Blockchain Technology and Its Transformative Impact on Library Development: Postprint

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Date: 2023-08-27T00:00:00+00:00

Abstract

[Purpose/Significance] This paper elucidates the development background of blockchain technology. Based on an analysis of its three major technical characteristics—decentralization, data reliability, and automation, it summarizes the transformative impact of blockchain technology on libraries by drawing upon practices and research findings from the American library community and academia, thereby proposing strategies for Chinese libraries to respond to the blockchain technology transformation. [Method/Process] The study employs literature research and comparative analysis methods. First, from the resource dimension, it analyzes the impact of blockchain technology on the establishment of novel library metadata systems, digital resource rights confirmation, and resource sharing. Second, from the service dimension, it examines the influence of blockchain technology on traditional library circulation services, research services, and service performance evaluation. [Results/Conclusion] The Chinese library community lags significantly behind foreign counterparts in areas such as the formulation of blockchain technology application standards for libraries. However, based on the current technical capabilities of China's internet enterprises and the vigorous development of the blockchain industry, the Chinese library community possesses a late-mover advantage in applying blockchain technology. Therefore, Chinese libraries should strengthen connections with internet enterprises, blockchain technology companies, and relevant upstream and downstream industries, actively apply blockchain technology, develop related software applications and practical activities, continuously improve their service content and quality, and actively embrace the transformation brought by blockchain technology.

Full Text

ChinaXiv Partner Journal, Vol. 62, No. 13, July 2018

The Reformative Effect of Blockchain Technology on Library Development

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Abstract

[**Purpose/Significance**] This paper introduces the development background of blockchain technology and, based on an analysis of its three major technical characteristics—decentralization, data reliability, and automation, summarizes the transformative impact of blockchain on libraries according to practices and research findings from American libraries and academic communities, thereby proposing countermeasures for Chinese libraries to address this technological transformation.

[**Method/Process**] This study employs literature review and comparative analysis. First, from the resource dimension, it analyzes blockchain technology's influence on libraries regarding the establishment of new metadata systems, digital resource rights confirmation, and resource sharing. Second, from the service dimension, it examines the impact on traditional library services such as circulation, research services, and service performance evaluation.

[**Result/Conclusion**] Chinese libraries lag far behind their foreign counterparts in formulating application standards for blockchain technology in libraries. However, given the current technological capabilities of Chinese internet enterprises and the booming blockchain industry, Chinese libraries possess late-mover advantages in adopting blockchain technology. Therefore, Chinese libraries should strengthen connections with internet enterprises, blockchain technology companies, and related upstream and downstream industries, actively apply blockchain technology, conduct relevant software application and practical activities, continuously improve their service content and quality, and embrace the blockchain technology revolution.

Keywords: blockchain; libraries; service transformation
DOI: 10.13266/j.issn.0252-3116.2018.13.002

1. Development Background of Blockchain Technology

Blockchain technology, also known as distributed ledger technology, represents an innovative application model in the internet era based on distributed data storage, peer-to-peer transmission, consensus mechanisms, and cryptographic algorithms. Essentially, blockchain can be understood as an open ledger based on computer programs that independently records all transactions occurring on the chain. Each node in the system can update its recorded data to the network, and every participating maintenance node can obtain a complete copy of the database, forming a decentralized distributed data structure that enables peer-to-peer transactions and interactions without third-party intervention.

In terms of actual development scale, more than 21 countries worldwide have invested in or explored blockchain. It is predicted that by 2025, 10% of global GDP will be stored using blockchain technology. The McKinsey report identifies blockchain as the core technology with the potential to trigger the fifth wave of disruptive revolution following the steam engine, electricity, information technology, and internet technology. Blockchain provides a new type of social trust mechanism, laying a new foundation for the development of the digital economy and heralding new directions for industrial innovation and public services.

Currently, blockchain has demonstrated significant benefits in optimizing business processes, reducing operational costs, and improving collaborative efficiency. Based on this, the domestic library community has actively explored the possibility of applying blockchain technology to library operations, with American libraries leading these efforts. In November 2017, the U.S. government allocated $100,000 to the Institute of Museum and Library Services (IMLS) to explore blockchain applications in library digital management, with San Jose State University as the main implementing institution. The project has assembled over 20 experts from libraries, blockchain technology, and urban planning, focusing on using blockchain to advance library services to achieve urban or community goals. Additionally, the American Library Association (ALA) designated “Blockchain & Possibilities for Libraries” as a key topic at its Computers in Libraries 2018 conference in April 2018. Several libraries, including San Jose State University Library, have begun practical explorations of blockchain applications.

