Research on the Construction of a Demand Indicator System and Innovation Paths for Smart Services in University Libraries in the Metaverse Environment*

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Full Text

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Abstract Driven by metaverse technologies, smart services in university libraries face the challenge of mismatch between supply and demand. This study constructs a multidimensional demand indicator system covering 6 first-level indicators and 21 second-level indicators, innovatively integrates a three-dimensional evaluation mechanism consisting of expert judgment, reader perception, and objective data, and applies the Analytic Hierarchy Process (AHP), Exploratory Factor Analysis (EFA), and the CRITIC method for combined weighting. The empirical findings show that, in the metaverse environment, readers' needs exhibit characteristics of structural reconstruction: demands for privacy protection and research data management have surpassed traditional resource-access functions to become core concerns, reflecting readers' deep-seated attention to data security and knowledge management. Accordingly, the study proposes a progressive path of service innovation from three levels—basic assurance, core efficiency enhancement, and forward-looking guidance—providing theoretical grounds and practical reference for resource allocation and service transformation in university libraries under metaverse scenarios.

[**Keywords**] metaverse; university library; smart service; user demand

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Introduction

With the rise of the concept of the "metaverse" and its deep integration with education and culture, university libraries are facing a critical opportunity for intelligent transformation. The *14th Five-Year Plan for National Informatization* clearly proposes building a digital infrastructure system centered on technologies such as big data and 5G, and accelerating their in-depth application in education and cultural services. As a three-dimensional Internet integrating technologies such as extended reality and digital twins, the metaverse breaks through temporal and spatial barriers by constructing a digital space in which the virtual and the real coexist, thereby providing technical support for the leap of library services from a planar mode to an immersive transformation[2].

In recent years, scholars have extensively explored pathways for integrating the metaverse with smart services in university libraries. Wu Jiang et al.[3], by mining library "14th Five-Year Plan" texts, clarified the technological and policy origins and proposed paths of integration and innovation. Guo Yajun et al.[4], through an empirical survey of 147 domestic "Double First-Class" university libraries, found that although basic metaverse technologies have been applied relatively widely in university libraries, the overall integration process remains in an initial exploratory stage and has not yet formed a mature and in-depth system of integrated applications. Amzat O. B. et al.[5] further pointed out that although the collaboration between the metaverse and AI can improve service efficiency, attention must be paid to users' deep-level needs regarding the digital divide and privacy security. Wang Jingyi et al.[6] introduced scene theory and constructed an all-scenario subject service model from the perspective of user needs, emphasizing the prediction and satisfaction of users' real needs through data collection and user profiling. However, existing research focuses mostly on constructing supply-side technical architectures. Although user needs are considered to some extent, there is still a lack of a quantitative evaluation indicator system capable of dynamically reflecting readers' diverse needs in the metaverse environment, which also leads to the risk of supply-demand mismatch in the transformation of smart services.

In view of this, this study aims to construct a multidimensionally integrated reader demand indicator system for smart services in university libraries, innovatively integrating a ternary evaluation mechanism of "expert judgment, reader perception, and objective data." It extends user demand theory into the metaverse field and enriches quantitative research on user profiling in smart libraries. At the same time, it comprehensively applies the Analytic Hierarchy Process (AHP), Exploratory Factor Analysis (EFA), and the CRITIC method for scientific combined weighting, thereby constructing a more robust demand indicator system. At the practical level, through empirical analysis, this study accurately identifies readers' core demands in the metaverse environment and can effectively avoid blind technological

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investment and construction risks caused by excessive accumulation, thereby providing decision-making evidence for university libraries to optimize resource allocation and reconstruct service models.

1 Initial Construction of the Demand Indicator System

1.1 Principles for Constructing the Indicator System

To ensure the scientific rigor and application value of the indicator system, this study follows the following five core principles. First is the principle of scientificity: variables are selected on the basis of rigorous theories and scientific methods to ensure that the structure of the indicator system is logically sound. Second is the principle of systematicity: hierarchical logic is followed to decompose the complex demands in the metaverse environment into a multidimensional structure with progressive relationships. Third is the principle of operability: indicator definitions are made clear and quantifiable, so as to support effective measurement. Fourth is the principle of dynamism: the openness of the system is maintained so that it can be dynamically adjusted as technologies iterate and readers' expectations change. Fifth is the principle of orientation: the reader-centered philosophy is implemented to precisely guide the formulation of service innovation strategies.

