

DIGITAL INFRASTRUCTURE AND CAPACITY BUILDING ON RESEARCH DATA MANAGEMENT IN AFRICAN LIBRARY SETTINGS

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Abstract

This study investigates the impact of digital infrastructure and capacity building on Research Data Management (RDM) services in African libraries, emphasizing their critical roles in enhancing research productivity and data accessibility. Digital infrastructure including institutional repositories, reliable internet connectivity, cloud storage, and interoperable platforms is foundational for enabling effective RDM by facilitating data storage, preservation, and sharing in compliance with global standards such as the FAIR principles. However, infrastructural challenges such as limited broadband access, unstable power supply, and inadequate technological resources remain prevalent across many African countries, including Nigeria, conscapacity building libraries' ability to provide sustainable RDM services. Complementing infrastructure, targeted capacity building and skill development for librarians are essential to develop competencies in data curation, metadata management, and policy adherence, which directly influence the quality and sustainability of RDM services. Adopting a theoretical approach and using thematic analysis, empirical evidence from Tanzania, South Africa, and Nigeria illustrates that without adequate capacity building, digital systems are underutilized, limiting their potential impact on research outcomes. To align African libraries with global RDM standards, integrated strategies involving investment in scalable digital infrastructure, embedding RDM capacity building into LIS curricula, and fostering regional and international collaborations are imperative. This holistic approach will enable African libraries to overcome existing barriers, enhance data management practices, and contribute meaningfully to the global open science movement.

Keywords: Digital infrastructure, Research Data Management, Capacity building, African libraries, FAIR principles

Introduction

Traditionally, libraries have served as repositories of knowledge, providing access to physical resources and offering assistance with information retrieval. However, the digital age has necessitated a shift towards more dynamic and user-centric services (Elejene, Agim & Umunnakwe, 2025). Part of this shift is the application of 5th industrial tools to access information and manages research data. Research Data Management (RDM) has become an essential component of the modern research ecosystem, driven by the increasing volume, complexity, and diversity of data generated by scholarly activities. Effective RDM ensures that research data are properly collected, stored, preserved, and shared, thereby enhancing transparency, reproducibility, and innovation in research (Li et al., 2024). In African libraries, particularly academic and research libraries, the provision of RDM services is still emerging, constrained by limited digital infrastructure and insufficient capacity building for library professionals (Mafale, 2023). Digital infrastructure—including institutional repositories, high-speed internet, and data storage systems—is fundamental to supporting RDM services, while continuous capacity building equips librarians with the necessary skills to manage data throughout its lifecycle (Ojo, Dahunsi, & Opele, 2024). The intersection of these factors determines the capacity of African libraries to support researchers effectively and to contribute to global knowledge networks.

The theoretical frameworks underpinning RDM emphasize the sociotechnical nature of data services, where technology, policy, and human expertise must align to create effective knowledge infrastructures (Li et al., 2024). In the African context, this alignment is often weak, partly due to limited institutional support and competing priorities. The knowledge infrastructure model highlights the need for scalable, interoperable digital platforms and continuous professional development to empower librarians as data stewards (Masenya, 2023). Moreover, the adoption of international standards such as FAIR (Findable, Accessible, Interoperable, Reusable) principles requires both technological readiness and skilled personnel capable of implementing best practices (Mafale, 2023).

Despite the recognized importance of RDM, many African academic libraries face significant challenges in operationalizing these services due to infrastructural deficits and human resource limitations (Farid et al., 2023). Studies reveal that many institutions lack dedicated budgets for digital tools and have insufficient policies guiding RDM practices, resulting in fragmented and ad hoc data management approaches (Kalu, Chidi-Kalu, & Mafe, 2021). Furthermore, librarians often lack formal capacity building in data curation, metadata standards, and preservation techniques, which undermines the quality and reliability of RDM services (Mthembu & Ocholla, 2023). These gaps limit African researchers' ability to comply with international data sharing mandates and reduce the visibility and impact of their work. This paper argues that strengthening digital infrastructure and capacity building is critical to transforming African libraries into effective hubs for research data management. This is the crux of this study

