Multiple Pathways for Research Data Services in Academic Libraries (Postprint)

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Abstract

[Purpose/Significance] This study investigates the existing diverse data service pathways in academic libraries, providing references for pathways and models for other domestic libraries exploring data services. [Method/Process] Based on prior surveys of comprehensive services in 14 academic professional libraries, digital scholarship services in 15 university libraries, and data services in 3 Canadian university libraries, this research summarizes five primary pathways of library data services: data platforms and data services, "one-stop" resource discovery systems and data discovery, integrated digital scholarship spaces and data services, open data resource navigation and data services, and comprehensive data consultation and support services. Typical case studies are conducted for each pathway, with considerations for issues requiring further research and corresponding solutions. [Results/Conclusion] Different service pathways each possess distinct advantages, disadvantages, and applicable conditions; they can function independently while also synergizing with one another. All five pathways hold value and necessity for existence. The presence of any single data service pathway contributes to constructing a complete data service system, enabling libraries to better establish their "territory" in data services and maintain initiative in data service provision amid competition and collaboration with publishers, information technology and service organizations, and other entities.

Full Text

Preamble

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Abstract

[**Purpose/Significance**] This study examines existing data service pathways in academic libraries to provide reference models for domestic libraries exploring data services. [**Method/Process**] Based on prior investigations of 14 academic professional libraries' comprehensive services, 15 university libraries' digital scholarship services, and 3 Canadian university libraries' data services, this paper summarizes five main pathways for library data services: data platforms and data services, "one-stop" resource discovery systems and data discovery, integrated digital scholarship spaces and data services, open data resource navigation and data services, and comprehensive data consulting and support services. Each pathway is illustrated through typical case studies, with further discussion of issues requiring additional research and potential solutions. [**Result/Conclusion**] Different service pathways each have distinct advantages, disadvantages, and applicable conditions, and can function both independently and collaboratively. All five pathways possess inherent value and necessity; the existence of any single data service pathway contributes to constructing a complete data service system, helping libraries better establish their "territory" in data services and maintain initiative in competition and cooperation with publishers, information technology, and service organizations.

Classification Number: G250
Keywords: academic library, research data services, data management platform, resource discovery system, digital scholarship

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1 Literature Review

Research on library research data or scientific data services has become increasingly abundant both domestically and internationally, primarily falling into two categories: studies focused on scientific data management, and theoretical and practical research on data services from broader perspectives. Overall, foreign research emphasizes practical exploration of data services supplemented by relevant discussions, while domestic research focuses more on theoretical exploration and studies of foreign practices, with data service practice implemented in only a small number of libraries.

Research achievements focusing on research data management are relatively rich. Early theoretical research by foreign scholars laid a solid foundation for practice and applied research. For example, M.S. Nelson [2] argued that connecting with data represents the first step toward emerging library service areas, requiring librarians to update old skills and learn new ones, promptly capture user needs, and master relevant tools to identify the needs of researchers and students. Foreign library communities emphasize survey feedback on the current state of library data service practices, such as the June 2012 survey and report *Academic Libraries and Research Data Services: Current Practices and Future Plans* by the Association of College & Research Libraries (ACRL) on

U.S. and Canadian academic libraries [3], and the December 2016 survey and report *Research Data Services in European Academic Libraries* by the Association of European Research Libraries (LIBER) [4]. These surveys reveal that: (1) an increasing number of libraries provide or plan to provide research data services, highly recognizing their importance and offering professional training and career development opportunities for data service librarians; (2) libraries predominantly provide consulting-type research data services, with fewer technical/practical services; (3) libraries collaborate with other campus units and research institutions to deliver research data services; and (4) libraries should actively seek opportunities and initiative in data services (such as formulating research data policies) and need to cross disciplinary boundaries to provide more diverse services to broader research communities.

