A Decade of Smart Library Practice: Progress, Challenges, and Solutions

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Abstract

Purpose/Significance By examining the decade-long practical research on smart libraries in China from a literature review perspective, this study analyzes the practical progress, dilemmas, and explores potential solutions for smart libraries in China. Method/Process Comprehensive retrieval tools were utilized to search and screen data on smart library practices in China from 2013 to 2022. Through extraction and integration of data content, the decade-long practical progress of smart libraries in China was systematically reviewed across six dimensions: smart services, smart management, smart spaces, smart librarians, new-generation service platforms, and supporting institutional systems, while analyzing the dilemmas faced and exploring future development pathways. Results/Conclusion The study reveals that domestic smart library practices involve extensive dimensions, diverse stakeholder types, broad geographical coverage, and varied application technologies, achieving certain practical progress. However, due to numerous issues encountered in practice, current smart library construction remains insufficiently systematic, in-depth, and balanced, falling into a relatively stagnant predicament. Future practical construction and theoretical research require targeted efforts and focused discussions on existing problems and dilemmas.

Full Text

A Ten-Year Practice Research on Smart Libraries: Progress, Dilemmas, and Future Pathways

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Abstract

[**Purpose/Significance**] This paper systematically examines the practical progress, dilemmas, and future pathways of smart library development in China over the past decade from a literature review perspective. [**Method/Process**] Comprehensive retrieval tools were employed to search and screen practical data on smart libraries in China from 2013 to 2022. Through extraction and integration of data content, this study reviews the ten-year practical progress of Chinese smart libraries across six dimensions: smart services, smart management, smart spaces, smart librarians, new-generation service platforms, and supporting institutional systems, while analyzing the challenges faced to explore future development pathways. [**Result/Conclusion**] The research reveals that Chinese smart library practice covers extensive dimensions, diverse entity types, broad regional coverage, and varied application technologies, achieving certain practical progress. However, due to numerous practical problems, current smart library construction remains insufficiently systematic, in-depth, and balanced, falling into a dilemma of relative stagnation. Subsequent practical construction and theoretical research require targeted efforts and focused discussion on existing problems and dilemmas.

Keywords: Smart library; Practical progress; Construction dilemma; Development strategy

Introduction

The emergence and development of emerging information technologies such as the Internet of Things, cloud computing, big data, and artificial intelligence have provided opportunities and technical foundations for a new round of transformation and development in libraries, giving rise to smart libraries. As an important component of the smart earth, smart libraries play a significant role in the knowledge economy society. Driven by both internal library development needs and external factors, theoretical research and practical construction on smart libraries have developed rapidly [1]. Since 2013, discussions on smart library construction have emerged in China, with research gradually extending from theory to practice [2]. In 2021, multiple national policy documents—including the *14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives Through 2035*, *Opinions on Promoting High-Quality Development of Public Cultural Services*, *14th Five-Year Plan for Culture and Tourism Development*, and *14th Five-Year Plan for Public Cultural Service System Construction* —repeatedly emphasized "strengthening smart library construction,"setting forth requirements for practical smart library development. The focus on "practice" has become the current and future trend in smart library development, aligning with national policy and practical development requirements. Against this background, systematically reviewing past practical research on smart libraries in China is both necessary and important.

On May 20, 2012, Nanjing University celebrated its 110th anniversary and unveiled its "Smart Library" service system, which has since become a model for smart library practice through ten years of construction and development [3]. Based on the authors' background and the trend of Chinese smart library research gradually shifting from theory to practice since 2013, this study limits its timeframe to 2013-2022.

As a hot topic for both academia and industry, domestic scholars have conducted literature reviews on smart library research development. For instance, Li Weichao et al. [4] (2018) retrieved and reviewed research papers on smart libraries in China from 2008-2017; Ding An et al. [5] (2019) used CNKI as a data source to reveal research status and hotspots on smart libraries in China from 2009-2018, summarizing service models, existing problems, and coping strategies. However, existing reviews have primarily focused on theoretical research or specific content areas, lacking comprehensive reviews specifically targeting the practical dimension. Moreover, the practical aspects covered in these reviews mostly predate 2018, not aligning well with the ten-year development trajectory of smart libraries.

Therefore, this paper aims to combine practical research on smart libraries in China over the past decade (2013-2022), systematically review practical progress, analyze facing dilemmas, and explore future pathways. This study addresses the gap in systematic review research on the practical dimension of smart libraries and seeks to provide reference for promoting practical construction processes and meeting national social and cultural development needs.

