

Theoretical Mechanism and Implementation Path of Intelligent Technology Enabling Intelligent Transformation of Libraries

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Abstract: This study employs research surveys, expert interviews, and literature analysis to explore the fundamental concepts, driving mechanisms, internal principles, challenges, and implementation pathways of digital intelligence technology in library intelligent transformation. Through both exogenous and endogenous drivers, digital intelligence technology is integrated into library construction, operations, services, governance, and resource systems, empowering libraries to achieve digitalization, efficiency enhancement, smart transformation, and low-carbon transition. Challenges in implementing intelligent transformation through digital intelligence technology include high renovation costs, fragmented smart modules, outdated conceptual understanding, talent shortages, and lack of standardized frameworks. Implementation strategies encompass: adhering to the "reader-first" principle in intelligent transformation, rationally advancing operational mechanism reforms, strategically selecting intelligent transformation models based on institutional conditions, guiding transformation with national standards, and enhancing governance capabilities through interdisciplinary talent development.

Keywords: Digital intelligence technology; Library; Intelligent; Theoretical mechanism; Implementation path.

1. Introduction

"Building New Advantages in the Digital Economy" is a core component of China's 2035 Long-Range Objectives and the 14th Five-Year Plan [1]. In December 2019, seven government agencies including the National Development and Reform Commission issued the "Guidelines for Promoting Internet Plus Social Services," explicitly requiring accelerated development of digital cultural centers and smart libraries [2]. The August 2, 2022 release of the "14th Five-Year Cultural Development Plan" proposed establishing smart library systems, promoting cloud-based reading services, advancing digital transformation of reading rooms, and creating intelligent management platforms [3]. In February 2025, Tianjin Municipal Market Supervision Administration took the lead in formulating provincial standards and officially implemented the "Smart Library Evaluation Guidelines" [4]. Consequently, how to leverage digital intelligence technologies for library smart transformation has become a new research focus. Current academic studies have explored [5] intelligent library management, behavioral models [6], international best practices [7], logical evolution in library automation, and key elements of reading experience [8]. However, there remains insufficient in-depth research on empowering libraries with digital intelligence for smart transformation. This paper investigates theoretical mechanisms, driving forces, internal dynamics, practical challenges, and implementation pathways to provide insights for libraries' intelligent transformation.

2. Clarifying the connotation of intelligent technology enabling intelligent transformation of libraries

2.1. The connotation of digital intelligence technology

Digital intelligence technology refers to innovative tools and methodologies based on digital and intelligent technologies, such as AI, big data, blockchain, cloud computing, and the Internet of Things (IoT), which can be applied to library planning and construction, reader services, operation maintenance, and management (Table 1). Its functional value includes digitization, platformization, and intelligence, enabling the creation of a twin virtual space between the "physical world" and the "digital world". This creates matching effects, multiplier effects, and spillover effects [9].

2.2. Intelligent transformation of libraries

The development of libraries in China has progressed through three distinct phases. The first phase, prior to 2001, focused on traditional library services centered around reading support to meet basic needs for learning and reading. The second phase (2001-2014) introduced smart libraries that prioritized enhanced security, comfort, intelligent systems, and user-friendly reading environments. The third phase (post-2014) marked a significant upgrade, evolving from smart libraries to intelligent libraries designed to address modern challenges like high energy consumption, overcrowding, and low operational efficiency. As outlined in the "14th Five-Year Plan for Public Cultural Service System Construction" released by China's Ministry of Culture and Tourism in 2021[3], efforts are being accelerated to build

cloud infrastructure, integrate knowledge content repositories, and establish smart knowledge service ecosystems for smart libraries.

2.3. The connotation of intelligent technology enabling the transformation of libraries with wisdom

The concept of "empowerment" originates from empowerment theory, referring to the provision of energy to individuals or organizations to enhance their sense of capability and achieve goals more efficiently. Building smart

platforms for physical libraries is a crucial component in leveraging digital intelligence technologies to drive their intelligent transformation and upgrading. The rapid development of digital intelligence technologies empowers libraries to undergo smart upgrades, revitalizing them in resource management, service innovation, and user experience. Through technologies like artificial intelligence, big data, and machine learning, libraries can provide intelligent information services that offer personalized recommendations, consultations, and guidance to better meet user needs, thereby promoting knowledge dissemination and cultural innovation.

