

Constructing a Smart Library Ecosystem Integrating the Virtual and the Physical for a New-Type Research University^{*}

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Full Text

[Professional Work • Management]

Constructing a Smart Library Ecosystem Integrating the Virtual and the Physical for a New-Type Research University*

—Exploring the “15th Five-Year Plan” Development Path of the ShanghaiTech University Library

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Abstract During the “15th Five-Year Plan” period, the construction of smart libraries is a key measure for universities to implement the strategy of educational digitalization and support high-quality development. This paper aims to explore a development path for smart libraries that aligns with the mission and characteristics of new-type research universities. Taking the “15th Five-Year Plan” of the ShanghaiTech University Library as the research object, it systematically analyzes the construction plan and implementation strategies formulated around the concept of virtual-physical integration and based on the three dimensions of space, resources, and services. The study finds that its development practice follows the systemic logic of “strategic coordination—ecological goals—three-dimensional collaborative implementation.” Through analysis of this case, the paper summarizes a set of construction ideas and practical essentials that

can serve as a reference for libraries of similar new-type research universities, providing experiential guidance for the innovative development of university libraries during the “15th Five-Year Plan” period.

[Keywords] smart library; virtual-physical integration; new library ecosystem; “15th Five-Year Plan” ; new-type research university

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Introduction

The *Outline of the Fifteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China* (hereinafter referred to as the *Outline*) focuses on coordinated education for scientific and technological innovation, industrial development, and national strategic needs, and points the way for universities to advance the integrated development of education, science and technology, and talent cultivation [1]. As a key component of the education system, university libraries shoulder the mission of promoting knowledge sharing, supporting scientific research innovation, and carrying forward outstanding culture. Their scientific planning is of far-reaching significance for serving university teaching, research, and talent cultivation.

The high level of attention paid at the national level to the construction of smart libraries has provided policy support for the transformation and development of university libraries. In 2021, the *Outline of the Fourteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Long-Range Objectives Through the Year 2035* [2] incorporated smart libraries into national planning; the *Opinions on Promoting the High-Quality Development of Public Cultural Services* [3] and the “14th Five-Year Plan” for the Construction of the Public Cultural Service System [4] further clarified construction goals and development paths. The *Outline of the Plan for Building China into a Leading Country in Education (2024-2035)* [5], issued in January 2025, proposes promoting educational transformation empowered by artificial intelligence, providing a new policy direction for the “15th Five-Year Plan” development planning of university libraries. After exploration during the “14th Five-Year Plan” period, university libraries have achieved phased results in cloud infrastructure, knowledge repositories, intelligent management systems, and physical smart spaces. However, with profound changes in the global environment, the accelerated iteration of digital-intelligent technologies, the continuous evolution of industry forms, and the deep restructuring of their own organizations, university libraries are facing new challenges and opportunities.

The *Outline* clearly proposes deeply implementing the strategy of educational digitalization, optimizing public services for lifelong learning, and using artificial intelligence to lead transformations in scientific research paradigms [1]. This establishes new goals for the construction of university smart libraries: to build a new ecosystem of knowledge services integrating the virtual and the physical through digitalization and artificial intelligence technologies.

Against this background, the transformation of university libraries during the “15th Five-Year Plan” period

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upgrading is critically important. The smart library not only promotes the digital upgrading of traditional resources, but also serves as a strategic platform that reshapes knowledge services through intelligent technologies and empowers innovation in teaching and scientific research[⁶]. This transformation is especially crucial for new-type research universities. In 2020, General Secretary Xi Jinping emphasized at the Scientists’ Symposium the need to develop new-type research universities[⁷]. As one of the first new-type research universities in China to explore and undertake such development, ShanghaiTech University (hereinafter “ShanghaiTech”) was jointly established by the Shanghai Municipal People’s Government and the Chinese Academy of Sciences, and is an important component of the Shanghai Zhangjiang Comprehensive National Science Center. The university is primarily oriented toward science and engineering, targets

frontier areas of basic research, and has actively deployed efforts in fields such as artificial intelligence and biomedicine. By undertaking and participating in the construction of major scientific facilities, it is closely connected with the surrounding research and industrial ecosystem, cultivating high-level talents for scientific and technological innovation and entrepreneurship. In 2022, the university was selected into the second round of “Double First-Class” construction universities^[8]. Therefore, driven jointly by national strategy and the wave of smart development, exploring a pathway for building a smart library aligned with the characteristics of a new-type research university is not only a concrete action to implement national policy, but also a strategic support for enhancing the university’s core competitiveness, with important theoretical value and practical significance.

