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Digital and academic libraries through cloud computing

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ABSTRACT

In an era characterized by the dominance of digital information, libraries have undergone significant transformations, evolving from traditional brick-and-mortar institutions to dynamic hubs of digital knowledge. The emergence of digital libraries, which give users access to vast collections of digital resources, has facilitated this evolution. However, effective management of digital resources poses numerous challenges, including issues related to storage, preservation, and accessibility. In response, cloud computing has developed as a powerful solution for addressing these challenges and revolutionizing how libraries operate. Cloud computing reduces the need for expensive infrastructure expenditures and increases flexibility and scalability by allowing libraries to store, manage, and access digital resources remotely over the internet. This paper examines the intersection of digital libraries and cloud computing, examining the role of cloud computing in modern libraries and its implications for the future of information management. By analyzing current trends, case studies, and best practices, this paper provides insights into the benefits and challenges of adopting cloud computing in the context of academic libraries.

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1. INTRODUCTION

Libraries have undergone a significant transformation in an era where digital information predominates, evolving from static brick-and-mortar institutions to dynamic hubs of digital information [1]. The emergence of DL, which gives users access to vast collections of digital resources, has facilitated this evolution. According to [2], DLare establishments that offer the resources, with specific staff, to choose, organization, provide intellectual access (IA) to, allocate, Read, realm the truth of, and confirm the perseverance above time of gatherings of digital mechanisms therefore that they are effortlessly and affordably accessible aimed at usage by a definite open or established of societies [3]. The advent of digital libraries has taken almost important modifications in the method information are accessed, stored, and disseminated. However, the effective management of digital resources poses numerous challenges, including issues related to storage, preservation, and accessibility [4]. In this context, cloud computing has occurred as an authoritative resolution for addressing these challenges and revolutionizing the way libraries operate. Cloud computing offers libraries the ability to store, manage, and access digital resources remotely over the internet, thereby eradicating the essential for expensive structure investments and enabling greater elasticity and scalability. As noted by [5], "Cloud computing signifies unique of the greatest important changes in information technology (IT) in current years, offering unprecedented opportunities for innovation and efficiency. The resolve of this research paper is to explore the intersection of DL with cloud computing (CC),

examining the role of CC in modern libraries and its implications for the future of information management [6]. By analyzing current trends, case studies, and best practices, this study goals to deliver visions keen on the profits and encounters of adopting cloud computing in the context of AL.

It is noted that African librarians have a limited comprehension of the cloud computing concept. Although certain academic libraries across the continent have unintentionally incorporated CC applications into its processes, many of these libraries are prevented from using cloud services by security concerns to secure institutional intellectual aspect without knowledge about CC applications. Africa academic libraries have very lower adoption rates of CC, despite the technology's benefits for managing investigation data.

The study aimed to establish ways to protect the research data and assets stored in the cloud as well as recognize and review feasible protections that university libraries may take into account to secure data in the cloud.

The following research queries are articulated under the objectives:

- RQ1: How do academic libraries use CC platforms to archive and manage their research data collections'?
- RQ2: Which security measures and best practices can academic libraries put into action to protect sensitive research data stored in cloud environments?
- RQ3: What are consumers concerns from cloud computing standards and policies implementation?

The sections that follow will demonstrate both the actions taken in this study and their relevance to the evolution of academic libraries through cloud computing integration. Here, section 2 provides an overview of previous research on digital libraries and cloud computing. Section 3 introduces core cloud computing concepts and technologies by establishing the necessary background for understanding its application in libraries. Then section 4 examines real-world case studies and show how cloud computing is adopted and why it is crucial for modern library systems. The section 5 highlights the advantages such as scalability, cost-effectiveness and improved accessibility, which enhance library functions and resource management. Section 6 outlines the research design and methods to validate the findings. Section 7 shows the outcomes and discussion of cloud computing on library operations. Then section 8 summarizes the study's key findings, stating its contribution to the field. Finally, section 9 will explore emerging trends and challenges in cloud computing, emphasizing the relevance of this study in the context of Future technological advancements in academic libraries.