Table 1. The functional positioning of intelligent technology in the intelligent transformation of libraries

Functional localization	Library planning and design	Library construction	Books Stock up and check out	Individuation recommend	Reader serve
BIM	√	√			
Internet of Things technology			√	√	√
5G			√	√	√
Cloud computing		√		√	
Artificial intelligence			√	√	√
Big data			√	√	√
Blockchain				√	
Digital twins		√		√	
Human-computer interaction techniques			√	√	√

3. The driving mechanism of intelligent technology to empower the intelligent transformation and development of libraries

3.1. External supply traction

3.1.1. Requirements of national policies for intelligent transformation of libraries

The National 14th Five-Year Plan proposes to actively develop smart libraries. With the promulgation and implementation of the Public Library Law of the People's Republic of China and the Law on Guaranteeing Public Cultural Services [10], breakthroughs have been made in legal system construction for public cultural services. Systemic reforms and institutional mechanisms continue to deepen, laying new institutional foundations for the library sector. The "14th Five-Year Development Plan Outline" by the Chinese Library Association emphasizes the need to continuously build smart library systems, closely monitor societal demands for intelligent development, actively participate in the construction of the national smart library system, and vigorously expand and implement practical projects such as smart library construction and service support plans. These efforts aim to drive sustainable development in the intelligent transformation of China's libraries.

3.1.2. Social development requires the intelligent transformation of libraries

In recent years, the Chinese government has issued multiple policy documents on public reading and library operations at the national strategic level. Since 2014, "national reading" has been included in the government work report for 12 consecutive years. In October 2014, the State Council explicitly proposed in its annual work report to continuously advance the legalization and standardization of

basic public cultural services to promote nationwide reading. The 2021 "14th Five-Year Plan and Long-Range Objectives Through 2035" incorporated national reading initiatives and the creation of a learning-oriented China into the overall plan, actively developing smart libraries and encouraging the development of "internet-based public services," while continuously innovating service models and products. The 2025 government work report reaffirmed "deepening nationwide reading activities." As key platforms for public reading, libraries must meet higher standards in both fulfilling public reading demands and expanding per capita accessible space. To achieve the national reading strategy and build a more advanced public reading service system, the intelligent transformation of libraries has become imperative.

3.1.3. Requirements of scientific and technological revolution for intelligent transformation of libraries

While providing reading spaces, major libraries also host reading promotion events and academic lectures, requiring continuous intelligent upgrades to meet diverse needs. Rapidly evolving technologies like blockchain, identity verification, artificial intelligence, and cloud computing [9] have been widely adopted in library operations, making regular smart upgrades inevitable. The extensive application of big data, AI, cloud computing, and IoT enables libraries to better understand user needs, optimize resource allocation, and deliver personalized services. Automated information retrieval and recommendations enhance user experience, while cloud computing offers flexible resource management that allows instant access to information anytime, anywhere – meeting modern people's demand for instant access. IoT technology further smartens physical resource management, improving borrowing and returning efficiency while reducing labor costs.

3.2. Endogenous demand is driven by dynamic forces

3.2.1. The needs of teachers, students and readers for the intelligent transformation of libraries

Teachers, students, and readers require more accurate, dynamic, and comprehensive information about reading venues. They should be able to perform basic operations like searching, booking, and browsing through mobile internet terminals, enjoying faster services. Readers have diverse needs beyond just reading, which necessitates more varied formats such as reading workshops. As reading activities increase in number and coverage expands, libraries often need to provide information platforms that allow real-time access to event details, online registration, discussions, authentication, reviews, and participation in offline events – thereby enhancing engagement comprehensively. The intelligent transformation of libraries is not only a means to improve service quality but also a crucial approach to meet the demands of teachers and students for efficient, personalized, and convenient services.