1.1 Data Sources

To comprehensively understand practical research on smart libraries in China over the past decade, this study used the Chinese resource discovery system as a retrieval tool, with its internal databases as data sources, limiting the timeframe to 2013-2022. The search query "SU= 智慧图书馆 or (SU= 图书馆 and KY= 智慧服务/智慧空间/智慧管理/智慧馆员)" was used for precise retrieval on January 3, 2023.

Following retrieval, results underwent manual screening and cleaning in three steps. First, screening by thematic relevance retained only data focusing on "smart library practical construction," determined by reading titles, keywords, and abstracts to delete irrelevant or low-relevance data. The scope of "smart library practical construction" was defined as: implemented smart library practices, pilot or trial implementations, and specific proposals that could directly guide practical implementation. Second, duplicate data were removed following a descending priority order of "books, journal articles, patents, yearbooks, reports, newspapers/information resources." Third, further cleaning by data quality removed low-quality papers and conference proceedings based on journal source importance, and eliminated highly similar content based on citation frequency and completeness. The final sample comprised 383 items, including

journal articles, master' s/doctoral dissertations, books, yearbooks, patents, reports, newspapers, and information resources.

1.2 Research Methods

This study primarily employed literature investigation, statistical analysis, and inductive methods to systematically analyze practical research on smart libraries in China from 2013-2022, reflecting practical progress, dilemmas, and future pathways from a literature research perspective.

1.3 Analysis Results

Excel was used for preliminary analysis and organization of sample data, including temporal distribution statistics, preliminary statistical analysis by data category, and extraction, classification, and integration of thematic content.

1.3.1 Temporal and Category Analysis This study conducted overall temporal distribution statistics on the 383 items, followed by separate temporal and quantity statistics by data category. Specifically, 141 high-quality journal articles were analyzed separately for temporal distribution; newspapers, reports, and information resources—being numerous and similar—were combined for separate temporal analysis; books, yearbooks, and dissertations with smaller quantities were not analyzed separately. The final temporal distribution results are shown in [Figure 1: see original paper].

As shown in [Figure 1: see original paper], literature data on smart library practice was relatively scarce from 2013-2016 but increased annually, surging in 2017. From 2017-2021, growth was fluctuating but remained at relatively high levels overall, though 2022 saw a significant decline. This indicates that practical construction and research on smart libraries continued advancing throughout the decade, intensifying in 2017 and maintaining momentum thereafter, but encountering implementation difficulties in 2022. Journal articles showed fluctuating increases over the decade, with small peaks in 2017 and 2021, suggesting intensified theoretical summarization and transformation of practical achievements around those years. The curve for newspapers, reports, and information resources initially aligned with overall data trends, with promotional coverage following practical advancement. Notably, however, these sources declined after 2019, diverging from the continued advancement trend, indicating either insufficient follow-up in publicity or a lack of innovative points for promotion in later practical advancement.

1.3.2 Thematic and Content Analysis Through extraction, classification, and integration of sample data themes, this study found that practical research on smart libraries from 2013-2022 primarily covered six aspects: smart services, smart management, smart spaces, smart librarians, new-generation service platforms, and supporting institutional systems. The following review of domestic smart library practical progress will be organized along these six dimensions.

Additionally, classification and integration revealed that current smart library practice entities in China mainly include university libraries, public libraries, and industry-leading enterprises; practice locations cover libraries and subordinate units across multiple provinces, cities, districts, and counties; various technology types are applied throughout, with RFID, IoT, intelligent robots, and facial recognition mentioned most frequently.

2.1.1 Mobile Services in Smart Libraries

Mobile services represent one of the earlier smart service practices, primarily implemented through smart library apps and mobile social media platforms like WeChat and Alipay.

Ningbo University implemented mobile services including catalog search, micro-book reading, book transfer, bookstore borrowing, online borrowing orders, and offline book delivery through its "Smart Library" app [6]. Chongqing University Library utilized its smart library app for mobile services, achieving mobile functions such as QR code access control, unified literature resource retrieval, and business reminder interactions [7]. Zhejiang Province' s Anji County Library used WeChat public accounts for online processing of services like "reader cards" [8]. Shaanxi Province' s Xianyang Library used Alipay for mobile book borrowing and electronic reading [9].