1.2 Screening and Optimization of Demand Indicators

To ensure the scientific rigor and forward-looking nature of the indicator system, this study adopted the literature analysis method to determine the initial indicators. Given that smart services in university libraries under the metaverse environment are still in the exploratory stage of application, and to avoid possible bias caused by users' lagging cognition in direct research, this study first drew on existing high-quality theoretical achievements in academia. With "metaverse library smart services" as the theme, more than 60 representative papers published in recent years in CSSCI and Peking University Core Journals were screened.

In constructing the secondary indicators, this study was not limited to simple statistics on the frequency of literature keywords, but instead conducted an in-depth analysis of the intrinsic logic between metaverse technological characteristics and services. On the one hand, from the reader' s perspective, the technological supply elements extracted from the literature were logically transformed into service-demand dimensions perceptible to readers; on the other hand, taking into account the particularity of university libraries as distinct from public libraries, characteristic indicators such as "academic resource recommendation," "virtual teaching support," and "research data management" were emphasized. Through layer-by-layer deduction from general services to university scenarios, six primary indicators were ultimately summarized and further decomposed into 28 secondary indicators, forming an initial indicator set that is both forward-looking and targeted, as shown in Table 1.

To ensure the scientific validity of the indicators, this study adopted an expert survey method and selected 34 senior experts with associate-senior or higher professional titles for investigation. In terms of professional composition, the group included 12 researchers in library and information science, 10 library managers, and 12 technical personnel; in terms of title distribution, there were 18 experts with full senior titles and 16 with associate-senior titles. Questionnaires were distributed to these 34 experts in the field of library and information science, and a dual quantitative screening was conducted using the coefficient of variation method and the fuzzy membership degree analysis method; that is, indicators with a coefficient of variation below 0.25 and a membership degree above 0.6 were retained. Based on the statistical results, five indicators with relatively low expert consensus or poor fit with core demands—namely, interaction feedback mechanism, multi-end environment adaptability, virtual identity security, AI ethics and risk management, and academic exchange support capability—were removed. Meanwhile, expert opinions were incorporated to optimize the indicators: academic resource recommendation capability was incorporated into intelligent recommendation capability, and virtual learning space and immersive interactive space were integrated into immersive study space. Ultimately, a reader-demand indicator system for smart services in university libraries was established, consisting of six primary indicators and 21 secondary indicators.

Table 1 Sources of Reader Demand Indicators

Primary Indicator	Secondary Indicator	References
P1 Resource Service Capability	Breadth of collection resources	Zhou Di [7]
P1 Resource Service Capability	Accessibility of digital resources	Dong Tongqiang et al. [8]
P1 Resource Service Capability	Intelligent retrieval capability	Guo Yajun et al. [9]
P1 Resource Service Capability	Resource sharing and interoperability capability	Rao Quan [10]
P1 Resource Service Capability	Intelligent recommendation capability	Lin Mei et al. [11]
P2 Intelligent Service Capability	Intelligent question-answering service	Cai Zifan et al. [12]
P2 Intelligent Service Capability	Intelligent knowledge management	Cai Yingchun et al. [13]
P2 Intelligent Service Capability	Virtual librarian service capability	Guo Yajun et al. [14]
P2 Intelligent Service Capability	Service response efficiency	Zhao Zhiyun et al. [15]
P3 Reader Experience Capability	Multimodal interaction experience	Dong Tongqiang et al. [8]
P3 Reader Experience Capability	Ease of operation	Li Mo [16]
P3 Reader Experience Capability	Intelligent navigation experience	Ma Jie et al. [17]
P3 Reader Experience Capability	Interactive feedback mechanism	Chen Yuan et al. [18]
P4 Spatial Integration Capability	Virtual learning space	Chu Jiewang et al. [19]
P4 Spatial Integration Capability	Immersive interactive space	Jin Jiali et al. [20]
P4 Spatial Integration Capability	Convenience of space use	Ma Jie et al. [17]

Primary Indicator	Secondary Indicator	References
P4 Spatial Integration Capability	Coherence of virtual-real integration	Lin Mei et al. [11]
P4 Spatial Integration Capability	Multi-end environment adaptability	Du Xilin et al. [21]
P4 Spatial Integration Capability	System stability	Yang Ling et al. [22]
P5 Security Governance Capability	Virtual identity security	Wang Liguo et al. [23]
P5 Security Governance Capability	Reader privacy protection	Du Xilin et al. [21]
P5 Security Governance Capability	Data security	Chen Li et al. [24]
P5 Security Governance Capability	AI ethics and risk management	Bu Miao [25]
P6 Academic Support Capability	Academic resource recommendation capability	Chen Guanting et al. [26]
P6 Academic Support Capability	Academic exchange support capability	Li Li [27]
P6 Academic Support Capability	AI research support capability	Bu Miao [25]
P6 Academic Support Capability	Research data management capability	Cai Zifan et al. [12]
P6 Academic Support Capability	Virtual teaching support capability	Guo Hailing et al. [28]