Domestic scholars have conducted multi-dimensional research on data services, mostly theoretical thinking and exploration with strong guiding significance. These include: (1) earlier researchers discussing data services as a new field of library services (particularly reference services) [5-6]; (2) studies on the overall practical progress of foreign academic library data services in North America and Europe [7-9], individual practice cases [10], or specific aspects of data services (such as metadata [11]); (3) theoretical explorations of library data service models and ecosystems [12-13], where theoretical foundations and infrastructure, data resources and service capabilities, and technical support and application platforms are essential elements of data service systems; (4) explorations of library data service content and implementation pathways, including data development and promotion, retrieval and discovery, management and curation, storage and linking, consulting and analysis, and technical support [14-16], with service approaches such as “integrated display” and “embedded discipline”; and (5) attention to data librarian service models and skill training, including data librarian position establishment, data literacy, and training mechanisms [17-18].

In summary, domestic and foreign scholars have accumulated certain research achievements on library research data services (this study’s term “research data” includes data from humanities, social sciences, and natural sciences). Building on existing research, this study aims to understand library data services and their position within overall library services on a larger scale, thereby presenting a more systematic and comprehensive picture of library data service content and forms to provide reference for different types of libraries in selecting suitable data service pathways. Therefore, the author conducted three rounds of investigations following a “from broad to narrow” topical scope, summarizing five common current library data service pathways, elaborating and illustrating each (cases include but are not limited to libraries from the three investigation rounds), and conducting comparative analysis to clarify the content, characteristics, and applicability of different pathways.

2 Research Foundation and Investigation Clues

2.1 Comprehensive Practice Investigation of 14 Academic Professional Libraries

Considering factors such as national/regional scientific and technological development levels, library development levels, and balanced geographical coverage, this study initially selected the United States, United Kingdom, Canada, Australia, Germany, Japan, Russia, and China's Taiwan region as targets. After pilot investigations and considering representativeness, 14 academic professional libraries were finally identified as investigation objects: German National Library of Science and Technology [19], German National Library of Medicine [20], U.S. National Library of Medicine [21], U.S. National Agricultural Library [22], U.S. National Institute of Standards and Technology Library [23], Canadian Federal Science Library [24], Canadian National Science Library [25], Australian Commonwealth Scientific and Industrial Research Organisation Library [26], Australian Geoscience Library [27], Japanese National Institute of Informatics Library [28], Japanese Atomic Energy Agency Library [29], Russian National Public Library for Science and Technology [30], UK National Physical Laboratory Library [31], and Taiwan's Academia Sinica Library [32] (investigation period: July-December 2017). Through library website visits, library association website searches, and literature and web material reviews, we examined the libraries' parent institutions and/or professional library profiles, development strategies and action plans, resource construction, user services, research and development activities, and pressures and challenges. These 14 professional libraries fall into four categories: national scientific/professional libraries, large/medium professional libraries within national research institutions, small/medium professional libraries within national and subordinate research institutions, and professional library virtual consortia, making the selection highly representative.

The investigation revealed that professional library data services mainly include: (1) Data identifier services (primarily DOI): such as DOI registration services at the German National Library of Science and Technology, German National Library of Medicine, and Canadian National Science Library; (2) Data management and consulting: including data management platform construction and maintenance, data consulting and support, and related training; (3) Data storage: storing research data through digital repositories or data knowledge bases, such as the German National Library of Science and Technology serving as a data storage library and operating a digital preservation system; (4) Data publishing: including data publishing platform operation, data storage and publishing, data publication indexing, and dataset download and citation, such as the German National Library of Medicine's digital preservation system receiving Data Seal of Approval (DSA) certification, the U.S. National Library of Medicine's bulk data download, the U.S. National Agricultural Library's five data integration platforms, the Canadian Federal Science Library's dataset retrieval, and the Australian Commonwealth Scientific and Industrial Research Organisation Library's data portal; and (5) Data visualization: including data

visualization tools, training, and results display, such as the U.S. National Institute of Standards and Technology Library providing researchers with data visualization wall usage and visual analysis of research impact.

2.2 Digital Scholarship Service Investigation of 15 University Libraries

Using existing literature [33-35] on library digital scholarship surveys as clues, exploratory pre-investigations were conducted on several academic libraries, ultimately selecting 15 university libraries: Chinese University of Hong Kong Library [36], University of Washington Libraries [37], Brown University Library [38], University of Richmond Library [39], University of Oregon Libraries [40], University of California, Santa Cruz Library [41], New York University Library [42], Lafayette College Library [43], McMaster University Library [44], Case Western Reserve University Library [45], Emory University Library [46], Georgia State University Library [47], Columbia University Library [48], University of Notre Dame Library [49], and University of Illinois at Urbana-Champaign Library [50] (investigation period: July-September 2017). Through library website visits and digital scholarship literature and web material reviews, detailed investigations were conducted on each library's digital scholarship concepts, spaces, tools, resources, services, personnel, and technology.

