Data-Driven Construction and Service Planning for University Smart Libraries: With a Discussion on the Development Path During the 14th Five-Year Plan Period (Postprint)

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Abstract

[Objective/Significance] Against the backdrop of comprehensive datafication of scientific research and the "14th Five-Year Plan", the construction direction and path of university libraries exert significant influence on teaching and research. This paper aims to propose practical approaches for the next steps in implementing library smart transformation. [Method/Process] By reviewing the current development status of university libraries, analyzing new development trends, and taking data awareness as the starting point, this study attempts to construct development schemes for smart libraries across technology, services, and space. [Results/Conclusions] Smart library construction should devote substantial effort to intelligent equipment, smart service platforms, and smart spaces; furthermore, in-depth consideration is required regarding librarian roles and consortium development.

Full Text

Data-Driven Construction and Service Planning of Smart University Libraries—Also on the Development Path of Smart Libraries During the 14th Five-Year Plan Period

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Abstract: [Purpose/Significance] Against the backdrop of comprehensive data-driven scientific research and the 14th Five-Year Plan, the direction and path of university library construction have significant impacts on teaching and research. This paper aims to propose practical approaches for the next phase of

library intelligent transformation. [Method/Process] This study reviews the current development status of university libraries, analyzes emerging trends, and constructs development plans for smart libraries in terms of technology, services, and space from a data-conscious perspective. [Result/Conclusion] Smart library construction should focus intensively on smart equipment, smart service platforms, and smart spaces. Additionally, deep consideration must be given to the evolving role of librarians and alliance building.

Keywords: university library; smart library; data service; 14th Five-Year Plan
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In recent years, big data and artificial intelligence have become core drivers of industrial development and economic planning. The IFLA Statement on Libraries and Artificial Intelligence [1], released in September 2020, states that AI is reshaping library business models and advocates for libraries' involvement in cultivating users' data literacy, arguing that libraries should naturally become leaders in the scientific research data chain. The transformation of domestic university libraries in recent years has consistently revolved around "data." Reviewed along the timeline of national economic and social development planning, the library sector achieved remarkable results during the 13th Five-Year Plan period. First, the Public Library Law was promulgated. Second, during these five years, library work achieved significant breakthroughs, which can be summarized by three keywords: resource construction, service innovation, and platform iteration. These included literature resource construction oriented toward "Double First-Class" disciplines, library service innovation focusing on academic evaluation, institutional repositories, and space services, and most importantly, in-depth exploration in building and implementing new-generation library platforms. Overall, from literature resources to research services, and from librarian competencies to business processes, libraries have consistently followed the principle of "data-driven" development, moving toward digitization and intelligence.

The year 2020, as a critical year for the 14th Five-Year Plan, marks an important inflection point for the transformation of university libraries. Through preliminary theoretical exploration, university libraries have already established a "smart" development path. This paper proceeds from this standpoint, aiming to investigate planning approaches for university libraries at the 14th Five-Year Plan juncture in terms of achieving data-driven functions, deeply participating in teaching and research, and reconstructing library alliance services.

2. Research Status and New Development Opportunities of Smart University Libraries

2.1 Current Status of Domestic Smart Library Research

Current academic research on smart libraries is extensive. Upon closer examination, research on smart libraries focuses primarily on three aspects. First is the conceptual analysis of smart libraries. Scholars such as Chu Jingli et al. [2] and Li Yuhai et al. [3] have distinguished and connected smart libraries with digital libraries and intelligent libraries, while other scholars have also differentiated traditional libraries from mobile libraries, digital libraries, and smart libraries from various perspectives. Second is the specific analysis of library connotation elements, including discussions on librarians [4], users [5], and spaces [6] in smart environments. Intelligent technology serves as an important driving force for smart library development. Technologically, smart library research primarily centers on the Internet of Things, artificial intelligence, and blockchain to optimize library functions and service experiences through technology. Third is the exploration of library smart services, including service platforms [7], service systems [8], and service evaluation [9]. Smart library development has progressed from conceptual and theoretical discussions to practical implementation, gradually moving from an embryonic stage to a period of accelerated growth. It represents a model driven by policies, demands, and environments in the new era. Within the "Double First-Class" construction and smart campus environment, smart libraries have taken a leading position in university construction planning, with their pace gradually accelerating and their responsibility for supporting teaching and research growing ever larger. Smart buildings, smart resources, humanistic services, and smart system platforms have become important focal points for smart services in university libraries [10].

