Construction of an Evaluation Index System for the Capability Maturity of Digital Scholarship Services in Academic Libraries

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Abstract

Purpose/Significance: This study constructs an evaluation index system for the capability maturity of digital academic services in university libraries, providing a basis for assessing their digital academic service capabilities and thereby promoting their enhancement and refinement. Method/Process: Drawing upon the fundamental principles of the Software Capability Maturity Model, a capability maturity model for digital academic services in university libraries is established; by compiling and analyzing existing policies, literature, and cases, a preliminary evaluation index system is drafted; the Delphi method and Analytic Hierarchy Process are employed to determine the importance and weights of the indicators. Results/Conclusion: This paper ultimately develops the "Evaluation Index System for the Capability Maturity of Digital Academic Services in University Libraries," comprising 7 first-level indicators and 19 second-level indicators, providing a reliable assessment tool for the targeted development and improvement of digital academic service capabilities in university libraries.

Full Text

Construction of an Evaluation Index System for Digital Scholarship Service Capability Maturity in University Libraries

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Abstract:
[Purpose/Significance] This study constructs an evaluation index system for digital scholarship service capability maturity in university libraries, providing a

diagnostic framework for libraries to assess their digital scholarship service capabilities and thereby promoting their improvement and refinement.
[Method/Process] Drawing upon the fundamental principles of the Capability Maturity Model, we developed a digital scholarship service capability maturity model for university libraries. By systematically reviewing existing policies, literature, and case studies, we preliminarily formulated an evaluation index system. The Delphi method and Analytic Hierarchy Process were then employed to determine the importance and weight of each indicator.
[Result/Conclusion] This paper ultimately establishes an "Evaluation Index System for Digital Scholarship Service Capability Maturity in University Libraries" comprising 7 first-level indicators and 19 second-level indicators, offering a reliable assessment tool for the targeted development and enhancement of digital scholarship service capabilities in university libraries.

Keywords: digital scholarship service; university libraries; evaluation index system; maturity model
Classification Number: G251

Digital Scholarship Service (DSS) refers to the comprehensive academic support that libraries provide throughout the entire scientific research lifecycle. This service addresses the interdisciplinary collaboration needs of researchers across multiple fields by leveraging emerging information technologies to organize, index, mine, and utilize various resources [Error: Reference source not found]. In recent years, university libraries both domestically and internationally have been actively developing and promoting digital scholarship services. For instance, Peking University Library offers digital publishing services to help researchers resolve copyright issues, while the Li Wenzheng Library at Southeast University has established a Digital Scholarship Center to support interactive learning methods including group discussions and self-service equipment experiences, aiming to provide specialized research services for users. The 13th Advanced Seminar on Digital Library Frontiers in 2016, themed "Digital Scholarship and Citizen Science: The New Ecology of Digital Libraries," focused on sub-topics such as "Digital Scholarship and Digital Humanities," drawing greater attention from domestic scholars and yielding promising research progress. However, a research gap exists in evaluating the implementation level and service capacity of digital scholarship service projects, which hinders the promotion of the digital scholarship service concept and the development of practice. Some scholars have also noted that current digital scholarship services in Chinese university libraries remain limited [Error: Reference source not found]. Therefore, this study attempts to establish an evaluation index system for digital scholarship service capability maturity in university libraries, aiming to enhance their digital scholarship service capabilities, strengthen subject service awareness, and effectively advance university teaching, research, and the "Double First-Class" construction initiative.

Several maturity studies have focused on specific aspects of digital scholarship services or related academic services in university libraries. For example, A.M.

Cox et al. developed a research data management maturity model to capture the development trajectory of research data services and assess their impact on the nature of university libraries [Error: Reference source not found]. A. Marquet created a digital transformation maturity model for libraries and archives from four dimensions: technology, process, organization, and staff []. Zhang Xu et al. proposed an evaluation index system for the maturity of university library think tank service capabilities from perspectives such as resource integration and decision support []. Gao Fan et al. presented a framework for evaluating long-term preservation capability maturity []. Xu Yu conducted research on the evaluation system for digital publishing service capabilities in university libraries []. Dang Hongli and Tan Haibing constructed a library data management and service capability maturity model and explored its application in university libraries []. Nevertheless, maturity research specifically targeting digital scholarship service capabilities remains scarce both domestically and internationally. This study collects and selects key elements for evaluating digital scholarship service capabilities in university libraries from existing literature, policies, and cases, and constructs an evaluation index system for digital scholarship service capability maturity based on the Software Capability Maturity Model (CMM) using the Delphi method and Analytic Hierarchy Process.