The investigation found that library digital scholarship services mainly include physical spaces, digital research tools, research data services (some libraries treat research data services as parallel to digital scholarship rather than included within it, such as McMaster University Library), academic communication and digital publishing services, digital humanities services, digital scholarship seminars and training, and digital infrastructure support services, with librarians playing diverse roles and responsibilities. Research data services specifically include data management plan consulting, metadata services, data repository and preservation services, data publishing services, data analysis and visualization services, etc.

2.3 Data Service Investigation of 3 Canadian University Libraries

Using the investigation of McMaster University Library's digital scholarship services as a clue, and considering the reference value of library data service pathways for future data service practice, McMaster University Library [51] and two similar libraries—University of Windsor Library [52] and York University Library [53]—were selected for in-depth investigation. Library website visits were conducted to understand data sources, data resource presentation methods, and service items (investigation period: September-December 2017). The investigation revealed that these three university libraries' "data services" have two main aspects: (1) Data resource integration and discovery, where libraries integrate authorized statistical data, researcher-generated data, open-access third-party data, and helpful/learning data resources, such as some statistical data from Statistics Canada, data video courses, and data and data product citation guides, with navigation by discipline or data function; and (2)

Data management and services, such as software support, statistical consulting services, full lifecycle research data management, and map and geospatial thematic data.

2.4 Summary of Data Service Pathways and Representative Libraries

Using the above investigations as foundation and clues (not as strict interpretations), and collectively referring to university and professional libraries as "academic libraries," this study summarizes five common data service pathways based on the "column 归属" (column 归属) of data services on library websites and overall service design: (1) Data platforms and data services, (2) "One-stop" resource discovery systems and data discovery, (3) Integrated digital scholarship spaces and data services, (4) Open data resource navigation and data services, and (5) Comprehensive data consulting and support services. These five pathways and their representative libraries are shown in Table 1 . The following sections will elaborate, illustrate, and discuss these five pathways. Note that these pathways can exist independently or work collaboratively, and may have overlapping aspects in special cases (such as providing comprehensive data consulting and support services within the "integrated digital scholarship space and data services" pathway).

3 Five Library Data Service Pathways and Illustrations

3.1 Data Platforms and Data Services

According to relevant research [54], data management and service platforms built by teaching and research institutions, research funding agencies, and international organizations are now common, with libraries increasingly organizing or participating in platform construction and maintenance. Currently, library-organized or -participated data platforms fall into two categories: (1) Open research data management platforms oriented toward the data curation lifecycle, such as Johns Hopkins University Library's Data Conservancy, Peking University Library's Peking University Open Research Data Platform, and Fudan University Library's Fudan University Social Science Data Center; and (2) Data portals oriented toward institutional data resource integration, browsing, and retrieval, such as the Australian Commonwealth Scientific and Industrial Research Organisation Library's Data Access Portal and the German National Library of Science and Technology's RADAR [55].

3.1.1 Research Data Management Platforms Different libraries' data management platforms have different functional emphases. Data Conservancy emphasizes its function as data curation technical infrastructure, while Peking University Open Research Data Platform and Fudan University Social Science Data Platform emphasize data collection, preservation, retrieval, and utilization services based on the platform.

Data Conservancy, initiated by Johns Hopkins University's Sheridan Library

in 2009 and developed based on the Fedora system prototype with funding from the U.S. National Science Foundation's DataNet program, provides data preservation, sharing, and discovery services [56], but currently does not support data browsing, retrieval, and download functions. Data Conservancy has developed five types of software with functions for metadata capture, data capture/preservation/visualization, and data organization and description, available for free download, including FedoraAPI-X, RMap, Data Conservancy Packaging Specifications, Packaging Tool GUI, and Package Ingest Service.