2.1.2 Self-Service in Smart Libraries

Self-service is currently one of the more widely 普及 smart service practices, including self-service borrowing, reservation, printing, payment, and 24-hour unmanned self-service libraries. University of Electronic Science and Technology Library implemented facial recognition self-service borrowing using facial recognition technology and RFID self-service machines [10]. Shanghai Jiao Tong University Library applied a multi-terminal self-service system for library venues, achieving integrated self-service reservation [11]. Beijing Normal University branch libraries launched a network roaming self-service printing system providing self-service printing, copying, and scanning, with users able to settle payments by swiping campus cards after printing [12]. The 24-hour unmanned self-service library represents the most significant application achievement in smart library self-service, primarily using RFID self-service systems, electronic card systems, access control systems, and electronic monitoring systems to establish independent spaces for round-the-clock user access [13]. Currently, 24-hour unmanned self-service libraries are mainly implemented by public libraries, with examples including libraries in Shijiazhuang City, Hebei Province [14], Tongling City, Anhui Province [15], Meizhou City, Guangdong Province [16], Laibin City, Guangxi Province [17], and Jing' an County, Jiangxi Province [18].

2.1.3 Intelligent Interactive Services in Smart Libraries

Intelligent interactive services are hallmark features distinguishing smart libraries from traditional ones, 主要包括 intelligent consultation, book location, navigation/guidance, and broadcast/push services. China University of Mining and Technology Library designed and deployed an intelligent service robot using AI technologies including speech recognition, robot motion control, and four-element microphone arrays, achieving voice interaction, intelligent consultation, information broadcasting, and route guidance in practice, providing users with intelligent interactive experiences [19]. Tsinghua University Library conducted mobile secondary development of its intelligent chatbot "Xiaotu" based on the ALICE open platform, implementing intelligent consultation, book guidance, and training services on "Xiaotu" WeChat and app platforms [20]. Nanjing University Library uses its intelligent inventory robot for book inventory, accurately locating every book and using real-time inventory data to provide intelligent book-finding services, with ultra-high frequency RFID positioning enabling optimal path planning to guide readers or librarians to books [21]. Shaoxing City Yuecheng District Library in Zhejiang Province launched a "720 Panoramic Navigation Touch Screen System," three-dimensionally displaying library environments and venues to help readers comprehensively understand library layouts, achieving intelligent navigation [22]. Shanghai Library' s app provides Beacon-based message push services and reading room location services, sending floor location prompts when users pass reading rooms and enabling them to view the latest reader activities [23].

2.1.4 Personalized Services in Smart Libraries

Personalized services represent a key focus of smart library practice, embodying a "user demand-centered" approach through two main implementation forms. The first form involves libraries providing comprehensive, diverse service options for specific services like retrieval, borrowing, and reference consultation, allowing users to choose according to personal needs. For example, Zhejiang Library' s smart library system established a personalized intelligent navigation database, providing unified retrieval, provincial union catalog alphabetical navigation, document type, subject themes, database classification, and popular resource navigation to meet diverse retrieval needs. Additionally, Zhejiang Library, jointly with Nanjing and Shanghai libraries, launched an online joint knowledge navigation system offering robot consultation, knowledge bases, message halls, reference teams and expert databases, and commissioned services, allowing users to either designate experts for consultation or enjoy customized, diversified thematic consultation services [24]. The second form involves capturing and mining user behavior to analyze and predict preferences, with smart libraries proactively making recommendations. For instance, Chongqing University Library' s "Smart Portal" system, launched in 2016, perceives and captures user behavior information including devices used, browsing data, search records, borrowing history, favorites, subscriptions, and comments, conducting

deep mining and analysis based on user behavior models and presenting results through a "Guess You Like" section to achieve personalized, precise resource recommendation services [25, 26].

2.1.5 Knowledge Services in Smart Libraries

Knowledge services represent a form of smart service that analyzes user needs and information resources to provide different users with different content or forms of knowledge, including subject services, intelligence services, and think tank services [1]. Chongqing University Library organized digital and paper resources effectively through its smart library platform, exemplified by course libraries serving teaching, research topic libraries serving scientific research, virtual branch libraries serving discipline construction, and personal resource libraries serving readers, making subject services more diverse, concrete, and effective [27]. Shanghai Jiao Tong University Library conducted specific technology field patent analysis, institutional patent competitiveness analysis, inventor and team patent analysis, national major science and technology project patent services, patent early warning services, and technology transfer support, providing patent intelligence analysis including application trend analysis, regional and technology source country distribution, competitive landscape analysis, core patent mining, litigation analysis, inventor distribution, patent transfer status, and core patent analysis to support school research and technology development [28]. Changshu Institute of Technology Library provided domestic and international cooperative education theoretical research, practical cases, and status analysis of similar universities when its institution formulated cooperative education strategies, offering information support for subsequent strategic decision-making [29].