2.1 Digital Scholarship

Clarifying the connotation and denotation of digital scholarship services as a developing concept requires first analyzing the concept of digital scholarship itself. Zeng Xi et al. analyzed the origins and evolution of digital scholarship and distinguished it from related concepts, identifying its characteristics and summarizing its definition as a new research model that employs digital technologies and methods throughout the entire academic research process []. Many scholars and organizations have also described digital scholarship by examining its entire lifecycle across aspects such as digital humanities, digital preservation, data analysis, and digital publishing. A.S. Rumsey, Huang Xiaojun, E Lijun, and the Association of Research Libraries (ARL), among others, view digital scholarship as research activities that utilize digital evidence and methods with digital technologies as tools [-]. R. Mulligan proposes that digital scholarship includes but is not limited to data analysis and visualization, text encoding, computational text analysis, GIS and digital mapping, 3D modeling, digital collections and exhibitions, digitization and imaging, audio and metadata creation [], aiming to enable broader future development of digital scholarship.

2.2 Digital Scholarship Service

Correspondingly, Yu Defeng summarizes digital scholarship services as a general term for a series of services that support teaching, research, and learning using digital technologies and tools []. Tu Zhifang et al., building upon their understanding of the digital scholarship concept and investigating similar terminology used across different libraries, propose that digital scholarship service embod-

ies both individual digital elements such as space, resources, and projects, and serves as a collective term and integration of these elements []. The Association of Research Libraries (ARL) notes that digital scholarship services represent an extension of digital humanities services, providing support to a broad range of disciplines beyond just the humanities.

Evidently, digital scholarship service itself possesses rich connotations and denotations, with its concept still evolving and expanding dynamically. After comparing these various perspectives, this study adopts the definition of digital scholarship service provided by the Association of College and Research Libraries (ACRL) cited at the beginning of this paper as the foundation for subsequent research.

2.3 The CMM Model

The earliest maturity model can be traced back to 1986, when it was developed by the Software Engineering Institute (SEI) of the U.S. Department of Defense. In 1991, after refinement, the model evolved into a comprehensive framework identifying process areas and practices—the Software Capability Maturity Model (CMM). The CMM model comprises five levels: Initial, Repeatable, Defined, Managed, and Optimizing. Except for the Initial level, each level's core structure consists of several Key Process Areas (KPAs), which represent the goals and requirements needed to achieve that level. Each KPA further contains Key Practices (KPs) that demonstrate the specific activities of the process area. To date, the CMM model has been widely applied to other fields including library and information science due to its well-developed theoretical methodology, giving rise to numerous maturity models and improved versions such as the Capability Maturity Model Integration (CMMI). Although CMMI represents the latest version of CMM, it emphasizes coverage across multiple different domains to achieve an "integration" effect. This study aims to create a new model for digital scholarship service capability maturity in university libraries, focusing on level division and characteristic descriptions of key practices. Moreover, evaluating the maturity of digital scholarship service capabilities in university libraries essentially assesses the development of an organization's service capability, which aligns with the original principles of the capability maturity model. Therefore, the CMM model is more applicable to this research.

3 Construction of a Digital Scholarship Service Capability Maturity Model for University Libraries

As no digital scholarship service capability maturity model currently exists domestically or internationally, this study designs and proposes key process areas for each maturity level and describes the key practices to construct a digital scholarship service capability maturity model for university libraries.

3.1 Maturity Level Division for Digital Scholarship Service Capability in University Libraries

Based on the CMM model, this study divides digital scholarship service capability maturity in university libraries into five hierarchical levels. This research only proposes the key process areas for each level and characterizes the key practices, assuming that each higher maturity level fully encompasses the key process areas of lower levels. Non-critical process areas and common practices with universal characteristics (such as staff responsibilities in service processes, pre-established implementation plans for each 环节, and attention to legal risk avoidance) are not elaborated here.

(1) Initial Level: At this stage, university libraries can complete some processes in digital scholarship services, but project completion is somewhat accidental and relies more on individual librarians' competencies, lacking wholeness and collaboration. Meanwhile, the organization lacks systematic understanding of the digital scholarship service concept, may not even have a fixed implementation location, and the effective accumulation of relevant technologies and equipment remains haphazard.

(2) Repeatable Level: University libraries can adopt a replication strategy based on previous successful case experiences for subsequent similar projects, conducting standardized operations and initially formulating operational rules. However, although libraries begin to possess environments for conducting digital scholarship services, they cannot completely replicate successful cases to generalize and serve other projects. The key process areas and key practice descriptions are shown in Table 1 .