3.2.2. The demand of smart campus for intelligent transformation of libraries

The evolution of smart campus needs has progressed through three distinct phases: initial campus informatization, mid-stage digital transformation that integrates digital elements into educational institutions, and the current phase of comprehensive digitalization. As outlined in the "Digital Campus Construction Standards for Higher Education Institutions" issued by China's Ministry of Education, universities should further explore applications of information technology, artificial intelligence, and big data in talent development, establishing intelligent facilities like smart libraries and digital history museums to create innovative learning environments. This transformation demonstrates libraries' evolution from passive service providers to proactive smart hubs, effectively engaging more readers in nationwide reading initiatives. In this era dominated by digital intelligence technologies, libraries now face a golden opportunity for modernization. By leveraging mobile IoT and big data solutions, they can achieve seamless inter-library coordination and optimized operational efficiency.

3.2.3. Librarians' demand for intelligent transformation of libraries

In their daily work, librarians actively embrace advanced digital tools and intelligent systems to streamline traditional management processes. For instance, they utilize big data analytics to identify user needs, thereby optimizing resource allocation and service strategies. Simultaneously, they leverage automation technologies to enhance operational efficiency, reduce repetitive tasks, and dedicate more time to user services and professional development. Librarians seek training and support for emerging fields like data management, information retrieval, and user experience design. Additionally, they aim to participate in smart library development initiatives by providing expert insights and feedback, ensuring that all transformational measures genuinely meet user requirements.

4. The internal mechanism of intelligent technology enabling the intelligent transformation and development of libraries

4.1. Embed the library construction system to realize the digitization of the library

Building Information Modeling (BIM) is a data-driven system primarily used in construction management. By leveraging architectural data models from the library, it facilitates data transmission and sharing throughout the project lifecycle. This enables all stakeholders to swiftly grasp construction directions, accurately address critical issues, and enhance collaboration among construction teams, supervisors, and operators, thereby shortening timelines and reducing costs. Firstly, from the client's perspective, BIM technology enables intelligent design, construction, and operation of facilities. Secondly, for designers, BIM supports collaborative design processes and evaluates construction feasibility. Thirdly, professional designers and component manufacturers are responsible for implementing specific design elements and executing detailed drawings and construction components.

4.2. Embed into the library operation system to realize the intelligent library

The intelligent operation management system powered by digital and smart technologies is built on IoT and AI foundations, providing systematic support for library operations. It emphasizes big data management and efficient access to practical information, serving as a crucial component in empowering libraries with smart capabilities. IoT technology involves installing sensors within library facilities, where the collected data forms a comprehensive database for infrastructure maintenance. The integration of AI and IoT not only streamlines daily operations such as book search, lending, return, recommendations, inventory management, online sentiment monitoring, location services, and library statistics, but also offers specialized management solutions for library equipment and environments. These include construction equipment, energy consumption measurement devices, thermal imaging temperature detection, smart lighting, environmental monitoring, security systems, intelligent access control, fire surveillance, smart parking, and locker management.

4.3. Embedding the library service system to realize the intelligence of the library

The intelligent transformation of libraries should prioritize service excellence, focus on smart technologies, and drive practical application of research outcomes. This approach helps refine service models, enhance reading experiences, and boost readers' willingness to engage with books. For instance, AI-powered recommendation systems can automatically suggest tailored resources based on users' borrowing history and search patterns, significantly improving discovery efficiency. By leveraging artificial intelligence and natural language processing (NLP) technologies, libraries can implement intelligent Q&A services that address real-time needs during information searches and consultations, making services more efficient and precise. Additionally, initiatives like virtual book clubs, online lectures, and thematic discussions can expand service scope and depth while

fostering user participation and sense of belonging.