At the research level, ALA has listed blockchain as a transformative technology for future libraries and has recently initiated related research activities. Building on the aforementioned U.S. government funding, San Jose State University has also established “LibChain,” a blockchain library application platform on GitHub, which has attracted technical personnel from research institutions including Cornell University and uploaded relevant blockchain software modules and materials. The platform’s current main research direction is applying blockchain technology to build a distributed library environment. Scholars such as Matthew Bey and Tara Brigham have also published research papers on applying blockchain technology in specialized libraries like medical and law li-

braries. As blockchain technology continues to mature, the trend of researching its library applications will continue to heat up, and blockchain's transformative impact on libraries is gradually becoming reality. Therefore, studying how blockchain technology affects libraries and influences their development direction and path based on current research findings and cases holds important theoretical and practical significance as the transformation arrives.

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2. Analysis of Blockchain Technology Characteristics

Blockchain works by having any number of nodes in the system use cryptographic algorithms to calculate and record interaction data within a certain period into a block, generating a digital fingerprint (hash function) of that block to link to the next block for verification. All participating nodes in the system jointly verify the authenticity of the records. Each data block consists of a block header and a block body. [Figure 1: see original paper] briefly illustrates the basic architecture of a block.

The block header stores various information for connecting to the previous block, verification information, and timestamps. It mainly includes: block number, address of the previous block, hash value of the previous block (used to establish a one-to-one mapping relationship between this block and the previous block, forming an interlocking chain), a random number for verifying proof-of-work difficulty (generated randomly and requiring corresponding computing power, such as Bitcoin mining), a timestamp (for recording the specific time when data is stored in this block), and a total Merkle tree hash for verifying block transactions. The block body mainly includes the Merkle tree hash (excluding the root, which is stored in the block header), which records the key array of various stored information in this block. Clients must obtain the password to access specific data stored in the block.

Based on this, all blocks in a blockchain application are linked in chronological order to form a complete chain. This single chain can gradually add blocks; when a new block is created, it is appended after the last block, while the single block can also trace back all transaction information to ensure security and reliability.

Therefore, blockchain can be understood as an open ledger based on computer programs that independently records all transactions occurring on the chain. Each node in the system can update its recorded data to the network, and every participating maintenance node can obtain a complete copy of the database, forming a decentralized distributed data structure that enables peer-to-peer transactions and interactions without third-party intervention.

Based on the above technology, blockchain exhibits three major characteristics:

(1) Decentralization. Encrypted data on the blockchain is distributed across all computer terminals connected to the blockchain, rather than being centrally

stored on a single server as in traditional models. In traditional centralized databases, customers must conduct business activities around intermediary organizations, making direct business relationships difficult. Blockchain does not require a central authority or intermediary to store data; each terminal device can be considered a node, and each node maintains a complete blockchain ledger. Accessing any node allows viewing all transaction information. After blockchain updates transaction information, all nodes on the chain synchronize the relevant data simultaneously, achieving decentralization. See the comparison between [Figure 2: see original paper] and [Figure 3: see original paper].

(2) Data Reliability. First, through cryptography, timestamps, and other technologies, the data code on the blockchain is unique to objective factual data code. Second, nodes with maintenance functions on the blockchain jointly perform maintenance work according to consensus mechanisms to verify the authenticity of data on the chain. When individual nodes on the blockchain contain errors, fraud, or tampering, as long as the majority of nodes are correct (51% for Bitcoin), the minority obeys the majority, and the authenticity and accuracy of the entire blockchain ledger remain unaffected. Finally, transaction data generated by any node on the blockchain network must be confirmed by other nodes on the chain to be effectively incorporated into the entire blockchain. Therefore, blockchain ensures data security and reliability with the support of cryptography and consensus mechanisms.

(3) Automation. Blockchain adopts publicly agreed-upon protocols or algorithms (such as a set of publicly transparent mathematical algorithms) that enable all nodes in the system to automatically and securely exchange data in a "trustless" environment without any human intervention. Programmable code built on blockchain is called smart contracts, which are automatically executed by machines when trigger conditions are met without manual intervention.