Table 1 Repeatable Level of Digital Scholarship Service Capability Maturity in University Libraries

Key Process Area	Key Practice Description
Institutional Development	Forming service awareness and philosophy, establishing service policies and strategic deployment
Infrastructure Development	Organizational system construction, establishing dedicated service departments and positions
Physical Space Creation	Creating physical venues for digital scholarship spaces
Technical Equipment Provision	Possessing a certain scale and quantity of technical equipment to support academic research

(3) Defined Level: University libraries possess clear understanding of digital scholarship service concepts and adopt standardized methods to control all

aspects of project implementation. Both librarians and departments can cooperate and adjust according to project needs, with service capabilities meeting users' basic requirements. Libraries at this stage have recognized the benefits that digital scholarship services bring to research development and aspire to further enhance their service capabilities through comprehensive systems. The key process areas and key practice descriptions are shown in Table 2 .

Table 2 Defined Level of Digital Scholarship Service Capability Maturity in University Libraries

Key Process Area	Key Practice Description
Project Management Mechanism	Implementing comprehensive control from project application evaluation and review to project initiation and monitoring
Collaboration Support	Establishing long-term cooperation with other university departments and open collaboration with external third-party institutions to enhance digital scholarship project management capabilities
Resource Development	Conducting comprehensive management of project funding usage and acquisition
Digital Resource Management	Improving library collection digitization to ensure diversity, comprehensiveness, and accuracy of digital resources
Research Service Platform	Building web pages, websites, databases, and other research service platforms

(4) Managed Level: With clearly defined missions and objectives, digital scholarship services receive comprehensive support including advanced facilities, technologies, and funding. Service projects are diverse with quantified quality requirements, demonstrating foresight regarding potential deviations and problems in the process, with capabilities to respond and improve to fully ensure smooth service delivery. At this point, the digital scholarship service capability of university libraries has entered a mature stage. The key process areas and key practice descriptions are shown in Table 3 .

Table 3 Managed Level of Digital Scholarship Service Capability Maturity in University Libraries

Key Process Area	Key Practice Description
Academic Consultation	Providing targeted academic consultation and teaching services that meet researchers' digital scholarship project needs

Key Process Area	Key Practice Description
Data Creation	Data creation work such as metadata creation and digital collection production
Data Analysis	Data analysis work including digital imaging and visualization
Data Management	Data management encompassing digital repositories, data archiving, preservation, and utilization
Copyright Services	Improving supporting services for copyright issues including post-project digital publishing, ensuring standardized open access data and reusability

(5) Optimizing Level: University libraries optimize existing service project processes. Through quantitative statistical data analysis, they fill gaps in current weak links, improve service levels, innovate service content, and perfect service systems. Libraries enter the highest maturity level with outstanding digital scholarship service capabilities, continuously generating benefits and actively engaging in new project incubation. The key process areas and key practice descriptions are shown in Table 4 .

Table 4 Optimizing Level of Digital Scholarship Service Capability Maturity in University Libraries

Key Process Area	Key Practice Description
Service Innovation	Transforming from passively serving digital scholarship project activities to proactively planning digital scholarship project development
Professional Training	Conducting internal professional training to enhance service technologies and capabilities of specialized personnel
User Satisfaction	Collecting user feedback to improve service quality and efficiency

3.2 Digital Scholarship Service Capability Maturity Model for University Libraries

Based on the characteristics of each maturity level of digital scholarship service capability in university libraries, this study constructs a digital scholarship service capability maturity model, as shown in Figure 1 [Figure 1: see original paper].

4 Preliminary Construction of the Evaluation Index System for Digital Scholarship Service Capability Maturity

The core elements of digital scholarship services reveal the complete picture of how university libraries implement these services, providing a reference for determining maturity evaluation indicators. Centering on the key process areas and key practices in the digital scholarship service capability maturity model constructed above, this study selects core elements for digital scholarship services primarily by integrating existing relevant policy standards (including important international conference reports on digital scholarship), extracting relevant core elements from the perspectives of service evaluation and practice analysis based on existing literature research. After integrating and analyzing these core elements, we determined element classifications and identified evaluation dimensions and indicators.

4.1 Selection of Core Elements for Digital Scholarship Service Capability Maturity

(1) Existing Relevant Policies, Standards, and Reports

As university libraries serve as the primary vehicle for digital scholarship services, national policies, international reports, and industry standards such as library evaluation indicators and library regulations provide important guidance for extracting evaluation indicator elements for digital scholarship service capability maturity in university libraries, in addition to existing university digital scholarship standards. These are summarized in Table 5 .

