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The Role of Libraries in FAIR Data Management: Trends, Challenges and Future Directions

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ABSTRACT

FAIR data management has become an important area of research support in academic and research libraries because it promotes the organization, preservation, discovery, accessibility and reuse of research data. FAIR stands for findable, accessible, interoperable, reusable and these principles are increasingly linked with open science, research transparency, reproducibility and responsible scholarly communication. This descriptive narrative review examines the role of libraries in FAIR data management with particular focus on major trends, challenges and future directions. The article synthesizes recent scholarly and professional literature on research data management, data stewardship, institutional repositories, metadata, data literacy, data curation and open science. The review indicates that libraries are increasingly involved in data management planning, metadata support, repository services, research data training, data curation, policy guidance and FAIR awareness. However, several challenges limit effective implementation, including insufficient technical infrastructure, lack of professional data skills, weak institutional policies, low researcher engagement, ethical and legal concerns, privacy issues, sustainability problems and limited funding. The article argues that libraries are well positioned to support FAIR data management if they strengthen professional capacity, improve repository infrastructure, promote data literacy and collaborate with researchers, IT departments, research offices and policy makers.

Keywords: FAIR Data; Research Data Management; Academic Libraries; Data Stewardship; Open Science; Data Curation; Institutional Repositories; Data Literacy; Metadata; Information Management.

Introduction

Research data has become a central component of modern scholarly communication, open science and evidence-based knowledge production. In contemporary research environments, data is not only a by-product of research activity but also a valuable scholarly output that can support verification, transparency, reproducibility and future discovery. As research becomes increasingly digital, collaborative and data-intensive, researchers and institutions face growing pressure to manage, preserve and share data in ways that support long-term access and reuse. The FAIR Guiding Principles were introduced to improve the management and stewardship of research data. FAIR stands for findable, accessible, interoperable and reusable. These principles require that research data should be described with rich metadata, assigned persistent identifiers, made accessible through standardized protocols, connected with interoperable vocabularies and accompanied by clear reuse conditions. Wilkinson et al. (2016) emphasized that FAIR data is not only designed for human users but also for machine-actionable discovery and reuse. This means that data should be organized in a way that both people and computer systems can locate, understand and reuse it effectively.

Libraries have a natural connection with FAIR data management because they have long experience in organizing knowledge, creating metadata, managing repositories, preserving information resources and supporting users in information discovery. As research data management becomes part of institutional research support, libraries are increasingly expected to help researchers prepare data management plans, select suitable repositories, apply metadata standards, understand funder requirements, preserve datasets and improve data discoverability. The role of libraries in FAIR data management is also linked with wider developments in open science. Open science promotes transparency, collaboration, reproducibility and public access to research outputs. FAIR data supports these goals by ensuring that data is not only available but also understandable, discoverable and reusable. However, FAIR does not always mean fully open. Some data may require restricted access because of privacy, ethics, intellectual property, commercial sensitivity or cultural concerns. Therefore, libraries must help researchers understand the difference between making data open and making data FAIR.

This review article examines the role of libraries in FAIR data management. It focuses on major trends, challenges and future directions. It argues that libraries can play a central role in building FAIR-aware research cultures through metadata expertise, data literacy instruction, repository support, policy guidance, ethical data stewardship and collaboration with researchers, IT units, ethics committees, research offices and funding bodies.

Objectives of the Study

The main objective of this review article is to examine the role of libraries in FAIR data management. The specific objectives are:

1. To explain the concept of FAIR data management and its relevance to libraries.
2. To identify major trends in library involvement in FAIR data management.
3. To examine the role of libraries in metadata creation, repository services, data curation, data literacy and research support.
4. To analyze the major challenges libraries, face in implementing FAIR data services.

5. To suggest future directions for strengthening library-based FAIR data management services.

Literature Review

Conceptual Foundation of FAIR Data Management

FAIR data management is grounded in the FAIR Guiding Principles, which were introduced to improve the stewardship and reuse of research data. FAIR stands for findable, accessible, interoperable and reusable. These principles emphasize that research data should be described with rich metadata, assigned persistent identifiers, made accessible through standardized protocols, connected with interoperable vocabularies and accompanied by clear reuse conditions. Wilkinson et al. (2016) argued that FAIR data is not only intended for human users but also for machine-actionable discovery and reuse. This makes FAIR data management especially important in modern research environments where data-driven scholarship, digital repositories and automated discovery systems are becoming increasingly common.