1 Existing Research and Practice: A Review

At present, libraries at home and abroad are in a period of transformation, a trend that has been clearly reflected in strategic planning and industry practice.

1.1 International Industry Trends

Relevant foreign associations and organizations have issued strategic development plans for the coming period. The *Association of European Research Libraries Strategy 2023-2027*^[9] notes that technologies such as artificial intelligence will accelerate digital transformation and profoundly influence scientific research. The Association of Research Libraries (ARL) and the Coalition for Networked Information (CNI) released *ARL/CNI AI Scenarios: The Future Under the Influence of AI*^[10], emphasizing that research libraries need to fully apply and share professional expertise to ensure the responsible use of artificial intelligence. Japan’s Ministry of Education, Culture, Sports, Science and Technology proposed in the *Roadmap for Promoting Digital Libraries toward 2030*^[11] that technologies such as artificial intelligence should be used to build hybrid learning environments integrating virtual and physical spaces, and to establish a cross-institutionally connected virtual-space architecture for libraries.

University libraries in Europe and the United States are actively exploring the integration of new technologies and service models^[12]. The University of California San Diego Library^[13] emphasizes the democratization of knowledge and enhances academic impact through open-access strategies and digital resources. The University of California, San Francisco Library^[14] plans to create a Technology Innovation Center to improve the use of cutting-edge technologies and professional expertise within library spaces. The University of Chicago Library^[15] leads a campus-wide generative AI initiative, integrating artificial intelligence into services in a responsible manner. Duke University Libraries^[16] use new tools to help researchers apply emerging technologies legally and ethically, mining value from massive datasets and online resources. University

College London Library^[17] uses artificial intelligence to improve the discoverability of research publications. The University of Leeds Library^[18] develops a digital ecosystem to support high-quality user experiences.

1.2 Domestic Research and Practice

Domestic research mainly unfolds at two levels: macro and micro. At the macro level, it focuses on directions of transformation^[6,19-23], such as promoting the transformation of libraries into public creation spaces, innovation enablers, and development accelerators; emphasizing the synergy of data integration, spatial upgrading, knowledge empowerment, and artificial intelligence; paying attention to governance modernization, data infrastructure, and full-chain support for teaching and research; and carrying out systematic planning around value positioning, technological integration, and talent development.

At the micro level, attention is directed toward two major directions. First is digital transformation and smart service innovation^[23-26]: strengthening digital infrastructure, using emerging technologies such as generative artificial intelligence to support service-model innovation, supporting smart activities, and promoting the leap of libraries from “knowledge centers” to “smart hubs.” Second is resource restructuring and discipline-ecosystem empowerment^[23,25,27-28]: leveraging the coordination of smart services, discipline empowerment, and resource construction; using artificial intelligence to improve the efficiency of integrating and utilizing knowledge resources; promoting the evolution of resource platforms toward agents; constructing intelligent discipline-service systems; empowering interdisciplinary research and knowledge innovation; and supporting “Double First-Class” construction.

In practice, Tsinghua University Library^[29] has established AI+ workshops to promote scenario implementation; Peking University Library^[30] has advanced the digital-intelligent transformation of ancient books and revolutionary literature; Fudan University Library^[31] has built a digital foundation for smart libraries to rapidly construct data capabilities; Shanghai Jiao Tong University Library^[32] has developed artificial-intelligence knowledge bases and AI librarians, providing personalized services and trend analysis; and Sichuan University Library^[33] has launched GenAI workshops to explore a new “AI+XR” learning model.

Driven by artificial intelligence, the core functions of libraries continue to expand, and their capabilities in information-resource mining and services have improved significantly, providing theoretical and practical references for the construction of ShanghaiTech’s smart library.

2 Typical Practice in Constructing a Virtual-Physical Integrated Smart Library Ecosystem for a New-Type Research University—A Case Study of the Development of ShanghaiTech University Library

2.1 Development Practice of ShanghaiTech University Library

Since its establishment, ShanghaiTech University Library has closely centered on the university's educational philosophy and developmental positioning. Upholding the principle of "letting knowledge advance in step with the university's development," it has continuously optimized service effectiveness, actively explored pathways for smart library construction, and comprehensively supported the university's teaching, research, and talent cultivation.