Table 5 Core Elements from Relevant Policies, Standards, and Reports

Policy/Standard/Report (Year)	Core Elements
Digital Library Service Policy Guidelines (2010)	Service objects, service methods, service strategies, service content, service commitments, service supervision and evaluation
Evaluation Indicators for Regular Higher Education Institution Libraries (2014)	Library conditions; literature resource development; automation, networking, and digitalization; reader services; scientific management

Policy/Standard/Report (Year)	Core Elements
Middle Tennessee State University Digital Scholarship Standards (2015)	Digital scholarship labs, project development, data management, digital publishing platforms, team building, open access, metadata development, digital storage
Regulations for Regular Higher Education Institution Libraries (2015)	Professional librarians, funding support, infrastructure development, digital information resource management and service systems, resource digitization, digital preservation, service spaces, subject services, research projects
Implementation Measures for Coordinated Advancement of World-Class Universities and First-Class Disciplines (Interim) (2017)	Talent cultivation, scientific research, social services, cultural inheritance and innovation, faculty development, international exchange and cooperation
13th Advanced Seminar on Digital Library Frontiers (2016)	Scientific data sharing, multilingual digital scholarship service platforms
LIBER–European Research Library Research Data Services Report (2016)	Digital consultation, technical support, librarian training, institutional cooperation

Policy/Standard/Report (Year)	Core Elements
ARL–SPEC Kit 350: Survey on Supporting Digital Scholarship (2016)	GIS and digital mapping, digitization/imaging of analog materials, creating digital collections, metadata creation, digital preservation, data curation and management, 3D modeling and printing, statistical analysis/support, digital exhibitions, project planning, digital publishing, project management, computational text analysis/support, interface design and/or usability, visualization, database development, technical maintenance, encoding content, developing digital scholarship software
CNI&JISC–International Developments in Digital Scholarship (2016)	Infrastructure, open access, digital preservation, librarian roles, digital work development and editing, digital publishing, funding
RLUK–The Role of Digital Scholarship and Research Libraries (2019)	Services/support, staff, staff organizational structure and location, staff skills, partnerships, funding sources, service evaluation, digital transformation of collections

Policy/Standard/Report (Year)	Core Elements
ACRL–Top Trends in Academic Libraries Report (2020)	Organizational structure, system support, open access, research data service innovation (financial, human, technical), position establishment
2nd Research Library Digital Scholarship Services Seminar (2021)	Space design, digital publishing, data management, collection digitization, talent team capability building

(2) Existing Relevant Evaluation Research

As comprehensive evaluation research on digital scholarship services is currently lacking domestically, and numerous references exist on library service evaluation based on different evaluation objects and perspectives, this study includes highly valuable literature on library service evaluation to ensure reliability and comprehensiveness in selecting core elements. Digital scholarship services ultimately fall within the scope of library services. The literature review on digital scholarship service evaluation in China is summarized in Table 6 .

Table 6 Core Elements from Relevant Evaluation Research

Source	Core Elements
Liu Ziheng, Tu Zhifang []	Digital scholarship space, data resource development (digitization, open sharing), digital scholarship user services (information literacy services, research data services, publishing services)
Li Huinan, Wang Xiaoguang []	Digital humanities, project platforms, visualization, sustainable development (long-term development and preservation, funding support, data management)
Wang Qiong, Wu Yu, Wu Yingmei []	ISO2789, IFLA, EQUINOX, ARL E-Metrics, SERVQUAL, LIBQUAL+
Shang Xiaoqian []	Digital scholarship, data management services, librarian teams, professional skills, collaboration, funding sources
Duan Meizhen, Zhao Yuan []	Service platforms, reference consultation services, knowledge sharing, data management

Source	Core Elements
Ding Dong, Zhang Changxiu []	Digital scholarship publishing, publishing consultation, metadata organization and processing, open access, long-term preservation
Ye Jiyuan, Guo Weibing, Zheng Dejun, et al. []	Talent cultivation, teaching integration, research integration, cultural inheritance and innovation
Wang Shuohuan []	Equipment (technical) support, funding (resource) support, personnel (intellectual) support, management system scientificity, openness and attractiveness, resource access convenience, service quality excellence, user satisfaction
Shen Hongping []	Service environment, database construction, data processing, data storage, data sharing and security, consultation, training
(Additional sources) []	Resources, librarian competencies, knowledge bases, funding

(3) Existing Relevant Practice Research

By reviewing existing literature on digital scholarship service practice case studies in university libraries, this study gains additional reference experience for selecting evaluation indicator core elements. We selected 32 domestic literature pieces based on practice case surveys (due to space limitations, 10 comprehensive ones are listed) to deepen understanding of the implementation forms and pathways of digital scholarship services in university libraries both domestically and internationally, as summarized in Table 7 .