FAIR data management is closely connected with open science, research transparency and reproducibility. However, FAIR does not always mean fully open. Some data may require restricted access due to ethical, legal, privacy, commercial or cultural reasons. Therefore, FAIR data management focuses on making data understandable, discoverable and reusable under appropriate conditions. The European Commission: Directorate-General for Research and Innovation (2018) described FAIR implementation as a strategic requirement for open science and research innovation, arguing that institutions need policy, infrastructure, skills and incentives to turn FAIR principles into practical reality.

Libraries and Research Data Management Services

Libraries have become increasingly involved in research data management because of their traditional expertise in information organization, metadata creation, access services, preservation and user education. Research data management services generally include support for data management plans, metadata standards, repository selection, data curation, data citation, data preservation and data sharing. Tenopir et al. (2015) found that research data services were becoming an emerging role for academic libraries, especially as researchers required support in managing data across the research lifecycle.

Yoon and Schultz (2017) examined research data management services in academic libraries in the United States through a content analysis of 185 library websites. Their study found that academic libraries were providing different levels of RDM support, including information services, educational resources, consultation services and connections to internal or external data resources. However, they also found variation in the maturity and visibility of these services. This shows that libraries recognize the importance of RDM, but their ability to provide comprehensive services depends on institutional capacity, staff expertise and available infrastructure.

Cox et al. (2017) also highlighted the development of research data management in academic libraries and linked it with service maturity. Their study showed that libraries were providing leadership in areas such as advocacy and policy development, but more technical and advanced services were still developing. This suggests that libraries often begin with awareness, training and advisory support before moving toward more complex services such as repository management, data curation and preservation.

Libraries as Key Actors in FAIR Data Management

Libraries are well positioned to support FAIR data management because FAIR principles depend heavily on activities that are already close to library expertise. Findability depends on metadata, indexing, persistent identifiers and discoverability. Accessibility depends on repositories, access statements, licensing and preservation. Interoperability depends on standards, controlled vocabularies and machine-readable metadata. Reusability depends on documentation, data quality, licensing and citation. These areas are strongly related to library and information management.

Cox et al. (2019) argued that the growth of research data services is transforming academic libraries by moving them closer to the research process. Libraries are no longer only providers of books, journals and databases; they are also becoming partners in research data stewardship. This transformation is directly relevant to FAIR data management because FAIR implementation requires continuous support across the data lifecycle. Libraries can help researchers prepare data management plans, improve metadata quality, select repositories, apply licenses, document datasets and preserve research outputs for future reuse.

Faniel and Connaway (2018) identified several factors that influence librarians' ability to support research data management programmes, including technical resources, human resources and researchers' perceptions of libraries, leadership support, communication, coordination and collaboration. These factors are also important for FAIR data management. Even when librarians understand FAIR principles, successful implementation requires institutional support, researcher trust, technical systems and cross-departmental collaboration.

Metadata, Repositories and Data Curation

Metadata is one of the most important areas where libraries can contribute to FAIR data management. Without rich and accurate metadata, research data may remain invisible, difficult to understand or impossible to reuse. Libraries can support researchers by advising on metadata standards, keywords, controlled vocabularies, data documentation and persistent identifiers. This role directly supports the findability and reusability dimensions of FAIR data.

Institutional repositories also play an important role in FAIR data management. Repositories can provide storage, persistent access, metadata records, access control and preservation support. However, repositories must be more than simple storage platforms. To support FAIR principles, they need clear metadata policies, standardized deposit workflows, licensing information, preservation planning and interoperability features. Xu (2022) observed that research data management practice in academic libraries includes training, policy guidance, data sharing, metadata support and repository-related activities. This shows those repositories and data curations are central to library-based RDM and FAIR data services.

Data curation is also essential for FAIR implementation. Data cannot be reused effectively if users do not understand how it was collected, cleaned, structured, coded or analyzed. Libraries can support data curation by helping researchers prepare readme files, data dictionaries, codebooks, methodology notes and reuse licenses. These activities make data more understandable and reusable for future researchers.

