Exploring the Standard Framework for Smart Library Construction

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Abstract

Purpose: To promote evidence-based smart library construction and its development toward specialization and standardization, it is necessary to construct a standard framework system for smart library development.

Method: From the dual dimensions of theoretical research and practical development, this study reveals the general evolutionary path of industry (domain) standard-setting; combined with existing library standard systems, it explores the sources of guidance for smart library industry standard development.

Result: Based on the Open Systems Interconnection reference model (OSI model), it proposes a smart library standard framework model for China.

Limitations: It does not provide macro-level subdivision of the specific content of national standards, industry standards, local standards, social organization standards, and enterprise standards. As smart library represents the future development form of libraries, many new situations and problems not previously encountered will continue to emerge.

Conclusion: It proposes a smart library standard framework system from the four dimensions of resources, space, services, and technology.

Full Text

Exploration on the Standard Framework for Smart Library Construction

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Abstract

To promote evidence-based, professional, and standardized development of smart library construction, establishing a comprehensive standard framework system is essential. This study reveals the general evolutionary path of industry standard development from both theoretical research and practical development perspectives, and explores the foundational sources for smart library standardization by integrating existing library standard systems. Based on the Open Systems Interconnection Reference Model (OSI model), we propose a standard framework model for smart libraries in China. While this framework does not subdivide the specific contents of national, industry, local, social organization, and enterprise standards from a macro perspective, it provides a systematic approach to addressing the unprecedented challenges and emerging issues that smart libraries will face as the future evolution of libraries. The standard framework system is constructed from four key dimensions: resources, space, business, and technology.

Keywords: smart library; standard framework; evolution of standard development

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Since Finnish scholar Markus Aittola first proposed the concept of "smart library" in 2003 [1], nearly two decades of research and practice have seen the field expand from initial conceptualizations and characteristics to development strategies, management, technologies, services, architectural frameworks, and smart librarian training [2][3][4]. However, standards for smart library construction have received relatively limited attention. Liu Wei and colleagues argue that smart library standards primarily encompass four aspects: business, data, services, and products. With the National Library of China's proposal for a "National Smart Library System" [5] and the release of the *National Smart Library System Construction Plan (Draft for Comments)*, standardization issues in smart library construction have gained broader attention. Lu Xiaobin et al. [6] analyzed smart library construction standards from the perspectives of resource development, service models, and technology application, proposing strategies for building China's smart library standard system. Cai Yingchun et al. [7] explored the dialectical relationship between smart libraries and metaverse technology applications, suggesting that integrating libraries' "resources+," "services+," "platform+," and "space+" elements into smart libraries and constructing an "expert wisdom repository" represents a practical pathway. Following the official release of OpenAI's ChatGPT, the tremendous potential of artificial intelligence technologies exemplified by such conversational systems promises applications in smart libraries, spawning new software/hardware products and technical methods that will require corresponding technical standards.

Smart library construction has now entered a new phase of substantive advancement [8], yet numerous challenges have emerged. Incomplete, unclear, or superficial understanding of top-level design among individual libraries has de-

layed development progress, reduced service quality and operational efficiency, and even led to low-level redundant construction and excessive economic costs at the societal level. Therefore, this study examines the general path of industry standard development to reveal the characteristics and patterns of library standardization, exploring the foundational sources for smart library construction standards: related institutions, related roles, and related businesses. Building upon this analysis, we propose a standard framework model for smart library construction in China, providing a reference for future development.

1. Standard Development: The Foundation for Smart Libraries

In contemporary standardization practice, definitions typically follow the International Organization for Standardization (ISO) framework. Through systematic analysis, standards are documents established by consensus and approved by recognized bodies [9], primarily codifying identified and repeatedly applicable rules and guidelines in written form to promote standardized and professional industry development. Library standards serve as guidelines for library operations, providing norms for common and repeated use within the library profession while balancing patron satisfaction. They represent the targets and necessary conditions libraries should achieve in management, funding, collections, equipment, and services, encompassing all normative documents including construction standards, service specifications, management measures, professional codes, and evaluation criteria [10], presented in forms ranging from regulations and guidelines to operation manuals and work instructions.

To achieve high-quality development, smart libraries must prioritize standardization development [11], establishing rigorous enterprise standards while also developing industry-recognized professional standards and accelerating the introduction of relevant national standards to avoid detours caused by absent or incomplete standards.