Table 7 Core Elements from Relevant Practice Research

Source	Core Elements
Tu Zhifang, Xu Huifang []	Physical space, digital research tools, librarian roles, research data services (data management, metadata, data repositories and preservation, data analysis, visualization), consultation services, digital publishing, digital humanities, training
Cheng Wenyan []	Staffing, team building, software support, technical support, collaboration support, policy and strategic support
Zeng Yueliang []	Team building, software and hardware facilities, internal collaboration, digital humanities, open access, data services, digital publishing and copyright, digitization and metadata, teaching

Source	Core Elements
Li Tianyue []	Physical space, software and hardware facilities, technical support, human support, funding support, project development, training, data assurance (e.g., digital processing, data storage, data curation), visualization, open access, digital publishing
Song Jiamei, Wang Fang, Bai Rujiang []	Technical support, human support, professional teams and departments, funding support, metadata creation, collection digitization, digital curation and management, digital preservation, digital publishing, project development
Yu Defeng []	Department composition, position establishment, technical support, physical space, software and hardware facilities, funding support, human support, training seminars, consultation services, project incubation, data storage, digital publishing, open access, collection digitization
Jie Feng, Sheng Xingjun []	Physical space, human support, intra-campus collaboration, resource digitization, consultation services, seminars, digital resource repositories
Yang Min [Error: Reference source not found]	Team building, position establishment, physical space, hardware facilities, training, open access, digital processing, digital humanities, data management, digital publishing
Zhou Lihong, Yuan Yuan, Han Yingying []	Physical space, infrastructure, team building, teaching and training, consultation services, information resource services, bibliometric services, project incubation, data management, project management, digital preservation, digital publishing

4.2 Initial Determination of Digital Scholarship Service Capability Maturity Evaluation Indicators

Through comprehensive integration of relevant policies, standards, conference reports, service evaluations, and practice analyses related to digital scholarship services, we classified the core elements based on their connotations. Elements with different concepts were separated, while those with similar concepts were merged. Core elements were summarized and refined to form evaluation indicators. Considering the rationality and usability of evaluation indicators, and in conjunction with the digital scholarship service capability maturity model established above, this study uses each maturity stage as an evaluation dimension,

key process areas within each stage as first-level indicators, and key practices as second-level indicators to establish a maturity evaluation index system, as shown in Table 8 .

Table 8 Preliminary Evaluation Index System for Digital Scholarship Service Capability Maturity in University Libraries

Maturity Stage (Dimension)	Key Process Area (First-Level Indicator)	Key Practice (Second-Level Indicator)
Repeatable Level	Institutional Development A1	Policy and Strategy B1
		Department Establishment B2
	Infrastructure Development A2	Physical Space B4
		Software and Hardware Equipment B5
Defined Level	Project Management Mechanism A3	Project Control B6
		Collaboration Support B7
		Funding Management B8
	Resource Development A4	Resource Digitization B9
		Research Platform B10
Managed Level	Service Implementation A5	Academic Consultation B11
		Data Creation B12
		Data Analysis B13
		Data Management B14
		Copyright Services B15
Optimizing Level	Innovation and Upgrade A6	Project Incubation B16
		Professional Training B17
	Feedback Mechanism A7	User Satisfaction B18

(1) At the Repeatable Level, the two key process areas of institutional development and infrastructure development contain five key practices. First, **Policy and Strategy** represents the significance of digital scholarship services, addressing questions of how to serve, who to serve, self-positioning, and future development directions. Second, **Department Establishment** and **Dedicated Librarians** play a bridging role in connecting and supporting digital scholarship services in university libraries to meet researchers' needs. Currently, most university libraries in mainland China have not established specialized departments or positions for digital scholarship services, and professional digital scholarship service positions are not fixed [Error: Reference source not found]. Even when digital scholarship service departments are established, their specialized team

composition may be inadequate in both quality and quantity, or the service department construction remains in the planning stage, requiring librarians to assume digital scholarship service responsibilities concurrently. Therefore, when evaluating the key process area of institutional development, both department establishment and dedicated librarians should be examined. Third, **Physical Space** constitutes a fundamental element for university libraries to conduct digital scholarship services, typically named "Digital Scholarship Space" or "Digital Scholarship Center." Fourth, **Software and Hardware Equipment** serves as the tool for smooth digital scholarship service delivery. Both computer software and supporting hardware have undergone fundamental changes in the "digital intelligence technology empowerment" ecosystem, creating more possibilities for innovative services.

