

Exploring the Theoretical Frontiers and Practical Blind Spots of Smart Libraries

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Abstract

Purpose To effectively advance the development process of smart libraries, this paper explores the theoretical and practical issues in smart library construction.

Methods Primarily employing literature review and data analysis methods, this study constructs a theoretical framework for smart library research, analyzes the theoretical frontiers that need to be addressed; reviews the practical implementation of smart libraries, and summarizes the practical blind spots from a causal perspective.

Results Based on the proposed theoretical framework for smart library research, it analyzes the theoretical frontiers that need to be addressed; based on a summary of practical implementation models, it identifies the practical blind spots in smart library development.

Limitations The data and literature covered in this paper have not yet encompassed the entirety of smart library research and need to be further expanded.

Conclusion Smart library research needs to theoretically focus on key issues such as the relationship between technology and humanities, non-technical issues, and smart librarian development; practically, it needs to address development blind spots in technology, direction, and personnel.

Full Text

Preamble

The Highlands of Theory and Blind Spots in Practice for Smart Library Research

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Abstract:

[Objective] To effectively advance the construction of smart libraries, this paper examines the theoretical and practical challenges in smart library development. [Methods] Using literature review and data analysis, we construct a theoretical framework for smart library research, identify theoretical highlands that require conquest, and analyze practical implementation to summarize blind spots from a causal perspective.

[Results] Based on a proposed theoretical system for smart library research, we analyze the theoretical highlands to be overcome and summarize practical blind spots by reviewing implementation models.

[Limitations] The data and literature covered have not yet encompassed the entirety of smart library research and require further expansion.

[Conclusions] Smart library research must address key theoretical issues including the relationship between technology and humanity, non-technical challenges, and smart librarian development. Practically, it must resolve developmental blind spots in technology, direction, and personnel.

Keywords: smart library; theoretical highland; practical blind spot

Classification Number: G250.7

1 Introduction

The *14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Long-Range Objectives Through 2035* calls for developing advanced socialist culture, enhancing national cultural soft power, actively developing smart libraries, implementing a digital strategy for the cultural industry, and advancing the digital transformation of public libraries and other cultural venues [1]. To deepen this important task, the Ministry of Culture and Tourism, the National Development and Reform Commission, and the Ministry of Finance jointly issued the *Opinions on Promoting High-Quality Development of Public Cultural Services* in the same month, emphasizing the strengthening of smart library system construction and establishing a nationwide smart service and management framework for libraries [2]. In June, the Ministry of Culture and Tourism further issued the “*14th Five-Year Plan*” for *Public Cultural Service System Construction*, explicitly proposing to lead with the National Smart Library System Construction Project and the Public Cultural Cloud Project to achieve new breakthroughs in the digital, networked, and intelligent development of public cultural services [3]. This elevates smart library construction to a strategic priority. Standing at this new historical juncture and facing new development goals, smart libraries have rightfully become the main theme of library innovation. Meanwhile, emerging intelligent technologies in the new era provide favorable support for smart library implementation. The convergence of IoT, big data, cloud computing, and AI has profoundly transformed library business processes and service models, with successful development of unmanned smart bookmobiles, automated sorting systems, inventory robots,

reference consultation robots, and 24-hour self-service libraries, enabling intelligence across the entire book circulation process from sorting and shelving to borrowing, returning, collection management, and services.

However, library intelligentization faces significant threats. While internet, big data, and AI technologies bring digital dividends, they also place libraries in a dilemma. On one hand, the explosive growth of digital information resources has altered the structure of library collections, leading to some neglect of print resources and resulting in digital resource acquisition costs gradually exceeding those of print resources [4]. On the other hand, the vigorous development of database vendors and mobile media has weakened libraries' dominance in digital resource organization, transforming them into users of digital resource technologies and methods [5]. As library resources shift from "collecting for preservation" to "collecting for use," libraries have moved from "working alone" to "joint operation," forming a community of shared destiny with data vendors, collection suppliers, system providers, and equipment manufacturers—cooperating yet competing. The COVID-19 pandemic disrupted this balance, with some database vendors demanding price increases of 6%–10% despite widespread reductions in library acquisition budgets [6]. Simultaneously, under the flourishing development of self-media platforms like Toutiao, Weibo, and WeChat Reading, and the widespread adoption of smart terminal devices, users' cognition, emotions, and preferences have become increasingly sophisticated, placing higher demands on library services. The combined effect of internal and external factors has amplified calls for smart library construction.

Therefore, based on a review of smart library research status, this paper constructs a theoretical system for smart library research, summarizes practical models for smart library construction, and elaborates on the theoretical highlands that must be conquered and the practical blind spots that urgently need exploration, hoping to provide references for relevant scholars, institutions, and enterprises to jointly build smart libraries.

2.1 Funding Projects

Research projects are classified hierarchically as national-level, provincial/ministerial-level, departmental/bureau-level, national society/association-level, and provincial society/association-level projects. Among them, the National Social Science Fund is currently China's only national-level funding for philosophy, social sciences, and humanities, while the National Natural Science Fund is the primary national channel for supporting basic research. Their status determines their importance, and their funded projects and research outcomes guide and lead disciplinary development. Statistical analysis of national-level funded projects can reveal the latest development trends in smart libraries and provide useful insights for future research topics. (Funding data sourced from the National Natural Science Fund Project Database and National Social

Science Fund Project Database).