2.2.1 Intelligent Management of Information Resources

Information resource construction is the core business of libraries, and achieving intelligent management of information resources forms the foundation for other smart initiatives in smart library practice. Intelligent management 主要包括 intelligent acquisition and acceptance, intelligent classification and cataloging, automatic sorting and shelving, automatic inventory and positioning, and intelligent storage.

Chongqing University Library optimized its intelligent acquisition system workflow by setting business rules and decision weights based on discipline construction needs, publisher models, reader behavior analysis, reader recommendations, and book prices, enabling intelligent screening of paper documents to improve acquisition efficiency and collection quality [30]. Guangdong Provincial Central Library developed an intelligent book acquisition, classification, and cataloging system, with its pre-cataloging processing module launched in April 2021, achieving intelligent processing including barcode placement and verification on back and title pages, film covering, collection stamp placement on title pages, and RFID tag attachment on back page reverses [31]. Since 2014, Guangzhou Li-

brary's application of automatic sorting systems reduced shelving time for 30,000 daily circulating books from 2-3 days to 1-3 hours [32]. Nanjing University Library, jointly with the School of Computer Science, designed and implemented a proprietary ultra-high frequency RFID-based intelligent book inventory robot system, achieving efficient inventory and real-time positioning accurate to each book's order within a shelf [21]. In 2019, Suzhou Second Library launched China' s first large-scale intelligent storage facility, using intelligent robotic arms and fully automatic transport tracks to automate document storage and retrieval [33].

2.2.2 Intelligent Management of Library Facilities

Intelligent facility management is also crucial in smart library practice, currently focusing on two aspects: security management and environmental control. Security management 主要包括 access control recognition, intelligent monitoring and anti-theft, and intelligent early warning. For example, China Jiliang University Library independently developed a facial recognition access control system using Baidu AI platform' s facial recognition cloud interface for crowd and access permission management [34]. Nanjing University Library applied an RFID automatic identification collection management system, replacing barcodes and magnetic strips with RFID tags that combine data reading and anti-theft functions for intelligent book security. Shenzhen Yantian District Library established a cloud monitoring platform for timely detection and maintenance of system failures, achieving intelligent system monitoring and protection [35]. Ningbo Library established smoke perception at the system perception layer for fire early warning [36]. Environmental control involves using wireless sensors to intelligently adjust brightness, humidity, and other environmental factors. Shanghai Baoshan Library uses temperature and humidity sensors to adjust conditions in storage, ancient book, and server rooms, improving environmental comfort and safety for collections and equipment [37].

2.3.1 Physical Spaces in Smart Libraries

Physical space is the traditional form of library existence. Smart library physical space construction 主要包括 renovation of external architectural environments and internal space facilities. In its third renovation, Peking University Library repaired and decorated external buildings and reallocated internal spaces based on theoretical trends of future regenerative growth in smart library architecture. Specific measures included renovating all mechanical and electrical equipment and installing intelligent devices to integrate building intelligence with smart library management and user experience; presetting multi-functional meeting and exhibition spaces for diverse scenarios; establishing semi-open cafes to continue the library' s role in emotional and knowledge exchange; and using connected separate buildings and transport robots to separate book storage from reading areas [38]. Guangdong Tuodi Company' s "Smart Library Solution" uses glass-walled smart libraries integrating IoT and remote monitoring to build 24-hour

self-service borrowing platforms and reading spaces with intelligent control of lighting, temperature, and air quality to reduce costs, save energy, and create suitable environments [39]. Additionally, Shanghai Jiao Tong University Library, Nanjing University Library, and Shenzhen Bao' an District Library have conducted physical space smart renovations [1].

2.3.2 Virtual Spaces in Smart Libraries

Virtual space is an emerging form of library existence. Smart library virtual space construction 主要包括 online resource and service platform system construction and virtual venue scenarios. Shenyang Aerospace University used microservice systems to implement online reservation, reminders, virtual consultation, and information release services, continuously building virtual systems including resource maps, service maps, function maps, and space maps to establish a virtual resource and service platform seamlessly connected with physical resources and services [40]. Chongqing University Library launched a "Virtual Smart Library Service Navigation System"using virtual scene roaming and accompanying explanations for virtual freshman training. Xi' an Jiaotong University Library' s "Virtual Panoramic Layout" built virtual scenes of Qian Xuesen Library and Medical-Finance Library stacks and reading spaces, achieving comprehensive virtual display of physical venues [41].