(2) At the Defined Level, the two key process areas of digital scholarship project management mechanism and digital resource development also contain five key practices. First, **Project Control** comes into play when researchers submit project applications, implementing comprehensive oversight from application evaluation and review through project initiation to project monitoring. Second, **Collaboration Support** includes both intra-university cross-departmental cooperation and resource and technical support from external institutions, which further enhances digital scholarship service quality, creates a favorable atmosphere for project development, and provides strong guarantees for problem-solving. Third, **Funding Management** serves as a solid backing for the sustainable operation and development of digital scholarship services, encompassing funding sources for digital scholarship center construction, grants for digital scholarship project initiation, and comprehensive management of fund usage review, allocation, and transparency. Fourth, **Digital Collections** constitute the fundamental guarantee for conducting digital scholarship research, as any research outcomes benefit from the massive digital resources owned by university libraries. Traditional collection digitization combined with born-digital collections jointly supplies resources for user reference and use. Fifth, **Research Service Platform** belongs to virtual space, existing in forms such as online communities, web pages, and databases, providing continuous dynamic resources and mutual assistance exchange venues for digital scholarship services.

(3) At the Managed Level, **Service Implementation** reflects the entire lifecycle of research activities. From the preliminary work of academic consultation, through mid-stage execution work including data creation, data analysis, and data management, to the final outcomes work of copyright services, this encompasses the main activities and specific projects in which university libraries participate throughout the digital scholarship service process, forming a relatively complete service chain. When researchers have clear digital scholarship needs and seek fulfillment, libraries can cooperate with them to conduct relevant scientific research based on these elements. Notably, "Digital Humanities," as a phenomenal international discourse in the 21st century [], has received widespread attention from scholars and is frequently mentioned in digital scholarship literature, often used interchangeably with "digital scholarship." After

reviewing the concept of digital humanities, we believe that due to its interdisciplinary and digital fundamental attributes that align with the characteristics of specific digital scholarship projects conducted by libraries, it need not be listed as a separate second-level indicator.

(4) At the Optimizing Level, the two key process areas of digital scholarship service innovation and upgrade and feedback mechanism contain three key practices. First, **Project Incubation** primarily refers to university libraries shifting from passively participating in digital scholarship project services to proactively planning and innovating project development. Second, **Professional Training** is a program designed for digital scholarship service personnel in university libraries. Different from user professional skills training for teaching purposes, professional training is a self-improvement behavior fundamentally aimed at enhancing librarians' service operability and feasibility, accelerating service speed, and improving service quality, serving as the driving force guarantee for digital scholarship services. Third, **User Satisfaction**, as the sole key practice in the feedback mechanism, integrates processes including user feedback, service evaluation, and self-improvement, representing an essential component for digital scholarship services to progress from ordinary to excellent.

In summary, this study preliminarily constructs an evaluation index system for digital scholarship service capability maturity in university libraries comprising 7 first-level indicators and 18 second-level indicators, as shown in Table 8.

5 Determination and Evaluation of the Digital Scholarship Service Capability Maturity Evaluation Index System

To further optimize the preliminary maturity evaluation index system, this study employed the Delphi method to solicit expert opinions through questionnaire surveys, determining the evaluation indicators for digital scholarship service capability maturity in university libraries. Combined with the Analytic Hierarchy Process, we further clarified the weight of each indicator and proposed evaluation methods for empirical analysis of the index system.

5.1 Determination of Maturity Evaluation Indicators

For expert selection in the Delphi method, a panel of 10-50 experts is generally appropriate []. This study invited 11 experts to form an indicator review panel, comprising directors and deputy directors engaged in frontline university library work and scholars conducting digital scholarship-related research. All experts hold associate professor or higher titles and have over 10 years of experience in library-related work, indicating high authority.

The research process utilized questionnaire surveys distributed via WeChat to each invited expert. The review content primarily included: judging the "importance" of the preliminarily constructed first-level and second-level indicators using a five-point Likert scale, and providing open-ended feedback for indica-

tor modification or supplementation. To ensure optimal research outcomes, the questionnaire also provided detailed introductions and explanations of "digital scholarship services," the "CMM model," each indicator, and the specific Delphi survey process to ensure experts fully understood the research background and review content.