2.1.1 Initial Construction Period (2014-2015)

Beginning in March 2014, ShanghaiTech successively established reading rooms and a temporary library to meet the learning needs of the first cohort of graduate students, initially building the library's service framework.

2.1.2 The "13th Five-Year Plan" Period (2016-2020)

In September 2016, the ShanghaiTech Zhangjiang Campus Library officially began operation and gradually opened diversified reading spaces. In line with the university's development direction, it established a literature support and procurement management model centered on electronic resources, and improved basic systems such as retrieval, circulation, and space reservation.

In terms of knowledge services, the library built an institutional repository to support annual assessments of schools and departments and the presentation of scholars' achievements; developed a multi-level information-literacy education system covering the full range of needs from teaching to research; and established a university-development monitoring platform, creating a ShanghaiTech-specific discipline classification and multidimensional evaluation methods, carrying out research-performance analysis, and providing references for university decision-making. At the same time, it built a comprehensive intelligence-analysis framework to serve talent evaluation and disciplinary planning; worked with domestic literature and information institutions to establish a "small core, large network" cooperation mechanism; and founded a multimedia center and created the ShanghaiTech MOOC platform, promoting the open sharing of high-quality teaching resources.

2.1.3 The “Fourteenth Five-Year Plan” Period (2021–2025)

During the “Fourteenth Five-Year Plan” period, the library closely centered on the university’s development orientation and took “letting knowledge advance together with the university’s development” as its core philosophy. While consolidating basic services, it optimized the resource-support system, advanced the construction of a smart-library platform, and built a data-driven decision-support system, comprehensively supporting the university’s teaching, research, and talent cultivation. At the same time, it actively fulfilled its function of culture-based education, carried out reading-promotion activities, and introduced artificial intelligence to improve service effectiveness.

- (1) Consolidating the foundation and optimizing services. First, the library continuously improved the service effectiveness of its physical spaces. It upgraded shared, reading, and seminar spaces, and added distinctive functional areas such as a humanities classics room, an aesthetic-education reading area, and a visualized intelligent salon, achieving integration of collections and use as well as diversification of learning scenarios. The multimedia production and rehearsal center was also upgraded simultaneously to support the creation and production of various types of multimedia content. Second, the library optimized electronic-resource support and management. Based on the university’s positioning, it built distinctive collections, with a focus on supporting related disciplines such as physical science, life science, information science, and entrepreneurship and management, while progressively supplementing literature in the humanities, mathematics, and medicine. Expenditure on electronic resources accounted for 94%, and the overall level of resource construction was benchmarked against leading domestic science-and-engineering universities. Relying on a co-construction and sharing mechanism that combines consortial procurement with independent procurement, the library promoted standardized resource management and formed a support pattern of “small core, large network.” Third, it advanced coordination among smart-service platforms and data governance, building a reader-centered smart-service system. The basic operation system integrates core functions such as access control and reservations; a reader intelligent-service system was developed, relying on intelligent inventory and data interconnection to improve the efficiency of collection management. As the university’s sole data source for research achievements, the knowledge-management system provides authoritative data support for professional-title review and appointment, talent evaluation, and related work.
- (2) Strengthening cultural leadership and deepening brand connotations. First, the library promoted systematic development of cultural brands and activation of resources. Driven by the dual engines of cultural-brand development and resource activation, it systematically created a brand activity matrix of “two months, two seasons, and two holidays,” integrating diverse forms such as classics reading and intangible-cultural-heritage

experiences. In parallel, it implemented a “zero-circulation books” awakening plan, effectively revitalizing collection resources. The related cultural-practice achievements were included in the *Shanghai Culture Yearbook* for two consecutive years (2024-2025) and received municipal-level awards. Second, the library accelerated the serialized presentation of thematic exhibitions and cross-sector integration. Centering on the dual themes of “science and technology” and “humanities,” it holds nearly 20 thematic exhibitions each year, forming a rhythm in which “there are new exhibitions every month and highlights every season,” closely responding to the university’s academic and cultural cycles. It focused on creating the immersive exhibition “A Smart Tour of Mountains and Seas,” integrating artificial intelligence and interactive technologies to innovatively interpret traditional classics such as *The Classic of Mountains and Seas*. It also deepened cooperation with institutions inside and outside the university, enhancing the substance and influence of its exhibitions.