2 Comparative Validation of the Demand Indicator System

2.1 Expert Weight Calculation Based on AHP

To determine the relative importance of each indicator, this study used AHP to calculate weights from the expert perspective [29]. To ensure the authority and accuracy of the weighting results, 10 senior experts were further selected from the above-mentioned pool of 34 experts to form a core evaluation group. These experts all held full senior professional titles, had an average of more than 20 years of professional experience, and possessed profound academic expertise in the relevant fields. Through pairwise comparisons of indicators at each level by these 10 senior experts, judgment matrices were constructed. To ensure the logical consistency of the judgments, this study conducted strict consistency tests on all matrices. For

For the small number of samples that did not initially pass, the "maximum deviation correction method" was adopted for iterative adjustment until all matrices satisfied the consistency requirements[30].

By taking the arithmetic mean of the weight vectors provided by the 10 experts, the final AHP-based weight distribution was obtained, as shown in Table 2. The data indicate that, at the first-level indicator layer, P1 resource service capability ranks first, followed by P5 safety governance capability and P3 reader experience capability. At the second-level indicator layer, Q17 reader privacy protection, Q20 research data management capability, and Q11 operational convenience rank among the top indicators by weight. These results show that experts generally believe that, in the metaverse environment, smart services in university libraries should attach great importance to strengthening the bottom line of service security, enhancing academic and research support, and ensuring system usability.

2.2 Reader-perceived weights based on EFA

This study conducted an online survey of university library readers through the Wenjuanxing platform and collected 209 valid questionnaires. The sample was evenly distributed in terms of gender, identity, and disciplinary field, indicating good representativeness.

SPSS was used to test reliability and validity. The results show that the overall Cronbach' s α coefficient of the questionnaire was 0.926, and the coefficients for all dimensions were greater than 0.750, indicating excellent questionnaire reliability. The KMO value was 0.907, and Bartlett' s test of sphericity was highly significant ($p = 0.000$), indicating that the data were highly suitable for factor analysis.

On this basis, EFA was applied to examine the structural validity of the indicator system. To explore the latent structure behind the observed variables, this study used principal component analysis to extract common factors, adopted eigenvalues greater than 1 as the criterion, and combined this with the scree plot. Ultimately, 6 common factors were extracted, with a cumulative variance explanation rate of 76.473%, indicating good model fit. Finally, the factor loading matrix was rotated using the varimax method.

The results show that the loadings of the 21 indicators on their corresponding common factors were all greater than 0.7, and their factor affiliations were completely consistent with the six first-level indicators constructed through AHP, demonstrating that the indicator system developed in this study has excellent structural validity. Given the stability of the model structure, the rotated factor loading matrix was further used to calculate the weights of indicators from the perspective of reader perception. The specific results are shown in Table 2.

Reader-perceived weights were calculated based on the sums of squared rotated factor loadings from EFA[31]. The results show that there are certain differences between readers' and experts' demand preferences. Readers show relatively high dependency demands for P1 resource service capability, P2 intelligent service capability, and P3 reader experience capability. At the second-level indicator layer, readers are most concerned with Q20 research data management capability, Q21 virtual teaching support capability, Q2 digital resource availability, Q3 intelligent retrieval capability, Q4 resource sharing and interoperability capability, and Q5 intelligent recommendation capability. This fully indicates that, in the metaverse environment, readers' core demands still closely center on the practical dimensions of academic support, resource acquisition, and tool efficacy.

2.3 Objective weights based on the CRITIC method

To effectively avoid bias in subjective evaluation, this study introduces the CRITIC method to mine the intrinsic objective characteristics of the data. This method does not rely on prior judgment; instead, it determines objective weights by comprehensively measuring the contrast intensity and conflict among indicators[32].

The CRITIC calculation procedure is as follows: first, the matrix composed of the 209 questionnaire responses is subjected to range standardization to eliminate dimensional differences; second, the standard deviation of each indicator is used to quantify contrast intensity, and the correlation coefficients among indicators are used to measure conflict; finally, calculation is completed based on the comprehensive information content, followed by normalization, to obtain the objective weight of each indicator. The specific results are shown in Table 2.