The importance evaluation employed a five-point Likert scale with options ranging from "very unimportant" to "very important," assigned values 1-5. The mean importance value was calculated for each indicator across all expert reviews, and indicators with a mean value reaching 4.0 were retained.

Based on expert feedback from two questionnaire rounds, this study made partial modifications to the preliminary index system. First, indicator B3 "Dedicated Librarians" was revised to "Team Building" to better align with its subordination to the first-level indicator "Institutional Development." Second, second-level indicator B19 "Service Benefits" was added under first-level indicator A7 "Feedback Mechanism" to reflect the importance of researchers' actual participation effects and digital scholarship project output benefits for maturity evaluation. These two modifications, along with the other 17 second-level indicators, all achieved importance mean values of 4.0 or higher, as shown in Figure 2 [Figure 2: see original paper]. The seven first-level indicators remained unchanged and were all retained, ultimately forming a digital scholarship service capability maturity evaluation index system for university libraries comprising 7 first-level indicators and 19 second-level indicators across 5 dimensions.

5.2 Determination of Maturity Evaluation Indicator Weights

Building upon the Delphi method to determine the evaluation index system, this study employed the Analytic Hierarchy Process to calculate indicator weights, revealing their relative importance within each dimension and providing reference and decision-making support for evaluating university library digital scholarship service capability maturity.

The same 11 experts who participated in indicator review were invited to provide pairwise comparison results of indicator importance through questionnaires. In the questionnaire design, each maturity level stage served as an independent goal layer, first-level indicators within each stage formed the criterion layer for pairwise comparison (the Managed level had only one first-level indicator requiring no comparison), and second-level indicators as specific contents of first-level indicators formed the sub-criterion layer for mutual comparison. The comparison process utilized the "1-9" importance scale proposed by Professor T.L. Saaty, as shown in Table 9 , to construct 10 judgment matrices. Expert group review results were input, organized, and analyzed using MATLAB software to calculate and export indicator weights. After passing consistency tests, all indicator weights were obtained, as shown in Table 10 .

Table 9 "1-9" Ratio Scale

Scale	Meaning
1	Two indicators have equal importance
3	The former indicator is slightly more important than the latter
5	The former indicator is obviously more important than the latter
7	The former indicator is strongly more important than the latter
9	The former indicator is extremely more important than the latter
2, 4, 6, 8	Intermediate values between adjacent judgments
Reciprocal of above numbers	Importance when comparing the two indicators in reverse order

Table 10 Digital Scholarship Service Capability Maturity Evaluation Index System for University Libraries

Maturity Stage	Key Process Area (First-Level)	Key Practice (Second-Level)
Repeatable Level	Institutional Development A1	Policy and Strategy B1
		Department Establishment B2
		Team Building B3
	Infrastructure Development A2	Physical Space B4
		Software and Hardware Equipment B5
Defined Level	Project Management Mechanism A3	Project Control B6
		Collaboration Support B7
		Funding Management B8
	Resource Development A4	Resource Digitization B9
		Research Platform B10
Managed Level	Service Implementation A5	Academic Consultation B11
		Data Creation B12
		Data Analysis B13
		Data Management B14
		Copyright Services B15
Optimizing Level	Innovation and Upgrade A6	Project Incubation B16
		Professional Training B17
	Feedback Mechanism A7	User Satisfaction B18
		Service Benefits B19

As shown in Table 10, at the Repeatable Level, the first-level indicator Institutional Development and second-level indicator Policy and Strategy carry relatively high weights, indicating that experts believe institutional development significantly influences university library service planning, while Policy and Strat-

egy reflects the importance of clarifying digital scholarship service awareness and significance. At the Defined Level, the first-level indicator Resource Development carries a relatively high weight, suggesting that digital collections and virtual research service spaces better demonstrate the emerging characteristics of university library digital scholarship services compared to traditional information storage and exchange models. At the Managed Level, Data Analysis has a slightly higher weight than other second-level indicators, demonstrating that data mining, processing, and handling have core significance in digital scholarship service implementation. At the Optimizing Level, university libraries serve as campus digital scholarship project incubation centers [], dedicated to exploring and promoting personalized project development, fully reflecting the characteristics of the first-level indicator Innovation and Upgrade. Additionally, experts believe that Service Benefits play an indispensable role in perfecting the feedback mechanism.

