Review | Received 15 December 2023; Accepted 4 January 2024; Published 10 January 2024
https://doi.org/10.55092/blockchain20240001

Analysis and prospects for blockchain testing and evaluation

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Abstract: With the strong support of various countries' policies, blockchain technology is booming in all walks of life, and the demand for blockchain evaluation is also growing. Relevant authoritative organizations have begun to formulate blockchain evaluation standards and carry out evaluations on the blockchain platforms and application products, providing reliable information for the government, industry authorities, blockchain users and investors in the blockchain selection stage. This article introduces mainstream blockchain evaluation institutions, analyzes the status of blockchain evaluation standards, sorts out blockchain evaluation tools and methods, and summarizes the current development of the blockchain evaluation industry based on the relevant status quo. This article also gives some suggestions for future development in terms of improving the implementation of blockchain evaluation standards, improving blockchain evaluation tools, formulating international standards for blockchain evaluation, and strengthening the training of blockchain evaluation talents.

Keywords: blockchain; evaluation; test; standard; evaluation agency; evaluation tool

1. Introduction

Since the birth of Bitcoin, the development of blockchain technology has gone through three stages. The first stage is the digital currency stage represented by Bitcoin; The second stage is the smart contract stage represented by Ethereum; The third stage is the pan-blockchain application phase that goes beyond digital currencies and smart contracts. Today, blockchain,

as an important distributed ledger technology, has gradually penetrated in various application fields such as finance, government affairs, medical care, and energy.

Blockchain technology plays a transformative role in the economic development of society. The standardization work of verification and evaluation of blockchain has also received relevant policy support from various countries around the world. General Secretary Xi Jinping of the People's Republic of China once emphasized that blockchain should be used as an important breakthrough for independent innovation in core technologies [1]. Japan has released JIS X 0510:2021 "Blockchain Technology - Security Framework", which provides guidance for the security evaluation of blockchain systems. The National Institute of Standards and Technology (NIST) released NIST SP 800-56A-1:2022 "Blockchain Technology Security Framework", which provides detailed guidance for the security evaluation of blockchain systems. The U.S. Financial Stability Oversight Council (FSOC) released the Fintech Risk Management Framework, which requires financial institutions to conduct security evaluation of the blockchain systems they use. With the rapid development of blockchain technology and the implementation of blockchain applications in all walks of life, the demand for blockchain evaluation is also growing. More and more blockchain customers, enterprises and organizations are beginning to pay attention to how to evaluate and choose a blockchain product that suits their needs. Through blockchain evaluation, different blockchain technologies can be objectively evaluated and compared, which improves transparency and helps establish industry recognition for products. Standardized blockchain evaluation is conducive to guiding and standardizing the healthy development of the blockchain ecosystem. Therefore, research on blockchain evaluation is of great significance to the entire industry.

This article focuses on the current situation of blockchain testing and evaluation. Firstly, it introduces the mainstream blockchain evaluation institutions and organizations, and sorts out the evaluation content, basis standards, evaluation qualifications and evaluation scale of each institution, *etc.*, providing some reference for blockchain enterprises and users when they choose evaluation institutions. Then, it introduces the status of blockchain national standards, including national standards, local standards, industry standards, group standards, *etc.* related to blockchain assessment. Next, combined with the existing blockchain evaluation tools and methods, its current situation and shortcomings are analyzed. Finally, it comprehensively summarizes the current situation of blockchain evaluation and puts forward some suggestions and prospects for its future, hoping to provide some inspiration and thinking for the development direction of blockchain technology.

2. Introduction to blockchain evaluation institutions and organizations

2.1. International mainstream blockchain evaluation institutions

Internationally, institutions conducting research on blockchain standardization and evaluation include the International Organization for Standardization (ISO), the International Telecommunication Union (ITU), and the Institute of Electrical and Electronics Engineers (IEEE), *etc.*

In 2021, IEEE established the Blockchain Conformity Assessment Committee (BCAC), which is jointly organized by the IEEE Computer Society Blockchain and Distributed Ledger Standards Committee (IEEE BDLSC) and the IEEE Conformity Assessment Program (ICAP), Li Ming, director of the Blockchain Research Office of China Electronics Standardization Institute, serves as the chairman of BCAC. BCAC has launched the IEEE Blockchain Certification Program, which will develop and implement testing and evaluation specifications consistent with IEEE blockchain standards to ensure that blockchain systems and products comply with IEEE related standards [2]. Since there are currently few international blockchain standards issued by ISO and ITU, no work related to blockchain evaluation and certification has been carried out yet.

2.2. Mainstream blockchain evaluation institutions in China

2.2.1 China Academy of Information and Communications Technology

In 2017, China Academy of Information and Communications Technology launched the "Trusted Blockchain Evaluation". Over the past six years, a specialized evaluation service system has gradually formed, covering 7 modules including basic evaluation, supporting evaluation, application evaluation, software and hardware collaborative evaluation, independent innovation evaluation, capability evaluation, and project/topic acceptance. It has 31 specialized assessments and has also received widespread attention from the industry [3]. The trusted blockchain series evaluation is provided by China Telecommunication Technology Labs (TTL), which has the qualification of China National Accreditation Service for Conformity Assessment (CNAS) [4].

By the end of November 2023, the China Academy of Information and Communications Technology has completed more than 340 specialized assessments on more than 180 units, forming more than 30 international and domestic standards and specifications related to blockchain testing and evaluation, covering the evaluation of underlying technologies such as blockchain basic functions, performance, security, cryptography, BaaS, as well as evaluation of more than 10 application evaluations such as government affairs applications, certificate applications, supply chain finance, traceability, electronic bills, and copyright certificates [5]. The evaluation items provided by “Trusted Blockchain Evaluation”. The introduction to the Trusted Blockchain Evaluation is shown in Table 1.

Table 1. Introduction to the trusted blockchain evaluation.