2.2 New Development Opportunities for Smart Libraries

Facing the impact of the big data era and the normalization of the pandemic, research and teaching modalities have undergone dramatic changes, presenting two new development opportunities for libraries. First, smart library development has become an academic consensus. In an era where new-generation technologies such as big data, artificial intelligence, and the Internet of Things are widely applied, accelerating smart library construction and smart services with "data-driven" approaches as the core has become a consensus in both academia and the industry. University libraries should "proceed steadily" and leverage the fast train of intelligent technology to lead new forms of smart libraries. From an academic perspective, library and information science is currently in a "data-intelligence" context, which has changed the problem domain and resource perspective of the field to some extent, endowed library and information science with greater practical power, and expanded its influence [11]. Simultaneously, the industry has also begun to practice "data-driven" solutions.

Second, new online teaching formats in universities have expanded library ser-

vice boundaries. During the pandemic, universities adopted hybrid online-offline teaching models, with institutions, faculty, and students gradually adapting to this normalized online education situation. This new normal has also strengthened libraries' position as data managers in the teaching process. Statistics show that in early February 2020, when the pandemic was still severe, the usage frequency of online services at the University of Macau Library increased by 54% year-over-year [12]. The path of digital transformation is undoubtedly the best choice for libraries' 14th Five-Year Plan. Facing the normalization of the pandemic and the national "Double First-Class" strategic layout, university libraries should proactively build "bridges" between online teaching and students, consciously providing support, delivery, and guarantee services for online educational resources. By embedding teaching services, expanding teaching methods, optimizing teaching spaces, and broadening service boundaries, libraries can fully support education and teaching.

3. Development Paths for Smart Libraries from a Data-Driven Perspective

The transformation of university libraries is essentially the exploration process of smart libraries. Specifically, it requires "deep efforts" in three major dimensions: intelligent technology, smart platforms, and smart spaces, transitioning from "intelligent" to "smart" by integrating intelligent equipment with library services. This approach achieves "effortless" smart services between user needs and library resources, truly realizing "data-intelligence" empowerment and smart innovation, and further advancing the establishment of smart libraries and smart societies.

3.1 Leveraging Intelligent Technologies to Tap New Development Momentum

As an ever-growing organism, libraries' resources, services, librarians, and readers are endowed with deeper and broader connotations along with changes in the social environment and thinking. During the 13th Five-Year Plan period, libraries vigorously built digital resources and basically completed digital transformation. "Digitization" and "informatization" will inevitably be followed by "intelligentization." The concept and practice of smart libraries demonstrate that the connotation and extension of smart libraries are not fixed, and different technology applications can enable smart libraries to develop different smart services. Therefore, intelligentization is the foundation and prerequisite for smart library construction, which must follow certain processes and patterns in a step-by-step and orderly manner. Currently, research on smart library technologies mainly focuses on smart equipment and intelligent systems, detailed as follows.

(1) Intelligent Robotics Technology. After 60 years of development, the artificial intelligence discipline has built a vast knowledge system. Nowadays,

AI technology is being vigorously applied in libraries. Intelligent chatbots and inventory robots [13] have been implemented in multiple universities including Tsinghua University and Nanjing University, while smart book repositories have been launched at Suzhou Second Library. These smart devices serve as virtual assistants for libraries, helping provide information and related intelligent services to users. One indicator in the smart library metrics released by the Sino-Singapore Tianjin Eco-City is smart circulation, including the annual proportion of robot service 人次 and annual proportion of intelligent consultation volume. As more smart equipment "joins" in the future, staff in reference departments, cataloging departments, and circulation departments will gradually be replaced by machines, with data collection and management, user navigation and consultation all completed by machines [14].