- (3) Focusing on knowledge services and strengthening decision support. The library established an “intelligence + discipline” librarian system, providing integrated services across the full chain of “decision-making-discipline-literacy.” First, it emphasized the systematization and foresight of the intelligence-support system for strategic decision-making. It preliminarily built a flagship decision-intelligence matrix, producing monthly reports around dynamic monitoring of university development and in-depth case analysis; carried out inter-university benchmarking analysis centered on representative achievements and organizational synergy; embedded itself in the “Double First-Class” construction cycle for the materials discipline to conduct multidimensional evaluations; applied large models to monitor developments in clinical research; deepened third-party cooperation to conduct strategic research in frontier fields such as artificial intelligence and large-scale scientific facilities; and continuously carried out analysis of the research competitiveness of high-level talent, built a global talent-tracking database for basic disciplines, and expanded scenarios for intelligent evaluation services. The related achievements have been systematically integrated into decision-making processes such as the university’s “Fifteenth Five-Year Plan” and talent evaluation, forming a closed loop from intelligence to decision-making. Second, the library promoted precision and depth in discipline-intelligence services. For each research unit, it established an “inclusive + customized” discipline-service model and regularly pushed out “inclusive” discipline briefs. Around discipline development, teaching and education, and major research tasks, it provides “customized” in-depth analyses covering disciplinary trends, technology-roadmap assessment, and talent cultivation, thereby supporting the teaching and research planning of schools and departments. Third, it emphasized tiered coverage and integrated innovation in information-literacy education. It offered intensive training modules on literature discovery, the use of research tools,

academic writing, and related topics, deeply integrating them with the research and teaching milestones of schools and departments and embedding them into college courses, literacy competitions, and special college-based education programs. It created the digital resource brand “Little Library Micro-Courses,” launched 26 thematic micro-courses, and built an information-literacy education system with tiered coverage and end-to-end continuity.

- (4) Promoting technology empowerment and driving innovation-oriented transformation. In 2024, the university introduced GPT-series large models and independently developed the GenAI platform[34]. Taking this as an opportunity, the library comprehensively advanced the deep integration of artificial intelligence and services. For example, it carried out a series of AI-literacy training programs, offering training each semester on 16 types of topics around AI-enabled digital creation, intelligent office work, research integrity, and related themes, systematically improving the intelligent research literacy of faculty and students[35]; launched the campus intelligent assistant “Intelligent Xiao Q” [36], integrating campus-wide information flows and providing functions such as library literature searching, paper reading, and writing to improve research efficiency; created AI librarians by integrating systems such as “Intelligent Xiao Q,” literature discovery, and reader services, building an intelligent support system in which users can “ask and obtain immediately, use and learn immediately” ; advanced AI-enabled intelligence exploration by establishing an intelligent information-push mechanism and applying large models to clinical-research monitoring, intelligent literature discovery, and analysis of the innovativeness of research outputs; and promoted the integration of multimedia services and technology, innovatively incorporating frontier technologies such as artificial intelligence into MOOC production, exploring digital applications, and opening up “technology + teaching

a new path for the integration of “education + culture.”

2.2 Entry Points for the Development of the ShanghaiTech University Smart Library during the “15th Five-Year Plan” Period

During the “15th Five-Year Plan” period, the development of university libraries must closely align with industry trends and technological progress, and identify the appropriate entry points for smart-library construction.

ShanghaiTech University’s “15th Five-Year Plan” proposes building four major systems—top-tier talent cultivation, scientific research innovation and translation, human-resource development, and university governance—raising the level of core disciplines, integrating into the construction of Shanghai as a science and technology innovation center, and promoting new development driven by major

facilities and strategic cooperation. Against this background, user needs have become the core driving force for innovation in library services and functional development. As research paradigms transform and learning models become increasingly diversified[37], library users' needs have shifted from traditional resource acquisition toward personalized and intelligent service experiences. Accurately identifying the expectations of different user groups is of great significance for the functional positioning and planning of the library.

Through questionnaire surveys, the ShanghaiTech University Library investigated user needs across three dimensions: space, resources, and services. The results show that users' requirements for spatial comfort and convenience have increased; they expect expanded online resources and access to precise, comprehensive information and intelligent interactive experiences, thereby improving the efficiency of information retrieval. In addition, interest in practical tools, emerging technologies, and literature-retrieval training is also growing, and users' overall needs are upgrading toward intelligence and personalization.