Type	Evaluation	Standards
Blockchain technology platform	Function	Trusted Blockchain: Functional evaluation methodology
	Performance	Trusted Blockchain: Performance benchmarking approach
	Security	Trusted Blockchain: Blockchain security evaluation indicators and testing methods
	Cryptography	Trusted Blockchain: cryptography application verification specification for blockchain
	Interoperability	Trusted Blockchain：Technical requirements and assessment methods for inter-chain interoperability
Blockchain cloud services	BaaS	Trusted Blockchain: BaaS evaluation methodology
Blockchain application	Supply chain finance application	Trusted Blockchain: Blockchain supply chain financial system evaluation standards
	Traceability application	Trusted Blockchain: product traceability application specifications based on blockchain
	Certificate system application	Trusted Blockchain: blockchain certification system application specifications
	Government affairs	Trusted Blockchain: Government affairs blockchain technical specifications
	Electronic Invoice Application	Trusted Blockchain: Blockchain Electronic Invoice Application Technical Specifications
	Digital Identity authentication	Trusted Blockchain: Blockchain-based natural person digital identity system technology and application requirements
	Near Field Communication-based enhanced identity authentication	Trusted identity: Technical requirements of Near Field Communication-based enhanced
Digital Collection	Function of digital collection distribution platform	Trusted Blockchain: Digital collection issue platform technical requirements and evaluation methods
Blockchain hardware	Blockchain all-in-one machine	Trusted Blockchain: All-in-One technical specifications
Independent and innovation	Code self-research rate	/
	Domestic environmental compatibility	/
Capabilities of blockchain platform	Classification of blockchain platform	Trusted Blockchain: classification assessment requirements for blockchain platform
	Capability of public permission blockchain	Trusted Blockchain: Capability Requirements and Evaluation Guidelines of Public Permissioned Blockchain
Blockchain application level	Maturity of blockchain application	Trusted Blockchain: Blockchain Application Maturity Model and Evaluation Methods
	Capability of data collaboration	Trusted Blockchain: Technical requirement of distributed ledger-based data collaboration platform

2.2.2 China electronics standardization institute

In 2021, National Blockchain and Distributed Ledger Technology Standardization Technical Committee (TC590) was established [6]. The secretariat is assumed by the China Electronics

Standardization Institute. It is mainly responsible for the revision of national standards in the field of blockchain and distributed ledger technology, including basic standards, technology and platform standards, application and service standards, development and operation standards, and security standards, Corresponding to the work of Blockchain and Distributed Ledger Technologies (ISO/TC307) in ISO [7]. In addition, China Electronics Standardization Institute has led the establishment of the "China Blockchain Technology and Industry Development Forum" group alliance to organize the development of blockchain group standards. Since 2017, China Electronics Standardization Institute has relied on CESI Labs to carry out blockchain testing, including blockchain system function, performance, reliability testing and blockchain service capability maturity evaluation [8]. CESI Labs is an authoritative third-party testing organization approved by CNCA (National Certification and Accreditation Administration of the people's Republic of China) and accredited by CNAS (China National Accreditation Service for Conformity Assessment) [9].

By the end of November 2023, China Electronics Standardization Institute has completed a total of 100 blockchain tests on 77 enterprises. The blockchain system testing provided by China Electronics Standardization Institute include functional test, performance test and reliability test. Introduction to the blockchain evaluation system of China Electronics Standardization Institute is shown in Table 2. In addition to the group standard "Blockchain Reference Architecture" issued by the China Blockchain Technology and Industry Development Forum, the evaluation basis it refers to also refers to traditional software quality and indicator system standards.

Table 2. Introduction to the blockchain evaluation system of China Electronics Standardization Institute.

Evaluation type	Evaluation content	Evaluation standards
Function	User function Business function Management function Access management function Node management function Ledger application consensus mechanism Ledger records Encryption Summary Digital signature Timing services Smart contract Peer-to-peer network Storage Calculation	T/CESA 6001-2016 Blockchain - Reference Architecture GB/T 25000.51-2016 Systems and Software Engineering -- System and Software Quality Requirements and Evaluation (SQuaRE) Part 51: Requirements for quality of Ready to Use Software Product (RUSP) and instructions for testing

Table 2. *Cont.*

Evaluation type	Evaluation content	Evaluation standards
Performance	Basic account single Transfer test Smart contract transfer test Transfer test of Randomly contract call Transfer test Block Check Account verification Mixed load testing Stability test	GB/T 29835.1-2013 Efficiency of system and software - Part 1: Indicator System [10]
Reliability	Node reliability Basic transaction execution reliability System fault tolerance Failure warning Encryption technology reliability Smart contract reliability Permission management reliability Ease of recovery	GB/T 29832.1-2013 Reliability of system and software Part 1:Indicator system [11]

2.2.3 China Industrial Control Systems Cyber Emergency Response Team

In March 2021, China Industrial Control Systems Cyber Emergency Response Team launched the "Innovation Blockchain Promotion Action". The evaluation relies on the Key Laboratory Ministry of Industry and Information Technology [12]. The laboratory has taken the lead in research on the application of blockchain technology based on independent basic software and hardware environment and has formulated the "Evaluation Requirements for Information and Innovation Blockchain". The evaluation system mainly focuses on the compatibility and adaptation issues between blockchain and independent information technology systems, testing the blockchain's ability to operate on basic software and hardware products such as domestic chips and operating systems, while taking into account the function, performance, security, stability and other aspects of the blockchain, conducting an overall evaluation of the technology and products [13].

By the end of 2022, the " Innovation Blockchain Promotion Action" has completed 2 batches of tests, with a total of 16 units participating in the evaluation. The framework of the innovation blockchain evaluation system is shown in Table 3. The evaluation content includes compatibility testing, functional testing, performance testing, security testing, reliability testing and compliance assessment. The evaluation standards based on it include the areas under development. Blockchain national standards, published blockchain group standards and traditional software quality standards [14].

Table 3. Introduction to the framework of the innovation blockchain evaluation system.