The Peking University Open Research Data Platform officially launched at the end of 2015, co-sponsored by Peking University Library, National Natural Science Foundation, Peking University Management Science Data Center, Peking University Research Department, and Peking University Social Sciences Department, with Peking University Library responsible for operation and maintenance. The platform has integrated 28 data spaces, 153 datasets, and 533 data files (as of January 31, 2018), covering social sciences, medical health and life sciences, computer and information science, business and management, and earth and environmental sciences [57].

3.1.2 Institutional Data Portals The Commonwealth Scientific and Industrial Research Organisation (CSIRO) [58] is Australia's largest national research institution. CSIRO places its library and information services under the "Publications" section, including CSIRO publishing, data portal (data access portal), research publications institutional repository, and CSIRO library services [59], providing comprehensive information resource support for scientific research.

The CSIRO Data Access Portal [60] integrates research data, software, and other digital assets published by CSIRO institutions and researchers, currently containing over 2,000 data and software resources (as of January 31, 2018). Users can browse, search all data, and use domain-specific search tools for retrieval.

3.1.3 Sustainable Development of Data Services Based on Data Platforms The sustainable development of data services based on data platforms has attracted scholars' attention, including sustainable platform operation funding, data resource growth pressure, data reuse rate improvement pressure, uncertainties in cross-institutional cooperation, uncertainties in researcher demand, and uncertainties in data policies [61].

For example, in January 2016, OCLC explored seven possible funding solutions for libraries facing difficulties in data management services due to funding shortages and staffing constraints: (1) securing institutional budget support; (2) incorporating data curation costs in budgets; (3) charging researchers; (4) charging users; (5) fundraising; (6) data repository funding; and (7) other possible solutions. OCLC further surveyed 2,010 faculty at the University of North Carolina, finding that none believed users should pay, while other options had supporters, suggesting that combining various funding methods may be necessary [62].

Additionally, in December 2017, Peking University Library, Peking University Department of Information Management, South China Sea Big Data Application Research Institute, and other organizations launched the first National University Data-Driven Innovation Research Competition, which received enthusiastic responses [63]. Participants had to use data already existing on the Peking University Open Research Data Platform or their own original data for research and submit original data to the platform. This competition effectively solicited new data resources from cooperating units and participants, representing beneficial exploration for promoting data resource accumulation, improving data reuse efficiency, and facilitating sustainable platform development.

3.2 "One-Stop" Resource Discovery Systems and Data Discovery

"One-stop" resource discovery systems are now common in libraries, such as the Canadian Federal Science Library's (FSL) "one-stop search box," UCLA Library's "OneSearch," Tsinghua University Library's "Shuimu Search," and National Taiwan University Library's "Integrated Query System."

3.2.1 Foreign Library Resource Discovery Systems and Data Discovery Using the Canadian Federal Science Library [24] as an example, FSL is a library resource portal composed of six professional libraries in different subject areas: Agriculture and Agri-Food Canada Library, Environment and Climate Change Canada Library, Fisheries and Oceans Canada Library, Health Canada Library, National Science Library, and Natural Resources Canada Library, similar to China's National Science and Technology Library (NSTL). The FSL discovery system, based on Summon 2.0, allows users to "one-stop" discover all print collections and database resources, repository resources, and open access resources from all six libraries, or limit searches to specific member libraries. Users can filter by content type, discipline, subject terms, etc. The searchable and accessible content types are highly diverse, including 40 types such as journal articles, book reviews, archival materials, video recordings, computer files, datasets, government documents, images, manuscripts, maps, microfilms, news announcements, patents, standards, presentations, technical reports, and web resources, covering 58 disciplines including agriculture, biology, chemistry, education, and engineering. Currently, the FSL discovery system has integrated over 30 million resource records, including 3,658 datasets, 44 images, 71,542 [Figure 71542: see original paper] maps, 2,302 video recordings, and 210 audio recordings (as of January 31, 2018). Taking "dataset" discovery as an example, most datasets in the FSL discovery system are open-access web resources. Users can browse all datasets or search for specific topics using "DataSet" as a filter condition. FSL only harvests metadata for open datasets, with users directed to original dataset sources for acquisition and utilization.