Data Literacy and Professional Competencies

The literature shows that FAIR data management requires librarians to develop new professional competencies. Traditional library skills remain important, but they must be extended toward data literacy, data stewardship, metadata standards, repository management, research workflows, licensing, data ethics and digital preservation. Federer (2018) found that data librarianship

involves a wide range of skills and knowledge, including communication, relationship building, data management, research support and technical understanding. This indicates that FAIR data services require both technical and interpersonal competencies.

Fuhr (2022) also emphasized that academic librarians need to develop data services skills as research data services become more common in academic libraries. The study found that librarians providing data services require training in areas such as technical skills, data management planning, metadata, repositories and data-related consultation. This finding is important for FAIR data management because libraries cannot provide effective FAIR support without trained and confident staff.

Data literacy is also important for researchers and students. Many researchers are experts in their disciplines but may not be trained in data documentation, metadata, repository selection, data citation, licensing or preservation. Libraries can extend their information literacy role into data literacy by offering workshops, guides, consultations and online learning materials. This educational role can help build a FAIR-aware research culture within institutions.

Institutional Policy, Collaboration and Open Science

FAIR data management cannot be implemented by libraries alone. It requires collaboration among libraries, research offices, IT departments, ethics committees, legal advisors, academic departments, funders and repository managers. Faniel and Connaway (2018) emphasised that communication, coordination and collaboration are key factors affecting research data management programmes. Similarly, Cox et al. (2019) argued that mature research data services require institutional transformation and cross-functional support.

Institutional policy is also necessary because FAIR data management depends on clear expectations for data planning, sharing, documentation, retention, access and preservation. Libraries can contribute to policy development by providing expertise in metadata, repositories, discovery, preservation and user support. The European Commission: Directorate-General for Research and Innovation (2018) also stressed that FAIR implementation requires policy alignment, infrastructure development, skills training and incentives. Therefore, libraries should not work in isolation but should become part of wider institutional open science and research governance strategies.

Open science has increased the importance of FAIR data management. FAIR data supports transparency, reproducibility and responsible reuse of research outputs. However, libraries must also help researchers understand that FAIR data is not always open data. Some datasets may be FAIR while access is restricted, provided that metadata is available, access conditions are clear and reuse is governed responsibly. This distinction is important for protecting privacy, confidentiality and ethical research practice.

Challenges in Library-Based FAIR Data Management

Although libraries have strong potential to support FAIR data management, the literature identifies several challenges. One major challenge is the lack of technical infrastructure. FAIR data requires repositories, persistent identifiers, metadata systems, secure storage, interoperability standards and long-term preservation mechanisms. Many institutions, especially in developing countries, may lack sufficient infrastructure to support advanced FAIR data services.

A second challenge is the skills gap among librarians. Data services require knowledge of metadata standards, data formats, repositories, licensing, data ethics, data citation and preservation. Fuhr (2022) showed that training and professional development are necessary for

librarians involved in data services. Without adequate capacity building, libraries may only provide basic awareness rather than advanced FAIR data support.

A third challenge is researcher engagement. Researchers may not always recognize libraries as partners in data management. Some may be reluctant to share data because of concerns about misuse, loss of control, lack of credit, ethical restrictions or additional workload. Libraries must therefore build trust, demonstrate value and offer practical support that aligns with researchers' disciplinary needs.

Ethical and legal challenges are also significant. Research data may include personal information, sensitive community knowledge, commercial data or confidential institutional records. Libraries must help researchers balance openness with privacy, consent, confidentiality and responsible reuse. This means that FAIR data services must be guided not only by technical standards but also by ethical data governance.

Future Directions for Libraries in FAIR Data Management

The literature suggests that the future role of libraries in FAIR data management will depend on their ability to move from basic advisory services toward more integrated data stewardship. Libraries should strengthen their role in data management planning, metadata support, repository guidance, data literacy training, data curation and digital preservation. They should also develop specialized roles such as data librarians, data stewards and research data specialists. Future library services should be more collaborative, discipline-sensitive and policy-aligned. Since different disciplines produce different types of data, libraries should avoid a one-size-fits-all approach. Instead, they should work with researchers to understand disciplinary standards, repository options, metadata needs and ethical requirements. Libraries should also participate in institutional open science strategies and advocate for sustainable funding, infrastructure and staff development.