(2) Data Mining and Machine Learning. While smart equipment enhances library service quality, service richness must be achieved through data technologies and intelligent systems [2]. For example, facial recognition systems and machine translation can be applied in access control and research services [15]. Intelligent systems also support libraries in processing massive amounts of user data and conducting intelligent and precise user behavior analysis to mine other implicit values in user behavior. Text analysis, machine learning, and natural language processing have made knowledge discovery a hot topic again, rendering knowledge systems and knowledge environments more open.

In summary, the addition of intelligent technologies can make library services integrated, open, data-driven, networked, real-time, visualized, interactive, and scenario-based [16]. Updates in smart equipment can not only reduce basic labor for librarians and improve work accuracy but, more importantly, embed intelligent technologies to explore new paths, expand new services, tap new momentum, and drive continuous transformation in smart libraries.

3.2 Improving Service Platforms and Establishing New Service Systems

Smart services refer to the intelligentization of all aspects of the entire process from resource collection to utilization and decision-making, oriented toward users. Therefore, smart service platforms include resource selection platforms, central knowledge bases for resource integration, service platforms providing smart services, and decision-making platforms for readers' resource utilization. Overall, optimizing user services remains the original intention of library transformation, supplemented by an open ecological environment and an integrated management model for print, electronic, and digital resources. These together constitute the core of the new-generation library smart service platform.

The first step in smart service construction is infrastructure supported by technology. Big data is the most important "digital gold mine" in the new era [17]. Library "big data" primarily includes libraries' own bibliographic data, electronic resource data, academic-related data, user perception data, building-

related data, space-related data, and decision-making-related data. As shown in Figure 1 [Figure 1: see original paper], for resource data, the service platform reduces the cost of organizing and obtaining electronic and digital resource lists for each library in the form of a central knowledge base, weakening resource base attributes. Through analysis of characteristic indicators, similar types of resources are tagged and correlated, then integrated and categorized, combining print, electronic, and digital resources into one entity, focusing on portal services to achieve integrated retrieval. For user data, smart service platforms collect users' background information and interest preference data, conduct user modeling through text mining, machine learning, and semantic analysis, and thereby outline user profiles including attribute characteristics, psychological mechanisms, and interests. Using cluster analysis combined with budget constraints and disciplinary specialties, relevant procurement information is obtained to provide more accurate and scientific predictions for collection development. Subsequently, based on users' tag data and behavioral data, specific information (resources, activities, etc.) is actively and personalizedly recommended to required users through algorithmic processing and calculation. Finally, based on readers' and librarians' operational data, library normal operation is monitored through large screens and other forms via data cleaning and analysis, analyzing library service effectiveness, and horizontally and vertically comparing resource usage and disciplinary development strengths and weaknesses. In addition, monitoring can provide intelligent decision-making basis for library resource procurement, clearly and intuitively understanding task allocation for library staff, and improving librarians' enthusiasm and job competency.

In the context of the Internet and big data, data-driven library service models are becoming increasingly clear. Large screens, mobile phones, and other terminals have become the destination for data applications: operation dashboards and traffic statistics on library large screens, knowledge discovery and information retrieval in OPAC systems and information portals, personalized resource recommendations on user mobile terminals, and librarian operation records in the background. Whether resource management applications oriented toward resources, service applications oriented toward users, or office applications oriented toward librarians, all will be presented on terminals such as APPs, PCs, WeChat, portals, and large screens for users to retrieve, browse, and use, and for libraries to support decision-making and teaching tasks. During the 14th Five-Year Plan period, libraries' data-driven full-terminal service models will gradually take shape.

The new-generation library smart service platform should be characterized by "integration" and "fusion," establishing a new service system architecture. It can be based on a reader-driven acquisition platform, adopt an integrated management model for print, digital, and electronic resources, support new linked data and metadata description standards, and employ cloud deployment for systems. Gradually integrating with resource providers such as database vendors and book vendors, it can achieve high integration of various compound resource

management systems.