Evaluation dimension	Evaluation content	Evaluation standards
Compatibility	Whether it can run normally on the domestic server or not Whether it can run normally on the domestic cloud server or not	GB/T 25000.51-2016 Systems and Software Engineering -- System and Software Quality Requirements and Evaluation (SQuaRE) Part 51: Requirements for quality of Ready to Use Software Product (RUSP) and instructions for testing T/CESA 6001-2016 Blockchain - Reference Architecture CBD-Forum-001-2020 Requirements for blockchain system evaluation SF/T 0076—2020 Technical specification for digital evidence preservation Information security technology—Security specification for blockchain information service
Function	User function Management function node management Consensus mechanism Encryption mechanism Smart contract Peer-to-peer network	
Performance	Transfer without contract Transfer with smart contract Call contract randomly Query information of transaction Query information of block Query information of account	
Security	Information processing Information storage Information destruction	
Reliability	Reliability of node Reliability of smart contract Recoverability of system Fault tolerance of System	
Compliance	Technology and Platform Services and operations Independent and innovation	

2.2.4 The Fifth Electronics Research Institute of the Ministry of Industry and Information Technology of the People's Republic of China

In April 2018, the Fifth Research Institute of Electronics of the Ministry of Industry and Information Technology of the People's Republic of China (also known as CEPREI) published group standard which named "*Grading Evaluation Specification for Blockchain and Distributed Ledger Information System*". This specification is a standard specification that meets the industry's testing needs for evaluating blockchain information systems in different industries and different security levels.

CEPREI has the qualifications of a laboratory accredited by the China National Accreditation Service for Conformity Assessment (CNAS) and a metrology certification (CMA) laboratory approved by the China Certification and Accreditation Administration. The blockchain evaluation system it provides includes comprehensive evaluation and specialized evaluation. Comprehensive evaluation includes blockchain platform testing,

BaaS testing, and application testing; Specialized evaluation includes performance evaluation and security evaluation, Password evaluation. Up to now, the blockchain products that have been evaluated include JINGTUM, BUBI, TIANDE, Asch, PDX, Ethereum, Thunder Chain, Libra, *etc.* The blockchain systems that have been evaluated include the "Netcom Law Chain" ecosystem and judicial blockchain of Guangzhou Internet Court, *etc* [15]. The evaluation is based on traditional software quality standards, industry standards, group standards and local standards [16]. The introduction to the blockchain evaluation system of CEPRI is shown in Table 4.

Table 4. Introduction to the blockchain evaluation system of CEPREI.

Evaluation type	Evaluation content	Evaluation basis
Comprehensive evaluation	Blockchain platform BaaS Application system	GB/T 25000.10-2016 Systems and software engineering -- Systems and software Quality Requirements and Evaluation (SQuaRE) -- Part 10: System and software quality models [17] GB/T 25000.51-2016 Systems and Software Engineering -- System and Software Quality Requirements and Evaluation (SQuaRE) Part 51: Requirements for quality of Ready to Use Software Product (RUSP) and instructions for testing [18]
Specialized evaluation	Performance Security Password	GB/T 42752-2023 Blockchain and distributed ledger technology -- Reference architecture JR/T 0184-2020 Financial distributed ledger technology security specification JR/T 0193-2020 Financial application of blockchain technology - Evaluation rules CBD-Forum-002-2020 Blockchain Application Service Middleware Reference Architecture CBD-Forum-001-2020 Requirements for blockchain system evaluation TBI/T-J-2018-01 Trusted Blockchain: Part 1 Technical Reference Framework TBI/T-J-2018-02 Trusted Blockchain: Part 2 General Requirements and Evaluation Indicators DB52/T 1466-2019 Blockchain -Application guide [19] DB52/T 1467-2019 Blockchain – Systems testing and selection specification DB52/T 1468-2019 Blockchain based data asset trading guide [20] DB4403/T 127-2020 Specifications of financial blockchain platform [21]

2.2.5 National FinTech Evaluation Center

The National FinTech Evaluation Center (Bank Card Test Center BCTC, Beijing UnionPay Gold Card Technology Co., Ltd.) was established with the approval of the People's Bank of China and is an authoritative testing institution with CNAS qualifications in my country's financial industry [22].

In 2020, the People's Bank of China published two industry standards, JR/T 0184-2020 Financial distributed ledger technology security specification and JR/T 0193-2020 Financial application of blockchain technology - Evaluation rules, to further promote the regional Blockchain technology provides guidance for the compliance application and healthy development of the financial industry. Based on these two industry standards, the National

Fintech Evaluation Center has designed and developed a blockchain technology evaluation system and carried out blockchain financial industry evaluation.

Up to now, the center has provided blockchain technology evaluation services for blockchain companies such as Hangzhou Qulian Technology Co., Ltd. and Tencent Technology Co., Ltd., including smart contracts, ledger data, consensus mechanisms, and peer-to-peer network, *etc.* from aspects such as functionality, stability, and security. and other basic features, as well as the account security, node security, data security, transaction security and other aspects of the underlying platform to conduct a comprehensive assessment [23]. The introduction to the blockchain evaluation system of National FinTech Evaluation Center is shown in Table 5:

Table 5. Introduction to the blockchain evaluation system of National FinTech Evaluation Center.

Evaluation dimension	Evaluation content	Evaluation standards
Function	A total of 276 evaluation items are included in 10 categories including ledger technology, consensus protocol, smart contract, node communication, event distribution, key management, status management, member management, trading system, and interface management.	JR/T 0193-2020 Financial application of blockchain technology - Evaluation rules
Performance	There are 33 evaluation items in 5 categories including transaction throughput rate, query throughput rate, transaction synchronization performance, deployment efficiency, and ledger data growth rate.	JR/T 0193-2020 Financial application of blockchain technology - Evaluation rules
Security	A total of 164 evaluation items in 12 categories including basic software and hardware, privacy protection, operation and maintenance, consensus protocols, smart contracts, ledger data, *etc.*	JR/T 0193-2020 Financial application of blockchain technology - Evaluation rules [24] JR/T 0184-2020 Financial distributed ledger technology security specification [25]

2.3. Comparative analysis of blockchain evaluation institutions

After sorting out and analyzing the launch time, laboratories and qualifications, evaluation dimensions and content of mainstream blockchain evaluation institutions, the evaluation standards based on them, and the scale of participation of evaluation units, it can be found that:

(1) China's blockchain evaluation-related work started in 2017 and gradually formed a complete system and scale by 2020.