Smart Library Projects Funded by National Social Science Fund

Smart Library Projects Funded by National Natural Science Fund

From the perspective of host institutions, except for the Military Academy of Sciences Military Science Information Research Center, all are universities, indicating that universities are the main force in smart library research. As shown in Table 1, Chongqing University received funding twice, reflecting its investment and emphasis on smart library research. In 2011, Chongqing University Library Director Yang Xinya [7] proposed using next-generation information technology to integrate three systems used by librarians (library management systems), readers (knowledge service systems), and library consortia (knowledge search engines) into a trinity Library 2.0 system. In November 2018, Chongqing University Library jointly established the “Smart Library Collaborative Innovation Alliance” with VIP Information and 28 domestic libraries to promote smart library construction through community-based models [8]. In 2020, Chongqing University Library co-developed the “+Collection” system with Beijing Adksun Company and incorporated smart library construction into its 14th Five-Year Plan [9]. This favorable atmosphere has promoted smart library development at the university. Regarding project themes, three projects contain the word “data,” reflecting the core importance of library resources. This also relates to policy orientation—the *Opinions on Improving the Market-oriented Allocation System and Mechanism of Production Factors* issued on April 9, 2020, explicitly identified data as a new type of production factor. Smart library research aligns with social development.

2.2 Academic Conferences

Academic exchange forms the foundation of scientific research, and academic conferences, as the primary mode of exchange, have always been important platforms for sharing cutting-edge issues and research outcomes, demonstrating strong foresight and sensitivity. Statistics show that over 20 academic conferences on smart libraries were held between 2020 and October 2021. Due to the strong timeliness of academic conferences, we only list and analyze conferences from January to October 2021.

Smart Library Themed Conferences

The timeline shows that smart library conferences maintain high discussion frequency and popularity, averaging one per month, with hosts spanning various organizations including universities, enterprises, and library societies. Among them, the Shanghai Library Society’s branded conference—Library Frontier Technology Forum (IT4L), established in 2009—focused on smart library technology and application in 2021, actively calling on all types of libraries and institutions to jointly build a smart library ecosystem. Meanwhile, the Smart

Library Technology Application Alliance's series of lectures on smart library technology applications promoted smart library implementation by sharing construction achievements. Regarding conference themes, discussions concentrated on space reengineering, supporting technologies, and next-generation service platform construction. This relates to the actual circumstances of host organizations. For example, the conference co-hosted by the China-Singapore Friendship Library shared the library's construction cases to promote smart library initiatives in building smart application scenarios and improving intelligent management efficiency.

2.3 Research Publications

We retrieved literature from CNKI using the search strategy: subject term limited to "smart library," journals limited to 10 highly library-related journals continuously appearing in the CSSCI source journal directory over the past decade (*Journal of Library Science in China*, *Journal of Academic Libraries*, *Journal of the National Library of China*, *Library and Information Service*, *Library and Information Knowledge*, *Library and Information Work*, *Library Tribune*, *Library Journal*, *Library Construction*, and *Library Science Research*). After removing invalid documents such as conference announcements, prefaces, and calls for papers, we obtained 308 papers and conducted visual analysis using VOSviewer software. Results are shown in Figure 1.

According to Figure 1 [Figure 1: see original paper], "smart library" is the core keyword with 188 occurrences, followed by smart services, artificial intelligence, big data, IoT, digital library, library, intelligent library, and university library. This aligns with Yang Siluo's [10] conclusion using Citespace that Chinese smart library research hotspots focus on big data and AI technology applications in libraries, smart service strategy exploration, and specific smart library practices. Overall, Chinese smart library research can be divided into four aspects:

Basic Theoretical Research on Smart Libraries

Main keywords include intelligent library, smart city, digital library, and IoT. Early smart library research focused on concepts, connotations, implementation methods, and relationship distinctions with intelligent libraries. Wang Shiwei [11] argued that the smart library concept surpasses intelligent libraries, featuring interconnectivity, efficiency, and convenience. Chu Jingli [12] distinguished smart libraries from intelligent libraries from perspectives of core driving forces, functional attributes, and target effects, deepening public understanding of smart libraries. These explorations of basic theory provided theoretical guidance for practical exploration.

Technology Application in Smart Libraries

Main keywords include artificial intelligence, big data, cloud computing, RFID, 5G, and blockchain. For instance, Su Yun [13] constructed a framework for library smart services based on big data and AI dual drivers. Zeng Qun [14]

proposed an innovative service model for smart libraries under 5G environments, providing personalized customized services, scenario-based experiential services, and specialized reference consultation services for different user types through deep analysis of user digital footprints, contextual data, and content preference data, building user scenario libraries, user profile libraries, and knowledge resource libraries. Hong Liang [15] explored construction approaches for big data-driven library smart information service systems and, based on information ecology chain theory and guided by library business processes, constructed a big data-driven library smart information service system.

Service Model Exploration for Smart Libraries

Main keywords include smart services, knowledge services, subject services, and library services. Ma Xiufeng [16] analyzed the practical necessity of reshaping library subject services from a smart perspective, investigated the current status of subject services in 42 “Double First-Class” university libraries, proposed value propositions for subject services, targeted personalized and precise service goals, and constructed a library subject service model architecture. Zeng Ziming [17] analyzed the smart service needs of personalized recommendations in libraries from the concepts and characteristics of smart libraries and smart services, and constructed a personalized knowledge recommendation service system for smart libraries based on ubiquitous smart services.

Specific Practices of Smart Libraries

Main keywords include Chongqing University Library, university libraries, and library service platforms. This aspect mainly introduces various implemented smart elements through case studies. For example, Yu Hejian [18] compared and analyzed two representative domestic smart library service platforms—DALIB Smart Library Data Service Platform and Chaoxing Smart Library Service Platform—from four aspects: product positioning, technical features, detailed functions, and vendor service capabilities. He Xinqian [19] assessed the smart service level of foreign libraries through website investigations of 60 top European and American university libraries and 60 large and medium-sized European and American public city libraries.