2. LITERATURE REVIEW

This section explores recent studies focused on the integration of deep learning with cloud computing to enhance the functionality and accessibility of academic and digital libraries. It highlights how emerging cloud-based deep learning technologies are being leveraged to improve content organization, retrieval efficiency and user personalization in digital library systems. The review emphasizes the transformative potential of these innovations in supporting remote access, resource scalability and intelligent data management.

2.1. Definition and characteristics of DL

DL is online repositories of digital resources that offer right to use to a wide-ranging variety of information in several formats, including text, images, audio, and video [7]. These libraries are characterized by their ability to store, organize, and retrieve digital content efficiently. They often offer features such as search functionalities, metadata tagging, and browsing capabilities to facilitate user access. Digital libraries aim to preserve cultural heritage, support research and education, and facilitate knowledge dissemination on a global scale [8]. They enable users to access resources remotely, promoting convenient and equitable access to information. Moreover, digital libraries often collaborate with institutions and organizations to enhance their collections and services [9]. These collaborations may involve digitizing physical collections, sharing metadata, or developing interoperable systems. Overall, digital libraries show an essential character cutting-edge the digital age by democratizing right to use to information and preserving cultural heritage for future generations [10].

2.2. Evolution of digital libraries

The evolution of DL container outlined backbone to the 1980s with the advent of digital technologies and the internet. Initially, digital libraries focused on digitizing print materials to make them accessible electronically [11]. However, with advancements in technology, digital libraries have expanded to include a varied choice of digital resources, with multimedia content, datasets, and born-digital materials. Key milestones in the growth of digital libraries include the development of standards and protocols on behalf of digital preservation, such as the open archival information system (OAIS) mention perfect, also the

establishment of digital library initiatives by academic institutions and government agencies [12]. Figure 1 shows that digital libraries.