2.1 Industry Classification

China's industry sectors are numerous and finely divided. Referencing the United Nations' *International Standard Industrial Classification of All Economic Activities* (ISIC Rev.4, 2006 revision), China's *National Economic Industry Classification* (revised 2019) divides the national economy into 20 categories, 97 major divisions, 473 medium divisions, and 1,381 minor divisions across four levels. Regardless of industry—be it agriculture, forestry, animal husbandry, or fishery requiring standards to ensure product safety and quality for optimal productivity; mining, a high-risk industry for environmental pollution and safety requiring standards to regulate corporate behavior and protect lives, property, and the environment; or manufacturing, where the breadth, width, and depth of standardization largely determine development speed, quality, and efficiency—every industry requires unified standards for healthy and orderly development.

Industry standards serve as both the benchmark for product and service quality and the basis for evaluating organizational management. Comprehensive industry standards lead to regulated industry development.

2.2 General Path of Industry Standard Development

Industry standards, formulated by relevant State Council administrative departments for specific industries, are developed in the absence of corresponding national standards but must not conflict with existing national standards. Their development follows certain patterns, gradually becoming established, industry-recognized, and widely implemented. The development process is illustrated in [Figure 1: see original paper]. China's industry standard development is based on national policies and regulations, representing a progressive and continuously optimized process guided by market demand, with active participation from industry-leading enterprises and research institutes in establishing professional associations (societies) and drafting standards through consensus-building.

Based on the practices and experiences of over 200 enterprises and departments, renowned American information systems expert Richard L. Nolan proposed the Nolan Stage Model, which analyzes the objective path and general patterns of informatization development for regions and industries [12]. Inspired by Nolan's model, all developments follow certain patterns. For industry standard development, the initial stage involves "crossing the river by feeling the stones"—a bottom-up process where leading enterprises, driven by practical needs and technological advancement, develop internal standards suitable for their own development. Once enterprise standards can address common domain problems and mature technologically, industry administrative departments, relevant organizations, government agencies, industry associations, domestic testing institutions, and related production enterprises collaboratively negotiate and formulate industry standards, which gradually evolve into national and international standards, as shown in [Figure 2: see original paper].

2.3 Standard Development for China's Library Industry

According to the 2019 revision of *National Economic Industry Classification*, libraries belong to the culture, sports, and entertainment sector. Since the founding of the People's Republic, China's library industry has experienced significant ups and downs. After China resumed its ISO membership in 1978, library standardization began to align with international practices. Library industry standard development has involved formulating national standards based on international standards while continuously developing industry and enterprise standards under national guidance. For instance, the 1985 national standards *Rules for Bibliographic Description of Monographs*, *Basic Terminology of Information and Documentation Vocabulary*, and *Recommended Standards for Alphabetical Arrangement and Filing Order of Numbers and Symbols* partially adopted international draft standards with appropriate modifications and sup-

plements to better serve Chinese libraries [13]. In 2008, the National Library Standardization Technical Committee (NLSC) was established [14], after which national, industry, and local standards were successively introduced, gradually expanding from service specifications to business management, technology application, and performance evaluation [15], making library industry standards more regulated, professional, and comprehensive.

Library development has evolved through iterations from "traditional library → modern library → digital library → intelligent library → smart library" [16]. Smart libraries represent libraries' adaptation to emerging smart environments, reshaping their roles and functions within new ecosystems [17]. Smart library standardization builds upon existing foundations, requiring the integration of relevant resource, technology, management, and service standards from existing library industry classification systems into the smart library category. Additionally, based on the user-oriented nature of smart library services, new standards must be created for resources, equipment, spaces, activities, management, and services—both utilizing and innovating upon existing standards, as illustrated in [Figure 3: see original paper].

3.1 Theoretical Foundation

The concept of synergy, proposed by German physicist Hermann Haken, refers to the process or capability whereby two or more differentiated elements within a system interact and coordinate to achieve system development goals, forming a virtuous cycle of cooperation [18]. According to this theory, elements within a system are independent, possess distinct roles and irreplaceable functions, and achieve synergistic effects through division of labor, coordination, and complementarity [19].

3.2 Sources of Smart Library Standard Development

For smart library systems, resources, management, services, and operations constitute core elements [20], with synergistic forces from related institutions enabling effective management, related roles facilitating diverse information resources and smart services, and related businesses ensuring social value and enhanced discourse power. Therefore, we identify related institutions, related roles, and related businesses as the three foundational sources for smart library standard development.