3.1 The Theoretical System of Smart Library Research

From the perspective of Marxist philosophy, production relations have a reactive effect on productive forces—production relations adapted to productive forces development promote it, while mismatched relations hinder it. As a product of next-generation information technology practice and application, smart libraries represent advanced productive forces requiring advanced production relations—advanced smart library theory as guidance—to ensure healthy, coordinated, and sustainable development [20]. Therefore, smart library research must attend to theoretical system construction. Analyzing from research content perspectives, the theoretical system of smart library research should include the following

components (see Figure 2 [Figure 2: see original paper]).

[Figure 2: see original paper] Smart Library Theoretical System

(1) Basic Theory of Smart Libraries

Basic theory refers to systematic knowledge that expresses the essence and laws of objective things and phenomena through principles and concepts in practice and specific research [21]. Smart library basic theory builds upon general library theory to articulate fundamental concepts, categories, and principles of smart libraries, primarily addressing “what is a smart library,” “why build smart libraries,” and “how to build smart libraries.”

Smart library basic theory is the fundamental driving force for smart library development. Its research depth serves as an important indicator of smart library development levels and supports overall construction and development. Key to building smart library basic theory lies in the connection and integrated development between smart library research and existing library theory. Smart library basic theory is not about mechanically applying smart library content to existing library theory but rather referencing, drawing upon, integrating, and innovating general library theory considering new backgrounds, environments, and needs of contemporary library development. Therefore, from inheritance and development perspectives, smart library basic theory research includes: smart library concepts, development evolution, attributes and functions, and structure.

Smart Library Concept

Research objects are the starting point of theoretical research. Clarifying the smart library concept—identifying the research object—is a fundamental issue in smart library research that directly influences subsequent research methods and content. Debates over smart library connotations and extensions during construction reflect its development process. Currently, no unified understanding or definition of smart library exists, and with emerging needs and new technologies, research on this fundamental question will deepen, expanding and presenting new characteristics. From Finnish scholar Markus Aittola’s [22] definition of smart libraries as “spatiotemporally unrestricted, perceivable, wirelessly connected mobile libraries” to Chu Jingli’s [12] recent view of smart libraries as “advanced library forms dedicated to achieving knowledge services through human-computer interaction coupling, representing a comprehensive ecosystem,” these perspectives demonstrate increasingly rich connotations.

Smart Library Development Evolution

Libraries are products of social development at certain stages. Since their inception, libraries have evolved through forms including traditional libraries, electronic libraries, and digital libraries. Today’s smart libraries under construction represent a product of the big data era and accelerated informationization—a new form of library development. From a Marxist development perspective, smart libraries represent a “sublation” of previous library forms in historical development. Therefore, research on smart library evolution must clarify its position in overall library development and distinguish its relationships with ex-

isting forms, especially digital libraries. Meanwhile, smart library development remains relatively brief. As technologies mature and systems improve, smart libraries will generate different development stages, requiring accurate positioning of current development stages and proper handling of relationships among influencing factors to ensure healthy and sustainable development.

Smart Library Attributes and Functions

“Attributes” are inherent characteristics of things that embody their essence. As a social mechanism created through human social practice, library attribute understanding has undergone a lengthy process alongside deepening practice [23]. Smart library construction and development mark a new stage in library development. As a new library form, smart libraries possess not only general attributes of traditional libraries—intermediacy, sociality, dependency, academic nature—but also extended and developed new attributes worthy of attention, such as wireless ubiquity, comprehensive perception, and open interconnectivity [11]. Understanding smart library attributes is prerequisite to grasping their essence. Only by clarifying attributes can we deepen understanding and research and better construct smart libraries.

Functions are capabilities that organizations and institutions should possess and realize, determined by attributes. Whether individual smart library construction or overall smart library development, both constitute organizational systems whose functions are determined through attribute research. Meanwhile, library functions have varied emphasis across different historical stages, requiring analysis of dominant functions and their changes and progress in conjunction with new requirements and goals. Therefore, basic smart library research must summarize and understand smart library functions based on full attribute comprehension, rethinking and exploring these functions.

Smart Library Structure

From a Marxist systems perspective, libraries are organic wholes composed of different elements combined through certain structures, possessing specific functions, maintaining relative dynamic balance amid environmental changes, and continuously developing. In the new development stage, smart libraries incorporate new elements, making relationships among constituent elements and their functions more complex and diverse. Properly handling and coordinating relationships among smart library elements and first establishing a relatively stable and balanced smart library structure theoretically are important prerequisites for promoting coordinated and stable smart library development. Specifically, smart library structure includes two levels: macro-level structure of the entire smart library industry, clarifying planning and policy formulation, structural division, and industry construction; and micro-level structure oriented toward specific smart library workflows, including basic work processes, business process reengineering based on smart service needs, and intelligent transformation of work and service processes. Combining macro and micro perspectives enables analysis from both overall and detailed viewpoints.

(2) Smart Library Technology and Methodology Theory

Libraries have always been key arenas for advanced technology application, with new technologies permeating the entire library construction and development process. As products of next-generation information technology application, smart libraries rely irreplaceably on information technology for construction and development. In recent years, smart library construction has attracted widespread attention, with academic and industry research gradually deepening from initial concepts, connotations, and features toward technology applications and smart services. Given current development stages and situations, integration and application of new technologies, innovation in smart library construction methods and means, and handling of technology-humanity relationships have become important concerns. Smart library technology and methodology theory guides specific research and construction practices, focusing on exploring new methods, technologies, and business practices in smart library contexts, and researching effective responses to impacts of new technologies and methods on library development and existing library theory. Research content includes: smart library research methods, supporting technologies, and application research.