3.3 Strengthening Space Management and Innovating Development Approaches

During the 13th Five-Year Plan period, explorations of university library space models mainly included learning centers, digital centers, maker spaces, and information commons. Currently, research on library smart spaces remains in the exploratory stage. First, the basic environmental construction of libraries is in its initial stage. Although wearable technologies and virtual technologies have been embedded in libraries, cloud systems and local systems are unevenly matched, configurations are incomplete, space service capabilities are weak, and data acquisition accuracy is insufficient. To address these issues, the 14th Five-Year Plan period should guide future library space layout planning and construction with the concept of "space as a service." Based on underlying basic space construction, various smart devices should be gradually introduced to build middle-layer intelligent systems, ultimately transitioning to top-layer artificial intelligence data centers. Specific construction plans are as follows.

(1) Basic Space Construction. Library space re-creation is reflected in the transformation of service methods and management approaches [18]. First is the basic physical space. Students' learning and reading require high levels of quietness. Therefore, the principle of "separating noisy and quiet areas" [19] should be adopted, dividing the library into relatively independent learning spaces through physical partitions, primarily ensuring interactive teaching behavior spaces for disciplines and teaching. In this space, users can communicate and discuss, socialize, watch videos, and utilize academic conferences and lectures for collaborative learning. Libraries should respond to reforms in university education and teaching methods with brand-new spaces. Second is high-quality social resource space, such as maker spaces and innovation service spaces. Through reading booths, digital DIY, 3D printers, multimedia production tools, and other facilities, users' creativity can be stimulated in all aspects to incubate new achievements. In addition, libraries should create specialized independent spaces based on key university disciplines, special collections, and cultural heritage, modularizing and flexibilizing the library to customize specialized service spaces following changes in user demands. In summary, basic space transformation should start with special spaces, creating multi-functional spaces that interweave physical and virtual, online and offline, readers and spaces, building multi-functional physical spaces, flexible social spaces, and smart digital spaces.

(2) Middle-Layer Intelligent Space System Construction. Space transformation and re-creation urgently require more refined space management systems and more accurate location services. University library space management systems first need to establish space databases, primarily for storing location information of various library areas and facilities to help users precisely locate. In terms of accurate location services, libraries introduce geomagnetic positioning technology, artificial intelligence technology, and context-aware technology

to collect user ontology information and location data. Through management and transformation by backend servers, contextual education for users is completed, thereby deriving real-time services such as reading promotion, personalized recommendations, and information literacy education. Using the Internet of Things, cloud computing, and other technologies to deeply analyze and mine user behavior meets users' various complex needs, rather than merely staying at the level of intelligent terminal push. Using VR, AR, and other technologies enhances users' immersive experiences and improves real-time interaction between users and spaces. Introducing intelligent robots, inventory robots, sorting robots, etc., replaces manual labor in completing basic services such as consultation, shelving, and borrowing. A complete system architecture is key to middle-layer intelligent space system construction. Various user data collection systems, such as facial recognition gate systems, seat reservation systems, and multi-function room reservation systems, real-time record all library-related activities of readers (entry, in-library, exit) and generate individual user behavior reports. Therefore, the middle-layer intelligent space system serves as a middle-layer transfer platform for integrating multiple intelligent technologies to develop reader data services. Through technology introduction, it achieves service self-help, management intelligence, and interactive intelligence functions, providing data accumulation for top-layer library space construction.

(3) Top-Layer Artificial Intelligence Data Construction. The top-layer smart space utilizes massive user behavior habit data already collected in the middle and lower layers to form an artificial intelligence data center, achieving "hyper-convergence" of smart spaces. Through a microservices architecture, interactive systems in the space undergo unified top-layer architectural design, unified management and control, and unified analysis and storage. Data collection and aggregation are conducted from different dimensions, and the smart space unified platform is integrated through the slsp interface layer. Using high-end technologies for reader space data analysis and statistics, one-to-one intelligent push of resources and services, smart interaction, and other functions are provided. A "file" is created for each user and updated in real-time. Creating "files" for users also reduces cumbersome authentication, integrates users' use of all physical and virtual resources in the library, and gradually enables self-driven motivation, promoting users' intelligent feedback and interaction. Of course, during the "file creation" process, there will inevitably be user privacy data issues. This requires certain privacy data protection mechanisms during middle-layer data collection, such as generalizing, cleaning, and shielding user data, and strengthening data storage and protection in top-layer data construction. This achieves data-driven deep autonomous learning in smart spaces, actively dialogues with users, and continuously deepens and enhances library service effectiveness.