[Figure 4: see original paper] Sources of Smart Library Standard Development

(1) Related Institutions for Smart Libraries

China's public and academic library systems possess rich collections and strong technical capabilities, serving as documentation centers, service hubs, coordination platforms, and research institutions. Public libraries, primarily sponsored by national or local governments and administered by cultural authorities at

various levels, operate under regulations and statutes tailored to their specific contexts to ensure standardized management and effective service delivery. Academic libraries, as academic institutions serving teaching and scientific research, are guided by the Ministry of Education's Steering Committee for University Libraries, which is developing implementation guidelines and evaluation indicators for university library regulations to operationalize these policies [21]. Smart library development similarly requires relevant administrative authorities to issue standards and specifications to support healthy, rapid, and high-quality development.

Libraries are institutions that select and utilize documentary information, serving as transmission mechanisms for knowledge and culture [22]. From a resource optimization perspective, smart libraries require objective scientific standards to select suitable library material suppliers, enhancing procurement and distribution standardization and promoting healthy collaboration. As literature resources become digitized and information delivery networked, suppliers' services have expanded to include cataloging, processing, reader training, and collection analysis reports, necessitating the active participation of smart libraries, resource suppliers, equipment vendors, and platform technology service providers in developing relevant specifications and charters.

For smart libraries, industry associations such as the Chinese Library Association and provincial/municipal library societies, along with the National Library, provincial/municipal public libraries, university libraries, and research institutions, constitute the backbone of standard development. Library material suppliers, equipment vendors, and platform technology service providers also represent crucial links in the smart library ecosystem. The smart library standard framework must address the diverse needs of different related institutions, soliciting industry input and fully leveraging institutional roles in standard formulation.

(2) Related Roles in Smart Libraries

Related roles are the primary participants and driving forces in smart library standard development. To better regulate smart library management and promote high-quality, healthy development, standards should be formulated from three perspectives: library managers, service providers, and service recipients.

China's libraries primarily operate under a director responsibility system, and smart libraries are no exception. For long-term development, establishing director qualification standards specifying required educational levels, professional knowledge, and organizational management capabilities is essential. Simultaneously, to implement development goals and plans, libraries must hire professional librarians based on detailed job descriptions covering responsibilities, work norms, and service standards to achieve professional development. Librarians, as smart service providers responsible for both internal management and external services, constitute a critical factor in sustainable, healthy development, making smart librarian team building a primary concern for high-quality library development. Libraries must continuously optimize standards for team

development planning, training programs, performance evaluation schemes, and professional title review criteria to enhance service capabilities and quality.

As social service institutions, smart libraries serve diverse user groups including researchers, university faculty, students, and the general public with varying levels of information literacy. Unified user management regulations are needed to standardize user behavior and create a favorable service environment.

(3) Business-Related Standards

Since ancient times, libraries' fundamental functions have centered on "collection—organization—use" of documentary information [23]. As the most advanced form of library, smart libraries employ more diverse means to fulfill these basic functions. We contend that libraries' fundamental functions are primarily realized through operations and services. For instance, classification systems, subject headings, and microform techniques developed over decades ultimately serve to better organize collected resources [24]. The formulation and implementation of public library standards represent a continuous evolutionary process. Although China has promulgated *Public Library Business Specifications* and subsequently developed *Public Library Services for Children Specifications* and *Public Library Services for Hearing-Impaired Persons Specifications* since 2018, smart libraries' internal operations are being reshaped during the transition from traditional to smart libraries [25], with virtual-physical spaces, platform systems, and resource allocation becoming core business areas.

As intelligent shared spaces and distinctive cultural venues, smart libraries fulfill users' vision of accessing information anytime, anywhere. This spatial innovation necessitates new construction standards, particularly for cyberspace, including page layout and interface specifications. China's smart library construction remains in the initial transition phase from digital to intelligent libraries [26], creating friction between traditional Integrated Library Systems (ILS) and newly introduced commercial Library Service Platforms (LSP) [27]. This requires developing transition-period system selection guidelines. Furthermore, since all services on LSP platforms adopt vendor-defined development standards that cannot be customized by libraries or third parties, numerous constraints emerge for smart library development [28]. Consequently, forming development and service alliances between libraries and third-party developers/service providers represents the primary future trend, requiring corresponding cooperation standards.

Smart service constitutes the core of smart libraries. The May 2012 promulgation of *GB/T28220-2011 Public Library Service Specification* filled the gap in China's public library service standards [29], providing an effective basis for smart library service framework development. For smart libraries, service preparation, process design, and feedback collection have become critical factors affecting user satisfaction, necessitating standards for service content, collection management, equipment operation and maintenance, and access management.