Smart Library Research Methods

Research methods are tools and means to reveal 事物本质和规律, playing important roles in guiding practice. For a long time, domestic and international academia has generally discussed library research methods insufficiently, with the library profession focusing more on technology and work method research. This directly led to inadequate induction and summarization of library-related research methods and a relative lack of professional methods with library characteristics [23]. The incompletely formed library research methodology system has become a bottleneck for current smart library construction. Therefore, smart library research must establish and improve the smart library methodology system based on existing library research method systems, strengthening attention to specialized smart library methods while improving philosophical and general method research, continuously filling gaps and deficiencies. Simultaneously, balancing theoretical and practical aspects, the increasingly perfected methodology system should feedback into smart library research to drive further deepening.

Smart Library Supporting Technologies

Science and technology are the primary driving forces for library development. Every library form evolution and model transformation bears the “technology” imprint. In the intelligent Industry 4.0 era, humanity depends on technology more than ever. Smart library emergence and development largely depend on technological progress, and their knowledge service and smart service levels will continuously improve alongside deep technology integration and application. Therefore, researching smart library supporting technologies and exploring coordinated development between new technologies and smart library construction have important guiding significance and practical value. In supporting technology research, besides understanding basic principles of technologies including IoT, 5G, AI, blockchain, context awareness, and quantum computing, we must identify parts relevant and adaptable to smart library construction, handle pri-

vacy and security issues during technology introduction and application, and enable reasonable, demand-driven empowerment of smart library construction.

Smart Library Application Research

Smart library construction remains in its initial development stage, but has already achieved some phased results that can accumulate experience and provide references for future construction. Smart library application research refers to inducing common and specific issues from actual research activities and construction work, summarizing relevant experiences and patterns, establishing models, and generalizing them to provide guidance for solving practical problems during construction. Specific content includes: researching smart library scenario-based construction and specific application practices under demand-driven and scenario-driven principles, researching promotion and application of relevant practical achievements, and researching existing problems and solutions in smart library construction scenarios.

(3) Smart Library Management and Service Theory

From a philosophical perspective, management and service are contradictory yet unified, complementary and mutually reinforcing. In library construction, the contradictory movement between library management and service reveals development dynamics, and positioning their relationship directly impacts library practices and operational effectiveness [24]. Handling and coordinating management-service relationships is both a basic requirement for high-quality librarians and an important aspect of library work: managing resources including human resources, funds, literature information resources, and data while upholding the “user-centered” philosophy to serve users.

In the new stage of smart library construction, smart libraries pay greater attention to user needs and management efficiency, requiring clearer positioning of management-service relationships and actively promoting intelligent management and smart service under new technological environments. Smart library management and service theory provides direction and guidance for various management and service tasks, creating a healthy and stable environment, coordinating various elements, fully mobilizing all parties, and enhancing overall smart library effectiveness. From constituent elements perspective, main research content includes: smart library legal construction, space management, standardization construction, resource management, service management, and talent cultivation.

Smart Library Legal Construction

During smart library construction and development, contradictions between demands for strengthened interconnectivity and open sharing versus information and data security, privacy and property protection, ethics and morality have become sharper. Balancing and resolving these contradictions requires corresponding legal systems to provide solid institutional guarantees. Smart library legal construction is the political guarantee for smart library construction, providing legal basis from the superstructure level. Currently, provisions specifically addressing smart library construction are mostly scattered in national and gov-

ernment documents, limited in number, and mostly general. The legal basis for smart library construction is relatively scarce, systematic legal systems have not yet formed, and the legal foundation remains weak and unstable. Specialized smart library legal systems urgently need establishment and improvement. Research on smart library legal construction must systematically summarize and integrate existing laws and regulations, identify gaps and breakthrough points, conduct institutional planning and improvement from a top-level design perspective, and implement practical promotion paths and implementation plans to create a favorable institutional environment.

Smart Library Space Management

Library space research has a long history, from collection resource spaces to user personalized spaces. As a three-dimensional, multi-level cultural information space, library space research has always been an important component [25]. Supported by big data and emerging technologies, smart library space construction extends from physical buildings to virtual network levels, requiring “virtual-physical integration” and “smart sharing,” coordinating physical space layout while strengthening virtual space construction to achieve coordinated integration. Smart library space management must promote integrated construction of physical and virtual spaces under the user experience-centered principle, creating multi-dimensional smart spaces integrating maker spaces, learning spaces, knowledge sharing spaces, and perception spaces that are organically fused, highly interconnected, and intelligent, providing users with more convenient and diverse knowledge services.

Smart Library Standardization Construction

In October 2021, the CPC Central Committee and State Council issued the *National Standardization Development Outline*, requiring strengthened standardization construction and promotion of “basic public service standardization” [26]. Currently, smart library construction has become a development consensus, with preliminary understanding of concepts, functions, structures, and supporting technologies. However, China’s smart library construction remains in its initial stage, with many incomplete aspects. Lack of attention to standardization construction has hindered smart library development and practical implementation [27]. Therefore, emphasizing and strengthening smart library standardization research and building practical, domain-characteristic standard systems are key measures to advance smart libraries from theory to practice, significantly accelerating construction processes.

Smart Library Resource Management

In the new environment, smart library collections have undergone tremendous changes in quantity, form, structure, and quality: resources overall show a development trend from literature to data, with semi-structured and unstructured resources growing massively, and resource content developing toward rich media, interconnectivity, and open sharing [28]. Additionally, smart library human resources, technology resources, and other resource types exhibit specialization, complexity, and diversification. Addressing these new characteristics requires

smart library resource management research focusing on resource elements, clarifying “what to manage”—identifying smart library resource characteristics—to optimize resource allocation, ensure effective utilization, and improve overall smart library construction effectiveness.

