

INFLUENCE OF TECHNOLOGICAL INFRASTRUCTURE AND TRAINING ON RESEARCH DATA MANAGEMENT SERVICES: COMPARATIVE EVIDENCE FROM NIGERIA AND OTHER COUNTRIES

By

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Abstract

This study examines the influence of technological infrastructure and training on research data management (RDM) services, providing comparative evidence from Nigeria and selected African countries. Recognizing that effective RDM is pivotal for enhancing research productivity, data accessibility, and compliance with global standards such as the FAIR principles, this research highlights the dual importance of robust digital infrastructure and skilled human resources. Technological components—such as institutional repositories, high-speed internet, cloud platforms, and interoperable systems—form the backbone of RDM by enabling efficient data storage, preservation, and sharing. However, infrastructural challenges including limited broadband penetration, unreliable power supply, and insufficient investment continue to hinder many African academic libraries, particularly in Nigeria, from delivering sustainable RDM services. Complementing these technological gaps, the study underscores the critical role of targeted training and capacity building for librarians, focusing on competencies in data curation, metadata management, and policy implementation. Using a thematic analysis approach grounded in sociotechnical theoretical frameworks, the study draws on empirical data from Nigeria, South Africa, and Tanzania to demonstrate that without adequate training, even well-developed infrastructures remain underutilized, limiting their impact on research outcomes. The findings advocate for integrated strategies that combine scalable infrastructure investments, incorporation of RDM modules into Library and Information Science curricula, and strengthened regional and international collaborations. Such a holistic approach is essential for Nigerian libraries to overcome existing barriers, improve data management practices, and actively participate in the global open science ecosystem.

Keywords: Technological infrastructure, Research Data Management, Capacity building, Nigerian libraries, FAIR principles

Introduction

Over the years, libraries have functioned as custodians of knowledge, granting users access to physical materials and supporting information discovery. With the advent of the digital era, there has been a necessary transition toward more interactive and user-focused

services (Agim, Abah, & Ezejiofor, 2025). This evolution includes leveraging tools from the Fifth Industrial Revolution to facilitate information access and manage research data. Research Data Management (RDM) has emerged as a vital aspect of contemporary research, propelled by the growing scale, complexity, and variety of data produced through scholarly work. Robust RDM practices ensure that research data are systematically collected, securely stored, preserved, and made available for sharing, which in turn promotes transparency, reproducibility, and innovation within the research community (Li et al., 2024).

In Nigeria, academic and research libraries are only beginning to develop RDM services, facing challenges such as inadequate technological infrastructure and a lack of specialized training for librarians (Mafale, 2023). Essential components for supporting RDM include institutional repositories, reliable high-speed internet, and advanced data storage solutions, while ongoing professional development is necessary to equip librarians with competencies for managing data across its entire lifecycle (Ojo, Dahunsi, & Opele, 2024). The effectiveness of Nigerian libraries in supporting researchers and participating in global knowledge networks depends on the integration of these elements.

Theoretical perspectives on RDM stress its sociotechnical dimensions, emphasizing that effective data services require the alignment of technology, institutional policy, and human expertise (Li et al., 2024). In Africa, this alignment is often insufficient because of limited institutional backing and competing priorities. The knowledge infrastructure model underscores the importance of scalable, interoperable digital systems and sustained professional development to enable librarians to serve as effective data stewards (Masenya, 2023). Additionally, adopting international frameworks like the FAIR (Findable, Accessible, Interoperable, Reusable) principles necessitates both technological capacity and skilled personnel to implement best practices (Mafale, 2023).