4. Smart Library Standard Framework Model

As previously discussed, smart library standard framework development represents a progressive, evolutionary process from existence to excellence. Standard formulation must learn from digital library standardization experiences, draw upon general industry standard development paths, and address actual smart library development needs and key domains. For smart libraries, resources are the prerequisite for smart services; technology is the primary and direct driver of library intelligence; business operations are key to sustainable functioning; space represents innovation and value realization; and service is the ultimate goal for enhancing public cultural and information literacy.

[Figure 5: see original paper] Logical Architecture of Smart Library Standard Framework

As a new form of library, smart libraries remain open systems—expandable both vertically and horizontally with targeted focus. The relatively mature smart city standard system has laid a solid foundation for establishing the smart library standard framework. Therefore, combining the OSI model with smart city standard components, we propose the smart library standard framework system shown in [Figure 6: see original paper], comprising a basic common layer, resource layer, technical system layer, business layer, physical space layer, and other layer. Here, "ZT" represents the Chinese pinyin initials for "Zhitu" (smart library), with each subsystem numbered using Arabic numerals to ensure extensibility for future standards. The categories in this system are illustrative examples rather than exhaustive lists of all possible smart library-related standards.

[Figure 6: see original paper] Smart Library Standard System Framework

4.1 Basic Common Layer

The basic common layer encompasses universally applicable standards within the library profession that provide guidance, addressing common factors in smart libraries and offering consensus and norms for other standards. This includes specialized terminology, definitions, and abbreviations (A1). As smart libraries remain in the exploratory stage and represent a novel concept for most users, application guidelines (A2) are needed to explain, illustrate, and exemplify relevant standards. In response to national requirements for coordinated smart library system development, cultural authorities at all levels must develop smart library evaluation indicators (A3) to leverage evaluation results for guidance and leadership. However, given current development realities, individual libraries operating in isolation face enormous challenges, including substantial financial investment, human resource allocation, and construction scale pressures [30], necessitating collaborative development within and beyond the library industry. Therefore, establishing cooperation models and frameworks (A4) with multi-stakeholder participation centered on smart libraries is essen-

tial. Smart libraries must also formulate user privacy protection specifications (A5), emphasizing privacy protection when collecting data on reading behavior, identity characteristics, personal preferences, social relationships, and research fields through networks and big data platforms [31]. Improper privacy management could cause severe consequences for users and damage library reputations.

4.2 Resource Layer

[Figure 7: see original paper] Resource Layer

The resource layer comprises three components: literature resources, human resources, and data resources. Literature resources (B1) can be further subdivided into print resources (B101) and digital resources (B102). Human resources include librarians (B201) and users (B202). Data resources are categorized by classification (B301) and processing (B302).

Both public and academic libraries now possess rich collections, making collection and preservation no longer the core focus for future smart libraries. Instead, resource organization, integration, and innovation have become urgent tasks [32]. Print resources (B101) have established procurement, management, and storage standards, with detailed subdivisions omitted here. Digital resources (B102) build upon digital library standards to develop digitization and storage standards for the "smart" era, with encoding and reorganization processes adapting to smart library development pace.

In the human resources subsystem, both librarians and users as service providers and recipients require corresponding standards. For librarians, "smart consciousness" and "smart capabilities" represent key attributes [33], with training standards developed through detailed indicators covering demand mining, analytical abilities, and skill acquisition. Librarian evaluation and assessment standards reflect the formation of smart consciousness, requiring clear norms for processes and methods.

As the world's most valuable resource, data has become the driving force for future smart library development [34]. In the data resources subsystem, classification standards are based on subject objects and structural levels. Subject objects include metadata standards and user data standards. Most library data exists as metadata (text, images, audio, data) with well-established national metadata and processing standards that require integration with current data forms and processing changes in smart libraries. User data is critical for service quality improvement, requiring standardized classification of user behavior and attribute data. For processing standards, lifecycle theory describes functional modules including mining, analysis, fusion, and archiving [35].

4.3 Technical System Layer

[Figure 8: see original paper] Technical System Layer

The technical system layer comprises four components: general technologies (E1), domain-specific technologies (E2), software systems (E3), and development frameworks (E4). General technology standards from the digital library era, such as RFID, cloud computing, and IoT, can adopt mature national standards like ISO/IEC 1596 (GB/T 35660.3-2021) for partitioned RFID tag storage.

In the smart library era, key domain technologies (E2) focus on traditional library technologies, natural language processing, image recognition, computer vision, biometric identification, and human-computer interaction [36], providing technical support for enhanced services. Standards must specify usage environments, behavioral functions, performance descriptions, and output results. Traditional domain technologies such as library-specific retrieval, cataloging, and classification must be integrated with smart resources to reshape new standards. Additionally, the academically discussed digital twin technology, already partially applied in library operations, requires integration of current standards into the smart library framework.