In addition to questionnaires, the library relies on a regular "subject intelligence librarian-school/institute" liaison mechanism, using visits, discussions with school leaders, and in-depth interviews with research teams to grasp users' evolving needs. The analysis found that, in the face of changes in research and teaching models, the library needs to optimize its acquisition structure under limited funding, enhance its capacity to integrate multimodal resources, and adapt to faculty and students' expectations for AI-enabled resource services. In response to changes in the research landscape, it should respond rapidly and provide precise data services and diagnostic recommendations to support decision-making and interdisciplinary research.

At the level of knowledge services, as information needs become increasingly complex and the transformation of decision-making and research paradigms accelerates, it is necessary to integrate practical tools and emerging technologies and reconstruct the capability boundaries between supply and demand. To this end, the ShanghaiTech University Library plans to use artificial intelligence to promote the multimodal integration of resources and the scenario-based upgrading of services, building a new smart-library service model that is "demand-oriented, virtual-physical symbiotic, and human-machine collaborative." It will transform into a proactive, intelligent, and personalized knowledge-discovery center, comprehensively supporting teaching and research needs.

3 Framework and Pathways for Building a Virtual-Physical Integrated Smart Library at a New Research University

Through an in-depth analysis of the ShanghaiTech University Library's development practice, this paper systematically deconstructs the internal logic of

the library' s intelligent transformation from three levels—construction principles, goal setting, and core pathways—and, on this basis, summarizes common experiences and planning essentials of reference value for similar institutions.

3.1 Construction Principles

The construction of a smart library at a new research university should be aligned with its unique mission and constraints, and should follow the following core principles.

First, the principle of strategic coordination and precise response. The library should closely align with national science and technology strategies and the university' s development positioning, establish a rapid response mechanism for changes in the university' s internal research layout and teaching paradigms, and achieve precise investment under conditions of limited resources. Second, the principle of exploratory innovation and sustainable operation. The library should dare to break with convention in service models and technological applications, while emphasizing lightweight integration with the existing campus information ecosystem and sustainable operation, so as to avoid “technological islands” detached from reality. Third, the principle of deep embedding and demand orientation. Service capabilities should be extended to the front lines of teaching, research, and management; through institutionalized and regular mechanisms for demand sensing and collaboration, the library should ensure that service supply resonates in the same frequency with the university' s core development needs. Fourth, the principle of open collaboration and intensive efficiency. Relying on national- and regional-level alliances and networks of peer institutions, the library should build a resource and service community characterized by a “small core and large network,” amplifying its own effectiveness through collaborative mechanisms.

Based on the above principles, the smart library of a new research university should move beyond the traditional model of literature storage and strive to become an intelligent knowledge infrastructure and service platform embedded in the entire process of knowledge innovation.

3.2 Overall Goal: Building a Virtual-Physical Integrated Smart-Library Ecosystem

Build a virtual-physical integrated smart-library ecosystem. With artificial intelligence as the engine, deeply integrate emerging technologies such as large language models (Large Language Model, LLM) and agents to construct a Library-Inside[38] service model. The library should be positioned as a knowledge and cultural service system, integrated into users' learning, research, and work processes; through flexible invocation of tools and knowledge bases, it should realize the strategic transformation of library services[39–40].

The library will carry out empowerment in layers. First is the intelligent infras-

structure layer. Core facilities and services will be comprehensively upgraded to consolidate the foundation for intelligent transformation; by optimizing the spatial layout inside the library, improving the level of hardware facilities, and expanding intelligent service terminals, support will be provided for the implementation of intelligent applications. Second is the intelligent business-process layer. Technologies such as LLMs and agents will be used to reconstruct core business chains such as resource organization, knowledge discovery, and information analysis, realizing the automation and intelligence of business processes. Third is the intelligent service-delivery layer. Modular and scenario-based intelligent service capabilities will be cultivated, forming a service matrix that can both deliver independently and be collaboratively combined, thereby supporting teaching, research, and decision-making in all dimensions.

3.3 Core Pathways: Three-Dimensional System Integration of Space, Resources, and Services

To realize a new virtual-physical integrated ecosystem, systematic and coordinated construction must be carried out across the three dimensions of space, resources, and services.