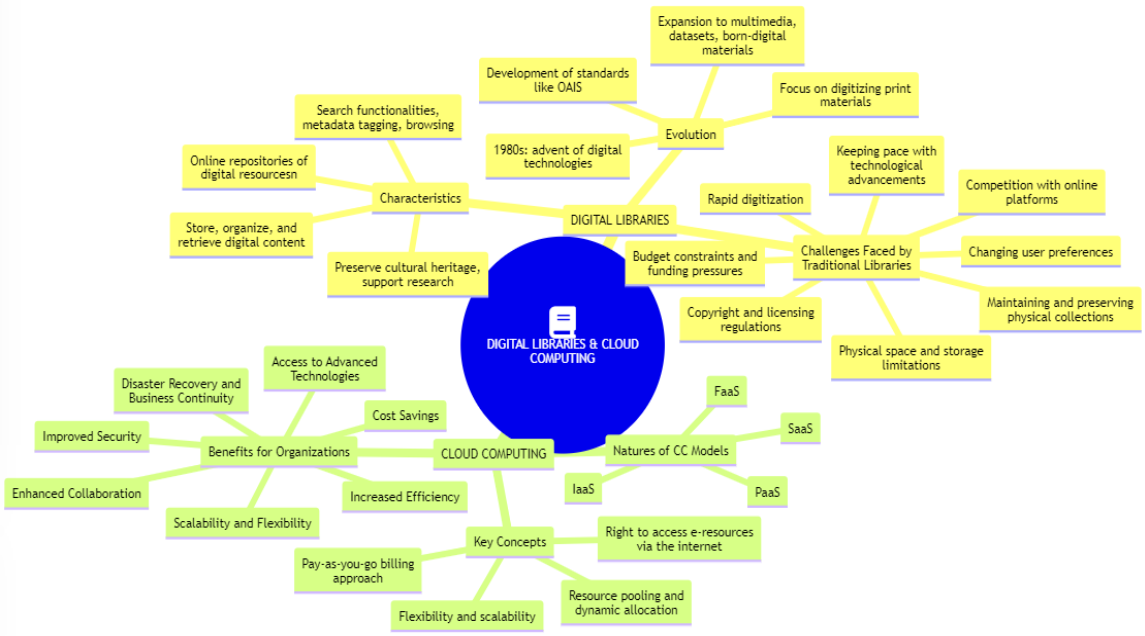

Figure 1. Digital libraries

2.3. Challenges faced by traditional libraries

Traditional libraries encounter various challenges in adapting to the evolving information landscape and meeting the changing needs of users. One significant challenge is the rapid digitization of information resources, which has led to increased demand for digital access and services. Additionally, traditional libraries face budget constraints and funding pressures, which limit their ability to invest in new technologies and resources [13]. Furthermore, changing user preferences and behaviors, such as the preference for online resources and remote access, pose challenges to traditional library models. Moreover, traditional libraries struggle to compete with online platforms and commercial providers that offer convenient access to digital content and services. Additionally, physical space constraints and storage limitations hinder the expansion of collections and services in traditional library settings [14]. Furthermore, maintaining and preserving physical collections present on going challenges, including issues related to conservation, storage, and access. Additionally, traditional libraries face challenges in keeping pace with technological advancements and ensuring digital literacy among staff and users. Lastly, evolving copyright and licensing regulations present complexities and uncertainties for traditional libraries in providing access to digital content [15].

3. CLOUD COMPUTING: A PRIMER

3.1. Definition and key concepts of CC

Cloud computing allows customers to access e-resources, such as software, databases, and servers, without maintaining physical infrastructure, as services are provided via the Internet. It offers flexibility and scalability by enabling independent deployment of resources like storage and processing power [16]. Users can access services from anywhere with an internet connection via devices like PCs and smartphones. Providers optimize efficiency by pooling resources and dynamically allocating them based on demand, allowing for rapid scaling to meet workload changes and business needs. Its metered billing model ensures customers only pay for what they use, enhancing cost-effectiveness [17]. This paradigm shift in IT management provides unparalleled flexibility, expandability, and cost-efficiency.

3.1.1. Natures of CC models

Cloud computing models can be categorized based on the services provided and the deployment method. Key models include infrastructure as a service (IaaS), where providers like Microsoft Azure, AWS,

and Google Cloud offer virtualized resources, like servers, storage, networking over the internet [18]. IaaS allows users to manage these resources on demand, ensuring flexibility and scalability. Platform as a service (PaaS) provides a development environment for building, deploying, and maintaining applications online without maintaining the basic infrastructure [19], examples are Heroku, Azure App Service, and Google App Engine. Software as a service (SaaS) provides applications via subscription, eliminating local installation and maintenance, with providers like Sales force, Google Workspace, and Microsoft Office 365 managing updates and security [20]. Figure 2 illustrates the key aspects of cloud computing, emphasizing its benefits for academic libraries.