Table 2 Indicator weights based on AHP, EFA, and CRITIC

First-level indicator	AHP	EFA	CRITIC	Second-level indicator	AHP	EFA	CRITIC
P1 Resource service capability	0.2116	0.196	0.158	Q1 Breadth of collection resources	0.0535	0.0486	0.0337
P1 Resource service capability	0.2116	0.196	0.158	Q2 Digital resource availability	0.0613	0.0494	0.0385

First-level indicator	AHP	EFA	CRITIC	Second-level indicator	AHP	EFA	CRITIC
P1 Resource service capability	0.2116	0.196	0.158	Q3 Intelligent retrieval capability	0.0372	0.0494	0.0381
P1 Resource service capability	0.2116	0.196	0.158	Q4 Resource sharing and interoperability capability	0.0596	0.0494	0.0428
P1 Resource service capability	0.2116	0.196	0.158	Q5 Intelligent recommendation capability	0.0542	0.0494	0.0494
P2 Intelligent service capability	0.1753	0.193	0.208	Q6 Intelligent Q&A service	0.0279	0.0487	0.0507

First-level indicator	AHP	EFA	CRITIC	Second-level indicator	AHP	EFA	CRITIC
P2 Intelligent service capability	0.1753	0.193	0.208	Q7 Intelligent knowledge management	0.0607	0.0477	0.0462
P2 Intelligent service capability	0.1753	0.193	0.208	Q8 Virtual librarian service capability	0.0325	0.0469	0.0556
P2 Intelligent service capability	0.1753	0.193	0.208	Q9 Service response efficiency	0.0536	0.0456	0.0402
P3 Reader experience capability	0.1788	0.191	0.198	Q10 Multimodal interactive experience	0.0276	0.0449	0.0559
P3 Reader experience capability	0.1788	0.191	0.198	Q11 Operational convenience	0.0655	0.0458	0.0385

First-level indicator	AHP	EFA	CRITIC	Second-level indicator	AHP	EFA	CRITIC
P3 Reader experience capability	0.1788	0.191	0.198	Q12 Intelligent navigation experience	0.0321	0.0485	0.0574
P4 Spatial integration capability	0.0852	0.140	0.154	Q13 Immersive study space	0.0373	0.0476	0.0543
P4 Spatial integration capability	0.0852	0.140	0.154	Q14 Convenience of space use	0.0315	0.0472	0.0456
P4 Spatial integration capability	0.0852	0.140	0.154	Q15 Continuity of virtual-real integration	0.0164	0.0454	0.0490

Table 2 (continued)

Primary indicator	Primary-indicator weight (AHP)	Primary-indicator weight (EFA)	Primary-indicator weight (CRITIC)	Secondary indicator	Secondary-indicator weight (AHP)	Secondary-indicator weight (EFA)	Secondary-indicator weight (CRITIC)
P5 Safety-governance capability	0.179 8	0.134	0.142	Q16 System stability	0.046 1	0.042 9	0.047 3
P5 Safety-governance capability	0.179 8	0.134	0.142	Q17 Reader privacy protection	0.076 1	0.044 1	0.047 5
P5 Safety-governance capability	0.179 8	0.134	0.142	Q18 Data security	0.057 6	0.039 0	0.042 7
P6 Academic-support capability	0.169 3	0.145	0.141	Q19 AI research-support capability	0.053 7	0.047 6	0.045 4
P6 Academic-support capability	0.169 3	0.145	0.141	Q20 Research data-management capability	0.067 9	0.051 3	0.047 1
P6 Academic-support capability	0.169 3	0.145	0.141	Q21 Virtual teaching-support capability	0.047 7	0.049 7	0.044 0

The calculation results show that, among the secondary indicators, those ranking highest in objective weight are Q12 Intelligent navigation experience, Q10

Multimodal interaction experience, and Q8 Virtual librarian service capability. This result indicates that the above indicators exhibit a relatively high degree of dispersion in the sample, meaning that readers have not yet formed a fixed consensus regarding demand for such emerging technology services. This is precisely a potential breakthrough point for libraries to innovate differentiated services and expand incremental value.