3.2.2 Domestic Library Resource Discovery Systems and Data Discovery Using Tsinghua University Library as an example, Tsinghua's "Shuimu Search" began trial operation in December 2011 [64], now based on the Primo

system prototype. Searchable resource types include research datasets, statistical data, maps, musical scores, audio-visual materials, databases, books, articles, journals, images, technical reports, legal documents, conference proceedings, dissertations, patents, ancient books, government publications, reference entries, reviews, and over 20 other types, supporting retrieval under specific conditions but not browsing all or certain content type resources.

Taking "image" retrieval as an example, searching for "woman" in any field yields 84,550 results (search date: February 2, 2018). Users can view image titles, subjects, descriptions, sources, and link to online resources for more detailed descriptions including image dimensions and historical stories, and select appropriate image sizes for download.

3.2.3 Promotion and Research of Data Discovery Functions Data discovery functions are often "deeply hidden" within discovery systems and not easily discovered or utilized by users. Libraries rarely promote data discovery functions. For example, when Shuimu Search launched, Tsinghua University Library introduced its massive resources, fast retrieval, result aggregation, multi-data source integration, and personalized services, but did not promote its data (datasets, statistical data) discovery functions. Meanwhile, current research on library resource discovery systems seldom mentions data discovery functions, focusing more on massive resources, quick access, and ease of use [65]. Therefore, strengthening promotion and research of data discovery functions in library resource discovery systems is necessary.

3.3 Integrated Digital Scholarship Spaces and Data Services

3.3.1 Digital Scholarship Spaces and Data Services Cases Digital scholarship is both a concept of digital technology and academic products, and a model of academic communication and teaching/research paradigm, constituting the digital academic environment in the digital, networked, and new media era [66]. Libraries provide digital scholarship services to adapt to environmental changes and user needs, such as at the University of Washington Libraries, University of California, Santa Cruz Library, and Chinese University of Hong Kong Library.

Different libraries present digital scholarship services under different specific names and forms, such as Digital Scholarship Commons, Digital Scholarship LAB, and Centre for Digital Scholarship, encompassing both individual elements like physical space, data resources, knowledge services, and digital humanities projects, and the integration of these elements.

Research data services within the "digital scholarship space" framework basically cover all aspects of the data lifecycle, particularly emphasizing consulting services and data analysis and visualization services: (1) Consulting services include data management plan outlines, guidelines, best practice consulting, and metadata scheme and standard consulting. For example, the University

of Oregon Libraries provides users with data management plan outlines [67] (how to describe data, select metadata and tools, organize/store/protect data, share data, long-term preservation, etc.) and data management plan best practices/guidelines [68] (such as recommended standard formats for video data, geospatial data, image data, and text data). (2) Data analysis and visualization services include providing or recommending data analysis software (such as ATLAS.ti, GRASS GIS, SPSS) and visualization equipment (such as high-resolution display screens, interactive walls) with corresponding venues. For example, the Chinese University of Hong Kong Library provides GIS software GRASS GIS, statistical analysis software IBM SPSS, statistical computing and graphics software R, and medical data imaging and analysis software TreeAge Pro Healthcare [69], while Brown University's Rockefeller Library Digital Scholarship Lab is equipped with a 7x16-foot high-resolution display wall [70].

3.3.2 Data Service Correlation and Collaboration Factors Comparing the above digital scholarship space-based data services with data management platform-oriented data services reveals that the former typically emphasizes data resource-driven services, while the latter emphasizes both data resources and supporting resources (software, hardware, space, technology, standards, guidelines). Thus, software, hardware, space, and technology are data service correlation and collaboration factors that enable data visualization, data interaction, digital humanities, data skills training, and display of data-driven research outcomes, enriching data service content and improving the data service system while better enhancing user experience and meeting user needs.

3.4 Open Data Resource Navigation and Data Services

3.4.1 Domestic and Foreign Library Data Resource Navigation Service Cases As the open access movement develops deeply, open innovation, open science, and open data are becoming academic consensus. With continuous improvement of open data sharing policies, standards, and technologies, and the growing volume of open data resources, open data has become an indispensable component of data resources. Currently, besides some libraries' "one-stop" resource discovery systems harvesting open data resource metadata, navigation of open data repositories has also become a form of data service, such as at York University Library, University of Windsor Library, and the Chinese Academy of Sciences Documentation and Information Center.