4.4. Embedding library governance system to realize efficient library

Artificial intelligence (AI), big data, and cloud computing empower libraries to build intelligent governance systems, significantly enhancing operational efficiency. AI enables smart business processes in governance, while cloud computing resolves data homogenization and multi-source heterogeneous data challenges, preventing data silos. Through big data analytics, comprehensive reports are generated to support management decisions. The integration of digital intelligence drives workflow digitization, empowering libraries to transform and optimize all operational models and processes, ultimately forming a digital, networked, and intelligent governance framework. These technologies enable precise recommendations for diverse user groups. By dynamically managing and analyzing smart library system data through AI and big data, libraries can deeply understand reader needs, maximize facility utilization, and provide patrons with quiet, comfortable, and convenient environments.

4.5. Embed the library element system to realize the low-carbon library

First, in library operations and management, technologies such as AI, IoT, and blockchain are utilized to achieve unified access for energy consumption management and security systems. This creates an intelligent library capable of real-time dynamic monitoring and information reduction, thereby lowering costs and improving efficiency. Second, regarding security, digital and smart technologies are applied in areas including early warning, perception, security, and parking management. Through 24/7 real-time security monitoring, the efficiency of responding to security incidents is significantly enhanced, ensuring smooth reading activities. Third, implementing green library goals involves establishing a diagnosable, controllable, and visible energy management system to achieve low-carbon operations.

5. Practical challenges of intelligent technology enabling intelligent transformation of libraries

5.1. Lagging concept cognition restricts the transformation of library intelligence and culture

As pioneers in the "reading + technology" integration, smart libraries still face challenges in public understanding. Many mistakenly equate digital transformation with smart functionality, or lump together facilities with online reservation systems, digital reading services, and self-service borrowing with the term. Operational managers often lack systematic frameworks for smart library architecture, particularly regarding its practical value and benefits. This results in unclear conceptual understanding and inadequate planning for smart library development. Furthermore, the current landscape of library administrators—primarily focused on reader engagement and digital technology partnerships—seriously hampers the intelligent transformation of libraries.

5.2. The excessive cost of renovation restricts the intelligent transformation of libraries

Currently, China's library smart transformation primarily follows two models: The first is the technology introduction model. While this approach reduces costs and provides ready-made technical solutions for libraries to reference, it also involves high retrofitting expenses and risks wasting funds and resources. For instance, smart parking systems widely used in residential areas, apartments, and shopping malls may not be suitable for library environments. Blindly copying existing models without adaptation might fail to meet specific needs. The second model is personalized customization. Although requiring substantial upfront investment and extended design cycles, this method achieves precise integration with operational requirements and technological capabilities to deliver desired outcomes. Field research and interviews reveal that most Chinese libraries adopt a hybrid approach combining both approaches to maximize cost-effectiveness while achieving high returns on investment.

5.3. The decentralized intelligent upgrading module restricts the transformation effect of libraries

For smart library construction projects, technology-leading enterprises can be entrusted to coordinate implementation from design, construction, operation, management, and intelligent functional layout. However, for existing libraries, more facility upgrades face numerous obstacles, resulting in fragmented implementation of smart transformations. Library intelligent management systems exhibit strong technical interdependencies, with business requirements and system data requiring high coordination to prevent issues like data silos, incompatibility, and chaotic operations after upgrades. Not only must comprehensive consideration be given to economic investment and fiscal scale, but also existing infrastructure conditions must be evaluated to avoid blindly copying models. Relevant functional departments should provide scientific guidance within their capabilities.

5.4. The lack of standards restricts the intelligent transformation of libraries

As the intelligent transformation and upgrading of libraries continue to advance, the need for supporting industry standards and national regulations has become increasingly prominent. Currently, there remains a significant gap in standardization efforts within this field that urgently requires improvement. The National Library Standardization Work Plan for the 14th Five-Year Plan period highlights that under China's "Smart Society" strategy, the demand for library digital transformation continues to rise. Key areas including technological development, platform construction, equipment upgrades, system integration, open sharing of knowledge resources, smart connectivity of terminal devices, public intelligent services, and physical smart service spaces all require accelerated standardization. Leveraging advancements in digital technology, intelligent systems, and data management, the plan proposes establishing a framework for smart library standards to guide their development. It emphasizes prioritizing technical standards for platform construction, resource organization, intelligent information delivery, and smart service protocols, thereby accelerating the standardization of digital library services to better adapt to evolving societal information environments.