(2) Most blockchain evaluation institutions have authoritative qualification certification, and some evaluation institutions have CNAS or CMA qualification. Blockchain companies can choose according to their needs when they conduct evaluation.

(3) The national standards for blockchain evaluation have not yet been implemented, and some evaluation institutions still refer to traditional software evaluation standards. The

development of evaluation standards suitable for the characteristics of blockchain should be strengthened.

(4) Most evaluation institutions lack universal blockchain evaluation tools, and functional evaluations are performed by each company self. Some evaluation institutions still use traditional software testing tools for performance testing. Research on blockchain assessment technologies and tools should be strengthened to improve assessment efficiency and credibility.

(5) In terms of evaluation content, mainstream evaluation institutions have covered the functions, performance, security, and other technology levels of blockchain. Some evaluation institutions provide blockchain application evaluation, independent and innovation evaluations, *etc.* The evaluation ecosystem is gradually improving with the development of the industry, which can meet the needs of different enterprises and users.

When blockchain companies, users, and government departments choose blockchain evaluation institutions, they can combine the needs of specific scenarios, comprehensively consider the institution's qualifications, scale, evaluation content, *etc.*, and select the appropriate evaluation institution as needed. The comparative analysis of blockchain evaluation institutions is shown in Table 6.

Table 6. Comparative analysis of blockchain evaluation institutions.

Institution	Launch time	Laboratory and qualifications	Evaluation dimension	Evaluation basis	Participates
China Academy of Information and Communications Technology	2017	China Telecommunication Technology Labs (CNAS)	7 modules including 31 specialized assessments	Group standards of TBI (Trusted Blockchain Initiatives)	180 companies
China Electronics Standardization Institute	2017	CESI Labs (CNAS, CNCA)	3 modules including function, performance, reliability	Group standards of CESA (China Electronics Standardization Association) and traditional software quality evaluation standards	77 companies
China Industrial Control Systems Cyber Emergency Response Team	2021	Key Laboratory Ministry of Industry and Information Technology	6 modules in domestic environment including compatibility, function, performance, security, reliability, compliance	Group standards (CESA, CBD – forum, *etc.*)， traditional software quality evaluation standards and national standards under development	16 companies

Table 6. *Cont.*

Institution	Launch time	Laboratory and qualifications	Evaluation dimension	Evaluation basis	Participates
The Fifth Electronics Research Institute of The Ministry of Industry and Information Technology of People's Republic of China	2018	CEPREI (CNAS, CMA)	6 modules including blockchain technology platform, BaaS, Application, performance, security, reliability, compliance	Group standards (BCTC, TBI, *etc.*) traditional software quality evaluation standards and national standards under development	10 companies
National FinTech Evaluation Center	2020	Bank Card Testing Center (CNAS)	3 modules including function, performance, security	Industry standards of blockchain in finance	2 companies

3. Current status of blockchain evaluation standards

3.1. Current status of international blockchain evaluation standards

Due to the different development directions and technical routes of blockchain at home and abroad, it is difficult to reach an agreement on the test methods and evaluation standards of blockchain at home and abroad, so there are relatively few international standards for blockchain assessment and evaluation. Currently, international standards for blockchain related to evaluation under development and published are shown in Table 7. Both ISO and ITU-T have published the blockchain reference architecture standards, ITU-T has published the evaluation and evaluation method standards and interoperability test requirements for the blockchain. ISO has published the use case standards for the blockchain and distributed ledger technology, which can be used as an important reference for the international blockchain evaluation. In addition, IEEE also has two blockchain evaluation standards under development, respectively for the cryptocurrency and Internet of Things, which can provide guidance for international digital currency circulation and blockchain-based IoT data management [26].

Table 7. International standards related to blockchain evaluation.

Standard encoding	Standard name	Institution	Standard status
ISO 23257:2022 [27]	Blockchain and distributed ledger technologies - Reference architecture	ISO	Published
ISO 3242:2022 [28]	Blockchain and distributed ledger technologies - Use cases	ISO	Published
ITU-T F.751.1 [29]	Assessment criteria for distributed ledger technology (DLT) platforms	ITU-T	Published
ITU-T F.751.2 [30]	Reference framework for distributed ledger technologies	ITU-T	Published

Table 7. *Cont.*

Standard encoding	Standard name	Institution	Standard status
ITU-T Q.4046 [31]	Interoperability testing requirements of blockchain as a service	ITU-T	Under development
ITU-T F.751.6 [32]	Performance assessment methods for distributed ledger technology platforms	ITU-T	Published
ITU-T F.751.11 [33]	Performance test suite for distributed ledger technology systems	ITU-T	Published
ITU-T H.DLT-SAM [34]	Stability assessment methods for distributed ledger technology platforms	ITU-T	Under development
IEEE P2143.2	Standard for Cryptocurrency Payment Performance Metrics	IEEE	Under development
IEEE P2144.3	Standard for Assessment of Blockchain-based Internet of Things (IoT) Data Management	IEEE	Under development

3.2. Current status of blockchain evaluation standards in China

By the end of November 2023, there are 9 national standards related to blockchain under development and published in China [35], mainly from the National Technical Committee for Standardization of Blockchain and Distributed Ledger Technology (TC590) and the National Information Security Standardization Technical Committee (TC260), as shown in Table 8. Blockchain national standard related work in China started in 2017. On May 23, 2023, three Chinese blockchain national standards were released, which are *Blockchain and Distributed Ledger Technology-Reference Architecture* from TC590, *Information Security Technology- Security Specification for Blockchain Technology* and *Information Security Technology- Security Framework* from TC260 [36]. The three national standards released for the development of domestic block chain industry has important guiding significance. In addition, there is a national standard related to blockchain testing "Blockchain and Distributed Bookkeeping Technology System Test Specification" in the approval stage, the standard will provide effective reference and guidance for blockchain evaluation.