4. Safeguard Mechanisms for Smart University Library Development During the 14th Five-Year Plan Period

4.1 Transformation of Librarian Roles

Nowadays, more and more users need not only constantly updated tools from libraries but also the skills to use these tools. University librarians in the new era should become professional librarians, with the responsibility and obligation to actively delve into academic knowledge in user service disciplines, identify needs, and provide corresponding services, serving as "gatekeepers" of knowledge and "sharers" of data. Based on this, librarian competency requirements can be summarized in three aspects:

(1) Data Provision and Support Capabilities for Discipline-Oriented Teaching and Research Development. Teaching support should become an important focal point for university libraries to explore new services and support the construction of first-class university disciplines. For example, American university libraries collaborate with writing centers and faculty to help nursing school students pursue professional doctoral degrees [20].

(2) Intelligence Competency. Intelligence services have always been the foundation of university library services. Only by conducting genuine intelligence services can libraries assist in university strategic decision-making and scientific research level improvement, thereby supporting the construction of first-class disciplines and first-class universities [21]. This requires librarians to be well-informed, capable of identifying basic disciplinary intelligence knowledge, analyzing disciplinary situations, completing intelligence analysis reports, and predicting and deciding on strategic knowledge.

(3) Intellectual Property Service Capabilities. In the process of intellectual property creation, operation, and management, libraries need to participate as knowledge managers in the full-process service. This requires librarians not only to understand relevant disciplinary knowledge and possess information retrieval skills but also to master intellectual property knowledge such as patent information and copyright information, use patent databases and analysis tools, create intellectual property service products, and promote the transformation of university intellectual property achievements, providing higher-level support services for "Double First-Class" construction [22].

4.2 Construction of Library Cloud Alliances

"Co-construction and sharing" has always been the consensus for library alliance development. Alliances have alleviated pressure on university libraries to some extent, integrated collection resources, and achieved co-construction, sharing, and common development among universities. However, alliance development to date has exhibited phenomena such as non-uniform standards, data silos, and uneven resources. Additionally, rapid technological updates and diversified user demands have made the functions and models of original digital

alliances unable to fully guarantee the construction of smart libraries. The construction of new-generation library cloud alliances depends on the building of new-generation library service platforms, integrating multiple sub-service platforms such as user data centers, library catalog data, unified retrieval service platforms, electronic resource management platforms, intelligence analysis service platforms, and factual data service platforms. With a unified window facing library users, data barriers are broken, and seamless connection of resources and services is achieved. Simultaneously, user data centers and standardized data interfaces are established to centrally manage data for all alliance users. Using a "public cloud + local private cloud" model, the original single-system alliance model is upgraded to an Internet cloud service-based alliance model. Based on data privacy, selective storage is implemented to ensure data security, jointly 致力于 improving alliance activity, supply capacity, openness, and diversified, precise knowledge services for readers.

Currently, China's smart libraries are experiencing an inflection point from theoretical construction to practical implementation, still in a period of continuous exploration. This paper attempts to provide overall planning for the development of university smart libraries during the 14th Five-Year Plan period, discussing "what," "why," and "how." Future libraries will be empowerment centers for learning, education, and creation that integrate personnel, knowledge, and technology. They will deal more with data, need to establish smart service platforms integrating procurement, collections, services, monitoring, and decision-making, and build smart spatial models from basic to intelligent layers to achieve new technology architectures, provide intelligent business processes, and construct new smart ecosystems.

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Author Contributions:

Shao Bo: Framework design, research guidance, paper writing, and revision.
Xu Miaomiao: Data collection and organization, paper writing.
Wang Yi: Data collection and organization, paper revision.

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