Foreign open data resource navigation services use York University Library as an example. The library primarily navigates open data from Canada, the United States, and international organizations [71]. To help readers accurately find needed data, York University Library classifies and navigates data resources by discipline, function, and region (providing original data resource links rather than direct downloads from York University Library), such as arts, culture and entertainment, census, elections and politics, human rights, women, and public sector.

Domestic open data resource navigation services use the Chinese Academy of Sciences Documentation and Information Center as an example. Besides promoting its collection data resources, the center also integrates and navigates large amounts of open data from data platforms, data journals, official statistical bureaus, and international organizations [72], including: (1) over 20 data platforms from the National Science and Technology Infrastructure Platform, such as the National Earthquake Science Data Sharing Center, National Agricultural Science Data Sharing Center, and National Population and Health Science Data Sharing Service Platform; (2) nearly 30 scientific databases from the Chinese Academy of Sciences, such as the Space Science Data Center, Materials Science Basic Database, and Fusion Database; (3) well-known general-purpose data repositories such as figshare, Dryad, and GenBank; (4) domestic and international open-access data journals such as *Scientific Data*, *Earth System Science Data*, and *China Scientific Data*; (5) open data platforms of international organizations such as World Bank Open Data, IMF Data, and OECD Data; and (6) statistical bureaus of major countries such as Canada, Singapore, and China.

3.4.2 Data Granularity and Quality in Resource Navigation Comparative analysis shows that York University Library and the Chinese Academy of Sciences Documentation and Information Center represent two different approaches to data classification navigation: the former uses a mixed direction of discipline and function with smaller classification granularity, while the latter uses common open data access pathways and rough disciplinary categories with relatively coarse data revelation. If the latter used smaller granularity (such as individual data papers within data journals, individual datasets or files within databases) for navigation, it could become "bloated" and "redundant" under continuous resource growth and navigation updates. Meanwhile, the massive growth of open data resources increases data quality control difficulty, consequently increasing the difficulty of selecting high-quality data resources for navigation. Therefore, data granularity and quality control issues in data resource navigation require further research.

3.5 Comprehensive Data Consulting and Support Services

According to multiple survey reports on library research data services [3-4, 73], libraries currently provide fewer technical/practical data services but more consulting/support data services. In fact, consulting/support services have become an increasingly common phenomenon.

3.5.1 Data Management Consulting and Support (1) "Self-questioning and self-answering" consulting. To help users better understand and accept data management requirements, libraries provide "self-questioning and self-answering" style consulting on data management necessity and importance, data management plans and tools, data policies, data file formats, data storage, and data citation guidance. For example, Harvard University's Institute for Quantitative Social Science (IQSS) organized

and maintains the data platform Harvard Dataverse, while Harvard Library provides consulting and helpful resources on data management plans (DMP) and tools, data policies and guidelines, data file formats and naming, data storage, and data citation. Regarding "data management plans," it addresses questions like "Why manage data?" "What is a data management plan?" "What should my data management plan include?" "Data management plan examples," and "Harvard Library's role in data management" [74]. Regarding "data management plan tools," it provides helpful resources like "What is DMP Tool?" "Ways to use DMP Tool at Harvard," and "Benefits of using DMP Tool (video)" [75].

(2) Lifecycle-spanning consulting. Even when only some libraries participate in data management platform construction or maintenance, providing educational and professional consulting services around the data management lifecycle has become increasingly common.

For example, McMaster University Library's consulting services covering the data management lifecycle mainly include [76]: (1) Data planning & preparation stage: data management self-testing (question format), data management plan interpretation, tools and template recommendations, and requirements of major Canadian research funding agencies for research data management; (2) Data collection & analysis stage: explaining metadata functions, providing general and discipline-specific metadata standard introductions, recommending metadata standards and best practices, data storage and security suggestions, and data formatting and conversion recommendations; and (3) Data preservation & archiving stage: data archiving and long-term preservation location and best practice guidelines, data sharing benefits and relevant regulations and restrictions, and data intellectual property and sensitivity factors.