Additionally, blockchain system information and operation rules are highly transparent, with data open to nodes within the system. The system program is open-source, attracting more institutions and individuals to participate in operations through open-source communities, thereby forming network effects and rapid collaborative development. Of course, blockchain can also protect personal privacy through encryption technology. Since nodes establish mutual trust through encryption technology and tamper-proof mechanisms, only interaction information needs to be open, while nodes themselves do not need to disclose their identities, allowing transactions to be completed anonymously.

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3. Transformative Impact of Blockchain Technology on Libraries

The three characteristics of decentralization, data reliability, and automation are not unique to blockchain technology; however, blockchain is currently the only technology that can efficiently integrate these three features. For example,

traditional server data storage and access models can achieve data reliability and automation but cannot achieve decentralization. Peer-to-peer (P2P) technology can achieve decentralization and automation for digital resource sharing but cannot achieve data reliability (data rights confirmation). The combination of these three characteristics enables society to efficiently possess the prototype of a "trustworthy internet." For libraries, the decentralization characteristic transforms libraries' traditional historical status as "information provision and preservation" centers; the data reliability characteristic liberates libraries from traditional data storage, provision, and application models; and the automation characteristic further improves library work efficiency and greatly enhances resource utilization efficiency. Based on this, blockchain technology integrating these three features is disruptive for libraries. The following analysis examines the transformative impact of blockchain technology on libraries from both resource and service dimensions.

3.1 Blockchainization of Library Resources

(1) Blockchainization of Metadata Systems. The blockchainization of metadata systems may be the most disruptive transformation in the library field. As is well known, libraries are comprehensive information repositories containing various types of information metadata, both paper-based and electronic. Querying this data requires searching through specific databases, which was the purpose of establishing the Online Computer Library Center (OCLC). OCLC organically connects metadata systems of libraries worldwide. However, OCLC still follows the traditional center-client service model, maintaining a massive central database system. Moreover, OCLC's information update speed can only achieve daily updates, which still lags far behind higher demands for real-time information updates.

If all library metadata systems were connected in blockchain form, there would be no need for an organization like OCLC, because blockchain itself is decentralized. All nodes (information sources) on the chain completely record information from all nodes. Traditional data disaster recovery centers and other infrastructure would become completely meaningless. After metadata updates, through chain information transmission, almost all nodes can be notified quickly, achieving real-time metadata updates. The blockchainization of metadata systems makes information storage more secure (equivalent to each node being a disaster recovery center) and retrieval and update speeds faster. Based on this, researchers have proposed the concept of OCLCBlockChain, and OCLC has recently responded positively to this idea. Simultaneously, blockchainization of metadata systems can further save libraries' information systems and human resource expenses, as library management of information resources can be entirely achieved through blockchain without purchasing IT servers or establishing storage systems.

(2) Blockchainization of Digital Resource First-Sale Rights. The first-sale rights of digital resources have always been the most concerned research

area in the entire information publishing field. Currently, most digital resources (such as electronic book editions, audio-visual electronic editions) are distributed through digital resource distributors, which have monopolistic positions that are unfavorable to both readers and authors. Taking Amazon as an example, as the world's largest digital resource owner and distributor, through the Kindle terminal, subscribers must pay monthly fees ranging from $11.99, and users must pay for bundled digital resources as a whole package. Additionally, users cannot borrow more than one e-book per month from other users. On the author side, digital resource authors may pay up to 50% of the sales price to Amazon.

The reason the traditional digital resource distribution model can exist is that a powerful "rights confirmation" institution must certify the first-sale rights of digital resource authors. Distributors like Amazon act as "rights confirmation" authorities, and the trust cost of this "rights confirmation" is enormous. Blockchain breaks this monopolistic existence. On the blockchain, digital resource "rights confirmation" is jointly completed by all nodes on the chain. The first-sale rights of each digital resource can be guaranteed through blockchain's smart contract mechanism and can flow freely, just like physical book lending between independent individuals in the real world. Furthermore, blockchain technology can authenticate works, provide certification services, ensure the authenticity and uniqueness of ownership, record subsequent transactions in real-time, achieve full lifecycle management of the cultural and entertainment industry, and serve as technical guarantees in judicial evidence collection. Digital certification can ensure data integrity and consistency, protecting intellectual property rights.