Table 8. Chinese National standards related to blockchain.

Standard encoding	Standard name	Technical committees	Standard status
GB/T 42752-2023 [37]	Blockchain and distributed ledger technology - Reference architecture	TC590	Published
20213310-T-469 [38]	Blockchain and distributed ledger technology - System testing specification	TC590	Being approved
20210929-T-469 [39]	Blockchain and distributed ledger technologies - Vocabulary	TC590	Being approved
20201612-T-469 [40]	Blockchain and distributed ledger technology - General service guidelines for preserve evidence	TC590	Being approved

Table 8. *Cont.*

Standard encoding	Standard name	Technical committees	Standard status
20201615-T-469 [41]	Blockchain and distributed ledger technology - Technical specification of smart contract lifecycle management	TC590	Being approved
20213307-T-469 [42]	Blockchain and distributed ledger technology - Application interface - Technical guidelines of middleware	TC590	Being approved
20221465-T-469 [43]	Information technology - Blockchain and distributed ledger technology - Guidelines for applications of logistic tracking services	TC590	Under development
GB/T 42571-2023 [44]	Information security technology - Security specification for blockchain information service	TC260	Published
GB/T 42570-2023 [45]	Information security technology - Security framework for blockchain technology	TC260	Published

By the end of November 2023, there are 32 local blockchain standards that have been registered, and 9 blockchain evaluation-related standards [46]. The blockchain evaluation-related standards are shown in Table 9. Among them, there are 6 local standards related to blockchain evaluation published by Hunan Province. From blockchain Detection standards have been proposed from different perspectives such as consensus security, contract security, network security, encryption security, application security and data security.

Table 9. Local standards related to blockchain evaluation.

Standard encoding	Standard name	Province	Standard status
DB32/T 4197-2022 [47]	Blockchain information system general testing specification	Jiangsu	Published
DB43/T 1838-2020 [48]	Information security technology – Evaluation requirements for blockchain consensus security technology	Hunan	Published
DB43/T 1839-2020 [49]	Information security technology - Evaluation requirements for blockchain contract security technology	Hunan	Published
DB43/T 1840-2020 [50]	Information security technology - Evaluation requirements for blockchain network security technology	Hunan	Published
DB43/T 1841-2020 [51]	Information security technology - Evaluation requirements for blockchain encryption security technology	Hunan	Published
DB43/T 1842-2020 [52]	Information security technology - Evaluation requirements for blockchain application security technology	Hunan	Published
DB43/T 1843-2020 [53]	Information security technology - Evaluation requirements for blockchain data security technology	Hunan	Published
DB52/T 1467-2019 [54]	Blockchain - System testing and selection specification	Guizhou	Published
DB61/T 1283-2019 [55]	Blockchain Security Assessment - Indicator system	Shanxi	Published

By the end of November 2023, there are 10 blockchain industry standards have been published, of which 5 standards related to evaluation or security as shown in Table 10, respectively in the cryptography, finance, and communication industries.

Table 10. Industry standards related to blockchain evaluation or security.

Standard encoding	Standard name	Industry sector	Standard status
GM/T 0122-2022 [56]	Cryptography test specification for blockchain	Cryptography	Published
GM/T 0111-2021 [57]	Technical requirements for blockchain cryptography application	Cryptography	Published
JR/T 0193-2020	Financial application of blockchain technology - Evaluation rules	Finance	Published
YD/T 3747-2020 [58]	Security requirements for blockchain technical architecture	Communication	Published
YD/T 4055-2022 [59]	Security Protection Requirements for Telecom Network and Internet Blockchain Infrastructure	Communication	Published

In recent years, there have been many blockchain-related group standards under research and published in China. By the end of November 2023, there are currently 180 blockchain group standards that have been published. Among them, 103 standards related to blockchain evaluation, which including 44 group standards for blockchain technology, 51 standards for blockchain application specifications, and 7 standards for blockchain enterprise and talent evaluation, and 1 group standard for blockchain service capabilities [60]. Statics of standards related to blockchain evaluation is shown in Figure 1. In Figure 1, the horizontal axis represents the category of blockchain evaluation standards, and the vertical axis represents the number of standards.

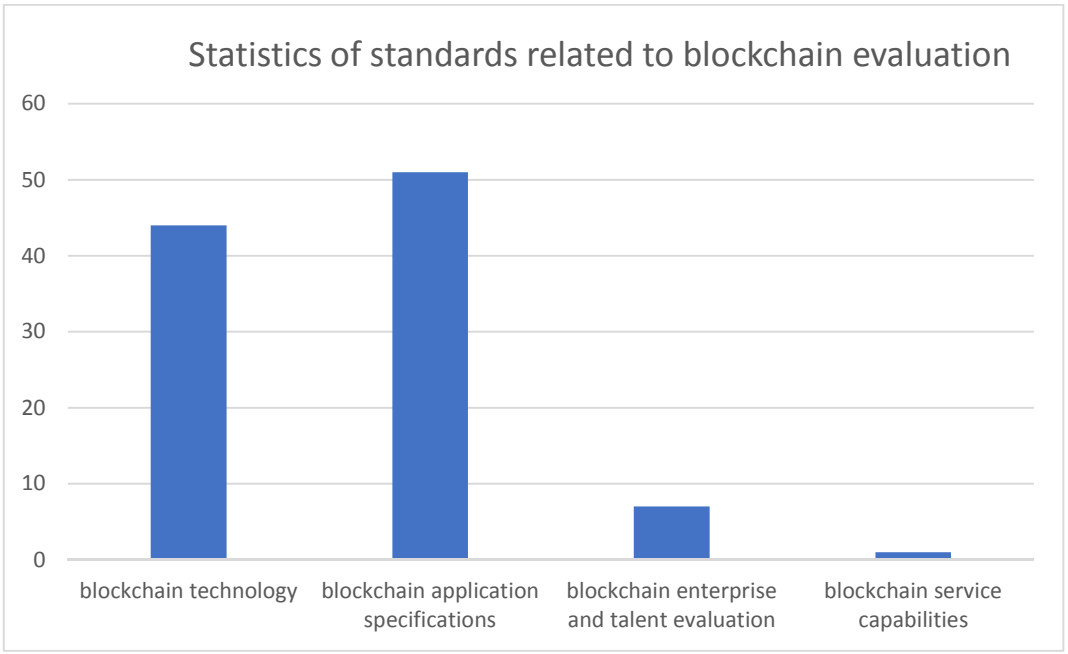

Figure 1. Statistics of standards related to blockchain evaluation.