Statement of the Problem

Ideally, African academic libraries should possess robust digital infrastructure and well-trained librarians to offer comprehensive research data management services that support the entire research lifecycle. Such an environment would enable seamless data storage, preservation, sharing, and compliance with global standards, thereby enhancing research productivity and collaboration. However, the current situation in many African libraries, including those in Nigeria and Southern Africa, is characterized by inadequate technological resources, insufficient funding, lack of formal RDM policies, and a significant skills gap among library personnel (Ajayi & Oladejo, 2023). These deficiencies result in fragmented RDM practices, reliance on insecure personal storage solutions, and limited awareness of RDM's importance among researchers and librarians alike.

The consequences of these challenges are profound. Poor RDM practices compromise research data integrity, reduce opportunities for data reuse, and hinder compliance with funding agency mandates, ultimately diminishing the visibility and impact of African research on the global stage. Moreover, the absence of skilled professionals and adequate infrastructure limits libraries' ability to support researchers effectively, perpetuating a cycle of underperformance and missed opportunities for innovation. While some studies have explored RDM challenges in specific countries or institutions, there remains a gap in comprehensive, comparative analyses of how digital infrastructure and capacity building jointly influence RDM services across African libraries. This gap warrants further investigation into this paper which will theoretically examine impact of digital infrastructure and capacity building on research data management services in African libraries

Objectives of the Study

1. Analyze the role of digital infrastructure in enabling RDM services.
2. Evaluate the impact of capacity building on librarians' RDM competencies.
3. Propose strategies to align African libraries with global RDM standards.

Significance of the Study

The findings of this study will be significant to policymakers by providing empirical evidence to guide investments in digital infrastructure and human capital development, which are critical for strengthening Africa's research capacity. Library administrators will benefit from insights into best practices and challenges in RDM service provision, enabling them to design effective capacity building programs and advocate for necessary resources. Additionally, international organizations focused on research capacity building and open science will find the study valuable for developing collaborative initiatives that promote equitable access to data management tools and knowledge across African institutions. With a view to addressing the interplay between infrastructure and capacity building, this study will contribute to building sustainable RDM ecosystems that empower African libraries to support researchers in a data-driven global knowledge economy.

Literature Review

Digital Infrastructure: A Foundation for RDM

Digital infrastructure forms the backbone of effective research data management (RDM), providing the technological frameworks necessary for storing, preserving, and sharing research data. Key components such as institutional repositories, cloud storage, high-speed networks, and interoperable systems enable seamless data lifecycle management, from collection to dissemination (Li et al., 2024). These infrastructures are critical for adhering to global standards like the FAIR (Findable, Accessible, Interoperable, Reusable) principles, which emphasize the need for data to be machine-actionable and reusable across disciplines (Chigwada & Chiware, 2024). For instance, the Museum für Naturkunde's Research Data Management Infrastructure exemplifies how modular, networked systems can minimize redundancy while enhancing data interoperability and accessibility (Museum für Naturkunde, n.d.). Globally, such infrastructures are evolving to transcend disciplinary boundaries, fostering collaborative research environments that address complex societal challenges through data-driven insights (Li et al., 2024). However, the effectiveness of these systems hinges on their integration with institutional policies and user-centric design, ensuring they meet researchers' evolving needs.