Libraries' purchase of digital resources can directly achieve a "library-author" direct purchase model through blockchain without any third-party participation. Libraries act as agents for joint resource purchase for readers, effectively becoming "group purchase" agents for different digital resources, and can provide free lending to all readers in a non-profit manner. This model not only saves libraries' digital resource purchase costs but also enables point-to-point purchases based on reader needs rather than traditional bundled purchases. This represents a major transformation for libraries. For example, libraries can individually purchase digital first-sale rights for single documents directly from scientific literature (book) authors or journal publishers, and this purchase is real-time without needing to establish contracts and other cumbersome procedures.

Currently, blockchain applications based on digital first-sale rights are flourishing, such as the DECENTGO product. Created by the Swiss DECENT Foundation in 2015, DECENTGO is an open-source, non-profit digital content distribution protocol that uses blockchain technology to ensure security and trust. The platform operates independently and is open free of charge to creative individuals, copyright authors, self-media creators, publishers, fans, and all users with such needs, committed to reshaping the digital content distribution platform for the online publishing industry. The DECENTGO BLOCKCHAIN APP ap-

plication has already launched (http://blog.decent.ch/), and several libraries and institutions at home and abroad have begun DECENTGO BLOCKCHAIN applications (see [Figure 4: see original paper]). Meanwhile, platforms like UjoMusic have established new models for music copyright management platforms using blockchain, allowing song creators and consumers to establish direct connections and eliminating middleman commission fees. It can be expected that libraries will achieve major transformations in purchasing, lending, and managing digital resource first-sale rights by relying on blockchain technology.

(3) Blockchainization of Resource Sharing. Since China promulgated the "National Book Coordination Scheme" in 1957, resource co-construction and sharing among regional libraries has been emphasized by the library community, with many libraries and related institutions conducting beneficial explorations and practices, but with limited success. Apart from conceptual issues, technical management systems, funding support, and physical space distance are the three main factors hindering resource sharing.

- **Technical Management Systems.** Taking the resource sharing practice among multiple university libraries in Guangzhou University City as an example, 10 university libraries use 5 different library management systems (see). If the regional scope expands, system differences become more pronounced. These systems mostly adopt a center-client model, with different centers having various differences in authority management, making library resource sharing difficult to achieve. As mentioned above, after metadata system blockchainization, unified standards for resource and data management may be realized at the metadata level, fundamentally breaking the inconsistency among different library data management systems and laying the foundation for library resource sharing and even resource procurement and co-construction. With the formation of OCLC blockchain, resource sharing will not be limited to specific regions but can extend to global library resource sharing and co-construction.
- **Funding Support.** Traditional library resource sharing requires considerable funding to integrate different libraries' resource systems and technical systems, and the funding input and benefit distribution mechanisms among different libraries are unclear. A major advantage of blockchain-based library resource sharing systems is the ability to greatly reduce funding investment. Libraries may not even need to purchase resource management systems but simply operate according to protocols on the blockchain, 可以说几乎是零成本.
- **Physical Space Distance.** The physical space distance problem arises partly because resources must be "returned to their original location," meaning resources must return to "their 归属的图书馆 (center)" for processing before being used by the next requester—this is the traditional center-client model. Imagine that when a book's ownership is confirmed, its physical location is unimportant, and its circulation among different requesters does not necessarily require approval from the owning library.

Taking book resource blockchain as an example, book B1 belongs to library L1, but the physical entity of B1 can remain in library L2 or L3 without needing to be returned to L1. Moreover, inter-reader lending can achieve book circulation between readers as long as the lending party is confirmed through blockchain, without needing to return the book to library L1 first. This transforms traditional library lending services (discussed in detail in the next section). This transformation greatly reduces the physical space distance barrier to library resource sharing.

3.2 Blockchainization of Library Services

(1) Blockchainization of Traditional Circulation Services. Traditional circulation services mainly rely on libraries as the central hub (see [Figure 5: see original paper]), giving libraries significant control over book circulation but also hindering rapid book flow and turnover. Based on this, distributed library lending services (forming lending networks among readers without library participation) have gradually emerged globally, such as the Distributed Library Project (DLP) in San Francisco communities (see [Figure 6: see original paper]) and decentralized lending services (reader-to-reader lending networks based on authentication). The author previously published an analysis of these three services, concluding that decentralized lending services represent the future development trend. In decentralized lending services, libraries only act as resource providers and ordinary "reader" roles; inter-reader lending services do not require library participation but only mutual authentication between parties, which can be implemented after library confirmation.