5.3 Maturity Threshold Design and Evaluation Method

(1) Threshold Design

After determining the evaluation index system for digital scholarship service capability maturity, thresholds were designed according to maturity level divisions. By reviewing extensive literature on maturity evaluation index systems and referencing the threshold design approach in Chinese national standards "Data Management Capability Maturity Assessment Method GB/T42129-2022" and "Organizational Asset Management System Maturity Evaluation GB/T40829-2021," and considering the current development status of digital scholarship service capabilities in domestic university libraries, this study adopts the commonly used 100-point scoring method to set score ranges corresponding to each maturity level, as shown in Table 11 .

Table 11 Correspondence Between Maturity Levels and Scores

First-Level Indicator	Maturity Level	Score Range
Institutional Development & Infrastructure Development	Initial Level	$20 \leq D < 40$
	Repeatable Level	$40 \leq D < 60$
	Defined Level	$60 \leq D < 80$
Project Management Mechanism & Resource Development	Managed Level	$25 \leq D < 50$
	Optimizing Level	$50 \leq D < 75$
Innovation & Upgrade & Feedback Mechanism		$45 \leq D < 70$

Note: D represents the total score of first-level indicators at each goal layer

(2) Evaluation Method

The evaluation method combines qualitative and quantitative approaches. Based on actual library conditions, either self-assessment or expert assessment can be selected to evaluate the development degree of each second-level indicator. Qualitative assessment is used for indicators difficult to quantify, such as policy and strategy formulation and planning, while quantitative measurement is applied to quantifiable indicators, such as the number of software and hardware equipment in use. A 0-100 scale represents the development degree of each second-level indicator from low to high. Actual scores are calculated based on the weights of second-level indicators, and the scores of second-level indicators within each dimension are summed to obtain the total score for that dimension's first-level indicator. The maturity level is then determined by referring to Table 11.

5.4 Empirical Research and Analysis

The evaluation process for digital scholarship service capability maturity in university libraries involves: (1) comprehensively understanding the actual development status of the library's digital scholarship services through surveys and data collection; (2) calculating and determining the service capability maturity level based on the evaluation method and thresholds described above; and (3) identifying specific improvement directions and pathways based on the achieved maturity level.

Following the content of Table 10, this study investigated the digital scholarship service capability level of a university library in Beijing. Semi-structured interviews were conducted with the library's deputy director on April 23, 2023. The author scored based on interview records, while simultaneously inviting four digital scholarship service staff members from the library to score the indicator-related content, striving to comprehensively collect relevant information and objectively obtain indicator scores to ensure evaluation accuracy. By organizing the survey data and averaging the five score sheets, the results are shown in Table 12 .

Table 12 First-Level Indicator Scores for the Beijing University Library Digital Scholarship Services

Criterion Layer	Score
Institutional Development & Infrastructure Development (Criterion Layer 1)	56.4
Project Management Mechanism & Resource Development (Criterion Layer 2)	51.6
Service Implementation (Criterion Layer 3)	48.3
Innovation & Upgrade & Feedback Mechanism (Criterion Layer 4)	42.1

These survey results effectively illustrate the process of "determining service capability maturity level" and "proposing specific improvement strategies." The library's digital scholarship service capability maturity scored 51.6 points in "Criterion Layer 2," reaching the Managed Level. However, as maturity level increases, higher requirements are placed on previous criterion layers, with correspondingly higher thresholds (scores). The library's digital scholarship service capability scored 56.4 points in "Criterion Layer 1," only reaching the Defined Level and failing to meet the score requirements for the Managed Level at this criterion layer. Therefore, the library's overall digital scholarship service capability maturity is at the Defined Level. Since digital scholarship services are comprehensive projects spanning the entire research lifecycle, all key process areas require coordinated development. Consequently, the library should accelerate institutional and infrastructure development while further strengthening service implementation (as "Criterion Layer 3" also failed to reach the Managed Level) to improve weak links in the service implementation process.

Based on the CMM maturity model and starting from core elements of digital scholarship service capability maturity evaluation in university libraries, this study analyzed and organized evaluation indicators for each maturity stage. Using the Delphi method and Analytic Hierarchy Process, we constructed an evaluation index system for digital scholarship service capability maturity in university libraries. Digital scholarship services represent an inevitable trend for university libraries to further expand their service functions and improve service quality. This evaluation index system provides a tool for determining digital scholarship service capability maturity levels and offers strategies for targeted development and improvement in university libraries. Currently, research on digital scholarship services in university libraries remains in its initial stages, and the maturity evaluation index system designed in this study requires further testing through practical evaluation work. Based on evaluation results and combined with specific conditions of university libraries, more refined indicator compositions and more precise score ranges corresponding to maturity levels should be explored, with continuous revision and improvement in application to enhance the rigor and applicability of the entire evaluation index system.

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