Overall, the literature shows that libraries have a central role in FAIR data management because they connect metadata expertise, preservation knowledge, user education, repository services and ethical information management. However, this role requires stronger professional capacity, technical infrastructure, institutional collaboration and researcher engagement. FAIR data management should therefore be understood not only as a technical process but also as a professional, institutional and ethical responsibility for modern libraries.

Materials and Methods

This article adopted a descriptive narrative review approach to examine the role of libraries in FAIR data management. This approach was suitable because the purpose of the study was to describe, interpret and synthesize existing literature on trends, challenges and future directions rather than to conduct a systematic review, statistical meta-analysis or formal quality appraisal. The literature was searched through major academic and professional sources, including Google Scholar, Scopus, Web of Science, Library and Information Science Abstracts, Emerald Insight, Taylor & Francis Online, Science Direct, Sage Journals, Wiley Online Library, College & Research Libraries, Journal of eScience Librarianship, LIBER, GO FAIR and European Commission reports. The search focused on scholarly articles, professional guidelines, policy documents, institutional reports and review studies related to FAIR data and library-based research data management.

The main search terms included "FAIR data management," "libraries and FAIR data," "research data management in academic libraries," "data stewardship libraries," "FAIR principles libraries," "data curation," "institutional repositories and FAIR data," "data literacy librarians," "research

data services” and “open science libraries.” The main timeframe of the literature was 2016 to 2026. The year 2016 was selected because the FAIR Guiding Principles were formally published in that year. More recent literature from 2020 onward was given greater emphasis because library involvement in research data management, open science and data stewardship has expanded significantly in recent years. Broad literature selection criteria were used. Sources were included if they addressed FAIR principles, research data management, academic libraries, data services, metadata, repositories, data literacy, open science, data stewardship or professional competencies for librarians. Sources were excluded if they were purely technical data science studies with no direct relevance to libraries, duplicate materials, non-scholarly opinion pieces without professional value or publications unrelated to FAIR data management. Since this article is a descriptive narrative review, PRISMA-based systematic screening, statistical meta-analysis and formal quality appraisal were not conducted. Instead, the selected literature was analyzed thematically to identify major patterns related to trends, challenges and future directions.

Results and Discussion

The descriptive narrative review indicates that libraries are becoming increasingly important in FAIR data management because they occupy a strategic position between researchers, institutions, repositories and users of research data. Their traditional expertise in information organization, metadata, preservation, access and user education gives them a strong foundation for supporting FAIR data practices. However, the role of libraries is expanding from passive information provision toward active participation in the research lifecycle.

A major theme emerging from the reviewed literature is that libraries support FAIR data management through metadata and discoverability. Findability is the first FAIR principle, and it depends heavily on high-quality metadata, persistent identifiers and searchable repositories. Libraries can contribute by helping researchers describe datasets clearly, assign keywords, select metadata standards and use persistent identifiers such as digital object identifiers. Without proper metadata, research data may remain invisible even if it is stored in a repository. Therefore, metadata expertise is one of the most valuable contributions libraries can make to FAIR data management.

The review also shows that libraries support accessibility through repository guidance and access management. Accessibility does not necessarily mean that all data must be openly available. Rather, users should be able to know whether data exists, how it can be accessed and under what conditions. Libraries can help researchers select appropriate repositories, prepare access statements, choose licences and document restrictions. This is especially important for sensitive data, where ethical, legal or privacy concerns may limit open access. In such cases, libraries can help ensure that metadata remains visible while access to the data itself is responsibly controlled. Interoperability is another area where libraries can contribute, although it is more technically demanding. Interoperable data requires standard formats, controlled vocabularies and machine-readable metadata. Libraries can support interoperability by advising researchers on metadata schemas, disciplinary standards and documentation practices. However, this requires stronger technical skills and collaboration with IT professionals, data stewards and disciplinary experts. Many libraries may need additional training and institutional support before they can provide advanced interoperability services.