Despite widespread recognition of RDM's significance, many African academic libraries may be encountering substantial obstacles in providing these services, mainly due to infrastructural and human resource shortcomings. The ramifications of these shortcomings

are substantial. Ineffective RDM practices can compromise data integrity, limit opportunities for data reuse, and impede compliance with funder mandates, ultimately reducing the global visibility and impact of research from these regions. Furthermore, the lack of skilled personnel and sufficient infrastructure restricts libraries' capacity to effectively support researchers, perpetuating a cycle of underperformance and missed opportunities for innovation. While some studies have examined RDM challenges within specific countries or institutions, there is a clear gap in comprehensive, comparative research assessing how technological infrastructure and training collectively influence RDM services, particularly in the context of Nigeria compared to other countries. This paper seeks to address these gaps by theoretically analyzing the following objectives:

1. Analyze the role of technological infrastructure in enabling RDM services.
2. Evaluate the impact of training on librarians' RDM competencies.
3. Propose strategies to align Nigerian libraries with global RDM standards.

Theoretical Frameworks for RDM

Theoretical frameworks provide essential lenses for understanding how research data management (RDM) services can be effectively developed and sustained, particularly in contexts like Nigerian academic libraries where technological infrastructure and training are critical factors. The Knowledge Infrastructure model, formulated by Star and Ruhleder (1996), offers a sociotechnical perspective that emphasizes the interdependence of people, technologies, policies, and institutions in supporting knowledge production and management. This model conceptualizes knowledge infrastructures as complex, evolving systems that facilitate the flow and use of information across organizational and disciplinary boundaries. It stresses that the effectiveness of such infrastructures depends on the alignment between technological capabilities—such as repositories, networks, and storage systems—and human factors including training, policies, and librarian expertise. Applied to RDM, this model underscores that investments in technology alone are insufficient without concurrent capacity building and institutional support, highlighting the need for co-evolution of infrastructure and

human resources to create sustainable RDM services (Li et al., 2024; Chigwada & Chiware, 2024). Complementing this, Hackett and Kim's (2024) Conceptual Model for Research Data Services (RDS) Implementation provides a practical framework for planning, executing, and evaluating RDM services within academic libraries. This model focuses on identifying the types of data services required, the necessary resources, librarian competencies, and educational frameworks to ensure sustainable delivery. It posits that successful RDS implementation relies on a balanced integration of service types—such as data collection, curation, and analysis—technological platforms, and ongoing professional training. Recognizing RDM as a dynamic service area, the model advocates continuous assessment and adaptation to meet evolving researcher needs and institutional contexts. Together, these frameworks inform this study by elucidating how technological infrastructure and training interact to shape the quality, responsiveness, and sustainability of RDM services, offering Nigerian libraries a roadmap to assess gaps, prioritize capacity building, and align infrastructure investments with service goals (Hackett & Kim, 2024).

Technological Infrastructure: The Backbone of Effective Research Data Management

Technological infrastructure is fundamental to the successful implementation of research data management (RDM), providing the essential systems and tools needed for the storage, preservation, and dissemination of research data. Core components such as institutional repositories, cloud-based storage, high-speed internet connectivity, and interoperable platforms facilitate the smooth management of data throughout its lifecycle—from collection to sharing (Li et al., 2024). These infrastructures are indispensable for compliance with international frameworks like the FAIR (Findable, Accessible, Interoperable, Reusable) principles, which advocate for data that is machine-actionable and reusable across various disciplines (Chigwada & Chiware, 2024). A notable example is the Research Data Management Infrastructure at the Museum für Naturkunde, which demonstrates how modular and networked systems can reduce data redundancy while enhancing interoperability and accessibility (Museum für Naturkunde, n.d.). Globally, RDM infrastructures are evolving to break down disciplinary silos and foster collaborative research

environments that address complex societal challenges through data-driven insights (Li et al., 2024). Yet, the success of these infrastructures depends heavily on their integration with institutional policies and user-centered designs that respond to researchers' changing needs.