Blockchain technology enables libraries to further shed their role as confirmation authorities. Authentication between readers can be real-time known by everyone in the entire network (including libraries), and this authentication is cryptographically confirmed, with neither party able to deny it. This blockchain-based decentralized lending service model (see [Figure 7: see original paper]) greatly reduces library resource input, eliminates many procedures such as book re-registration, shelving, and management, and accelerates book circulation, representing one of the major transformations blockchain brings to traditional library services.

(2) Blockchainization of Research Services. Research services are important service content for libraries, especially professional and academic libraries. Services such as publication and citation retrieval are important value manifestations of libraries serving researchers. With the development of blockchain technology, academic blockchainization is spreading globally. For example, Elsevier has initiated blockchain technology trials, and companies like Google and Microsoft have also launched academic blockchain application explorations. After paper blockchainization, papers and information about authors, institutions, funding sources, etc., construct blockchain information nodes. Institutions, individuals, or other organizations worldwide can quickly obtain information about each person's and each institution's papers through blockchain, and this infor-

mation is updated in real-time. Once a paper is accepted or published, full-chain authentication can be achieved in the blockchain. Furthermore, some U.S. research funds have recently explored blockchainization of research projects. Once academic blockchainization becomes a global consensus, library research services such as citation retrieval will become worthless and may even threaten services like novelty searches, further weakening the value of library services—a major challenge to library research services.

(3) Blockchainization of Service Performance Evaluation. Library service performance evaluation data mainly comes from two sources: first, libraries themselves provide relevant data, including resource procurement quantity, resource usage, service population scale, and social benefits; second, through third-party independent surveys, such as reader satisfaction surveys and institutional service capability assessments. Although the above evaluation data are relatively mature, they still have certain gaps from truly reflecting library service performance. The first method's performance data, being provided by libraries themselves, is difficult for governments and the public to trust completely. The second method, being conducted by third-party institutions, cannot fully reflect all aspects of library service performance in terms of survey scale and depth. Therefore, how to establish a new library service performance evaluation method has become an important issue.

As analyzed above, blockchain technology introduction enables libraries to establish metadata-level management systems. From the blockchain, every social entity can real-time understand libraries' usage of every book, every document, and every digital video resource, including data such as book exchange lending volume and video viewing volume that can be easily obtained by blockchain nodes. Furthermore, data on library reader visits and reading (workspace) usage can also be blockchainized, making all library operations transparent and open. Governments can even provide precise support based on these metadata-level data on the blockchain, and society can better understand the precise use and effectiveness of government funding for libraries.

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5. Countermeasures for Chinese Libraries to Address Blockchain Technology Reform

(1) Join the International Standard-Setting Process for Library Blockchain Technology Applications. From the current application of blockchain in libraries, standard formulation is still in its infancy, with no international standards yet for data formats, smart contract standards for data rights, rights transfer standards, or authentication protocols between nodes. However, it is worth noting that the American library community has already taken action in this regard. At the Computers in Libraries 2018 forum held in the U.S. in April 2018, discussions on blockchain service standards for libraries were one of the main topics. Meanwhile, the OCLC blockchain research

group has also recently initiated research on standard formulation. Since the formulation of library blockchain application standards involves a wide range and has significant impact on global libraries, Chinese libraries should join this process to fully express Chinese libraries' needs for blockchain technology. Additionally, regarding the protection of intellectual property rights such as digital resource first-purchase rights, Chinese libraries should also propose China's opinions on library blockchain application standards based on current national conditions.

(2) Strengthen Blockchain Application Exploration with Chinese Internet Enterprises. By the end of 2016, nearly 100 blockchain-related companies had emerged in China, with many representative enterprises appearing. Influenced by blockchain alliances such as R3 and Hyperledger, Chinese internet enterprises have gradually formed blockchain application alliances. On January 5, 2016, China's first blockchain alliance, the "China Blockchain Research Alliance," was established in Beijing. On April 19, 2016, the China Ledger Alliance (ChinaLedger) was announced. These signs indicate that Chinese enterprises, especially internet enterprises, already possess the technological and industrial foundation for large-scale blockchain industry applications. As the main purchaser of information resources in China, libraries should strengthen blockchain exploration cooperation with Chinese internet enterprises. This can compensate for their own weak technological foundation and, through funding and resource support, promote Chinese enterprises' internet application exploration, achieving a win-win situation.