In addition to the classification and statistics of evaluation criteria, it can be found that the more active blockchain group standards alliances mainly include Jiangsu Internet Association, China Electronics Industry Standardization Technology Association, China Communications Standards Association, China Software Industry Association, Shanghai Blockchain Technology Association and Guangdong Food Circulate Association. The statistics of the contribution capabilities of top 8 group organizations is shown in Table 11.

Table 11. Statistics of the contribution capabilities of top 8 group organizations.

Institute	Standard number
Jiangsu Internet Association	blockchain technology 7
	blockchain application specifications 5
China Electronics Industry Standardization Technology Association	blockchain technology 6
	blockchain application specifications 5
China Communications Standards Association	blockchain technology 9
China Software Industry Association	blockchain technology 4 blockchain enterprise and talent evaluation 1
Guangdong Food Circulate Association	blockchain application specifications 5
Shanghai Blockchain Technology Association	blockchain technology 3
	blockchain enterprise and talent evaluation 2
Jiangsu Software Industry Association	blockchain technology 1
	blockchain application specifications 2
	blockchain enterprise and talent evaluation 1
The Shenzhen Commercial Cipher Industry Association	blockchain technology 4

4. Blockchain evaluation tools and methods

4.1. Difficulties and challenges of blockchain evaluation

The reason why there are many difficulties and challenges in blockchain evaluation lies in the characteristics of the blockchain itself. The essence of blockchain is a distributed, decentralized database that integrates multi-disciplinary fields such as computer science, distributed storage, cryptography, mathematics, consensus mechanisms, smart contracts, and network security [61,62]. The difficulties and challenges of blockchain evaluation mainly include the following aspects:

(1) The complexity and diversity of blockchain technology [63]. Different blockchains involve different components, protocols and algorithms. Different components, protocols and algorithms are constructed differently based on the usage scenarios and advantages and characteristics of each component when creating a blockchain platform, which creates the functional differences, performance differences and architectural differences. The skill requirements of blockchain testers are also very high. Only testers have a comprehensive understanding of the overall development of the blockchain and have the ability of accurately analysis of different blockchain platforms, can they develop accurate, applicable, fair and objective test strategies and evaluation standards.

(2) Multiple factors influence the performance of blockchain systems [64]. To test the performance of blockchain systems needs to measure multiple factors, including the complexity of the distributed environment, the diversity of consensus algorithms, the complexity of smart contracts, the number of concurrent transactions, and the storage scale, the execution efficiency of algorithm encryption and decryption, the difference of network topology structure, the limited resources of the test environment, *etc.* The objective existence of many factors makes it difficult to completely unify the standards for blockchain performance evaluation, and also makes the performance testing of blockchain systems very complex and challenging.

(3) Blockchain system security has a wide range [65]. The scope of blockchain system security testing is broader than traditional security testing, including smart contract security, consensus algorithm security, privacy and identity verification, computing power attacks, network communication security, and social engineering attacks, *etc.* Smart contract security and consensus algorithm security are the top priorities in blockchain system security testing. Due to the language diversity of smart contracts, differences in writing and execution in different blockchain systems, business complexity and flexibility, it increases the difficulty of security testing for smart contracts. The consensus algorithm of the blockchain system is used to ensure data consistency [66]. Vulnerabilities in the consensus algorithm may lead to double-spending attacks and forking problems. Blockchain testers need to have a comprehensive understanding of different consensus algorithms and master the fault tolerance range of different consensus algorithms in order to complete security verification of different consensus algorithms.

(4) Interoperability of blockchain systems. With the widespread application of different blockchain systems, sharing and collaboration between blockchain systems has become one of the current important tasks. Interoperability testing between blockchain systems involves the interaction of different blockchain platforms, networks and protocols. Therefore, interoperability testing of blockchain systems also faces a series of challenges [66]. Interoperability testing needs to deal with the differences at many different levels between different blockchain platforms, including differences in smart contract languages and virtual machines, diversity of network protocols, differences in data formats and communication standards, differences in consensus algorithms, differences in security requirements during data transmission, data writing and governance under different data governance frameworks, *etc.*

(5) Difficulties in simulating the blockchain system test environment. It is difficult to meet the diversity and real-time requirements of the real environment when constructing a realistic environment to simulate actual application scenarios for blockchain system testing.

Therefore, when designing and developing blockchain testing tools, it is necessary to consider the universality, scalability, and maintainability of the tools, but this requires overcoming many challenges for evaluation tool developers and testers.

4.2. Current status of blockchain assessment tools

With the rapid development and widespread application of blockchain technology, many blockchain testing tools have emerged at home and abroad, mainly smart contract testing and blockchain performance testing tools, but there is a lack of general functional testing tools. Blockchain performance testing tools are shown in Table 12.

Table 12. Statistics of blockchain performance testing tools.

Name	Open source	Testable blockchain types
Hyperledger Caliper [68]	Yes	Hyperledger Besu Hyperledger Burrow Ethereum Hyperledger Fabric FISCO BCOS Hyperledger Iroha Hyperledger Sawtooth
Hyperbench	Yes	Hyperchain Fabric,etc.
TrustedBench	No	All blockchain system which implements 9 general interfaces it needs.