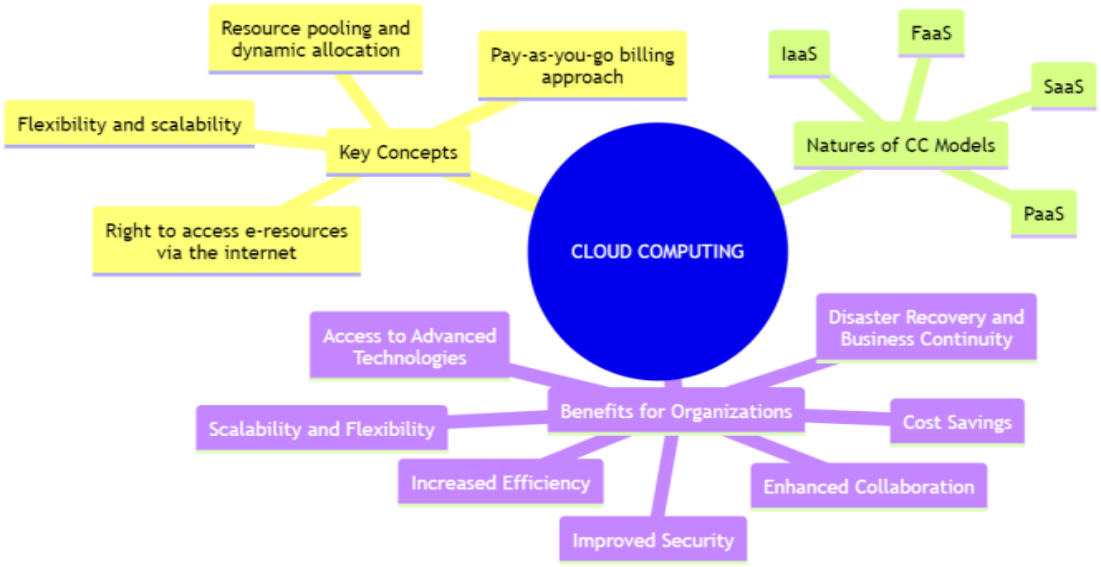

Figure 2. Cloud computing

Cloud computing offers flexibility and scalability allowing libraries to dynamically allocate resources and ensure efficient use of computing power. Key concepts include resource pooling, dynamic allocation and cost-effectiveness through pay-as-you-go billing. Cloud-based systems enhance access to e-resources providing greater service extension and an improved user experience. The figure highlights different cloud computing models: IaaS offers virtualized hardware, PaaS supports application development, SaaS provides software management and FaaS simplifies serverless computing. For academic libraries these models allow them to leverage advanced technologies without significant capital investment. The benefits of cloud computing for organizations include scalability, automation, enhanced security, disaster recovery and cost savings. Cloud platforms enable seamless collaboration, making information-sharing easier for library staff and users worldwide while ensuring the library remains technologically advanced and cost-efficient. Function as a service (FaaS) or Serverless Computing: FaaS enables designers to deploy particular utilities or bits of encryption in answer to actions, deprived of the essential to succeed the underlying infrastructure [21]. Serverless computing is more often known as cloud computing. Providers automatically scale resources in response to demand, and users are only charged for the resources that are used while functions are being executed using those resources [22]. There are several examples of FaaS structures, like Amazon Web Services Lambda, Azure Functions, Google Cloud Functions [23]. These are providing varying degrees of abstraction and administrative responsibilities, enabling businesses to choose the model that is most suitable for meeting their needs and achieving their goals via cloud computing.

3.1.2. Merits of cloud computing for organizations

Several advantages that may be gained by firms operating in a variety of sectors by using cloud computing. Following are some of the furthermost significant benefits:

Cloud computing provides several benefits, including cost savings by reducing the necessity of investments in hardware, infrastructure, and software licensing, with businesses opting for pay-as-you-go services to lower both initial and on-going expenses. It offers scalability and flexibility, agreeing organizations to adjust resources based upon demand without upfront hardware investments, ensuring efficient resource use and optimal performance [24] shared documents and communication channels.

Efficiency is improved through automation of IT tasks like provisioning and maintenance, freeing resources for strategic projects and enhancing service levels. Security is bolstered as cloud providers invest heavily in protecting data and infrastructure through advanced encryption, compliance standards, and security protocols, safeguarding against breaches and cyber-attacks [25]. Additionally, cloud services support disaster recovery and business continuity with built-in redundancy and data replication across multiple locations, ensuring swift recovery and minimal operational disruption. Lastly, the cloud computing enables access to advanced technologies, such as big data analytics and AI without significant costs, fostering innovation and competitive advantage [26].

3.2. The incorporation of cloud computing (CC) into academic libraries (AL)

3.2.1. Adoption of CC in AL

AL is increasingly adopting CC technologies to increase their services, streamline functioning, and improve accessibility to digital resources. According to, the implementation of CC in AL offers several advantages, including cost savings, scalability, and increased collaboration. Cloud-based solutions enable academic libraries to overcome limitations associated with traditional IT infrastructure, such as high capital expenditures, limited storage capacity, and maintenance overhead [27].