3.3.1 Space Construction: Creating a Scenario-Driven Immersive Interactive Environment

The teaching and research activities of new research universities are highly frontier-oriented, interdisciplinary, and team-collaborative. They require physical space to break through the traditional function of “collection and reading” and become a catalytic field that inspires ideas, promotes in-depth exchange, and fosters collaborative innovation. Therefore, space construction will take the library’s physical space as its base, use an Outside-In mechanism driven by LLMs and agents, aggregate multimodal external resources, and create “cultural ...a new “Library+” ecosystem of “scenarioization,” “teaching scenarioization,” and “technology scenarioization,” as shown in Figure 1.

Figure text: multimodal external resources; Outside-In; space, resources, services; cultural scenarioization; teaching scenarioization; technology scenarioization.

Figure 1 A New “Library+” Ecosystem

- (1) Integrating multimodal external resources. Using LLMs and intelligent agents, multimodal external resources such as text, audio, and video are combined with the library’s physical spaces, digital resources, and knowledge services to form a knowledge-service system rich in resources and diverse in form.
- (2) Upgrading library spaces and integrating the virtual with the physical. Infrastructure should be comprehensively upgraded, the potential of internal

library spaces deeply explored, and cultural activities and themed exhibitions integrated to build immersive interactive spaces. Three-dimensional modeling and panoramic technologies should be used to visualize spatial resources and improve the intelligent level of space management and governance support. A three-dimensional panoramic virtual library should be constructed so that users can browse activity spaces in the library online, customize on-site facilities and services on demand, and receive personalized service recommendations based on user profiles.

- (3) Integrating cultural activities with technology. Adhering to the dual-wheel drive of “technology + culture,” libraries should implement programs to explore outstanding traditional culture, focus on the publicity and promotion of ancient books and intangible cultural heritage, introduce digital technologies, and build interactive platforms. Comprehensive reading-promotion activities should be carried out by integrating text, audio, video, and interactive resources to meet diverse reading needs. Efforts should be made to build reading platforms that support multi-format resources such as e-books, audiobooks, and videos.
- (4) Intelligent services and a one-stop platform. The intelligence level of library systems and services should be improved by integrating intelligent and interactive device terminals and tools, thereby enabling functions such as intelligent navigation, ubiquitous reference consultation, and intelligent search and recommendation. Artificial-intelligence-based environmental perception systems should be deployed to realize space reservation, energy-consumption optimization, and device linkage. In addition, a one-stop knowledge-service platform should be created to enhance the precision and flexibility of personalized and process-based services. User needs should be distilled, connections to peripheral systems expanded, and personalized service push for users realized. By embedding services into teaching and research scenarios, professional and efficient personalized services can be provided.

3.3.2 Resource Development: Building an Intelligence-Driven Multimodal Resource System

In the face of rapid iteration in frontier fields and the increasingly blurred boundaries between disciplines, resource support for new research universities faces a dual challenge: the forward-looking identification of needs and the precise, efficient supply of resources. The paradigm of resource development must shift from “disciplinary coverage” to “frontier-driven, data-driven, and intelligently adaptive.” The core of resource development lies in consolidating the library’s foundation of literature resources, establishing a Library-Inside mechanism driven by LLMs and intelligent agents (see Figure 2), and building a multimodal knowledge-resource system capable of dynamically sensing research trends, intelligently associating cross-domain knowledge, and assembling and pushing resources on demand, thereby providing users with comprehensive resource-

discovery services.

Figure text: Outside-In; expanded resources—scientific data, audiovisual materials, courses, interactive resources, social media, multimedia, images; basic resources—papers, patents, software, monographs; LLM + intelligent agents; Inside-Out; users—resource search, acquisition, content organization and use; multimedia creation; teaching and research environment; boundaryless library.

Figure 2 The Library-Inside Mechanism

- (1) Building a demand-driven multimodal resource system. According to teaching and research needs, the structure of the library's literature resources should be optimized, and new resource types such as datasets, MOOCs, and multimedia content should be expanded, forming a multimodal resource system that covers the full chain of academic research.
- (2) Deepening AI-enabled knowledge-resource integration and improving the efficiency of resource discovery and use. Artificial intelligence should be used to analyze user needs, track disciplinary development trends, dynamically adjust resource-procurement strategies, and increase resource utilization. With the help of LLMs and intelligent agents, libraries should integrate their physical and digital resources, establish a unified resource-management platform, and improve the discoverability and accessibility of resources. Intelligent retrieval systems and personalized

personalized recommendation algorithms to help users quickly locate needed resources, while recommending related resources based on user profiles to enhance the user experience. Build AI-driven examples for MOOC content generation, automate the production of teaching resources, and improve the efficiency of content supply.

