contract relationship confirmation and settlement, greatly reducing duplicate payments, capital occupation, and related financial costs. The legal relationships behind on-chain settlement—generation, performance, and transfer of creditor-debtor relationships—rebuild mutual contract trust based on on-chain publicity, transparency, and traceability. Initial blockchain application scenarios involve relatively simple legal relationships. According to supply chain finance definitions,

China is currently in the supply chain finance 3.0 era—"logistics financialization" with joint efforts from e-commerce groups and financial institutions, where core enterprises maximize data sharing with banks and other financial institutions, shifting financial services from retail to wholesale finance. Blockchain technology application will hopefully bring supply chain finance into the 4.0 era, characterized by fully peer-to-peer precise arrangement of financial services in highly networked and organized communities—a vision of complete integration of logistics, capital flow, and data flow, achieving a supply chain finance ecosystem with blockchain technology as the underlying support. In March 2017, Dianrong.com (an internet lending information service intermediary company) and Fujinong (Foxconn Technology Group's industrial chain financial service platform providing one-stop capital demand solutions through commercial factoring, financial leasing, small loans, and other financing methods) announced the joint launch of a supply chain finance platform called "Chained Finance," connecting electronic equipment suppliers, automobile manufacturers, and service manufacturers in the manufacturing industry, especially providing services for SMEs in these industries. Using blockchain technology characteristics makes supply chain finance more efficient and enables online batch loan issuance. On-chain contracts, financing, and creditor-debtor transfer legal relationships are intensive and structured, significantly reducing financial compliance and legal compliance risks and financing costs (Wang Youqiang & Tu Jing, 2020) [13] (Preface 27).

(3) Blockchain Applications in Logistics, Finance, Insurance, and Copyright Protection

1. Blockchain in Logistics, Smart Securities Platforms, and Mutual Insurance In July 2016, Ant Financial, a subsidiary of Alibaba Group, already applied blockchain to Alipay's love donation platform and later extended it to mutual insurance applications. In October 2016, Alibaba jointly developed "Fachain" with Microsoft, Fadada (China's leading electronic signature and electronic contract cloud platform), and others, proposing email evidence products based on Alibaba Cloud platforms. Through email and cloud service backups on Fachain, Chinese judicial institutions can adopt digital evidence on a large scale. In March 2017, Alibaba invested in Symbiont (a blockchain smart securities issuance and trading platform focusing on private equity and corporate bond markets) to jointly build a smart securities issuance and trading platform based on blockchain technology. In November 2017, Tmall International announced upgrading its global origin traceability plan, covering 63 countries and regions, involving 3,700 categories, and 14,500 overseas brands, comprehensively empowering the entire industry. In February 2018, Cainiao and Tmall International launched blockchain technology to track, upload, and verify full logistics chain information of cross-border imported goods, covering production, transportation, customs clearance, and inspection processes, stamping each imported product with a unique "ID card" for consumer query and verification. In June 2018, Alibaba launched the first blockchain-based electronic wallet cross-border

remittance service (Fang Lifei & Liu Guiying, 2020) [11] (PP. 5-6).

2. Blockchain in Cross-Border Payments Blockchain has potentially huge application value in international exchange, letters of credit, equity registration, and stock exchanges. Applying blockchain technology in the financial industry can eliminate third-party intermediaries, enabling point-to-point direct docking, thereby greatly reducing costs while completing transaction payments quickly. Blockchain introduction solves information asymmetry problems in cross-border payments and establishes a certain degree of trust mechanism. Ripple (the world's first open payment network enabling transfers of any currency, including USD, EUR, RMB, JPY, or Bitcoin, with transaction confirmation completed within seconds, without cross-bank, remote, or cross-border payment fees), Circle (crypto payment company), Bank of China, China Merchants Bank, and others have entered this field.

For example, Visa launched Visa B2B Connect based on blockchain technology, providing institutions with a lower-cost, faster, and more secure cross-border payment method for handling global B2B transactions. Traditional cross-border payments require waiting 3-5 days and paying 1-3% transaction fees. Visa also partnered with Coinbase (the largest US cryptocurrency exchange) to launch the first Bitcoin debit card, while Citibank tested running cryptocurrency "CitiCoin" on blockchain. In August 2022, China's first digital RMB 穿透 payment business successfully landed in Xiong'an New Area, Hebei Province, achieving a new breakthrough in digital RMB application scenarios in the new area's blockchain payment field.

3. Blockchain in Copyright Protection After blockchain application to certification, both registration and query become very convenient without requiring running between various departments. In August 2016, electronic evidence blockchain alliance "Fachain" was established in Beijing by Onchain (a leading Chinese blockchain technology company), Microsoft (China), Fadada, and other institutions. In December 2017, the arbitration alliance chain jointly launched by WeBank, Guangzhou Arbitration Commission, and Hangzhou Yibi Technology was used for evidence storage in judicial scenarios. In March 2018, Guangzhou's first "arbitration chain" judgment was issued (Li Liwei, 2021) [3].