These blockchain performance testing tools are currently known to provide the ability to evaluate the blockchain base performance, with evaluation metrics including throughput, delay, resource consumption, success rate, and so on. Hyperledger Caliper is a part of the Hyperledger project, which allows users to customize test cases through plugins to test different blockchain solutions and obtain a set of performance test results [69]. Hyperbench is a blockchain performance testing tool independently developed by Hangzhou Qulian Technology Co., Ltd. It is mainly divided into four major functions: transaction sending, data statistics, resource monitoring, and report generation [70]. It allows users to conduct stress testing according to the set growth value within the set range. Users can also choose to use the dichotomy method to explore the best performance of the system. In addition, it also supports users to conduct distributed testing. Trustedbench is a tool designed for the performance testing of trusted blockchain evaluation, developed by China Academy of Information and Communications Technology. It supports clustered deployment, provides a graphical user configuration interface, uses the HTTP protocol to realize transaction sending and report generation [71].

Compared with blockchain performance testing tools, smart contract security testing tools are more diverse and mostly open source. The smart contract security testing tools are shown in Table 13.

Table 13. Statistics of smart contract security testing tools.

Name	Open sources	Smart contract	Feature
Mythril [72]	Yes	Solidity,Vyper	Static analysis; Dynamic analysis; Generate report; Automated security detection;
Securify [73]	Yes	Solidity	Static analysis; Dynamic analysis; Generate report; Setting Rules and Alert; Automated security detection;
Slither [74]	Yes	Solidity	Static analysis; Automated security detection; Draw the contract inheritance topology diagram and the contract method call relationship diagram;
Oyente [75]	Yes	Solidity	Static analysis; Automated security detection;
Mainticore [76]	Yes	Solidity, Vyper	symbolic execution;
Ethersplay	Yes	Solidity	Reverse analysis;
Maian	Yes	Solidity	Dynamic analysis; Automated security detection;
TeEther [77]	Yes	Solidity	Static analysis; Automated security detection;
Sereum [78]	No	Solidity	Dynamic analysis; Automated security detection;
ContractFuzzer [79]	Yes	Solidity	Dynamic analysis; Automated security detection;
Reguard [80]	No	Solidity	Dynamic analysis; Automated security detection;
ILF [81]	No	Solidity	Dynamic analysis; Automated security detection;
Vandal [82]	Yes	Solidity	Static analysis; Automated security detection;
Smartcheck [83]	Yes	Solidity	Static analysis; Automated security detection;
ContractGuard [84]	Yes	Solidity	Dynamic analysis; Automated security detection;
SaferSC [85]	Yes	Solidity	Automated security detection;
Rechecker [86]	Yes	Solidity	Automated security detection;
DR-GCN [87]	Yes	Solidity	Automated security detection;
TMP	Yes	Solidity	Automated security detection;
ContractWard [88]	No	Solidity	Automated security detection;
ZEUS [89]	No	Solidity	Static analysis; Automated security detection; Formal verification;
Vaas [90]	No	Solidity	Automated security detection; Formal verification

According to table statistics, it can be found that security testing tools for smart contracts can basically implement automated vulnerability detection. In terms of smart contract language support, they all support Solidity, and only a small part of them supports other languages such as Vyper. Mythril, Securify, and Slither provide richer functions. From the perspective of the types of vulnerability detection support, there is currently no smart contract security testing tool that can fully support 15 types of smart contract vulnerabilities in the Solidity code layer, EVM execution layer, and blockchain system layer. Among them, Security, ContractGuard, Myshril, Smartcheck, and Vaas support a relatively comprehensive range of vulnerability types. Overall, Securify and ContractGuard perform relatively well, and their vulnerability detection capabilities at three levels are relatively impressive [91]. The statistics of vulnerabilities detectable of relevant tools as shown in Figure 2. In Figure 2, the

horizontal axis represents the name of smart contract detection tools, and the vertical axis represents the number of vulnerabilities.

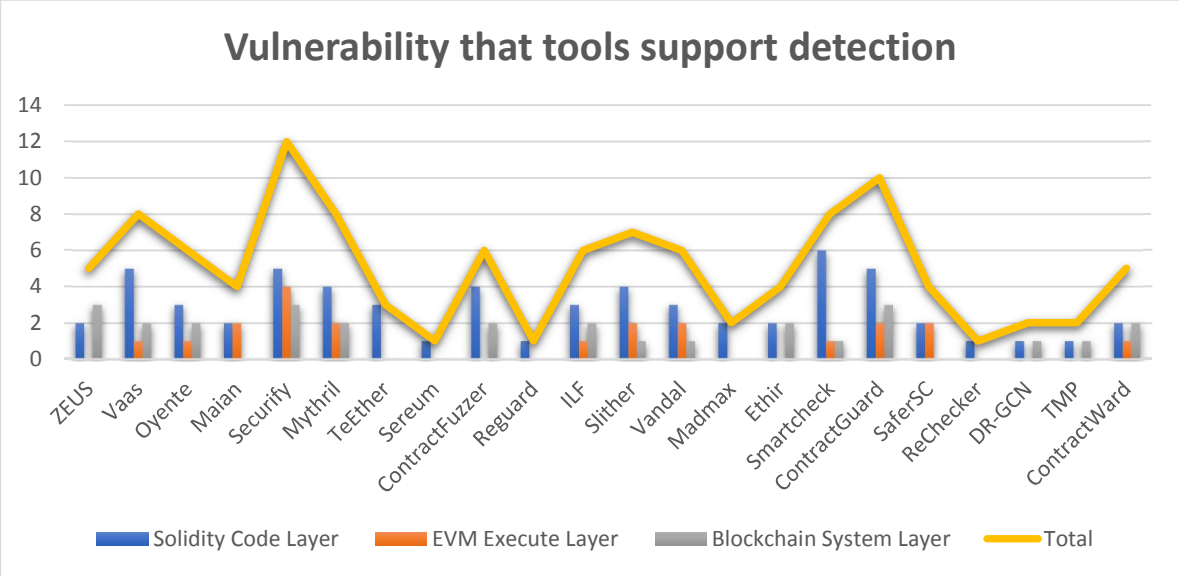

Figure 2. Statistics of vulnerabilities detectable of relevant tools.