(3) Strengthen technical support for resource creation and application. Build intelligent multimedia physical spaces, integrate artificial intelligence and virtual reality technologies, and improve the intelligence level of creative equipment. Design virtual-reality-based interactive teaching cases and expand the coverage of immersive learning content. Explore models for producing high-quality teaching content, promote intelligent content-creation tools and collaborative platforms, and support the updating and iteration of MOOC resources as well as the creation of multimedia content. Advance the development of multimedia creation methods, realize intensive resource sharing, and expand learning coverage.

3.3.3 Service construction: collaborative, embedded smart knowledge services

The research activities of new-type research universities are more problem-oriented, data-intensive, and collaborative across the entire chain. This requires knowledge services to be deeply embedded in the complete value chain from original ideas to the transformation of results. The service model must be

upgraded from providing standardized information products to collaboratively solving complex research problems. The implementation path takes the LLM- and agent-driven Inside-Out mechanism (see Fig. 3) as its core, building a user-driven service model featuring integrated multi-tool convergence and dynamic interactive iteration. In this way, it completes the transformation from intelligence personnel-led services to collaboration between users and agents, and from fixed product outputs to dynamic knowledge services, thereby providing users with a more flexible, efficient, and personalized knowledge-service experience.

In-figure text:

Multimodal resource system: basic data; intelligence data; domain data.

Intelligence personnel users.

Intelligent intelligence matrix: dynamic monitoring; disruptive prediction; talent analysis; university tracking; frontier identification; information literacy; competitive early warning.

Workflow 1; ...; workflow n .

Intelligence-analysis agent toolbox: general-purpose, flexible, customizable, and freely combinable; agent 1; ...; agent n .

Solution generation.

From intelligence personnel-led services to collaboration between users and agents.

From fixed product outputs to dynamic knowledge services.

Application scenarios: strategic planning; faculty development; curriculum and teaching; research layout; talent evaluation; integration of government, industry, universities, and research.

Fig. 3 Inside-Out mechanism

(1) Strengthen the development of foundational capabilities empowered by artificial intelligence, optimize tools and mechanisms, and improve overall service effectiveness. Using LLM- and agent-driven service mechanisms, automatically capture and process diverse heterogeneous texts and multimodal data, realizing an end-to-end intelligent intelligence-analysis service from resource collection and processing to diagnostic recommendations. Develop portable and customizable agent toolboxes to provide high-value, differentiated customized intelligence services, adapting to multi-scenario needs for knowledge acquisition and decision support. Promote the deep integration of artificial intelligence into intelligence services, assist users in constructing customized intelligence agents, support users' independent analysis and decision-making, and meet their customized intelligence needs.

(2) Build a knowledge-service system that supports strategic decision-making and strengthen intelligence-service capabilities. Focusing on frontier scientific and technological trends and layouts, major policies, mechanisms for educational development, mechanisms for research and innovation, and education and talent evaluation, form an agent-application matrix equipped with intelligent task planning, dynamic knowledge models, reliable evaluation

criteria, and other capabilities. Establish an intra-university collaborative working mechanism to support various units in achieving precise diagnosis and decision-making in areas such as strategic planning and faculty development.

(3) Promote the construction of scenario-driven disciplinary service mechanisms, realize multimodal resource supply across the full chain of teaching, research, and transformation, and provide precise intelligence services. Establish flexibly configurable method libraries and mechanisms, focusing on scenarios such as disciplinary evaluation, “Double First-Class” applications and assessments, and international evaluation, so as to provide rapidly customized, high-quality analytical results for different stages of disciplinary development. Expand the coverage of disciplinary services, build a disciplinary intelligence monitoring system, track the progress of interdisciplinary research and policy orientations, and provide dynamically adaptive cross-domain knowledge support for research teams. Integrate the resource system, knowledge-service system, and collaborative working mechanism to create scenario-driven intelligent and customized tools, providing multidimensional, high-quality resources and in-depth analysis for key links across the full chain of teaching, research, and transformation.