3.2.2. Examples of successful implementations

Cloud computing explanations have been successfully rummage-sale by a quantity of AL throughout the world in order to modernize their operations and deliver improved services to their patrons. Consider the case of the University of Michigan Library, which moved its digital repository to Amazon Web Services (AWS) in order to enhance its scalability, stability, and cost-effectiveness [28]. A similar approach was taken by the California Digital Library (CDL), which used cloud-based storage solutions in order to better manage its extensive collection of digital materials and to improve accessibility for users within the University of California system (CDL). Figure 3 shows that Cloud Computing into Academic Libraries.

Figure 3. Cloud computing into academic libraries

3.2.3. Challenges and barriers to adoption

Despite the benefits of cloud computing, academic libraries face various challenges and barriers to adoption. These include concerns about data security and privacy, compliance with regulatory requirements, vendor lock-in, and integration with existing library systems [29]. The limited IT expertise and budget constraints may hinder the adoption of CC technologies in AL, particularly smaller institutions with fewer resources.

3.3. The benefits of CC in AL

3.3.1. Improved accessibility and scalability

CC offers academic libraries improved accessibility to digital resources and enhanced scalability. By migrating library services and resources to the cloud, users can access information remotely from any location with internet connectivity [30]. This accessibility eliminates barriers related to physical distance and provides students, faculty, and researchers with convenient access to library resources, regardless of their location or device. Furthermore, cloud computing enables libraries to scale their infrastructure dynamically in response to changing demands. Cloud providers offer flexible pricing models that allow libraries to scale digital resources up or down established on usage patterns, safeguarding ideal show and profit-making [31].

3.3.2. Improved cooperation and efficient distribution of resources

Cloud computing facilitates enhanced collaboration as well as sharing of resources amongst academic libraries and their users. Cloud-based collaboration tools enable librarians and researchers to collaborate on projects, share data, and exchange ideas in real time, regardless of geographical location. Additionally, cloud-based repositories and platforms allow libraries to share digital collections and resources with other institutions, fostering collaboration and knowledge exchange within the academic community.

3.3.3. Efficiency and optimal use of resources

Cloud computing offers academic libraries cost-effectiveness and resource optimization through reduced capital expenditures and improved operational efficiency. By outsourcing infrastructure and services to cloud providers, libraries canister removes the essential for costly hardware investments and care overheads. Cloud-based solutions also proposal pay-as-you-go valuing representations, permitting libraries to pay only for the resources they consume, thereby optimizing resource utilization and reducing overall costs. Furthermore, cloud computing enables libraries to allocate resources more efficiently and scale infrastructure dynamically in response to changing demand, minimizing wastage and maximizing cost-effectiveness [32].

3.3.4. Digital repository implementation in academic libraries

The Digital Public Library of America (DPLA) provides access to a vast collection of digitized resources from U.S. libraries, museums, and archives, including images, manuscripts, books, and audio-visual materials [33]. Europeana, a digital repository, aggregates collections from European museums, libraries, and archives, offering millions of cultural items like artworks and publications. The Internet Archive, a free digital library, preserves websites, books, music, films, and software for future generations. The HathiTrust Digital Library (HTDL) grants access to millions of digitized books and materials from global research libraries, including public domain works. The National Digital Library of India (NDLI) provides access to digital resources such as books, papers, and audio-visuals sourced from Indian libraries and institutions to support education.

3.4. Method

This study analyzed data from fifteen academic databases, focusing on highly regarded journals from Africa, Europe, the USA, and Asia. Researchers, who were either middle-level or senior library managers, participated in an online survey at the Enterprise University of Pretoria in 2017, which assessed datasets in academic library catalogues. They then volunteered for a detailed review of cloud computing datasets in academic libraries. The research, approved through the Pretoria Research Ethics Committee University, was descriptive and revised literature from secondary sources, including books and journal articles from Ghana, Nigeria, and Tanzania. The study focused on four areas: current state of educational libraries as a service, cloud computing applications, data security and control, and adoption challenges. Researchers reviewed 59 relevant articles, with a detailed analysis of 50 to conclude the study.