2.3.3 Innovation Spaces in Smart Libraries

Innovation spaces are new types of spaces built by combining virtual and physical spaces with contemporary elements according to user needs [42], representing a special feature of smart library space construction. These include maker spaces, learning commons, innovation experience spaces, and multi-purpose fusion spaces. Shanghai Library' s "Innovation Space" built in 2013 is China' s first recognized library maker space, featuring five areas: reading space, IC sharing space, patent and standard service space, creative design exhibition space, and full-media communication experience space, enabling multiple functions including reading, leisure, teaching, interaction, and creation [43]. East China University of Science and Technology Library established an innovation and new technology experience space, building a new technology perception and learning space for students and providing 3D printing experiences [44]. Xi' an Jiaotong University' s Qian Xuesen Achievement Exhibition Room is a typical multi-purpose fusion space, organically integrating library and exhibition hall functions with both library space functions (reading, self-study, academic discussion) and exhibition hall functions (display, cultural exchange), demonstrating systematicity and flexibility [45].

2.4 Practical Progress of Smart Librarians

Librarians are indispensable roles in library systems, and cultivating smart librarians represents an important issue in smart library development. Over the

ten years of smart library construction, theoretical discussions on required qualities and training methods for smart librarians have been abundant, but these theoretical discussions have not been fully translated into practice. Current practices mostly involve short-term knowledge training. Qingdao University Library held smart library professional knowledge training to help librarians master new technologies and skills [46]. Xuchang Library in Henan Province conducted a "Smart Library Intelligent Book Inventory Robot" training activity to help librarians learn to use intelligent robots [47]. Zibo Library in Shandong Province held thematic training on "Smart Library Construction and Management" to improve librarians' professional levels and innovative awareness [48]. Additionally, libraries including Capital Library [49], Liaocheng Haiyuan Library in Shandong [50], and Yingkou Library in Liaoning [51] have organized or sent staff to short-term "Smart Library Construction and Management Training" programs to enhance librarians' abilities to apply new concepts, technologies, and methods in smart library construction.

2.5 Practical Progress of New-Generation Service Platforms

Smart libraries are architected around smart platforms. New-generation service platforms are integrated platforms specifically designed for smart libraries that reshape business and service modules to achieve unified management and resource/service integration. Domestic application practices fall into two forms. The first involves introducing foreign new-generation library service platforms such as Alma, WMS, and Sierra. In September 2014, Huazhong University of Science and Technology Library introduced Sierra as its management system. Beijing Normal University Library and Tsinghua University Library launched Alma in 2017 and 2018 respectively [52]. CALIS cooperated with EBSCO to promote FOLIO development and its localization in China [53]. The second form involves joint development and independent construction of new-generation service platforms. Chongqing University Library, jointly with Chongqing VIP Information Company, developed a new-generation library system, launching in 2016 a smart library portal characterized by "integrated metadata management of paper and digital resources, consistent service portals for PC and mobile, and library service alliances based on internet thinking," achieving integrated development of resources, management, and services [54]. Integrating resources and services is the goal of next-generation smart library system platforms. Smart services require advanced technology and comprehensive platform support. Nanjing University Library, cooperating with Jiangsu Tuxing Software Technology Co., Ltd., built the New-Generation Smart Library Service Platform (NLSP), integrating central knowledge bases, selection platforms, librarian smart service platforms, and reader application service platforms, launched in 2019 with phased practical results achieved [55].

2.6 Practical Progress of Supporting Institutional Systems

Smart library construction requires supporting institutional systems for efficient and sustainable development. These systems 主要包括 overall construction frameworks, relevant construction indicators and evaluation systems, management and service policies, and alliance cooperation and standardization. In 2020, the National Library launched the "1+3+N National Smart Library System"project, providing systematic support for unified national smart library construction: "1" refers to building a "cloud-based smart library" ; "3" refers to the integrated knowledge content repository, national smart library management system, and comprehensive smart knowledge service operation environment; "N" refers to establishing offline smart service spaces in libraries at all levels and grassroots service points nationwide. Additionally, three supporting guarantee systems were built: smart library evaluation system, smart library standardization system, and smart library research and talent training system [56]. In June 2020, the 4th World Intelligence Congress released the "Sino-Singapore Tianjin Eco-City Smart Library Indicator System," containing 5 first-level indicators and 26 second-level indicators, providing practical reference for public library smart development [57]. Shenzhen Yantian District issued the *Yantian District Public Library Management Measures*, clarifying responsibilities of district, street, and community levels in library construction, operation, and system guarantee, and implementing a "three unifications, six integrations" vertical management model with the district library as the hub, unifying funding, personnel, and resources, and implementing unified leadership, design standards, service catalogs, resource allocation, personnel training, and performance evaluation [35]. Additionally, Shenzhen Bao' an District Library [58] and Jiaxing' s urban-rural integrated smart study rooms in Zhejiang [59] have achieved notable results in management and service system construction. Shanghai Library, together with Shanghai Jiao Tong University Library and other renowned domestic libraries, as well as industry-leading companies like Jiangsu Jiatu Network Technology and Shanghai Afadi Intelligent Digital Technology, jointly established the "Smart Library Technology Application Alliance," creating websites, publishing newsletters, holding monthly lectures, and actively exchanging cooperation [60]. Chongqing University Library cooperated with VIP Company and 28 domestic libraries to establish the "Smart Library Collaborative Innovation Alliance," establishing five working groups for resource sharing research and training, data and process standards, promoting smart library construction through alliance cooperation and standardization [61].