2.4 Combination-weighting calculation and in-depth analysis of results

This study compares and analyzes the three sets of results from AHP, EFA, and CRITIC, revealing significant differences in demand preferences from different perspectives. The expert perspective emphasizes top-level design and risk control, giving priority to bottom-line security-governance concerns such as Q17 Reader privacy protection. The reader perspective focuses on practical effectiveness and depends heavily on rigid needs such as Q20 Research data-management capability and Q2 Availability of digital resources. The objective perspective, by contrast, highlights emerging indicators such as Q12 Intelligent navigation experience and Q10 Multimodal interaction experience. Although these indicators have relatively low weights in subjective evaluation, they show high volatility in the objective data, foreshadowing differentiated growth points in services.

To construct a robust indicator system that incorporates experts' forward-looking judgments, attention to readers' core needs, and the objective patterns in the data, this study adopts a subjective-objective combination-weighting method[^33] to conduct a comprehensive calculation of the indicator system. Considering that expert judgment, reader perception, and objective data characteristics have equally important reference value in smart-service decision-making, a linear weighting model is used to integrate the three categories of weights with equal weights. The comprehensive weights of indicators at all levels are ultimately determined, as shown in Table 3 and Table 4.

Table 3 Comprehensive weights and rankings of the primary indicators of reader needs

Ranking	Primary indicator	Comprehensive weight
1	P2 Intelligent service capability	0.190 0
2	P3 Reader-experience capability	0.188 2
3	P1 Resource-service capability	0.182 2
4	P6 Academic-support capability	0.156 9
5	P5 Safety-governance capability	0.153 0
6	P4 Spatial-integration capability	0.129 7

Based on the distribution of comprehensive weights and drawing on user-needs theory to conduct an in-depth analysis of the internal logic of the indicator system, it is found that reader needs in the metaverse environment present a distinct hierarchical structure of “survival—development—transcendence.”

Table 4 Comprehensive weights and rankings of the secondary indicators of reader needs

Ranking	Secondary indicator	Comprehensive weight
1	Q17 Reader privacy protection	0.062 3
2	Q20 Research data-management capability	0.062 1
3	Q7 Intelligent knowledge management	0.053 9
4	Q11 Operational convenience	0.052 0
5	Q5 Intelligent recommendation capability	0.051 4
6	Q4 Resource sharing and interoperability capability	0.050 8
7	Q2 Availability of digital resources	0.049 6
8	Q12 Intelligent navigation experience	0.048 8
9	Q19 AI research-support capability	0.048 8
10	Q13 Immersive study space	0.046 9
11	Q18 Data security	0.046 6
12	Q21 Virtual teaching-support capability	0.046 0
13	Q9 Service response efficiency	0.044 9
14	Q16 System stability	0.044 0
15	Q6 Intelligent Q&A service	0.043 2
16	Q14 Convenience of space use	0.042 8
17	Q10 Multimodal interaction experience	0.042 5
18	Q1 Breadth of collection resources	0.042 3
19	Q8 Virtual librarian service capability	0.041 4
20	Q15 Coherence of virtual–real integration	0.040 0
21	Q3 Intelligent retrieval capability	0.039 5

First, foundational security needs constitute the cornerstone of service survival. The comprehensive weights show that Q17 Reader privacy protection and Q20 Research data-management capability rank at the top, aligning with the “security needs” in Maslow’ s hierarchy of needs. In decentralized virtual scenarios, users’ reliance on trust mechanisms far exceeds sensory experience; data sovereignty and privacy security are the basic prerequisites for readers to enter a metaverse library.

Second, middle-level cognitive needs drive a paradigmatic leap from resource-centeredness to intelligence-centeredness. The comprehensive weight of P2 Intelligent service capability exceeds that of P1 Resource-service capability, indicating that although readers’ core demands still reflect instrumental rationality, the mode of knowledge acquisition has undergone a qualitative change. Intelligent

Algorithms have replaced traditional collections as the core carrier for satisfying cognitive needs.

Third, high-level experiential needs indicate the direction in which service innovation should transcend existing models. Although the current weight of the P4 spatial-integration capability indicator is not prominent, its high dispersion in objective weighting reflects users' desire to explore new things. This corresponds to the "self-actualization needs" at the top of Maslow's theory: after readers' basic and cognitive needs are met, they begin to pursue immersive creation and embodied participation in the high-dimensional space of the metaverse. Although such needs are not rigid demands at present, they are a key breakthrough point for university libraries to achieve service differentiation and value upgrading.