(3) Establish Regional Library Resource Sharing Blockchain Alliances. As analyzed above, blockchain technology overcomes inherent obstacles to resource co-construction and sharing among regional libraries and massively reduces the funding, technical, and resource costs of resource sharing. Especially for digital resource sharing, blockchain makes national and even global library digital resource sharing possible and may trigger a revolution in digital resource production, distribution, management, and transmission. Based on this, Chinese libraries should select mature regions to explore the construction of regional library resource sharing blockchain alliances, attempting to use new technologies such as private chains and consortium chains to build permissioned resource sharing.

(4) Strengthen Connections with Upstream and Downstream Entities in the Information Resources Industry. Blockchain's impact on libraries also extends to upstream and downstream entities in the information resources industry. For example, the reconstruction of digital resource distribution and copyright relationships described above will profoundly affect information resource integrators such as literature database providers and book publishers. Blockchain enables libraries to directly purchase, distribute, and use digital resources from individuals through blockchain software such as DECENTGO and UjoMusic. This reverses libraries' passive position when negotiating with information resource integrators but also reduces libraries' significance in meeting

public demand. Therefore, during the stage when blockchain technology has not yet produced disruptive innovation, libraries must strengthen connections with upstream and downstream entities in the information resources industry, researching and exploring a new industrial chain ecosystem that can both utilize blockchain advantages and expand the influence of all industry entities.

(5) Conduct Application Exploration of Library Blockchain Service Software. Currently, no software specifically for library blockchain services has emerged in China. This puts libraries in a passive position when applying blockchain technology, and most libraries lack technical teams for application and development. Based on this, Chinese libraries should actively cooperate with blockchain-related enterprises to explore the construction of library-oriented blockchain service software and fully express their own needs, social needs, and public needs to the blockchain industry. Data shows that 2018 is the explosive year for blockchain technology in China, with numerous startups and internet giants (Tencent, Alibaba) launching application-level products, and venture capital institutions investing substantial funds. This represents a strategic opportunity for libraries. How to utilize current hotspots and social resources is key to developing blockchain service applications for Chinese libraries.

(6) Continuously Optimize Library Service Content and Quality. As described above, blockchain development affects many library services, such as circulation services and novelty search services. Some services may need to adjust their forms, and some services may disappear. Therefore, Chinese libraries must continuously optimize their own service content to embrace the transformative impact brought by blockchain. Moreover, blockchain makes library service performance more transparent to society, government, and the public. This is a double-edged sword: if libraries can continuously improve service quality, they can attract more social funding (resources) for library development; otherwise, it may lead to reduced government support funding, further weakening the foundation for library development. Based on this, Chinese libraries must continuously optimize their service content and quality to continue exerting influence and developing in the blockchain era.

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Abstract

[Purpose/Significance] This paper introduces the development background of blockchain technology and, based on an analysis of its three characteristics—decentralization, reliable data, and automation, summarizes the transformative influence of blockchain technology on libraries according to practice and research by American libraries and academic communities, and proposes countermeasures for Chinese libraries to deal with the reform brought by blockchain technology.

[Method/Process] The research uses methods of literature review and comparative analysis. Firstly, from the resources dimension, this research analyzes the influence of blockchain technology on libraries from the following aspects: the establishment of a new type of library metadata system, the right to confirm

digital resources, and the sharing of resources. Secondly, from the service dimension, this research analyzes the impact of blockchain technology on library services, such as traditional circulation services, scientific research services, and service performance evaluation.

[**Result/Conclusion**] The libraries in our country have lagged far behind those abroad in drawing up the application standards of blockchain technology for libraries. However, with the current technological capability of Internet enterprises in China and the booming development of the blockchain industry, libraries in China have the potential cutting edge of deploying blockchain technology. Therefore, libraries in China should strengthen the relationship with Internet enterprises, blockchain technology companies, and other related upstream and downstream industries, actively deploy blockchain technology, carry out activities to use related software programs, continuously improve their service content and quality, and embrace blockchain technology reform.

Keywords: blockchain; libraries; service transformation

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