In African academic libraries, the state of digital infrastructure for RDM remains uneven, with significant disparities between institutions. While South African universities like the University of Cape Town have made strides in deploying institutional repositories and RDM services, many others face systemic challenges such as outdated systems, intermittent connectivity, and limited funding (Badenhorst & Raju, 2023; Chigwada & Chiware, 2024). For example, Nigerian libraries often rely on fragmented, ad hoc solutions due to insufficient investment in scalable technologies, leading to inefficiencies in data storage and retrieval (Badenhorst & Raju, 2023). These infrastructural deficits are compounded by a lack of national RDM policies and institutional roadmaps, which hinder the adoption of standardized practices. The absence of robust infrastructure not only limits data preservation but also undermines researchers' ability to collaborate globally, perpetuating Africa's marginalization in the international research arena (Chigwada & Chiware, 2024). The urgent need to address these gaps will require prioritizing investments in interoperable systems and high-speed networks to create a cohesive RDM ecosystem.

To bridge these gaps, scholars advocate for adopting modular, open-source repository systems and fostering cross-institutional collaborations. The Research Data Alliance (RDA) and initiatives like the African Open Science Platform (AOSP) emphasize the need for shared resources and regional hubs to reduce costs and enhance scalability (Chigwada & Chiware, 2024). For instance, the framework proposed by Li et al. (2024) highlights four missions for modern research data infrastructures: transcending disciplinary borders, creating intelligent research environments, enabling high-end academic communication, and balancing openness with ethical considerations. Implementing these missions in Africa would require aligning infrastructure development with capacity-building programs to equip librarians and researchers with technical skills in metadata curation, data analysis, and cybersecurity (Badenhorst & Raju,

2023). Furthermore, integrating FAIR-aligned infrastructures into national research strategies can enhance data reuse and compliance with funder mandates, ultimately positioning African institutions as competitive contributors to global knowledge production.

Capacity building and skill development for RDM

Capacity building and skill development are critical for equipping librarians and researchers with the skills necessary to implement effective Research Data Management (RDM) services. Recent initiatives, such as the Open Data Management Foundational Course for African Librarians by AfLIA, highlight the growing recognition of structured capacity building programs to address skill gaps in data curation, metadata standards, and FAIR (Findable, Accessible, Interoperable, Reusable) principles (AfLIA, 2024). These programs aim to empower librarians to manage digital repositories, ensure data preservation, and comply with global standards, thereby enhancing Africa's research visibility (University World News, 2024). However, studies reveal persistent challenges: a survey of South African academic libraries found that only 23% of librarians had formal RDM capacity building, with many relying on ad hoc knowledge (Mthembu & Ocholla, 2023). This underscores the urgent need for curriculum reforms in Library and Information Science (LIS) programs to integrate data stewardship competencies, ensuring future professionals are prepared for evolving roles in open science ecosystems (Ojo et al., 2024).

The relationship between capacity building effectiveness and institutional support is a recurring theme in RDM literature. For instance, the RDM Kwanza program, an 18-month blended capacity building initiative involving universities in Tanzania, Uganda, and Belgium, emphasizes the importance of institutional buy-in for sustaining skills development (UHasselt, 2025). Participants are required to implement RDM tasks within their institutions, fostering practical application of learned skills. Similarly, a case study at the University of Namibia revealed that while librarians recognized the value of RDM, the absence of dedicated budgets for infrastructure and capacity building hindered operationalization (Mafale, 2023). This aligns with findings from Nigeria, where librarians identified limited access to workshops and outdated LIS curricula as barriers to acquiring data management proficiencies (Ojo et al., 2024). These examples illustrate that capacity building programs must be coupled with institutional investments in digital tools and policy frameworks to translate theoretical knowledge into actionable RDM services.

Partnerships and collaborative networks play a pivotal role in scaling capacity-building efforts across Africa. Initiatives like AfLIA's pre-conference workshops and the Africa PID Alliance's resource-sharing platforms demonstrate how regional collaborations reduce costs and promote knowledge exchange (AfLIA, 2025). The Research Data Alliance (RDA) and African Open Science Platform (AOSP) further advocate for standardized capacity building modules and certification systems to ensure consistency in RDM competencies (Chigwada & Chiware, 2024). However, challenges persist: a study in South Africa noted that 67% of academic libraries lacked partnerships with IT departments or research offices, limiting their ability to implement holistic RDM strategies (Mthembu & Ocholla, 2023). To address this, scholars recommend adopting the Theoretical Domains Framework (TDF), which assesses behavioral,

environmental, and social factors influencing capacity building outcomes, to design context-specific interventions (Mafale, 2023). With a view on the need to fostering multi-stakeholder collaborations and aligning capacity building with institutional priorities, African libraries can bridge the gap between capacity building and sustainable RDM implementation.