3. Smart Service Innovation Strategies Based on the Demand Indicator System

Based on the empirical calculations above, readers' needs in the metaverse environment present a distinct hierarchical structure of "survival—development—transcendence." To enhance the scientificity and pertinence of the strategies, this study integrates comprehensive weight rankings with in-depth mapping of service paths, and establishes a supply logic of "basic assurance—core efficiency enhancement—forward-looking leadership." This strategy matrix is not a mechanical stacking of functions, but rather a scientific transformation that strictly follows the weighting results: indicators such as Q17 reader privacy protection, Q20 research data management capability, and Q11 operational convenience are identified as the basic assurance layer, intended to consolidate the service foundation; core needs such as Q7 intelligent knowledge management, Q21 virtual teaching support capability, and Q5 intelligent recommendation capability are transformed into the core efficiency-enhancement layer, driving the intelligent transformation of service paradigms; for potential needs with relatively high dispersion in objective weights, a forward-looking leadership layer is constructed to explore the boundaries of innovation. Following this progressive logic, this section constructs specific and operable innovation paths for smart services, thereby realizing a logical closed loop from empirical analysis to practical application.

3.1 Basic Assurance Layer: Consolidating the Service Foundation of Security and Usability

The three indicators Q17 reader privacy protection, Q20 research data management capability, and Q11 operational convenience are key indicators in the basic assurance dimension. This empirical result profoundly reveals that, in the complex environment of high-dimensional simulation and all-time online presence in the metaverse, readers' core anxieties have shifted from simple resource acquisition to concerns over virtual identity security and low-threshold interaction. To improve the scientificity and pertinence of strategy construction, university libraries must give priority to solving the foundational issues of controllable security, convenience, and efficiency, and build a robust digital service ecosystem through technological governance and process restructuring.

First, technological governance should be strengthened, and a comprehensive privacy-protection system for virtual identities should be established. Given readers' high level of concern for privacy protection, the boundaries of privacy protection in the metaverse environment need to be extended from static borrowing records to readers' biometric features and behavioral trajectories. University libraries should establish the principle of privacy by design and introduce blockchain technology to reshape trust mechanisms. The practice of Jiangnan University Library in using blockchain distributed storage to realize digital copyright confirmation is of great reference value[34]. University libraries should learn from this paradigm and use the decentralized and tamper-proof technical characteristics of blockchain to build a digital identity authentication system controlled independently by users, clearly define ownership of data assets generated during metaverse interactions, and provide underlying security guarantees for the activities of virtual avatars in digital space.

Second, data functions should be upgraded, and a research data management center oriented toward digital twins should be built. In response to readers' urgent demand for research data management capability and system stability, university libraries should extend their service objects from traditional texts to digital-twin assets such as virtual experimental simulation data and interaction logs. In specific practice, a dual governance mechanism of "full process + deep mining" should be constructed: first, a full-life-cycle paradigm should be established by benchmarking against Fudan University Library, implementing standardized governance from collection to archiving and ensuring that the entire data process is complete and traceable[35]; second, a secure mining mechanism should be built by drawing on the experience of Tianjin University Library, jointly working with blockchain laboratories to deeply extract implicit information from literature in encrypted environments, creating a metaverse data hub, and achieving secure and long-term governance of research assets[34].

Third, the principle of low-friction interaction should be followed to optimize a seamless virtual–physical access experience. In response to the high-weight demand for operational convenience, university libraries must resolutely avoid usability barriers caused by technological stacking, and ensure low latency and high fault tolerance at the entrance to the metaverse. In physical spaces, the experience of non-sensory services should be deepened. Drawing on the RFID three-dimensional positioning practices of Xidian University and the facial-recognition access-control experience of Shanghai Jiao Tong University, the physical operation costs of space reservation and borrowing can be greatly reduced. At the virtual interaction end, passive viewing modes should be avoided. Drawing on the intelligent triggering mechanism of Wuhan University' s virtual roaming system, virtual librarians can provide interactive services as users' perspectives change, realizing a transformation from "people looking for services" to "services finding people." In addition, before new VR and AR functions go online, strict usability testing must be carried out to ensure that, while smart services pursue visual presentation effects, usability and efficiency are given priority.

3.2 Core Efficiency-Enhancement Layer: Building an AI-Driven Personalized Knowledge Hub

High-weight indicators represented by Q7 intelligent knowledge management, Q21 virtual teaching support capability, and Q5 intelligent recommendation capability collectively reflect readers' urgent demand for improved smart service effectiveness, and embody their core expectation that services transform from static resource repositories into intelligent agents. In the metaverse environment, intelligence is reflected not only in data computation, but also more strongly in contextual perception and intelligent interaction. Therefore, the strategic focus should be on using AI and data technologies to realize a paradigm shift from "people looking for resources" to "knowledge finding people."