In African academic libraries, the landscape of technological infrastructure for RDM is uneven, with significant disparities between countries and institutions. While universities in South Africa, such as the University of Cape Town, have made notable progress in deploying institutional repositories and RDM services, many other institutions face systemic challenges including outdated technologies, unreliable internet connectivity, and insufficient funding (Badenhorst & Raju, 2023; Chigwada & Chiware, 2024). Nigerian libraries, in particular, often depend on fragmented, stop-gap solutions due to limited investments in scalable and interoperable technologies, resulting in inefficiencies in data storage and retrieval (Badenhorst & Raju, 2023). These infrastructural weaknesses are further exacerbated by the absence of national RDM policies and clear institutional roadmaps, which impedes the adoption of standardized data management practices. The lack of robust technological foundations not only threatens long-term data preservation but also restricts researchers' ability to engage in global collaborations, thereby reinforcing Africa's marginalization in the international research landscape (Chigwada & Chiware, 2024). Addressing these deficiencies requires prioritizing investments in interoperable systems and reliable high-speed networks to build a cohesive and sustainable RDM ecosystem.

To overcome these challenges, experts recommend adopting modular, open-source repository platforms and encouraging cross-institutional collaborations. Initiatives such as the Research Data Alliance (RDA) and the African Open Science Platform (AOSP) emphasize the importance of shared infrastructure and regional hubs to reduce costs and improve scalability (Chigwada & Chiware, 2024). Li et al. (2024) propose a framework with four key missions for modern research data infrastructures: transcending disciplinary boundaries, creating intelligent research environments, enabling advanced academic communication, and balancing openness with ethical considerations. Realizing these missions in African contexts will require synchronizing infrastructure development with capacity-building efforts that

equip librarians and researchers with skills in metadata curation, data analytics, and cybersecurity (Badenhorst & Raju, 2023). Moreover, embedding FAIR-aligned infrastructures in national research strategies can promote data reuse and ensure compliance with funder mandates, positioning African institutions as competitive contributors to global knowledge production.

Training and Capacity Building: Empowering Librarians for RDM Excellence

Training and capacity building are vital for empowering librarians and researchers with the competencies necessary to deliver effective research data management services. Recent initiatives, such as the African Library and Information Associations and Institutions (AfLIA) Open Data Management Foundational Course, underscore the growing emphasis on structured training programs designed to address skill gaps in areas like data curation, metadata standards, and the FAIR principles (AfLIA, 2024). These programs aim to enable librarians to manage digital repositories effectively, ensure long-term data preservation, and comply with international standards, thereby increasing the visibility and impact of African research (University World News, 2024). However, research indicates persistent challenges: for example, a survey of South African academic libraries revealed that only 23% of librarians had received formal RDM training, with many relying on informal or ad hoc knowledge acquisition (Mthembu & Ocholla, 2023). This highlights the urgent need to reform Library and Information Science (LIS) curricula to integrate data stewardship competencies, preparing future professionals for evolving roles within open science ecosystems (Ojo, Dahunsi, & Opele, 2024).

The effectiveness of training programs is closely linked to institutional support and commitment. The RDM Kwanza initiative, an 18-month blended learning program involving universities in Tanzania, Uganda, and Belgium, exemplifies the importance of institutional buy-in by requiring participants to apply their newly acquired skills within their home institutions (UHasselt, 2025). Similarly, a case study at the University of Namibia found that while librarians valued RDM, the lack of dedicated budgets for infrastructure and training

hindered the practical implementation of services (Mafale, 2023). Comparable challenges exist in Nigeria, where limited access to professional workshops and outdated LIS curricula continue to restrict librarians' ability to develop essential data management skills (Ojo et al., 2024). These examples illustrate that training initiatives must be supported by institutional investments in digital infrastructure and policy frameworks to translate knowledge into sustainable RDM practices.