4. Guangzhou Launches On-Chain Enterprise Service Platform to Support Business Environment Reform with Blockchain Guangzhou's on-chain enterprise service platform, based on enterprise chain code technology and centered on enterprises, provides on-chain services and on-chain spaces for "one enterprise, one code, one account." Using "blockchain + QR code" to grant enterprises trusted identity identification, it integrates basic enterprise information and credit information with blockchain accounts to form enterprise chain codes, achieving digital trusted identity mutual recognition and seal mutual recognition. It features precise service functions combining "enterprise credit" and "enterprise portrait," achieving full life-cycle services integrating enterprise on-chain spaces and on-chain services. Currently, Guangzhou has opened blockchain spaces with enterprise chain codes for over 3,700 enterprises,

enabling "one-network handling, one-chain 通行" blockchain services, reducing time and space costs for enterprises handling government services, and achieving circulation and sharing of enterprise-level government service data. Additionally, Guangzhou innovatively promotes "blockchain + public resource transactions," building a public resource transaction blockchain platform that enables cross-regional "mobile handling, anytime handling," reducing enterprise cash burdens by over 800 million yuan (Li Huiying & Sui Wangxin, 2024) [14].

Guangzhou actively uses blockchain to support business environment reform. Guangzhou's blockchain international trade platform has facilitated 7.8 billion yuan in trade business on-chain. Guangzhou Development Zone pioneered the creation of China's leading "tax chain" blockchain invoice platform and "policy credibility chain" government application. Hangxin Chain promotes blockchain technology implementation in civil aviation business, achieving record storage, data traceability, and other business functions in the civil aviation field. Guangzhou Internet Court launched the "Wangtong Falian" blockchain platform, using consortium chain forms to connect nine units including Guangzhou Intermediate People's Court and over 30 internet platform data from "BAT," building a digital governance ecosystem (Xu Wenwen, 2024) [15].

V. Blockchain Enhances Financial Data Stability and Reliability While Improving Audit Efficiency and Quality

Traditional audit models face numerous challenges including distorted corporate accounting information, time lags, limited audit coverage, easily tampered and low-security data, low audit efficiency, and service levels that cannot meet socio-economic development requirements. Blockchain technology will solve these problems. Building a comprehensive audit professional service system based on blockchain technology will bring the following transformations to audit work.

Blockchain-based auditing is significant: First, business behavior supervision and internal control will enhance corporate value to a certain extent. Second, risk management-oriented data enables commercial trade to be supervised by audited blockchain technology. Data encompassed in the network can be captured and audited anytime. Since block establishment, all data has been open-source, and data content cannot be changed or deleted. All data can be traced and 溯源. Therefore, audit or risk management workers must track and verify both parties' data in real-time. Blockchain technology can provide an undeletable record for goods and data information. Because of consensus algorithms, blockchain networks do not require third-party institution participation. Data chains continuously shorten, and transactions are visible to everyone, reducing audit difficulty and continuously improving audit work efficiency.

Blockchain audit technology can implement round-the-clock tracking and monitoring of business transactions, conduct real-time statistical analysis of data and form records, facilitate subsequent audit work, greatly improve audit efficiency, and make audit results more persuasive. The new audit model based on

blockchain technology uses modern computer technology to replace traditional manual labor, significantly reducing audit costs. Blockchain audit technology's transparency and immutability advantages can promote internal audit to establish a new mechanism, strengthen internal control functions, and provide trustworthy basis and tools for corporate risk identification and prevention.

(1) Distributed Decentralized Financial System: Improving Audit Data Quality and Authenticity

Enterprises build a distributed decentralized financial system based on blockchain technology where any data requires verification by other employees and transaction parties before verified and identified relevant economic data is recorded in the system. False information will be rejected, ensuring financial data is authentic, valid, accurate, and high-quality. The enterprise financial system is just one node in the entire blockchain; other nodes automatically record and store relevant data. This financial data is monitored in real-time by the entire blockchain network to ensure it cannot be tampered with. For example, when a company engages in trade with another domestic company, generating logistics, communication, and employee travel expense invoices, nodes on the company's blockchain system will receive information from logistics companies, hotels, and communication companies. Due to blockchain's timestamp function, economic activity records are irreversible, ensuring complete recording of the entire real economic activity panorama and greatly reducing financial fraud space.

(2) Authentic, Public, and Transparent Financial Data: Promoting Audit Model Transformation

Due to technical limitations and audit concepts, traditional audit work mainly focuses on ex-post auditing and supervision. As big data, cloud computing, and blockchain technology mature, audit concepts oriented toward ex-post auditing have fallen behind and cannot meet socio-economic development requirements. Traditional audit models and concepts must transform toward whole-process auditing covering ex-ante, in-process, and ex-post stages. Through comprehensive application of cryptographic algorithms, data hashing, and other cryptographic, mathematical, and computer technologies, third-party credit endorsement and guarantees are successfully eliminated while ensuring data authenticity, publicity, and transparency. This will increase audit report information content, enhance audit work transparency, and improve audit quality.

With blockchain technology assistance, audit models will transform as follows: from sampling auditing, periodic auditing, computer-assisted auditing, and single-object auditing to holistic auditing, whole-process auditing, blockchain automatic auditing, and automatic auditing of various nodes in blockchain systems.