Smart Library Service Management

Wu Jianzhong noted: “The value of libraries lies in services and their effectiveness [29].” User needs drive new service models and methods. During smart library construction, user needs exhibit personalization, refinement, and depth, placing higher demands on smart library services in terms of methods, means, and quality. In this context, smart library service management research from the user perspective has important value for deepening the “user-first” service management philosophy, strengthening and improving smart library service capabilities, enriching and expanding marketing and promotion paths, accelerating the transformation toward knowledge-intensive services, more precise personalized services, and smart services, and establishing comprehensive service systems providing literature services, subject services, data services, and think tank services throughout the entire process, better fulfilling cultural inheritance and knowledge dissemination functions.

3.2 Theoretical Highlands in Smart Library Research

“Highland” is often used metaphorically to describe areas with advantages that exert important influence on surroundings [30]. Based on smart library theoretical research, special attention must be paid to conquering theoretical highlands. Smart library theoretical highlands possess guidance, benchmarking, complexity, and innovation. Under their guidance, libraries at all levels can better master discourse power and initiative in smart library construction. Conquering these highlands should focus on several key issues.

(1) The Relationship Between Technology and Humanity

As social memory preservation and transmission devices, libraries possess inherent humanistic attributes. Since libraries shifted from “preservation for collection” to “use for collection,” they have consistently adhered to human-centered and user-centered principles, vividly demonstrating humanistic characteristics. Meanwhile, technology as a key driver of library innovation has promoted repeated transformations in library forms and models, fundamentally changing management and service patterns. Thus, humanity and technology share a natural, inherent relationship: humanity as essential connotation focuses on cultural values and social care, while technology as means drives knowledge dissemination and cultural inheritance.

New-era emerging technologies provide dual drivers for smart library construction, accelerating its progress. However, we must note that technology is a double-edged sword. While introducing and applying new technologies to achieve smart services, consequent information security, ethics, and morality

debates directly raise a series of “human” issues, plunging smart library construction into new dilemmas. Additionally, in the environment of fully building smart libraries, both researchers and constructors more easily lose themselves, falling into the 漩涡 of emphasizing technology while neglecting humanistic care, forming the mistaken notion that using new technologies and introducing intelligent equipment equates to smart libraries. The prevalence of “technology-only” theories represents a misunderstanding and alienation of library innovation development, leading smart library research and construction astray. These phenomena violate the original intention of smart library construction, requiring researchers and constructors to maintain clear minds, properly handle and coordinate the relationship between technology and humanity, and avoid falling into the “technology supremacy” trap.

Another important aspect of the technology-humanity relationship is “humanity.” Besides avoiding overemphasis on technology value and one-sided “technology-only” advocacy, we must always remember that user needs are the source and driving force of library survival and development. Libraries neglecting “human” needs cannot develop further and will ultimately be eliminated by society. Smart libraries as new library forms are not products of one-sided pursuit of new technology applications or quick success but rather expectations and requirements for further demonstrating smart power under the “people-oriented” development philosophy. That is, under the premise of ensuring humanistic care, using technology as means to serve users with library “wisdom” and better meet diverse and personalized needs. Therefore, in smart library research and development, whether business management, space reengineering, or smart services, we must emphasize human factors—more comfortable environments, more thoughtful services, more simplified processes—continuously highlighting human value in service and management. Simultaneously, under humanistic guidance, smart library research must increase attention to special populations, studying specialized services for people with disabilities, migrant workers and their children, the elderly, and prison inmates to comprehensively demonstrate human consideration and care.

(2) Attention to Non-Technical Issues

Smart library emergence further shifts library services and management from resource-centered to user-centered. Integration of IoT, 5G, AI, blockchain, and other technologies technically subverts library functions and connotations, promoting the transformation from digital libraries to smart libraries [31]. Research and discussion of non-technical issues trace back to the origins of smart library development, with relevant viewpoints and attitudes largely reflecting the “technology-only” malady in smart library construction. “Non-technical issues” here refer primarily to management, funding, and legal issues arising during smart library research and construction, as opposed to technical issues. We briefly discuss two major aspects: standardization issues in management and intellectual property protection in legal issues.

First, standardization issues. The *National Standardization Development Out-*

line states that “standards are technical support for economic activities and social development, important aspects of national basic systems. Standardization plays a fundamental and leading role in advancing national governance system and capability modernization” [26]. As an emerging phenomenon, smart libraries have incomplete infrastructure and superstructure, with relatively lacking standardization construction. On one hand, diverse and rapidly updating technologies supporting smart library construction make unified standards difficult to establish. On the other hand, the state lacks relevant planning for smart library standardization, forcing 相关单位 to build internal standards independently, resulting in scattered outcomes and lack of information exchange. Currently, China’s smart library construction is transitioning from theoretical research to practical implementation. Establishing a unified smart library standard system is crucial for practically advancing construction processes. Based on existing library construction standards, macro-level coordination and consensus-building are needed. Drawing on research by Liu Wei et al. (2018) [32], Ma Huiping (2020) [33], and Lu Xiaobin et al. (2021) [27], we believe smart library standard system construction should address: Data standards—exploring standardized definitions for unified data and resource description and interconnectivity;

Technical standards—specifying concrete specifications and norms for technology introduction and application; Building standards—establishing standards for smart library infrastructure equipment (including robots, sensors, 3D printing equipment, smart terminals) configuration, venue space construction specifications, and zoning; Business standards—regulating specific businesses including user authentication, space management, and information exchange; Service standards—defining smart library service content and forms, developing user service guides, and determining evaluation indicators. In practice, smart library standard system research remains insufficiently comprehensive and deep, without unified theoretical understanding, requiring further investigation.