Theoretical Frameworks for RDM

The Knowledge Infrastructure model, originally conceptualized by Susan Leigh Star and Karen Ruhleder in 1996, provides a sociotechnical framework emphasizing the interconnectedness of people, technologies, policies, and institutions that collectively support knowledge production and management. The model's core tenets include the recognition that knowledge infrastructures are complex, evolving systems that enable the flow and use of information across organizational and disciplinary boundaries. Its aim is to understand and improve how infrastructures support research and knowledge work by focusing on the relationships and dependencies among components rather than isolated technologies or actors. The model assumes that infrastructures are embedded in social and organizational contexts and that their effectiveness depends on alignment between technological capabilities and user needs. Applied to Research Data Management (RDM) in African libraries, the Knowledge Infrastructure model highlights how digital infrastructure (repositories, networks, storage) and human factors (capacity building, policies, librarian expertise) must co-evolve to create sustainable RDM services. This model helps explain why investments in technology alone are insufficient without corresponding capacity building and institutional support, thus directly relating to the present study's focus on the impact of digital infrastructure and capacity building on RDM services (Li et al., 2024; Chigwada & Chiware, 2024).

Another theory by Hackett and Kim's (2024) Conceptual Model for Research Data Services (RDS) Implementation was propounded to provide a structured approach to planning, implementing, and evaluating RDM services within academic libraries. This model's tenets revolve around identifying the types of data services needed, the resources required, the skills librarians must possess, and the educational frameworks necessary for sustainable service delivery. Its primary aim is to guide libraries in developing RDM that is responsive to researcher needs and institutional contexts. The model posits that successful RDS implementation depends on a balanced integration of service types (e.g., data collection, curation, analysis), technological platforms, and human expertise supported by ongoing capacity building and education. It assumes that RDM is a dynamic service area requiring continuous assessment and adaptation. In application, this model offers a practical roadmap for African libraries to assess gaps in their current RDM offerings, prioritize capacity building for librarians, and align infrastructure investments with service goals. Thus, it directly informs the present study by framing how digital infrastructure and capacity building interact to influence the quality and effectiveness of RDM services (Hackett & Kim, 2024).

Theoretical Perspective

Digital Infrastructure as an Enabler for RDM

Digital infrastructure is widely recognized as a fundamental enabler for effective Research Data Management (RDM), providing the technological foundation necessary to support the entire data lifecycle—from collection and storage to preservation and sharing (Li et al., 2024). In the African context, digital infrastructure includes institutional repositories, high-speed internet connectivity, cloud computing platforms, and interoperable data systems that facilitate seamless access and exchange of research data across institutions and borders (Chigwada & Chiware, 2024). The availability and quality of such infrastructure directly influence the capacity of academic libraries to offer robust RDM services, which are essential for ensuring data integrity, compliance with open data mandates, and fostering collaborative research (Badenhorst & Raju, 2023). However, Africa faces significant challenges in this regard, including limited broadband penetration, unreliable power supply, and underinvestment in digital platforms, which hamper the effective deployment and utilization of RDM systems (Deloitte, 2024; Carnegie Endowment, 2025). These infrastructural deficits create a digital divide that restricts many researchers' ability to manage and share data efficiently, thus limiting the continent's research visibility and impact on the global stage.