5.5. Talent shortage hinders the intelligent transformation of libraries

The transformation and development of smart libraries urgently require interdisciplinary capabilities. As the core support for digital library professionals, the construction and renovation processes of various smart libraries demand specialized talents to operate, maintain, and manage library equipment and systems. This imposes new requirements on traditional library management personnel, creating a pressing need for tech-savvy professionals proficient in library and information science, big data science, AI applications, sensor technologies, and related fields [11]. Currently, there remains a significant shortage of interdisciplinary talents combining library/information science and computer science expertise, coupled with outdated training systems and lengthy cultivation cycles. The talent development mechanism integrating library/information science and artificial intelligence technologies is still being refined, and its effectiveness requires further market validation.

6. The realization path of intelligent technology enabling the intelligent transformation of libraries

6.1. The principle of "reader first" should be adhered to in the intelligent transformation of libraries

First, the library's operations primarily focus on leveraging digital intelligence technologies to enhance operational efficiency, thereby freeing up more resources and human capital to achieve more cost-effective and environmentally friendly library management. Second, for readers, whether borrowing books or participating in reading activities, providing them with intelligent experiences remains the original aspiration and mission of libraries' smart transformation. During this transition, particular emphasis should be placed on bridging the gap between digitization and human-centric approaches, as well as standardizing services while accommodating personalized needs. Finally, smart libraries should prioritize the role of media communication, uphold a reader-first philosophy, and simultaneously utilize both traditional and new media technologies. While consolidating traditional broadcasting channels, they must seize development opportunities brought by new media technologies.

6.2. Lead the intelligent transformation and upgrading of libraries by formulating national standards

Currently, the intelligent transformation of libraries lacks unified national and industry standards, with issues such as insufficient iterative upgrades and overemphasis on hardware at the expense of applications remaining prevalent. At the national level, in 2017, the Ministry of Culture issued the "Cultural Development Plan for Public Digital Infrastructure during the 13th Five-Year Plan Period" [12]; in 2019, the Ministry of Culture and Tourism formulated the "Public Library Business Standards Part 1: Provincial Public Libraries" [13], which established requirements for information technology development. However, there remains a significant gap between current standards and the requirements for informatization, intelligence, and smart

transformation, failing to meet China's current needs for library digitalization. At the local level, Tianjin Municipal Market Supervision Administration pioneered regional standard development by releasing the "Smart Library Evaluation Guidelines" in 2025, marking the first provincial-level standard formulation in this field[4]. The establishment of national and industry standards plays a crucial role in library digital transformation, and efforts should continue to promote the release of relevant standards and regulatory documents for smart libraries.

6.3. Improve the intelligent governance ability of libraries based on talent training

First, building upon existing talent development systems in universities and vocational schools, we should actively optimize library management and enhance the quality of AI talent cultivation [14]. This involves deepening understanding and practical application of emerging technologies like digital networks and mobile communications to fundamentally address talent supply-demand imbalances. Second, libraries should prioritize cultivating specialized technical professionals for smart libraries by adopting a "go global, bring in" strategy. They need to actively build up relevant technical talent reserves while abandoning outdated notions about "library intelligentization transformation." Through corporate internships and research programs, leadership knowledge can be updated promptly. By focusing on intellectual property concepts as a starting point, staff capabilities can be enhanced. Third, governments should encourage collaboration between cultural, tourism, and technological sectors to form cross-industry, cross-departmental talent teams. Authorities at all levels and cultural institutions should be incentivized to establish smart library research projects, thereby nurturing national-level talent.