4. RESULTS AND DISCUSSION

This segment depicts the results of systematic literature review (SLR) with further discussion provided in the following subsections. The table highlights key studies, their objectives, findings, challenges and recommendations. It is evident from the table that cloud computing, digital libraries and internet of things (IoT) have been focal points in recent research particularly in the context of education and institutional repositories. The studies show that while cloud technologies offer substantial benefits in terms of cost savings, scalability and collaboration, difficulties like security concerns, resource management and technical support remain critical. Moreover, the focus on metadata management, interoperability and digital content access suggests that the approval of cloud-based solutions in academic settings is rise. However, the persistent concerns around security, energy efficiency and institutional resistance indicate that further developments in these areas are needed to fully leverage cloud computing's potential.

Table 1 shows various studies on cloud computing in security, education, IoT and cost optimization. Research shows cloud computing brings big benefits like scalability lower costs, and better e-learning platforms. But some big problems remain with security threats, energy use managing resources, and not enough cloud experts. Baker [2] say we need stronger security systems and many layers to protect against cloud security risks. Wu and Plakhtii [7] talk about growth in cloud services but say we need to invest in infrastructure and make e-learning systems work better all the time. For education, Matthew *et al.* [8] and Okechukwu and Ukeh [11] point out problems with energy use and people not knowing much about cloud computing. They suggest using resources better and training more people. Belgaum *et al.* [16] and Patel [21] look at ways to cut costs and use AI to run cloud systems better. Together, these studies show the good things about cloud computing but also call for answers to security, cost, and performance problems.

Table 1. Publications and the research focus

Reference	Objective	Findings	Challenges	Recommendations
Baker [2]	Cloud security protocols	Importance of cloud security in academic settings	Managing security threats in cloud environments	Adoption of multi-layered security approaches
Wu and Plakhtii [7]	E-learning and cloud computing	Investigated cloud-enabled e-learning platforms	Inconsistent access to e-learning systems	Investment in scalable cloud solutions for education
Matthew *et al.* [8]	Cloud computing and IoT in education	Benefits of cloud computing in educational IoT platforms	Energy consumption and cloud performance issues	Improved resource allocation for IoT systems in academia
Okechukwu and Ukeh [11]	Awareness of cloud services	Cloud computing services awareness level in tertiary institutions	Lack of cloud computing expertise	Increased training and support for cloud computing in higher education
Belgaum *et al.* [16]	AI in cloud computing and IoT	Role of AI in enhancing cloud and IoT systems	Scalability and reliability issues	Development of AI-driven cloud resource management tools
Nagendra and Subash [18]	Scheduling techniques for cloud	Optimization of workload scheduling in cloud environments	Energy efficiency in cloud systems	Energy-aware scheduling techniques for scientific workloads
Patel [21]	Cloud cost optimization	Focused on reducing cloud computing costs	Inefficient use of cloud resources	Adoption of cloud cost optimization techniques for institutions

4.1. The utilization of cloud computing platforms for archiving and managing research data in academic libraries (RQ1)

Data loss and security breaches are major concerns for college libraries using cloud platforms. Without proper backups, original data can be lost or altered, and doubts about cloud storage reliability arise due to potential unauthorized access. To mitigate these risks, libraries must ensure robust security measures, including data encryption, key management, and secure data transfer methods. Implementing intrusion detection systems, firewalls, and secure communication protocols is crucial. Establishing a trust model with cloud providers and adopting proactive measures to monitor and recover data can enhance the reliability and security of cloud-based storage for sensitive research data.

4.1.1. Security measures and best practices for protecting sensitive research data in cloud environments in academic libraries (RQ2)

Major cloud providers like Amazon AWS, Azure, Adobe, Google Cloud Platform, and VMWare are well-regarded for its reliability and data safety. However, academic libraries often struggle to trust these providers due to inadequate tools for assessing cloud security. Containers, which isolate applications, can pose privacy risks when shared among users. Studies highlight the different cloud services, which may exacerbate security concerns, making it crucial for libraries to handle sensitive research data carefully on public platforms. Challenges include limited control, transparency issues, integration difficulties, and reliance on a single provider. While AWS and Azure offer robust access management, they may lack sufficient data encryption methods. Libraries must implement strong access controls, advanced encryption, and continuous monitoring to safeguard their data. Future research should focus on developing security solutions tailored specifically for academic libraries' needs.