First, a three-dimensional immersive knowledge graph should be constructed to drive the explicitization of tacit knowledge. In response to the urgent need for intelligent knowledge management and intelligent retrieval, libraries should break through the linear organization of traditional metadata and make tacit knowledge explicit. For example, Stanford University Libraries have conducted three-dimensional processing of their collection resources on a virtual-space platform; by constructing virtual archives and three-dimensional exhibitions, they provide a typical demonstrative model[36]. University libraries can draw on this pathway to reorganize scattered literature into a structured and visualized three-dimensional knowledge network. This can not only optimize the precision of intelligent retrieval⋯

accuracy, and can better plan personalized knowledge-roaming paths for readers' virtual avatars, thereby promoting the association of knowledge and its in-depth discovery.

Second, embed services into research and teaching processes and provide accompanying research support based on artificial-intelligence-generated content (AIGC). In response to the integrated demand for intelligent recommendation, intelligent question answering, AI research support, and virtual teaching support, university libraries should upgrade their intelligent customer-service systems so that they are deeply embedded in the research workflows of teachers and students. At the level of tool empowerment, they should actively explore the localized deployment and full-scenario application of large models. Drawing on the successful experience of Zhejiang University' s "Mr. ZJU" deeply integrated intelligent-agent platform, they should build a university-level computing-power base, provide compliant and efficient AI research tools, and achieve full coverage of teaching consultation and academic assistance[37]. At the level of service deepening, the libraries of Renmin University of China and China Agricultural University have both deployed typical embedded AI customer-service systems[34]. In the future, such agents should be further endowed with intelligence analysis and judgment capabilities, and their natural-language understanding and contextual reasoning capabilities should be strengthened, so that they can be upgraded into virtual research partners capable of assisting with the generation of literature reviews and the prediction of academic frontier trends.

Third, build an all-domain resource middle platform to break down the barriers to virtual–real interaction in the metaverse. In response to practical pain points such as poor resource sharing and inconvenient access to digital resources, the key to solving the problem lies in constructing a unified resource pool that spans systems and terminals. By building the "Bailian Cloud" service system and relying on cloud-computing technology, the Library of Nanjing University of Information Science and Technology has effectively broken through the limitations of physical library buildings and successfully realized the virtual extension of service scenarios[38]. University libraries should learn from this model, build a unified API interface pool, and connect the data links between virtual bookshelves and physical terminals, ensuring that the digital resources readers obtain in the metaverse can flow seamlessly to various physical devices and realizing a "what you see is what you get" resource-service experience.

3.3 Forward-looking guidance layer: Exploring innovative directions of immersion and foresight

The empirical results show that indicators such as Q3 intelligent retrieval capability and Q1 breadth of library resources have relatively low weights, indicating that they have already become basic smart services in university libraries and are unlikely to generate significant innovation premiums. In combination with the CRITIC analysis results above, however, Q12 intelligent navigation experience, Q10 multimodal interaction experience, and Q8 virtual librarian service capability show relatively high dispersion and information load, fully demonstrating that these services are emerging areas with great development potential. Therefore, the future strategic focus of university libraries should be to lay out these emerging service scenarios in advance and cultivate differentiated growth points.

First, develop digital-twin training scenarios and deepen immersive learning experiences. In response to the potential needs for immersive learning spaces, convenience in spatial use, and coherence in virtual–real integration, the construction of smart spaces should break through the single "3D roaming" model and strengthen deep integration with professional disciplinary teaching. Drawing on the embedded paradigm of "physical space + VR teaching materials" at the Medical Library of Fudan University Library, university libraries can transform themselves into "virtual teaching-asset managers" and jointly build virtual simulation experiment platforms with schools of medicine, architecture, machinery, and other disciplines[34]. By introducing high-precision disciplinary models, they can transform broadly entertainment-oriented sensory experiences into rigid support for teaching and research, thereby significantly enhancing the academic value of physical spaces.

Second, expand the dimensions of intelligent navigation and realize guidance from physical space to knowledge space. The core value of intelligent navigation should go beyond single-route guidance and extend to the dimension of location-based knowledge association. The virtual navigation and roaming system developed by Wuhan University Library provides an excellent implementation paradigm: when a user' s virtual perspective moves to the information desk, the virtual librarian automatically triggers interaction; when the perspective shifts to the exhibition area, the system immediately presents detailed metadata for the artwork[34]. Drawing on this idea, university libraries can further introduce GIS and visualization technologies to construct visual knowledge maps, dynamically presenting the spatiotemporal distribution characteristics of collection knowledge in the form of heat maps and thematic maps, and providing teachers and students with in-depth navigation services that integrate location services and knowledge discovery.