(4) Build a multi-element literacy-education brand and optimize multi-level training and courses. Integrate online and offline resources, and develop self-directed learning resources and interactive courses to meet students’ diverse learning needs. Promote AI-empowered smart education services, provide personalized learning-path recommendations and intelligent tutoring tools, and improve students’ information literacy and innovation capabilities. Use virtual reality technology to create immersive learning scenarios and make learning more engaging.

3.4 Construction implications

For new-type research universities, whether they can successfully transform into smart libraries depends on whether they can integrate strategic principles, ecological goals, and an implementation path featuring three-dimensional coordination among space, resources, and services into a coherent and systematic construction process. Based on ShanghaiTech University Library’s “ten

the “15th Five-Year Plan” planning and practice. This paper systematically analyzes the construction pathway for the smart library of a new-type research university, providing a reference basis for the planning and practice of similar institutions.

First, planning must be premised on clear strategic principles. ShanghaiTech’s practice shows that smart library construction should closely align with the university’s mission of being “small in scale, high in level, and internationalized,” as well as with the need to serve national frontier strategies. This allows its development to follow principles such as strategic coordination, pragmatic innovation, and open sharing, ensuring that every investment can precisely serve

the university' s overall development goals.

Second, goal setting must achieve a leap from functions to an ecosystem. The case shows that the ultimate goal of the library of a new-type research university is not to become a larger repository of resources, but to build a human-centered, physical-virtual integrated new ecosystem of smart services. Through the Library-inside model, this ecosystem transforms the library into a knowledge service component that can be embedded in users' workflows, thereby providing intelligent support for the entire chain of teaching, research, and translation.

Finally, the key to implementation lies in the coordinated support of space, resources, and services. ShanghaiTech' s practice reveals that building a smart ecosystem depends on the simultaneous transformation and deep integration of the three pillars of space, resources, and services. This requires, in terms of space services, the creation of scenario-based environments that link physical and virtual spaces and enable interdisciplinary interaction; in terms of resource services, the construction of an intelligent, multimodal resource system responsive to frontier needs; and in terms of knowledge services, the development of a dynamic knowledge system that is deeply embedded in the research process and characterized by human-machine collaboration. These three elements are interdependent and together constitute the practical foundation of a smart library ecosystem integrating the physical and the virtual.

4 Outlook

Under the guidance of university library planning for the "15th Five-Year Plan," smart library construction has become a core pathway for the high-quality development of libraries. This study shows that the key to the successful transformation of libraries at new-type research universities does not lie simply in adding technologies or expanding resources, but in achieving a systematic improvement in service effectiveness through institutional innovation, scenario-driven development, and human-machine collaboration. The exploration undertaken by the ShanghaiTech Library provides a concrete and feasible practical model for this pathway.

To continuously deepen smart construction, libraries need to establish dynamic tuning mechanisms during implementation, closely track the evolution of intelligent technologies and the development needs of their universities, and flexibly optimize implementation pathways; strengthen organizational and resource support, and ensure the effective realization of strategic goals through cross-departmental collaboration and coordinated funding from multiple sources; and continuously improve talent echelons, enhance teams' digital-intelligent literacy and capacity for operational coordination, and consolidate the talent foundation for sustainable development.

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Virtual-Real Integration in the Smart Library Ecosystem of New Research Universities: Exploring the Construction Path of ShanghaiTech University Library During the 15th Five-Year Plan Period

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Abstract During the 15th Five-Year Plan period, the construction of smart libraries is a key initiative for universities to implement the digital transformation strategy in education and support high-quality development. This paper aims to explore a smart library development path that aligns with the mission and characteristics of new research universities. Taking the 15th Five-Year Plan of ShanghaiTech University Library as the research object, it systematically analyzes the construction plans and implementation strategies formulated around the concept of virtual-real integration from three dimensions: space, resources, and services. The study reveals that its development practice follows a systematic logic of “strategic synergy—ecosystem-oriented goals—three-dimensional coordinated implementation.” Through the analysis of this case, the paper summarizes a set of construction ideas and practical guidelines that can serve as a reference for similar new research university libraries, offering valuable experience for the innovative development of university libraries during the 15th Five-Year Plan period.

Keywords Smart library; Virtual-real integration; New library ecosystem; 15th Five-Year Plan; New research university

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

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