(3) Tamper-Proof Financial Data: Reducing Audit Supervision Resistance

Under existing accounting systems, due to position and authority limitations, enterprise audit personnel inevitably face intervention from enterprise leaders in audit records and supervision, creating adverse effects on audit work, reducing audit quality, hindering audit transparency improvement, and making audit independence difficult to guarantee. However, blockchain-based financial systems feature timestamp functions and distributed bookkeeping characteristics that ensure data cannot be arbitrarily altered. Even if enterprise audit personnel attempt to tamper with accounting data under duress from enterprise leaders, actions to conceal or fabricate false transaction records cannot be achieved. Blockchain's immutability will enhance financial data stability and reliability, improving auditor independence.

(4) Blockchain's Anonymous, Open, and Autonomous Nature: Improving Audit Efficiency and Report Quality

Blockchain technology's open and autonomous characteristics ensure that recorded ledger information undergoes strict review, layer-by-layer monitoring, and cannot be tampered with, ensuring data authenticity and integrity. Blockchain systems conduct real-time auditing and automatic pre-audits according to preset audit standards, detecting and identifying abnormal matters, and drawing preliminary audit conclusions. Using blockchain systems to comprehensively, systematically, holistically, and structurally collect various audit data enables global, systematic, comprehensive, and structural review and analysis, screening out abnormal extreme data, reducing subjective assumptions in manual review, analyzing problem severity and urgency, and saving substantial economic resources. This will greatly improve audit efficiency and audit report quality, enabling limited audit personnel to concentrate human and material resources on reviewing key matters (Chen Hua & Hu Xiaolong, 2020) [4] (PP. 8-10).

VI. "Blockchain + Audit": Transformation and Reconstruction of Internal Control and Risk Management in the Digital Intelligence Era

(1) Innovation in Audit Operation Models: "Real-Time Audit" and "Smart Audit" as Future Development Directions

Blockchain technology offers unparalleled advantages in improving audit efficiency, providing real-time payment and settlement services, ensuring authentic and reliable audit data, and broadening audit scope. In blockchain network systems, audit personnel collect audited entity financial data online in real-time and establish data mining analysis models to conduct continuous, dynamic, and tracking real-time audits of audited entity economic business activities, promoting "real-time audit" model development. Meanwhile, blockchain systems' pro-

grammability enables audit personnel to design personalized audit models based on specific audited entity situations, enhancing audit work intelligence, promoting "smart audit" model transformation, and improving audit work efficiency and report quality.

(2) Innovation in Audit Risk Prevention and Control Systems: Online Real-Time Risk Assessment and Early Warning on Blockchain Platforms

During audit activities, audit personnel can obtain systematic structured data and fragmented, trivial unstructured data from financial information in blockchain systems. Using data mining processing technology to form relationship maps of audited entities and their related parties, they can analyze industry, regional, and individual risk factors from massive information, achieving online real-time risk assessment and early warning. Simultaneously, using gradually improving artificial intelligence learning capabilities, blockchain systems automatically register indicators exceeding early warning values and possible suspicious points as potential risk factors. Based on this, the system automatically generates audit working papers and sends them to on-site audit personnel for verification according to risk early warning levels. On-site audit personnel use blockchain system's timestamp function to reproduce economic business scenarios, combining online real-time risk assessment and early warning with offline risk prevention and control.

(3) Integration of Blockchain and Big Data Technologies: Data Analytics Becomes Audit Core

Under blockchain systems, the audit process involves audit personnel using data information provided by blockchain to design corresponding intelligent audit procedures for analyzing audit data. Based on data analysis, audit personnel make audit evaluations and draw audit conclusions. In the future, data analytics will become the core tool of "blockchain + audit." Due to blockchain technology's relatively weak statistical analysis capabilities, while big data technology encompasses massive data analysis, storage, and processing technologies, the organic integration of blockchain and big data technologies represents an inevitable trend for "blockchain + audit" future development. This will greatly enhance blockchain data value and application space. Future "blockchain + big data" audit business development will present the following process: obtaining massive, authentic, and reliable data through blockchain network systems to provide original data support for auditing, using big data analysis technology to conduct quantitative and qualitative analysis of audited entity data, and precisely locking audit clues.

In conclusion, the essence of enterprise internal control management lies in risk control. Therefore, enterprises should maintain risk prevention awareness against the backdrop of "Internet +," "Intelligence +," and "Blockchain +," achieve effective risk identification and evaluation, summarize potential factors

causing enterprise risks based on existing internal control problems, analyze their specific impact levels, compile specific risk lists, and establish risk case databases based on practical experience in risk prevention to further improve enterprise internal control risk system construction. "Accelerating digital development and building digital China" is an important component of the national "14th Five-Year Plan" and 2035 远景目标纲要. Enterprise internal control and risk management also face opportunities and challenges from digital transformation. Digitalization, networking, and intelligence will help enterprise internal control become more rigorous, timely, precise, and efficient. In digital transformation, enterprises should continuously improve and strengthen internal control and risk management functions, continuously enhance internal control effectiveness, and support high-quality enterprise development.

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Note: Figure translations are in progress. See original paper for figures.