Similarly, York University Library guides and helps researchers manage research data from three stages: "before starting research," "during research," and "after completing research" [77]: (1) "Before starting research": researchers should understand research funding agencies' data policies, follow research ethics, and create research data management plans (guided questions); (2) "During research": researchers should pay attention to data storage, sharing, security, and preservation issues (guided questions), document research data (guided questions), and learn how to discover and cite research data (providing data repository lists and registration systems for data discovery, and data citation guidelines and examples); and (3) "After completing research": researchers need to store data (providing institutional repositories and other storage pathways) and clarify data licenses (listing common license agreements such as CC0, CC-BY).

3.5.2 Other Data Consulting and Support Services Besides data management consulting, libraries also provide diverse data consulting and support services, including DOI registration, data publishing, seminars and training, etc. For example, in DOI allocation, the German National Library of Science and Technology provides DOI registration services for research data and other

research products in technology and engineering, architecture, chemistry, computer science, mathematics, and physics [78]. The Canadian National Science Library and its parent organization, the National Research Council Canada, are founding members of DataCite and created DataCite Canada, responsible for extensive cooperation with various Canadian data centers and libraries to provide research data DOI services [79], committed to improving data discoverability, accessibility, and reusability.

In data publishing, when researchers publish articles in *German Medical Science* (GMS), the German National Library of Medicine (ZBMED) stores and publishes corresponding research data in the data repository Dryad and establishes links between them, bearing the costs of research data publishing. Additionally, ZBMED provides two independent data publishing methods: (1) researchers can store and publish data of various formats alone or together with articles in expert repositories; and (2) discipline-specific data repositories for storing and publishing corresponding research data in agriculture, biology, environment, medicine, neuroscience, nutrition, and other specific disciplines [80].

3.5.3 Differentiated Strategies for Data Consulting and Support Services The investigation found that foreign libraries provide more research data management consulting while domestic libraries provide less, with policy orientation being an important reason. For example, the U.S. National Institutes of Health began requiring (encouraging) recipients of funding over $500,000 to submit data sharing plans in 2003 [81], and the U.S. National Science Foundation began requiring funding applicants to submit data management plans in January 2011 [82]. Subsequently, U.S. research universities gradually began emphasizing data management, and libraries gradually assumed data management responsibilities according to their circumstances (e.g., the University of Illinois at Urbana-Champaign recognized that it produced many publications and datasets but did little data management work, inadvertently creating obstacles for data-intensive research) [61]. However, major Chinese research funding agencies such as the National Natural Science Foundation, National Social Science Foundation, and Chinese Academy of Sciences have not yet established explicit data management requirements. Therefore, libraries' user-oriented data management consulting services may not be applicable for now. Instead, content such as open data acquisition, data rights, data licensing, data intellectual property, and classic cases of data-driven research may be more welcomed. Thus, exploring differentiated data consulting and support services under different academic mechanisms, data policies, and disciplinary characteristics will help provide more precise data services and better meet user needs.

4 Conclusion

The five pathways of academic library data services described above each have distinct characteristics and applicability. Clearly, the five pathways can exist independently and work collaboratively. For example, libraries can operate

data management platforms while providing comprehensive data consulting and support services (such as Peking University Library), or conduct open data resource navigation while providing comprehensive data consulting and support services (such as York University Library).

In fact, different service pathways each have advantages, disadvantages, or applicable conditions. For example, comprehensive data consulting and support services have a lower "threshold" and are most convenient and quick, but pure consulting and support services tend to be "superficial" and may have limited sustained effects. Data platform construction has a higher "threshold," requiring adequate funding, technology, policy support, and may face pressures from data growth, slow updates, or even sustainability challenges, and may fall into the predicament of data "dormancy" due to low reuse rates. Some libraries' "one-stop" resource discovery systems do not cover web resource discovery, requiring suitable system construction or transformation opportunities and strong technical support. Data services within integrated digital scholarship systems need to collaborate with space, software, hardware, and other factors to maximize effectiveness. Open data resource navigation services are highly operable with lower thresholds, but libraries only play an "intermediary" role, making it difficult to form core competitiveness and user stickiness.

However, all five data service models and pathways have their value and necessity. The existence of any data service model contributes to constructing a complete data service system, helping libraries better occupy the "domain" of data services and maintain initiative in competition and cooperation with publishers, information technology, and service organizations.

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