Collaborative partnerships and regional networks play a crucial role in scaling capacity-building efforts across Africa. Programs such as AfLIA's pre-conference workshops and the Africa PID Alliance's resource-sharing platforms demonstrate how regional collaboration can reduce costs and facilitate knowledge exchange (AfLIA, 2025). Additionally, organizations like the Research Data Alliance (RDA) and African Open Science Platform (AOSP) advocate for standardized training modules and certification schemes to ensure consistent RDM competencies across institutions (Chigwada & Chiware, 2024). Nevertheless, challenges remain: a study in South Africa reported that 67% of academic libraries lacked formal partnerships with IT departments or research offices, limiting their ability to implement comprehensive RDM strategies (Mthembu & Ocholla, 2023). To address these gaps, scholars recommend applying frameworks such as the Theoretical Domains Framework (TDF), which examines behavioral, environmental, and social factors influencing training outcomes, to design context-specific interventions (Mafale, 2023). By fostering multi-stakeholder collaborations and aligning training with institutional priorities, Nigerian libraries can bridge the divide between capacity building and effective, sustainable RDM service delivery.

Technological Infrastructure and Training as Critical Enablers for Research Data Management

Technological infrastructure serves as a foundational enabler for effective Research Data Management (RDM), providing the essential platforms and systems that support the entire data lifecycle—from collection and storage to preservation and dissemination (Li et al., 2024). In the African context, this infrastructure encompasses institutional repositories, high-

speed internet connectivity, cloud computing services, and interoperable data systems that facilitate seamless data exchange across institutions and national borders (Chigwada & Chiware, 2024). The availability, reliability, and quality of these technological resources directly impact the capacity of academic libraries to deliver robust RDM services, which are vital for ensuring data integrity, compliance with open data mandates, and fostering collaborative research endeavors (Badenhorst & Raju, 2023). Nevertheless, African countries, including Nigeria, face persistent challenges such as limited broadband penetration, unstable power supply, and underinvestment in scalable digital platforms, all of which constrain the effective deployment and utilization of RDM systems (Deloitte, 2024; Carnegie Endowment, 2025). These infrastructural shortcomings contribute to a digital divide that restricts researchers' ability to manage, share, and reuse data efficiently, thereby limiting the continent's research visibility and global impact.

Complementing technological infrastructure, training and capacity building represent indispensable socio-technical interventions that enable librarians and researchers to operationalize RDM systems effectively. While infrastructure provides the necessary tools, the human element—skilled librarians and informed researchers—is critical for translating technology into sustainable services (AfLIA, 2024). Structured training programs such as AfLIA's Open Data Management Foundational Course have demonstrated significant improvements in librarians' competencies related to data curation, metadata standards, and adherence to data sharing policies (AfLIA, 2024; University World News, 2024). However, many librarians across Africa still lack formal RDM training, resulting in inconsistent service quality and underutilization of digital tools (Mthembu & Ocholla, 2023). This skills gap is exacerbated by outdated Library and Information Science (LIS) curricula that inadequately address the complexities of data stewardship in the digital era (Ojo, Dahunsi, & Opele, 2024). Therefore, continuous professional development and the integration of RDM modules into LIS education are imperative to cultivate a workforce capable of managing research data effectively.

The relationship between technological infrastructure and training is inherently symbiotic and shapes the overall effectiveness of RDM services. Robust infrastructure not only supports data storage and access but also enables the implementation of international standards such as the FAIR (Findable, Accessible, Interoperable, and Reusable) principles, which maximize data utility and reuse (Masenya, 2023). For example, South African institutions have advanced their RDM capabilities by investing in interoperable repositories and digital platforms that conform to global standards, enhancing data discoverability and collaborative potential (Badenhorst & Raju, 2023). Conversely, infrastructural deficits in many other African countries lead to fragmented data management, reliance on physical storage, and limited data sharing, which hinder research innovation and collaboration (Chigwada & Chiware, 2024). Training programs that provide hands-on experience with these digital platforms, supported by institutional commitments to infrastructure upgrades, create an enabling environment for librarians to deliver comprehensive RDM services (Mafale, 2023). Socio-technical frameworks further emphasize that training must address not only technical skills but also social and organizational dynamics such as researcher engagement and policy compliance (Hackett & Kim, 2024). Collaborative capacity-building approaches—including train-the-trainer models and regional workshops facilitated by organizations like AfLIA and the Research Data Alliance—have proven effective in scaling RDM competencies across diverse African contexts (AfLIA, 2025). Ultimately, the synergy between well-developed technological infrastructure and targeted training interventions determines the extent to which Nigerian libraries and their counterparts in other countries can support researchers in navigating the complexities of data management, thereby enhancing research productivity and fostering global scientific collaboration.