Reusability is closely connected with documentation, licensing and data quality. Data cannot be reused effectively if users do not understand how it was collected, processed, structured or

licensed. Libraries can support reusability by teaching researchers how to prepare readme files, data dictionaries, codebooks, methodology notes and reuse licenses. They can also promote data citation practices so that datasets are recognized as scholarly outputs. This helps researchers receive credit for data sharing and encourages responsible reuse.

The review further suggests that libraries are becoming important centers for data literacy. Many researchers and students need guidance on file organization, metadata, ethical data sharing, repository selection, data citation and funder requirements. Libraries already have strong experience in information literacy instruction, and this experience can be extended to data literacy. However, data literacy requires librarians to move beyond traditional database searching and citation instruction toward research workflow support.

Another major finding is that FAIR data management requires collaboration. Libraries cannot implement FAIR practices alone. Effective FAIR data services require partnerships with research offices, IT departments, ethics committees, legal advisors, repository managers, academic departments and funding bodies. Libraries can coordinate many of these activities, but institutional leadership and policy support are essential. Without collaboration, FAIR data services may remain fragmented and dependent on individual librarians rather than becoming part of institutional research infrastructure.

The review also shows that professional capacity is one of the strongest challenges. FAIR data services require new skills, including data curation, metadata standards, repository management, licensing, digital preservation and research data policy. Studies on academic library data services show that librarians often need additional training to provide effective support. Therefore, professional development is not optional; it is central to the future of FAIR data management in libraries.

The ethical dimension of FAIR data management is also significant. Libraries must balance openness with privacy, confidentiality, intellectual property and cultural sensitivity. Some datasets may include personal, medical, legal, indigenous, commercial or security-sensitive information. In such cases, responsible data governance is more important than simple openness. Libraries can help researchers understand consent, anonymization, access restrictions and responsible reuse. This ethical role is important because libraries are trusted institutions committed to access, privacy and public good.

Overall, the discussion shows three major patterns. First, libraries are well positioned to support FAIR data management because of their expertise in metadata, discovery, preservation, repositories and user education. Second, the implementation of FAIR data services is limited by skills gaps, infrastructure constraints, weak policies, researcher reluctance and sustainability challenges. Third, the future role of libraries depends on their ability to become active partners in research data stewardship, open science and institutional research support.

Recommendations

- Libraries should develop clear FAIR data service strategies that define their role in data management planning, metadata support, repository guidance, data literacy training, data curation and preservation.
- Libraries should provide regular professional training for librarians on FAIR principles, metadata standards, data curation, licensing, data ethics, repository systems and digital preservation.

- Academic and research libraries should collaborate with research offices, IT departments, ethics committees and academic departments to create coordinated institutional support for FAIR data management.
- Libraries should promote data literacy among researchers and students through workshops, online guides, consultations and integration with research methods training.
- Institutional repositories should be improved to support FAIR practices through rich metadata, persistent identifiers, clear licenses, access conditions and long-term preservation planning.
- Libraries should support researchers in preparing data management plans that address the full data lifecycle, including collection, storage, documentation, sharing, preservation and reuse.
- Libraries should develop ethical guidance for sensitive data, including privacy protection, anonymisation, restricted access, consent and responsible reuse.
- Future research should examine FAIR data management practices in developing countries, public research institutions, agricultural research organizations, school and college libraries and non-English research environments.

Conclusion

FAIR data management has become an important part of modern research support, open science and scholarly communication. Libraries have a significant role in this area because they possess long-standing expertise in metadata, information organization, repositories, preservation, user education and access services. The review shows that libraries can support FAIR data through data management planning, metadata creation, repository services, data literacy training, data curation, policy support and ethical guidance. However, several challenges limit the full implementation of FAIR data services. These include limited technical infrastructure, insufficient staff skills, weak institutional policies, low researcher engagement, ethical and legal concerns, sustainability problems and lack of funding. FAIR data management is therefore not only a technical issue but also an institutional, professional and ethical responsibility. The article concludes that libraries should position themselves as active partners in FAIR data stewardship. Their future role will depend on continuous professional development, stronger institutional collaboration, better repository infrastructure, data literacy education and responsible data governance. If libraries strengthen these areas, they can become central actors in promoting findable, accessible, interoperable and reusable research data while supporting transparency, reproducibility and long-term knowledge creation.

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