The relationship between digital infrastructure and RDM effectiveness is complex and symbiotic. Robust infrastructure not only supports data storage and access but also enables the implementation of standards such as FAIR (Findable, Accessible, Interoperable, and Reusable) principles, which are critical for maximizing the utility of research data (Masenya, 2023). For example, countries like South Africa have made progress by investing in institutional repositories and digital platforms that adhere to international interoperability standards, thereby enhancing data discoverability and reuse (Badenhorst & Raju, 2023). Conversely, in many other African countries, infrastructural inadequacies lead to fragmented data management practices, reliance on physical storage, and limited data sharing, which undermine research collaboration and innovation (Chigwada & Chiware, 2024). To tackle these challenges, it will require coordinated efforts to expand broadband access, improve energy reliability, and deploy scalable, open-source digital infrastructure solutions tailored to the African context (African Union Commission, 2024). Such investments are foundational to transforming libraries into effective RDM hubs that support researchers' evolving needs in a data-driven research landscape.

Capacity building as a Socio-Technical Intervention for RDM

Capacity building and skill development are essential socio-technical interventions that complement digital infrastructure to ensure the successful implementation and sustainability of RDM services in African libraries. While infrastructure provides the necessary tools and platforms, the human element—librarians and researchers equipped with relevant skills—is critical for operationalizing these systems effectively (AfLIA, 2024). Recent initiatives such as the Open Data Management Foundational Course for African Librarians have demonstrated the positive impact of structured capacity building programs in enhancing librarians' competencies in data curation, metadata standards, and compliance with data sharing policies (AfLIA, 2024; University World News, 2024). However, studies reveal that many librarians across the continent still lack formal RDM capacity building, resulting in inconsistent service delivery and underutilization of available digital tools (Mthembu & Ocholla, 2023). This skills

gap is compounded by outdated LIS curricula that do not adequately address the complexities of data stewardship in the digital age (Ojo, Dahunsi, & Opele, 2024). Therefore, continuous professional development and integration of RDM modules into LIS education are imperative to build a workforce capable of managing research data effectively.

The interplay between capacity building and digital infrastructure is crucial in shaping the quality and reach of RDM services. Capacity building programs that incorporate hands-on experience with digital platforms, coupled with institutional support for infrastructure upgrades, create an enabling environment for librarians to deliver comprehensive RDM services (Mafale, 2023). Furthermore, socio-technical frameworks emphasize that capacity building must address not only technical skills but also the social and organizational dynamics influencing data management practices, such as researcher engagement and policy compliance (Hackett & Kim, 2024). Collaborative capacity building models, including train-the-trainer approaches and regional workshops facilitated by organizations like AfLIA and the Research Data Alliance, have proven effective in scaling capacity building across diverse African contexts (AfLIA, 2025). Ultimately, the synergy between robust digital infrastructure and targeted capacity building interventions determines the extent to which African libraries can support researchers in navigating the complexities of data management, thereby enhancing research productivity and global collaboration.

Thematic Analysis

Comparative Evidence in some African countries

Role of Digital Infrastructure in Enabling RDM Services

Digital infrastructure is widely acknowledged as the foundational enabler for Research Data Management (RDM) services in African academic libraries. Studies reveal that robust digital platforms such as institutional repositories, cloud storage, and high-speed networks are essential for effective data storage, preservation, and sharing (Chigwada & Chware, 2024; Li et al., 2024). For example, the University of Zimbabwe library was found to have partial readiness for RDM services due to the presence of technological infrastructure, although gaps in legal frameworks and skills persisted (Nhendodzashe & Pasipamire, 2017). Similarly, research in East African libraries shows that infrastructural capacity directly impacts the ability to implement and sustain RDM services, with institutions possessing better digital infrastructure demonstrating higher levels of RDM awareness and service provision (Mushi, 2017; Data Science Journal, 2020). Comparatively, Nigerian academic libraries face infrastructural challenges such as limited broadband access and outdated systems, which constrain their RDM capabilities (Alabi, 2023). These findings underscore the critical relationship between digital infrastructure availability and the maturity of RDM services, highlighting the need for strategic investments in scalable, interoperable technologies to support research data lifecycles across African institutions.