Thematic Analysis: Comparative Evidence from African Countries

Role of Technological Infrastructure in Enabling RDM Services

Technological infrastructure is widely recognized as the cornerstone for effective Research Data Management (RDM) services within African academic libraries. Robust

digital platforms—including institutional repositories, cloud storage solutions, and high-speed internet connectivity—are critical for efficient data storage, preservation, and sharing (Chigwada & Chiware, 2024; Li et al., 2024). For instance, the University of Zimbabwe library demonstrates partial readiness for RDM services, supported by existing technological infrastructure, though it still faces challenges related to legal frameworks and skills shortages (Nhendodzashe & Pasipamire, 2017). Similarly, research conducted in academic libraries in Eastern Nigeria highlights that infrastructural capacity significantly influences the implementation and sustainability of RDM services. Institutions equipped with better technological resources tend to exhibit higher levels of RDM awareness and more comprehensive service offerings (Mushi, 2017; Data Science Journal, 2020). In contrast, Nigerian academic libraries frequently encounter infrastructural limitations such as restricted broadband access and outdated systems, which hamper their ability to develop and maintain effective RDM services (Alabi, 2023). These findings underscore the vital connection between the availability of scalable, interoperable technological infrastructure and the maturity of RDM services, emphasizing the urgent need for strategic investments to support the full research data lifecycle across African institutions.

Impact of Training on Librarians' RDM Competencies

Training and capacity building emerge as equally pivotal in determining the quality and sustainability of RDM services. Empirical evidence from Tanzania and South Africa reveals that while technological infrastructure provides the foundation, the skills of librarians in data curation, metadata creation, and adherence to data policies are critical for successful RDM implementation (Mafale, 2023). The University of Dodoma exemplifies this dynamic, where low awareness and limited training opportunities among librarians and researchers have significantly impeded the growth of RDM services, highlighting the need for targeted awareness campaigns and skills development through workshops and customized training programs (Mushi, 2017). In Nigeria, the shortage of librarians with formal RDM training correlates strongly with underdeveloped RDM services, despite some infrastructural improvements (Alabi, 2023). These insights establish a clear link between focused training

initiatives and enhanced librarian competencies, suggesting that capacity building must be integrated with infrastructure development to unlock the full potential of RDM services in Nigerian academic libraries.

Strategies to Align Nigerian Libraries with Global RDM Standards

Aligning Nigerian libraries with global RDM standards requires a comprehensive approach that combines infrastructure upgrades, targeted training, and robust policy frameworks. Adoption of international guidelines such as the FAIR principles and the Digital Curation Centre (DCC) standards has been widely recommended to harmonize data management practices and improve interoperability (Corrall, Kennan, & Afzal, 2013; Chigwada & Chiware, 2024). Regional initiatives like the African Open Science Platform (AOSP) and collaborative efforts through the Research Data Alliance (RDA) provide valuable models for resource sharing, joint capacity building, and policy harmonization (Masenya, 2023). Case studies from South Africa and Tanzania illustrate the benefits of institutionalizing RDM policies and embedding RDM training into Library and Information Science (LIS) curricula to foster sustainable service delivery (Mafale, 2023; Mushi, 2017). In Nigeria, calls for increased government funding and stronger institutional commitment highlight the critical need to align national research policies with global open science mandates (Alabi, 2023). Collectively, these strategies emphasize the importance of coordinated action among policymakers, academic institutions, and stakeholders to build interoperable infrastructures, cultivate skilled personnel, and create enabling environments that meet international RDM expectations.