The ultimate goal of smart libraries is enabling users to access needed resources anytime, anywhere, with software system construction serving as a powerful driver. Software system standards (E3) should encompass heterogeneous system data exchange and transmission formats, hardware specifications and compatibility for people, machines, objects, and environments, and collaborative performance of smart library software. Development frameworks (E4) involve reusable designs that enhance efficiency and save time across the technical software layer, with standards focusing on interface specifications for key domain technologies and defining commonalities for specific software.

4.4 Physical Space Layer

[Figure 9: see original paper] Physical Space Layer

Smart library space design and planning meet the needs of new library construction while providing a foundation for upgrading existing spaces. Libraries generally comprise physical and virtual spaces, with their fusion creating smart spaces where users can freely choose learning formats across temporal and spatial boundaries supported by information technology. Given the similarities between virtual space construction and smart space services, virtual space is considered part of smart space. Therefore, we address smart library space standardization through physical space (C1) and smart space (C2).

Smart buildings (C101) integrate advanced technologies in architecture, communications, computing, and control to provide services including smart security, smart home systems, and smart energy management, crucial for scientific and intelligent building management and immersive user experiences. Physical space planning standards (C102) address diverse user needs for learning, reading, discussion, communication, leisure, and entertainment, covering print resources, space allocation, and infrastructure configuration [37].

Smart space services exhibit "human-like" characteristics, perceiving user needs and proactively delivering services [38]. For different stakeholders, corresponding standards are required. From a technology trend perspective, digital twin integration with other intelligent technologies enables smart space development. Smart devices such as smart bookshelves, smart furniture, smart control equipment, smart interactive devices, facial recognition systems, and smart navigation equipment support personalized services. However, efficient and rational equipment procurement is difficult for library staff alone without external assistance [39], necessitating smart equipment recommendation guidelines (C201). From libraries' subjective needs, data service space specifications (C202) are required for environmental and spatial transformation. With user experience at its core, characterized by high perceptibility, interconnectivity, and intelligence [40], smart spaces require space management service specifications (C203), interactive navigation service specifications (C204), and operation and maintenance management service specifications (C205) to ensure user experience continuity across multiple platforms.

4.5 Business Layer

[Figure 10: see original paper] Business Layer

The business layer represents smart library applications and services. Building upon the resource and technical system layers, it constructs internal business operations (D1) and provides smart services to the public (D2). The internal business system focuses on knowledge resources [41], including intelligent acquisition (D101), automated batch acceptance (D102), intelligent cataloging (D103), smart stack management (D104), intelligent circulation (D105), and smart statistical analysis (D106) [42], achieving automated and integrated lifecycle management of documentary information. External smart services (D2) rely on platforms, systems, products, and tools with intelligent functions, encompassing resource services (D201), knowledge services (D202), connection services (D203), and value-added services (D204) [43]. Resource services (D201) enable rapid and efficient library resource utilization and self-service. Knowledge services (D202) provide smart reference consultation and precise resource recommendation. Connection services (D203) enable region-wide borrowing and integrated print-digital-library-bookstore services. Value-added services (D204) provide data reports, reading reports, and disciplinary analysis for users and third-party institutions.

4.6 Other Layer

As smart libraries continue to be explored and information technology advances, future development will witness continuous innovation and upgrading amid the new round of scientific and technological revolution characterized by multi-point breakthroughs and convergence. The ultimate form of smart libraries remains exploratory, making smart library construction a dynamic rather than static process, with innovative development always ongoing [44]. Therefore, we must re-

serve space for smart library standard development by creating an "other layer" to address current unresolved challenges and future phenomena and problems.

Smart library development is a product of its times, with technological advancement and equipment updates enabling smart capabilities. This study examines smart library construction standards, using related institutions, roles, and businesses as 线索来源 (sources), and proposes a smart library standard framework system from four dimensions: resources, space, business, and technology. This system serves as a powerful cornerstone for high-quality smart library development, accelerating construction pace and providing effective foundations for all work and operations. However, this study does not subdivide the specific contents of national, industry, local, social organization, and enterprise standards from a macro perspective, representing a limitation. Moreover, as the future development form of libraries, smart libraries will encounter unprecedented situations and problems, requiring continuous improvement of relevant regulations, standards, specifications, guidelines, and provisions to keep pace with the times—an area requiring ongoing attention.

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