2.7 Summary of Practical Progress

Smart library practical construction and related discussions lagged behind theoretical research, but after ten years of practice, certain progress has been achieved across multiple dimensions including smart services, smart management, smart spaces, smart librarians, new-generation service platforms, and supporting institutional systems. The following summary evaluates current

practical progress from three new perspectives—practice entities, geographical coverage, and technology application—to provide multi-angle comprehensive understanding.

Smart library practice entities are diverse and expanding. Current smart library entities 主要包括 university libraries, public libraries, enterprises, hospitals, and primary/secondary schools, with types diversifying as construction develops, such as Changchun Metro Smart Library [62] and Guangzhou Children' s Library' s mobile library [63]. University and public libraries remain the main entities, with Nanjing University Library and Chongqing University Library as typical university examples, and Shanghai Library and Shenzhen Yantian District Library as typical public examples. In recent years, enterprises have deepened participation, mainly through cooperation with university and public libraries.

Smart library practice covers broad geographical levels but exhibits internal regional and hierarchical differences. Construction has spread across all provinces and cities nationwide, reaching provincial, municipal, district/county, street/township, and community/village administrative levels. Guangdong, Jiangsu, Shanghai, and other economically and culturally advanced provinces and cities started earlier, achieved deeper administrative coverage, and show better current progress. Additionally, "street-community" levels show higher practice 普及 rates and richer project types than "township-village" levels, though grassroots projects mainly focus on free resource access, quick borrowing, 24-hour self-service, interlibrary loan, and mobile applications.

Smart library practice employs rich technology types but at a shallow application level. Current construction applies big data, AI, IoT, cloud technology, VR/AR, 5G, facial recognition, intelligent robots, RFID, Beacon, and other technologies in scenarios including data integration and analysis, intelligent reference consultation, intelligent facility management, self-service, and intelligent storage. RFID, intelligent robots, facial recognition, and IoT have more mature application cases, while other technologies have limited actual applications and remain at a shallow level.

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3. Analysis of Dilemmas Facing Ten-Year Practice

Despite progress across various aspects, fully-formed smart libraries have not yet been built. Practical construction and research still face difficulties and problems that create dilemmas.

3.1 Vulnerabilities in Technology Application and System Equipment Deployment

Technology and intelligent system/equipment introduction constitute the core thread running through smart library practice, but the ten-year practice reveals

vulnerabilities in actual introduction and application, hindering comprehensive and deep development.

First, technology and system equipment introduction lacks autonomous choice. Currently, independent R&D of smart library technologies and systems is limited, with most libraries purchasing or outsourcing. This approach is heavily market-influenced, resulting in high costs and generic products that cannot fully match actual needs.

Second, actual technology and system equipment introduction is incomplete. The lack of autonomous choice, combined with limited construction funding, leads to incomplete introduction of required intelligent equipment, leaving libraries in a semi-smart state. For example, although most libraries have introduced RFID technology, only a few have purchased intelligent shelves, mobile inventory carts, or sorting systems, with most only having self-service borrowing equipment, remaining semi-intelligent [64].

Third, integration of introduced technologies and systems with library operations is poor. On one hand, incomplete technology introduction prevents full utilization of introduced equipment; on the other hand, technical barriers, application difficulties, and mismatches between equipment and business processes result in poor application effects.

Fourth, technology and system equipment migration and deployment are difficult. Smart library construction is a long-term, multi-module process, often facing incompatibility between old and new systems and difficult module integration. Without proper migration planning, libraries cannot introduce new technologies or achieve integrated platform management, causing construction stagnation.

3.2 Lack of Systematic and In-Depth Practical Work

Although smart services, management, and spaces have achieved progress, and libraries across regions, levels, and types have produced results, the past decade' s practical work has lacked systematic and in-depth development.