Second, intellectual property protection issues. The contradiction between libraries’ goal of comprehensive resource open sharing and legal intellectual property protection has long existed. On one hand, property protection safeguards legitimate rights of rights holders over their intellectual labor achievements, ensuring creative enthusiasm and providing sources for library collection enrichment. On the other hand, property protection restricts resource sharing to some extent, hindering library goal achievement. In the new era of smart libraries, construction demands higher degrees of open sharing for library data and resources, hoping to provide more convenient and precise smart services through establishing reasonable, efficient, and integrated resource interconnectivity networks. However, the contradiction between property protection and open sharing goals remains fundamentally unresolved and may become increasingly acute. This means smart library construction will likely involve a series of intellectual property issues: infringement from improper link settings and usage; infringement from unauthorized information resource digitization; information security issues and infringement from illegal user access in cloud service environments [34]. Additionally, smart library construction encompasses more diverse

and complex resource types than before, creating greater potential infringement risks. With China's imperfect intellectual property system, determining infringement nature becomes increasingly difficult. Moreover, existing intellectual property protection measures are not fully applicable to smart library construction, and specialized systems and legal frameworks for smart library intellectual property protection require further strengthening and improvement. From these perspectives, intellectual property protection is an important issue requiring balance and coordination in smart library construction. Strengthening property issue research significantly promotes achieving smart library resource open access goals. Scholars have proposed countermeasures including improving smart library property protection legislation, strengthening smart library platform and service personnel management, and enhancing system security levels, but their effectiveness, feasibility, and specific norms require more in-depth research.

(3) Smart Librarian Development

Smart library construction cannot proceed without high-quality human resources. As a core element of smart library construction, smart librarians' professional competency directly impacts construction effectiveness and social value, representing a key factor ensuring smart service capability and quality. Correspondingly, deep development from digital libraries to smart libraries and growing user demands for smart services provide conditions and opportunities for traditional librarian transformation into smart librarians. However, current problems including low construction levels of librarian teams, missing relevant systems, and smart librarian shortages have become major bottlenecks for contemporary smart library innovation development, attracting widespread academic and industry attention. Hunan University Library Director Zheng Zhangfei proposed at the March 2018 "Innovation and Development: Libraries and Library Science in the New Era" high-level forum that from a career development perspective, the main contradiction in new-era libraries could be defined as "the contradiction between rapid informationization development and lagging librarian professional capabilities" [35]. Peking University Library Director Chen Jianlong also noted at the October 2019 "12th Library Management and Service Innovation Forum" that "the main contradiction has shifted from insufficient collections to insufficient librarian capabilities," requiring cultivation of "professional librarians with professional spirit" [36]. Facing such dilemmas requires further assessment and improvement of competency characteristics demonstrated by librarians during smart management and service processes to promote smart librarian selection and cultivation [37].

Regarding specific improvement paths for smart librarian professional competency, scholars have proposed various countermeasures and suggestions from different research perspectives: improving smart librarian selection, introduction, and cultivation mechanisms; establishing smart librarian professional competency standards; establishing long-term training and learning mechanisms to improve comprehensive literacy; strengthening smart librarian team building with emphasis on overall performance assessment; constructing dynamic evalu-

ation systems to promote comprehensive smart librarian development [37][38]. However, these studies and suggestions are mostly theoretical assumptions with relatively strong subjective coloring. How to improve their operability and effectively enhance overall smart librarian team construction levels requires more robust theoretical basis and support.

4 Urgent Practical Blind Spots to Explore

While smart library transformation has gained universal recognition and a few pioneering libraries have developed reference construction plans—such as Wuhan University Library’s “software-hardware integration for smartness,” Jiaxing Library’s “venue-based self-service library smart enhancement,” and Guangdong Provincial Sun Yat-sen Library’s “Acquisition and Cataloging Turing—Intelligent Book Acquisition and Cataloging Operation System”—smart library construction still faces problems [20] and misconceptions [39]. This paper sorts out and interprets existing smart library practice models to deeply explore construction blind spots, providing basis for “blind spot elimination” in smart library construction.

4.1 Smart Library Practice Models

(1) Technology Transplantation and Cross-Border Symbiosis

Throughout library form evolution—traditional libraries, electronic libraries, mobile libraries, digital libraries, and smart libraries—information technology has provided powerful driving forces. The cross-integration of emerging technologies including big data, IoT, cloud computing, AI, and 5G constitutes the technology chain for smart library operation [40]. Introducing new technology products or equipment has become the preferred transformation model. Some practical achievements are shown in Table 4 .

Practical Achievements Under Smart Library Technology Transplantation and Cross-Border Symbiosis Model

The library profession has consistently maintained high attention and sensitivity to information technology [41]. Therefore, each emerging technology debut signals a new round of library innovation exploration. Among various technology innovations, RFID technology started earliest, with practical achievements permeating self-service borrowing/returning, document positioning, collection inventory, and shelving management. For example, Shenzhen Library fully deployed RFID tags in its new building opened in October 2006, and combined with its actual conditions and RFID’s unique advantages, developed an RFID intelligent document management system integrating multiple management processes, achieving innovations in technology, services, and management. Subsequently, Shenzhen Library developed a city block 24-hour self-service library system based on RFID technology, consisting of self-service library machines,

library service and monitoring center systems, and logistics management systems. Each device occupies less than 10 square meters yet enables self-service card registration, borrowing/returning, book reservation, collection inquiry, and other unattended 24/7/365 services [42].