The above is an analysis of performance testing tools and smart contract testing tools in blockchain evaluation. Currently, due to the complexity of blockchain technology, the diversity of blockchain types, the differences in network architecture, *etc.*, it is difficult to build a universal blockchain function testing tools and testing standards. In function testing of blockchain, manufacturers follow their own testing tools and methods which they have developed. Currently, there are no universal functional testing tools and method interfaces. In general, the development of blockchain evaluation tools and methods is still in its early stages, and more in-depth research and improvements are needed in terms of versatility, evaluation standards, simplification of evaluation methods, and actual environment simulation [92].

5. Analysis and outlook on the current status of blockchain evaluation

5.1. Analysis of the current status of blockchain evaluation

Based on the analysis of blockchain evaluation institutions, blockchain evaluation standards and the current status of blockchain evaluation tools, this article summarizes the following key points:

(1) Blockchain evaluation in China has reached a scale. With the rapid development of blockchain technology, the blockchain evaluation industry in China has gradually formed a scale [93]. More and more evaluation institutions and blockchain companies have begun to focus on the evaluation and testing of blockchain projects, providing strong support for the development of the blockchain industry. This large-scale evaluation activity helps promote the maturity and credibility of blockchain technology.

(2) Blockchain evaluation extends from the technical level to the product application level. With the policy support of the country and various government departments, the application of blockchain continue to be implemented in various industries. Blockchain evaluation is no longer limited to underlying technologies such as function, performance, and security. Blockchain application evaluations for different industries have begun to appear, such as finance, government affairs, energy and carbon, *etc.* The expansion from technical to application demonstration marks the gradual improvement of the domestic blockchain evaluation ecosystem.

(3) The grading standards for blockchain evaluation have emerged. At present, the technology of blockchain has gradually matured, and most blockchain products can meet the basic evaluation requirements. A single evaluation standard can no longer meet the needs of blockchain enterprises and users. In order to evaluate the technical capabilities of different blockchain products, some blockchain standards and evaluation institutions have developed blockchain grading standards. Based on the differences of functional completeness, performance efficiency, security and other capabilities of blockchain products, blockchain products are classified into basic level, professional level, or enhanced level, distinguishing the ability level of blockchain products and providing reference for blockchain users to choose blockchain products.

(4) The autonomy and controllability of blockchain technology have become a trend. Some evaluation agencies have launched information and innovation evaluations for blockchain, which evaluates the independent reliability of blockchain products from aspects such as the degree of self-research of blockchain codes, compatibility with domestic software and hardware, and national secret algorithms. The evaluate can help select blockchain products and applications that meet the needs of special industries such as finance, government, and military industry.

5.2. Shortcomings and prospects

Currently, the evaluation ecosystem of the blockchain industry has gradually formed, but there is still some room for improvement.

(1) The implementation of blockchain evaluation standards needs to be strengthened. At present, blockchain standard organizations are relatively active and have published a lot of blockchain testing, application specifications and evaluation standards, but there are very few standards that are used by evaluation institutions. The practicality and implementation of blockchain evaluation standards should be improved to provide effective reference and guidance for blockchain enterprises, users and evaluation institutions when conducting blockchain technology and application testing.

(2) Blockchain evaluation tools still need to be improved. Although some progress has been made in the development of blockchain evaluation tools, there is still room for improvement. Due to the complexity, diversity and rapid development of blockchain technology, more efficient and comprehensive tools are needed to evaluate the functional

perfection, security, performance and reliability of the blockchain system. Further improving and innovating blockchain evaluation tools is a key step in improving the quality of blockchain systems.

(3) The development of international standards related to blockchain evaluation needs to be followed up. At present, the specific international standards for blockchain evaluation are still limited. With the rapid development and widespread application of blockchain technology, international standardization organizations and relevant institutions should accelerate the formulation of standards and frameworks suitable for blockchain evaluation. This will help to uniformly evaluate and compare the quality of blockchain projects and promote cooperation and development on a global scale.

(4) It is necessary to strengthen the training of blockchain evaluation talents. With the increasing demand for blockchain assessment, cultivating professional blockchain evaluation talents has become crucial. It is necessary to strengthen the education and training of blockchain assessment personnel and provide systematic blockchain assessment knowledge and skills training. At the same time, it is recommended that academia, industry organizations and blockchain companies cooperate to jointly promote the cultivation of blockchain assessment talents to meet the needs of the industry and promote the sustainable development of blockchain technology.

6. Conclusion

Blockchain evaluation is an important means to measure the quality, reliability, and security of the block system. It is also an important part of the healthy development of the blockchain ecosystem. With the development and application of blockchain, blockchain evaluation has made certain progress. It not only has a certain scale in China, but also provides strong support for the development of the industry. However, the development of the blockchain evaluation industry still faces problems and challenges that need to be solved urgently. In terms of standard formulation for blockchain evaluation, the development of international blockchain evaluation standards requires increased investment. It is necessary to accelerate the development of standards and frameworks suitable for blockchain evaluation to promote cooperation and development on a global scale. In terms of the development of evaluation tools, it is necessary to improve the universality and scalability of evaluation tools to adapt to different blockchain system evaluation needs. In terms of blockchain evaluation methods, continuous innovation and improvement are needed to cope with the evolving blockchain technology and application scenarios. In addition, strengthening the training of blockchain evaluation talents is the key to the sound development of the blockchain evaluation system. It is necessary to carry out precise education and training for blockchain evaluation, thereby accelerating the cultivation of professional blockchain evaluation talents to meet industry needs and promote Sustainable development of blockchain technology.

Acknowledgments

This work was funded by the National Key Research and Development Program of China with grant number 2022YFB2703200 and Zhejiang Digital Economy (Blockchain) Provincial Standardization Major pilot Project.

Conflicts of interests

All authors declare that there is no conflict of interest.

Authors' contribution

Conceptualisation, X.C.; Investigation, P.Z., M.H.; Writing - original draft, P.Z., M.H.; Writing - review & editing, P.Z., M.H.; Project administration, X.C., H.Y.; Supervision, X.C., H.K.; All authors have read and agreed to the published version of the manuscript.

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