On one hand, individual smart library construction entities lack systematic and in-depth work. Except for relatively comprehensive examples like Nanjing University Library, Chongqing University Library, and Shenzhen Yantian District Library, most entities have scattered practices, following trends to introduce specific equipment, services, management processes, or space types, with work remaining at a shallow level without systematic construction or deep, continuous development.

On the other hand, national smart library construction overall lacks systematic and in-depth development. Over the past decade, construction has primarily been autonomous individual projects. Despite the National Library' s planning advocacy, unified systematic and continuous practice has been absent. Consequently, smart library levels vary significantly across regions and hierarchies,

with construction showing fragmentation and lacking unified data formats, technical interfaces, and business processes, hindering cooperative construction and balanced, sustainable development.

3.3 Lagging Smart Librarian Team Construction

Smart librarians are critical to smart library construction, requiring team development that matches development needs for effective service and management implementation. However, China' s smart librarian team construction remains immature and lags behind development requirements.

First, current librarian team structure is unreasonable. Smart librarian construction requires sufficient professional IT personnel, but most libraries lack reasonable proportions of technical staff, hindering independent exploration and application of emerging technologies.

Second, overall librarian team capability is insufficient. Smart librarian construction requires corresponding professional competence and innovation ability, but current librarian quality generally cannot meet smart transformation needs.

Third, a smart librarian training management system has not been formed. Current practices mostly involve short-term training for limited numbers, lacking systematic, universal training systems to meet capability improvement and continuous development needs. Additionally, corresponding assessment and incentive mechanisms are missing. High-quality librarians require incentive mechanisms, especially given smart libraries' higher demands. However, most libraries lack assessment and incentive practices for smart librarians, seriously affecting capability building and service/management implementation.

3.4 Lack of Stable Multi-Party Cooperation and Support

Although libraries are the main construction entities, smart library practice requires multi-party cooperation and support for steady development. Over the past decade, lack of stable cooperation and support has caused project interruptions or stagnation.

First, stable library-enterprise cooperation is lacking. Cooperation with industry-leading enterprises and research institutions can comprehensively enhance construction effectiveness by combining resources. However, smart libraries have not established stable cooperative relationships, causing previously cooperative projects to be interrupted, such as Nanjing University Library' s "Haitun" mobile service project developed with Alipay.

Second, effective inter-library cooperation and alliances are lacking. Although smart library construction has become common nationwide, with few inter-library cooperation cases, long-term effective alliances have not been formed, hindering copyright, technology, and resource integration and preventing comprehensive cooperation.

Third, high-trust user support is lacking. Smart libraries serve users, and high-trust user support provides continuous development momentum and confidence for trial and error. However, safety concerns from new technologies and insufficient analysis of personalized needs and emotional communication have resulted in low user support for some smart projects, causing interruptions or stagnation.

3.5 Weak Connection Between Theoretical Research and Practice

Smart library construction requires coordinated development of theoretical research and practice. However, the past decade has seen insufficient connection between theory and practice. On one hand, some discussions remained theoretical without effective transformation and timely application. For example, theoretical discussions on blockchain technology for security have existed for years without practical application results. Additionally, despite available design patents related to smart library construction, real-time application dynamics are absent. On the other hand, some practical projects lacked theoretical foundations, and most practical experiences failed to convert into theoretical research, especially regarding failure cases. The absence of a two-way conversion mechanism prevents theory and practice from entering a benign guidance cycle.

3.6 Publicity Failing to Match Practical Development Requirements

Smart library practice has become a hot topic in library and public cultural development, with considerable publicity coverage. While a favorable public opinion environment can promote construction, past publicity has failed to match practical development requirements, sometimes even hindering progress. Overall, past decade publicity has focused excessively on a few smart projects, lacked continuous tracking of the same projects, ignored failure cases, and failed to provide positive guidance for ongoing projects. The lack of positive guidance directly hinders project continuation, as seen in Nanjing University Library' s "WeChat Seat Reservation" project, which was interrupted due to controversy without timely positive guidance.

4.1 Strengthen Technology and System Equipment Introduction and Application

First, strengthen frontier tracking of emerging technologies, conduct independent R&D based on actual conditions through multi-party collaboration, and master application initiative and adaptability to fundamentally solve current introduction vulnerabilities. Second, construct a phased development path for externally introduced technologies and systems: rationally allocate introduction funds, optimize cost-effectiveness, determine introduction priorities and combinations based on importance and synergy, and increase investment when necessary; conduct localization and independent transformation after introduction to better match construction needs. Finally, plan deployment and migration to

ensure compatibility and integration between old and new systems and project modules, building a new-generation integrated service management platform. Additionally, strengthen tracking research on multi-source big data analysis and privacy security protection.