Meanwhile, robotics technology has emerged in various library businesses. In 2010, Tsinghua University pioneered the chatbot “Xiaotu,” which could reason and answer consultations based on AIML knowledge bases, providing library-related information services and integrated book search functions [43]. Beyond chatbots, libraries have introduced information communication robots for library situation introduction and user interaction, such as Shanghai Library’s Pepper robot serving as a “librarian” to assist with business consultation and processing [44]; learning assistance robots for interest cultivation and teaching, such as Yichun Library’s children’s robot “Tutu,” which relies on powerful cloud engines and rich cloud content to provide education, companionship, and entertainment services for children [45], and Weifang Library’s “Robot Dual-Teaching AI Salon” activities, where robots teach student readers from a friend’s perspective, popularizing robotics history, explaining programming principles, conducting science experiments with children, and encouraging hands-on exploration of smart technology mysteries [46].

Multi-Technology Integration

Introducing new intelligent technologies must consider coordination with existing technologies, with cross-technology integration achieving overall innovation in application scenarios. For example, Nanjing University Library’s self-developed inventory robot “Tuke” relies on IoT, AI, and robotics integration to achieve fully automated book inventory, with autonomous navigation, book positioning, and intelligent hazard avoidance functions [47]. In 2021, Guangdong Provincial Sun Yat-sen Library deployed the “Acquisition and Cataloging Turing” intelligent book acquisition and cataloging operation system, which combines IoT, AI, and industrial robotics technologies. By simply batch-placing books on the automatic supply platform, “Acquisition and Cataloging Turing” can precisely identify and automatically complete over ten operations including book information collection, posture adjustment, label/barcode printing and application, information reading/writing, page turning, and collection stamping, achieving transformation and upgrading from traditional manual operations to automated intelligent operations [48].

(2) Local Adaptation and Independent Innovation

At the end of the 19th and beginning of the 20th century, modern libraries and library science were imported from the West into China [49]. Therefore, China’s library development cannot entirely copy Western theories while ignoring local cultural backgrounds. Rebuilding our own discourse system and constructing localized smart achievements not only demonstrates our independent national value consciousness but also helps change the single-pattern landscape centered on Western discourse in world library science [50]. Development of new-generation library service platforms and library space reengineering are

main directions under this model.

System Platforms

With upgraded demands, expanded resources, and restructured businesses, library integrated management systems struggle to adapt to new development, prompting new-generation library service platforms. Currently widely used platforms include ProQuest ExLibris's Alma, OCLC's Worldshare Management Services (WMS), and Innovative's Sierra. Strictly speaking, these belong to second-generation platforms, and due to differences in Chinese and foreign library business priorities, foreign platforms show obvious applicability defects. Some pioneering libraries have successively developed self-researched service platforms based on local conditions (see Table 5).

Main Practical Achievements of Third-Generation Service Platforms

For example, Chongqing University Library partnered with Chongqing VIP Information to develop a smart library system architecture including three major data platforms (metadata database, operation database, data warehouse) and four application systems (comprehensive library management system, reader knowledge community, literature resource search system, data mining system), along with customizable personalized smart library portals with scenario-adapted sections [51]. Nanjing University jointly developed China's first next-generation library platform NLSP with Jiangsu Library Software, with NLSP 3.0 officially released in September 2020. NLSP benchmarks against Alma, adopts cloud computing and microservices architecture, and integrates four modules: central knowledge base, selection platform, librarian smart service platform, and reader application service platform [52]. Shanghai Library began localizing FOLIO in 2021, launching a FOLIO library service platform with partial circulation functions in April to provide backend support for various scenarios including self-service borrowing/returning, automated sorting, reservation lockers, and mobile borrowing. In October, it launched the Sinicized FOLIO—Yunhan—serving as both a next-generation library service platform and a set of application components replacing traditional integrated library systems, as well as an open-source community operating under open concepts, introducing middle platforms and developing a Yunhan platform integrating cloud-native microservices architecture with smart services based on Chinese characteristics [53].

Space Reengineering

Specific construction paths for library space reengineering mainly include two approaches: First, relying on unique resources and using new technologies or equipment to refine or extend library space functions. For example, Nanjing Library created “ancient-modern integrated” cultural spaces including “Chinese Studies Hall,” “Ten Virtues Hall,” and “Cherish Time Hall” based on its historical characteristics using modern reading equipment [54]. Taiyuan Library actively cooperated with social forces from the supply side, seizing the opportunity of Marx's 200th birthday to open a Marx Study Room, achieving cross-disciplinary literature integration with teaching lectures, exhibitions, fun activities, and dig-

ital reading functions [55]. Second, integrating urban cultural positioning and jointly building integrated main-branch library service systems with multiple libraries within regions to achieve networked library layout. By 2019, China had 41,338 library branches, a 62% increase from 25,430 in 2018 [56], forming many typical main-branch development models. For example, Hangzhou Library explored a themed branch construction Hangzhou model based on regional culture and readers' differentiated and personalized cultural needs through self-construction and cooperation with social enterprises, establishing 28 themed libraries by the end of 2020 including music, wellness, intellectual property, and party-building branches, with Hangzhou Study Rooms continuously advancing [57]. Suzhou Library formed a close main-branch relationship through innovative "flattened" structure management and added district management layers, achieving universal borrowing and returning based on dynamic asset rights, fully ensuring service effectiveness. By the end of 2020, Suzhou Library's main-branch service system had established 96 branches with nearly 200 branch staff, with increasingly prominent social benefits [58]. Jiaxing City excavated urban cultural connotations and optimized public cultural service quality. Jiaxing Library, focusing on the strategic goal of building a water-town ecological cultural city, established 2 district branches, 18 township (street) branches, 32 village (community) branches, 20 smart study rooms, 1 mobile library, and over 300 book circulation stations at the municipal level, creating a construction model with various branch forms including "My Jiaxing Study Room," "City Study Room," and "Smart Study Room" [59].