Third, pilot multimodal interaction methods and create metaverse-native pathways for information acquisition. In response to the high-potential demand for multimodal interaction experience, university libraries should adopt a tiered pilot strategy and gradually cultivate readers' new interaction habits. The practices of Zhejiang University Library, which uses AR technology to "activate" ancient paintings, and Tsinghua University Library' s "Tsinghua Imprint" interactive experience space show that multimodal technology can effectively break through the bottlenecks of static resource display[39-40]. In the future, multimodal interaction technologies such as gesture control, eye tracking, and motion capture should be further introduced to lower the operational threshold for readers, thereby realizing a qualitative transformation from one-way reading to fully sensory embodied interaction.

4 Conclusion

Focusing on the mismatch between supply and demand in smart services for university libraries in the metaverse environment, this study integrates the three perspectives of expert judgment, reader perception, and objective data, and comprehensively applies the combined weighting methods of AHP, EFA, and CRITIC to construct and validate a demand indicator system comprising 6 first-level indicators and 21 second-level indicators. This indicator system effectively overcomes the subjective bias of a single perspective and provides a more robust quantitative analysis tool for understanding readers' complex needs in metaverse scenarios.

The empirical results reveal a profound transformation in the logic of reader demand: the weights of indicators related to security and data governance, such as privacy protection and research data management, have risen significantly, becoming the core foundation of smart services. Meanwhile, intelligent experience and immersive interaction constitute the core expectations and potential growth points of services. This finding clarifies the hierarchical logic of resource allocation in university libraries: under the premise of ensuring security and controllability, they should collaboratively promote the transformation of services toward greater efficiency and immersion.

Based on the empirical analysis, this study proposes a three-layer progressive service strategy: consolidating the foundation of security and usability, building an AI-driven personalized knowledge center, and exploring immersive and forward-looking innovation directions. This strategy matrix accurately aligns the technological characteristics of the metaverse—such as virtual-real integration and digital twins—with reader needs, clarifying the development direction of "what to do" in the smart transformation of university libraries, while also providing a practical…

paths. Through systematic layout, a logical closed loop from theoretical model construction to practical strategy guidance can be realized, providing scientific support for service reconstruction in university libraries in metaverse scenarios.

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Research on Optimization Strategies for Short Videos Promoting Ancient Books in University Libraries from a Narrative Perspective

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Abstract Taking as research subjects 58 university libraries designated as "National Key Protection Units for Ancient Books," this paper, based on the framework of classical narratology, analyzes their short videos for promoting ancient books from four dimensions: narrative theme, narrative structure, narrative perspective, and narrative discourse. On this basis, it summarizes existing shortcomings and proposes corresponding improvement strategies: strengthen narrative awareness to broaden the channels for ancient books promotion; identify appropriate narrative themes to advance the promotion process in an orderly manner; adopt diverse narrative structures and perspectives to present the stories of ancient books in a multi-dimensional way; and enrich narrative discourse to enhance the appeal of the promotional short videos.

Keywords Ancient books promotion; Short videos; Narrative strategy; University libraries

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Research on the Construction of Demand Index System and Innovation Path for Smart Services in University Libraries under the Metaverse Environment

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Abstract Driven by metaverse technology, smart services in university libraries are facing the challenge of supply-demand mismatch. This study constructs a multidimensional demand index system covering 6 primary indicators and 21 secondary indicators. It innovatively integrates a ternary evaluation mechanism consisting of expert judgment, reader perception, and objective data, utilizing the Analytic Hierarchy Process (AHP), Exploratory Factor Analysis (EFA), and the CRITIC method for combined weighting. Empirical findings reveal a structural restructuring of reader needs in the metaverse environment; specifically, the demand for privacy protection and research data management has surpassed traditional resource acquisition functions to become core concerns. This reflects readers' deep-seated concerns about data security and knowledge management. Based on these findings, a progressive service innovation path is proposed, encompassing basic guarantee, core efficiency enhancement, and forward-looking exploration. This study provides a theoretical basis and practical reference for resource allocation and service transformation in university library metaverse scenarios.

Keywords Metaverse; University libraries; Smart services; User needs

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