4.2 Conduct Systematic and Innovative In-House Construction

For systematic construction, libraries need systematic planning for their smart library construction process, including rational resource allocation across dimensions like services, management, spaces, and librarians, and arranging phased construction models and project priorities to avoid subsequent difficulties from scattered practices.

For innovative construction, libraries need in-depth practice of smart projects, including innovative transformation of existing projects and trial-and-error experimentation for planned projects, to continuously improve management and service intelligence levels. Using smart services as an example, libraries need to accelerate new service content construction, innovate service methods, expand service scenarios and capabilities, and ultimately build a comprehensive, deep, precise smart service system.

4.3 Strengthen Smart Librarian Team Cultivation

First, optimize librarian team construction systems through top-level design and operational planning based on actual smart library development requirements, including setting high standards for new librarian recruitment and targeted performance assessment and incentive systems. Second, adjust librarian team structure by strengthening IT personnel recruitment to optimize talent layout. Finally, build systematic, universal education and training systems to improve librarians' professional competence, innovation ability, and technology forecasting and application capabilities.

4.4 Unify Relevant Standard System Construction

Following the National Library' s "1+3+N National Smart Library System" requirements, construct unified standard systems for nationwide coordinated smart library construction to lay foundations for inter-library cooperation, balanced regional development, and integrated national services and management. This includes establishing and aligning standards and specifications for data formats, technology applications, infrastructure, business processes, service norms, and product specifications, as well as building unified evaluation and feedback mechanisms.

4.5 Strengthen Multi-Party Cooperative Support

Build stable multi-party cooperative relationships to secure advantageous resource support, including three forces: first, domestic and international technol-

ogy enterprises, professional R&D institutions, and researchers to compensate for human and technical shortcomings; second, other smart library construction entities to build inter-library alliances for mutual learning and complementary advantages; third, smart library users, gaining trust and support through privacy protection, incentives, and emotional satisfaction, then inviting user participation in innovative project trials and mining user behavior data.

4.6 Strengthen Theory-Practice Mutual Conversion

Strengthen two-way conversion between theory and practice. On one hand, enhance conversion from theoretical research to practical application, focusing theoretical research on practical pain points and future needs, such as the new-generation integrated open service management platform FOLIO and its localized project "Yunhan," deep application of emerging technologies, systematic construction, and innovative service project design. Additionally, pay attention to the practical conversion dynamics of application-oriented patent research. On the other hand, strengthen conversion from practical experience to theory, including summarizing excellent cases, patenting independently developed technologies, and analyzing failure causes. This forms a positive conversion cycle guiding other libraries' practice.

4.7 Conduct Supporting Publicity Work

In terms of publicity methods, smart libraries should utilize user-facing platforms, social media accounts, and third-party coverage for multi-channel promotion. In content, achieve point-surface combination, continuous tracking, and balanced coverage of success and failure cases to help the public, peers, and society comprehensively understand practical construction. In timing, besides real-time project reporting, conduct timely guidance according to public opinion to prevent project interruptions caused by negative 舆论.

Conclusion

Domestic smart library research and practical construction have completed the basic process from nothing to something over the past decade. Through reviewing and analyzing 383 practical data items, this study reveals that current Chinese smart library construction covers multiple dimensions including smart services, management, spaces, librarians, new-generation platforms, and supporting systems, with diverse entity types, nationwide administrative coverage, rich technology applications, and certain achievements. However, due to vulnerabilities in technology application, lack of systematic and in-depth work, lagging librarian team construction, insufficient multi-party cooperation, weak theory-practice connection, and mismatched publicity, comprehensive, deep, and balanced smart library construction has fallen into relative stagnation. Based on these dilemmas, this paper explores solutions from seven aspects:

strengthening technology introduction, conducting systematic and innovative in-house construction, cultivating smart librarian teams, unifying standard systems, strengthening multi-party cooperation, enhancing theory-practice conversion, and improving publicity, aiming to provide references for subsequent practice and theoretical research. As external socio-economic environments continuously change and emerging technologies emerge endlessly, smart library practice requires continuous attention and summarization to achieve transformation to fully-formed smart libraries and meet national socio-economic development requirements.

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Li Yuanjie: Framework design, data collection and organization, paper writing and revision;
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Note: Figure translations are in progress. See original paper for figures.