(3) Breaking Through and Innovating

Smart libraries ultimately aim to achieve an interconnected, open, and shared knowledge service system. Interconnectivity involves not only individual libraries internally but also among libraries and various cultural centers. This model refers to libraries adopting more open management thinking, shifting from collections to connections and from collections to communities, comprehensively promoting smart development of the public cultural system. Representative examples include the "National Smart Library System" construction project and connections between libraries, museums, archives, and art galleries. In 2020, the National Library proposed the "National Smart Library System" construction concept, with an overall architecture summarized as 1+3+N: "1" refers to one "cloud-based smart library," "3" refers to the entire network knowledge content integrated storage, national smart library management system, and universal smart knowledge service operation environment built upon it, and "N" refers to establishing offline smart service spaces universally at all levels of libraries and their grassroots service points nationwide [60]. Tangshan City Library, Tangshan Museum, and Tangshan Mass Art Museum actively promoted cross-system and cross-industry exchange activities, forming a "three verticals, one horizontal" development model. The "three verticals" refer to three vertical lines of inter-museum exchange and cooperation: museum-to-museum, library-to-library, and mass art museum-to-mass art museum. The "one horizontal" refers to horizontal alliances and cross-boundary cooperation among museums,

libraries, and mass art museums, mainly including: libraries as leaders creating unique “city study rooms” with museums and mass art museums; museums as leaders launching “traditional culture entering campuses” projects with three-museum joint efforts; and mass art museums as leaders creating “Our Festivals” cultural brands with three-museum collaboration [61].

(4) Model Summary

This paper categorizes smart library practice models into three types: technology transplantation and cross-border symbiosis, local adaptation and independent innovation, and breaking through and innovating (see Figure 3 [Figure 3: see original paper]). Models 1 and 2 belong to individual library pilot construction, while Model 3 aims to achieve overall intelligentization of the library community. Although three different practice approaches, certain connections and interactions exist among them. Model 2’s local adaptation and independent innovation largely depends on dividends brought by technology introduction, and Model 3 upgrades and transforms based on certain achievements from Models 1 and 2.

[Figure 3: see original paper] Schematic Diagram of China’s Smart Library Practice Models

4.2 Analysis of Smart Library Practice Blind Spots

Although smart library construction has achieved a series of results, due to related technology maturity and library environment complexity, current smart library implementation remains limited, with significant gaps from expectations. To promote comprehensive smart library development, the following dilemmas must be resolved.

(1) Technology Bottleneck: Emphasizing Elements While Neglecting Ecosystem

Intelligent technology is one driving factor in smart library construction, permeating all intelligent transformation links. However, two erroneous cognitions currently exist. First, blindly pursuing technology without field investigation of library business adaptability, working behind closed doors, and slightly modifying existing products or technologies to practice as “local” smart library products. Smart equipment is mostly provided by suppliers who consider different application scenarios across industries during design, potentially resulting in insufficient personalized customization functions for library scenarios. Second, labeling existing library business and service automation as smart library functions while neglecting value growth from technology introduction. Simply purchasing equipment one after another without focusing on interconnections only creates isolated islands; local informationization will never form overall intelligentization. IoT perceives and collects various user data, libraries preserve massive resources, and AI simulates human consciousness and thinking. These three can form a complete service chain through technology. Overall, technology

triggers business and process reengineering, but traditional business should not become shackles for technology application. We must fully utilize technological advantages to create new library business ecosystems.

(2) Directional Deviation: Emphasizing Exogenous Issues While Neglecting Endogenous Philosophy

Smart library development philosophy was proposed under the background of major transformations in China's library development environment, conditions, tasks, and requirements, possessing distinct problem orientation. Smart library practical achievements should be based on new problems and dilemmas, rooted in real issues in library development, not virtual problems derived from conceptual interpretation. Currently, smart library practice exploration shows serious homogenization, with strong development in hot fields while other areas remain almost blank. Implementing smart library development philosophy requires connecting these principles and concepts with specific practical problems, deeply understanding and analyzing problems, and building corresponding service systems.

(3) Personnel Dilemma: Subject Displacement and Insufficient Participation

Under the strategic framework where smart library construction has risen to strategic goals, libraries, collection suppliers, users, and social forces should all join the library community of shared destiny, contributing collective wisdom and efforts to comprehensively build a smart library ecosystem. However, two problems exist in reality. First, at the library level, many traditional library leaders have not yet participated in smart libraries. Just as different library forms complement rather than replace each other, traditional library scholars should not be absent from the smart library construction stage. They know where libraries come from and consistently uphold the people-oriented development path. Their participation will surely bring fresh air to smart libraries. Second, at the non-library level, smart library construction requires collective wisdom. For example, library space reengineering requires participation from architecture and psychology professionals; smart library social image promotion requires marketing professionals; and at the point of increasingly expensive databases, library consortia or professional negotiation teams are needed.

5 Conclusion

Like the concepts of “metadata” and “cloud computing” in the past, “metaverse” has swept across various fields, captivating countless scholars. However, smart libraries have long gained recognition from domestic and international academia, industry, government, and business sectors. Their concepts are deeply rooted, their visions promising, their forms becoming clear, and their research highly promising. Even under the “metaverse” spotlight, smart libraries remain steadfast and will not lose their luster. As smart library theoretical highlands are

identified and conquered, their practical blind spots will certainly be clarified and eliminated. Let us uphold the original intention of smart library research, base ourselves on reality, target needs, and contribute to library development.

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