7. Conclusion

Amid the surging tide of digital economy development, intelligent technologies are driving libraries' smart transformation with revolutionary force. This not only aligns with national strategies for smart library construction but also serves as an essential choice to meet diverse reading demands and enhance public cultural service efficiency. By integrating these technologies into library infrastructure, operations, services, governance, and resource systems, libraries have achieved comprehensive upgrades from digitization to low-carbon practices. While reshaping physical spaces and service models, this evolution has activated knowledge dissemination's multiplier effect and innovative potential. However, challenges persist including outdated conceptual frameworks, high renovation costs, fragmented modules, lack of standards, and talent shortages. These issues fundamentally reflect deep-seated contradictions between technological empowerment and humanistic services, as well as traditional models and emerging needs. To achieve smart transformation, libraries should adhere to the "reader-first" principle, rationally reform operational mechanisms, and strategically choose intelligent transformation models based on their specific conditions. Guided by national standards and supported by interdisciplinary talent cultivation, libraries can ultimately build a modern knowledge service system that covers all citizens, offers convenience and efficiency, and radiates humanistic warmth. This will inject lasting

momentum into China's Book-Filled Nation initiative and its strategy to become a cultural powerhouse.

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References

- [1] Central People's Government of the People's Republic of China: Outline of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and Long-range Goals for 2035, March 13, 2021, http://www.gov.cn/xinwen/2021-03/13/content_5592681.htm, June 14, 2022.
- [2] National Development and Reform Commission. Opinions on Promoting the Development of "Internet + Social Services" [EB/OL]. [2019-12-12]. http://www.cac.gov.cn/2019-12/12/c_1577686267538210.htm.
- [3] The General Office of the CPC Central Committee and the General Office of the State Council issued the Notice on the 14th Five-Year Plan for Cultural Development [EB/OL]. [2022-08-16]. https://www.gov.cn/xinwen/2022-08/16/content_5705612.htm.
- [4] Tianjin Municipal Standard Release Notice (No.188) Smart Library Evaluation Guide, DB12/T 1437-2025. https://scjg.tj.gov.cn/tjsscjdglwyh_52651/zwgk/zfgznew/bdwwjnew/gzwjnew_1/202502/t20250214_6858374.html
- [5] Hu Qianfeng. Research on user profile data management in university smart libraries based on generative artificial intelligence [J/OL]. Library Work and Research, 1-13 [2025-06-11].
- [6] Cui Xu and Liu Xianghua. AOSA Model Construction for Library Interactive Digital Narrative Reading User Acceptance Behavior [J]. Library Forum, 2025, 45(05):106-114.
- [7] Shao Yan, Jiang Xiaoxi. Inspiration from foreign public library standardization to the standard formulation of China's grass-roots libraries [J]. Library and Information Work, 2012, 56(21):22-26.
- [8] Zhang Lei. Evolution logic and high-quality service path and strategy of patent information service in university libraries. Library Science Research, 2022, (03):52-58.
- [9] Gao Jin, Wu Lianquan, Chai Wangjun, et al. Theoretical Mechanism and Implementation Path of Digital Technology Empowering Smart Transformation of Sports Venues [J]. Journal of Sports Science, 2022, 36(05):63-73.
- [10] Law of the People's Republic of China on Guarantee of Public Cultural Services http://www.npc.gov.cn/npc/c2/c12435/201905/t20190521_274710.html.
- [11] Wu Aizhi, Yu Qu. Exploratory study on library services to facilitate the introduction of high-end talents in universities [J]. Library, 2025, (02):110-117.
- [12] Notice of the Ministry of Culture on Issuing the 13th Five-Year Plan for the Development of Cultural Industry, https://zwgk.mct.gov.cn/zfxzgkml/ghjh/202012/t20201204_906372.html.
- [13] Announcement of the Ministry of Culture and Tourism on the release of 5 industry standards including "Public Library Business Code Part 1: Provincial Public Libraries" https://zwgk.mct.gov.cn/zfxzgkml/kjy/202012/t20201206_917795.html.
- [14] Shang Dingyuan, Wang Dan, Xu Jitian. Research on the Training Mechanism and Path of Professional Technical Personnel in Public Libraries under the New Development Concept [J]. Library, 2023, (03):84-91.