Synergies between Technological Infrastructure and Training in RDM

Empirical evidence from case studies in South Africa and Nigeria underscores that technological infrastructure alone is insufficient to realize the full potential of Research Data Management (RDM) services without the parallel development of skilled human resources. For example, the University of Cape Town has successfully integrated advanced digital

repositories with comprehensive training workshops focused on the FAIR (Findable, Accessible, Interoperable, Reusable) data principles. This combined approach has led to a remarkable 40% increase in data reuse rates, demonstrating how infrastructure and capacity building can jointly enhance research outcomes (Masenya, 2023). In contrast, many federal university libraries in Nigeria report low levels of engagement with their digital repositories, primarily due to inadequate training and limited awareness among librarians and researchers (Ajayi & Oladejo, 2023). This disparity highlights the critical need for synchronized investments in both technology and professional development to ensure that RDM services are effectively utilized and sustained.

Issues with RDM Adoption in Nigerian Libraries

Despite the recognized importance of RDM, Nigerian academic libraries face several persistent challenges that impede the adoption and effective implementation of these services:

1. **Funding Constraints:** Budget limitations often lead institutions to prioritize physical infrastructure over essential digital tools and platforms necessary for RDM, restricting the development of comprehensive data management systems (Farid et al., 2023).
2. **Policy Fragmentation:** The absence of coherent national RDM policies in many African countries, including Nigeria, results in fragmented and inconsistent data management practices across institutions, undermining efforts to standardize and scale RDM services (Ojo, Dahunsi, & Opele, 2024).
3. **Cultural Resistance:** A prevailing perception among researchers that research data is proprietary and confidential discourages data sharing and collaboration, which are fundamental to the principles of open science and effective RDM (Mafale, 2023).
4. **Skills Deficit:** The lack of formal training for librarians and research support staff contributes to low engagement with digital repositories and suboptimal management of research data, further limiting the impact of existing technological investments (Ajayi & Oladejo, 2023).

Strategies for Strengthening RDM Services in Nigerian Libraries

To overcome these challenges and align Nigerian academic libraries with global best practices in RDM, a multi-pronged strategy is essential:

Infrastructure Development

- **Adopt Modular, Open-Source Repository Systems:** Deploying scalable and cost-effective platforms such as DSpace can reduce financial barriers while providing flexible solutions tailored to institutional needs.
- **Leverage Regional and Continental Initiatives:** Partnerships with programs like the African Open Science Platform (AOSP) can facilitate resource sharing, infrastructure pooling, and collaborative development of interoperable RDM systems.

Training and Capacity Building

- **Integrate RDM into LIS Curricula:** Embedding comprehensive RDM modules within Library and Information Science programs at African universities will prepare future librarians with the necessary skills to manage research data effectively.
- **Establish Regional Training Hubs:** Creating centers of excellence for cross-institutional training and knowledge exchange will enhance capacity building and foster communities of practice across the continent.

Policy Advocacy

- **Promote National RDM Frameworks:** Advocacy efforts should focus on encouraging governments to develop and adopt national policies aligned with international standards such as the UNESCO Recommendation on Open Science, providing a regulatory foundation for consistent RDM practices.

Conclusion

The transformation of Nigerian academic libraries into vibrant hubs of research data excellence depends on the strategic and synergistic investment in both technological infrastructure and human capital. With a view to adopting scalable and interoperable technologies, fostering partnerships at regional and international levels, and prioritizing comprehensive training programs, Nigerian institutions can overcome existing barriers. Such a holistic approach will enable these libraries not only to support their researchers effectively but also to contribute meaningfully to global knowledge ecosystems, advancing open science and scholarly collaboration worldwide.

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