4.1.2. Consumer concerns regarding the execution of cloud computing standards and policies (RQ3)

Consumers often question the incorporation of standards and policies in cloud computing, particularly regarding data security, privacy, and service reliability. These standards are crucial for users and service providers, but many SLAs limit cloud scalability, leading to issues like data unavailability, vendor lock-in, inadequate security. Concerns about interoperability and portability persist, as users struggle with

moving between cloud providers due to a lack of universal standards. National regulations may conflict with SLAs, raising privacy issues. Additionally, many cloud processes, including APIs, lack standardized protocols, complicating implementation. While cloud computing reduces capital investments and shifts risks to providers, it presents challenges like unreliable latency, network costs, and mobility support, especially for SMEs. To foster trust and address compliance, security, and legal concerns, cloud providers must enhance safety measures and guidelines.

4.1.3. Advantages of storage research data in the cloud

The advantages result from academic libraries archiving their institutions' research data on the cloud:

- Cost-effectiveness
- Visibility with accessibility
- Resource sharing · Interlibrary collaboration
- Unlimited storage capability/scalability

4.1.4. Ways of protecting academic library's research data/asset in the cloud

Research data archiving on the cloud requires academic libraries to maintain security, as evidenced by the literature. To prevent needless congestion and data susceptibility, these could be accomplished by implementing strong authentication, creating regulations and standards for cloud service access from secure networks, and scaling up cloud subscription as needed.

4.1.5. Challenges in implementing cloud computing faced by academic libraries

Even though cloud computing has many advantages, several obstacles have prevented academic libraries using the technology to store research documents. Some difficulties are network security, safety, worries about the continuity and dependability of cloud-based library services, and skill deficits.

5. CONCLUSION

This study examines the use of cloud computing by university libraries in Tanzania, Ghana, and Nigeria. It highlights the lack of hands-on research about cloud adoption in these libraries across Africa. The findings show that while African libraries have started to use cloud computing, they haven't made the most of its ability to store and manage research data. This is different from what see in more advanced parts of the world where libraries make better use of cloud services. Cloud computing has an influence on academic libraries in many positive ways. It saves money, keeps data safer, makes resources easier to access, grows with needs, and works well with other systems. More people may access and use research data globally when libraries store it on the cloud. Even with these good points African academic libraries face some hurdles in using cloud services. These include a deficiency in appropriate policy directives, insufficient authentication protocols from cloud service providers, problems with trust, and a lack of knowledge on the potential benefits of cloud technology for libraries. The research looks into what is next for college libraries focusing on new tech like AI, VR and AR. These tools could shake up how libraries offer services, support research and create learning spaces. But as libraries go digital, there are big worries about keeping data safe and private. To make the most of cloud computing and these new technologies, African college libraries need to tackle these issues. This means careful planning setting up rules and helping people understand what is at stake. By doing these libraries can reach more people worldwide, work better and stick around for the long haul.

6. FUTURE TRENDS AND IMPLICATIONS

Emerging technologies like augmented reality, virtual reality, blockchain, IoT, and artificial intelligence (AI) are significantly transforming academic libraries. VR and AR offer immersive learning experiences, while blockchain ensures the security of digital assets. IoT devices provide real-time data for service optimization, and AI enhances automation, search capabilities, and personalization of user experiences. AI-driven chatbots assist with inquiries and recommendations, and deep learning algorithms optimize resource allocation and collection development. Cloud computing is central to these advancements, overcoming infrastructure limitations, improving accessibility, and reducing costs through migration to cloud platforms. It facilitates remote access and collaboration, and its integration with emerging technologies and AI enhances library services. However, libraries must address ethical concerns like data privacy and algorithmic bias to ensure equitable access and maintain trust. Future research focus on experiments and adoption barriers, develop best practices for cloud implementation, and promote collaboration among libraries, cloud providers, and technology to drive innovation and improve services.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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