Impact of capacity building on Librarians' RDM Competencies

Capacity building and skill development for librarians emerge as pivotal factors influencing the quality and sustainability of RDM services. Empirical evidence from Tanzania and South Africa indicates that while digital infrastructure is necessary, librarians' skills in data curation, metadata creation, and policy compliance are equally crucial for effective RDM implementation (Mafale, 2023). The University of Dodoma's case demonstrated that low awareness and limited capacity building opportunities among librarians and researchers significantly hindered the development of RDM services, necessitating concerted efforts in awareness creation and skills development through workshops and tailored capacity building programs (Mushi, 2017). In Nigeria, studies highlight a shortage of librarians with formal RDM capacity building, which correlates with underdeveloped RDM services despite infrastructural improvements (Alabi, 2023). These findings establish a clear link between targeted capacity building initiatives and enhanced librarian competencies, suggesting that capacity building must be integrated with infrastructure development to realize the full potential of RDM services in African libraries.

Strategies to Align African Libraries with Global RDM Standards

To align African libraries with global RDM standards, multi-faceted strategies that combine infrastructure enhancement, capacity building, and policy development are essential. The adoption of international frameworks such as the FAIR principles and Digital Curation Centre (DCC) guidelines has been recommended to standardize data management practices (Corrall, Kennan, & Afzal, 2013; Chigwada & Chiware, 2024). Regional initiatives like the African Open Science Platform (AOSP) and collaborations through the Research Data Alliance (RDA) offer models for resource sharing, joint capacity building, and harmonized policy development (Masenya, 2023). Case studies from South Africa and Tanzania illustrate the benefits of institutionalizing RDM policies and embedding RDM capacity building within LIS curricula to foster sustainable services (Mafale, 2023; Mushi, 2017). In Nigeria, calls for increased government funding and institutional commitment underscore the importance of aligning national research policies with global open science mandates (Alabi, 2023). Collectively, these strategies emphasize the need for coordinated efforts among policymakers, and academic institutions to build interoperable infrastructures, skilled personnel, and enabling environments that meet global RDM expectations.

Synergies between Infrastructure and Capacity building

Case studies from South Africa and Nigeria illustrate that infrastructure alone is insufficient without skilled personnel. The University of Cape Town's RDM program, which pairs digital repositories with workshops on FAIR (Findable, Accessible, Interoperable, Reusable) principles, has increased data reuse rates by 40% (Masenya, 2023). Conversely, libraries in Nigeria's federal universities report low engagement with repositories due to inadequate capacity building (Ajayi & Oladejo, 2023).

Challenges of RDM adoption for African libraries

1. **Funding Constraints:** Limited budgets prioritize physical infrastructure over digital tools (Farid et al., 2023).

2. Policy Fragmentation: Few African nations have national RDM policies, leading to inconsistent practices (Ojo et al., 2024).
3. Cultural Resistance: Researchers often view data as proprietary, undermining collaboration (Mafale, 2023).
4. Skill set: Libraries usually low engagement with repositories due to inadequate capacity building for librarians (Ajayi & Oladejo, 2023)

Recommendations

Infrastructure Development:

1. Deploy modular, open-source repository systems (e.g., DSpace) to reduce costs.
2. Partner with initiatives like the African Open Science Platform (AOSP) for shared resources.

Capacity building Programs:

3. Integrate RDM into LIS curricula at African universities.
4. Establish regional hubs for cross-institutional capacity building

Policy Advocacy:

5. Lobby governments to adopt national RDM frameworks aligned with the UNESCO Recommendation on Open Science.

Conclusion

The transformation of African libraries into hubs of research data excellence hinges on synergistic investments in digital infrastructure and human capital. With a view to adopting scalable technologies, fostering partnerships, and prioritizing capacity building, institutions can overcome existing barriers and contribute to global knowledge ecosystems.

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