Chapter

# Developing a Cloud Computing Framework for University Libraries

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## Abstract

Our understanding of the library context on security challenges on storing research output on the cloud is inadequate and incomplete. Existing research has mostly focused on profit-oriented organizations. To address the limitation within the university environment, the paper unravels the data/information security concerns of cloud storage services within the university libraries. On the score of changes occurring in the libraries, this paper serves to inform users and library managers of the traditional approaches that have not guaranteed the security of research output. The paper is built upon the work of Shaw and the cloud storage security framework, which links aspects of cloud security and helps explain reasons for university libraries moving research output into cloud infrastructure, and how the cloud service is more secured. Specifically, this paper examined the existing storage carriers/media for storing research output and the associated risks with cloud storage services for university libraries. The paper partly fills this gap by a case study examination of two (2) African countries' (Ghana and Uganda) reports on research output and cloud storage security in university libraries. The paper argues that in storing university research output on the cloud, libraries consider the security of content, the resilience of librarians, determining access levels and enterprise cloud storage platforms. The interview instrument is used to collect qualitative data from librarians and the thematic content analysis is used to analyze the research data. Significantly, results show that copyright law infringement, unauthorized data accessibility, policy issues, insecurity of content, cost and no interoperable cloud standards were major risks associated with cloud storage services. It is expected that university libraries pay more attention to the security/confidentiality of content, the resilience of librarians, determining access levels and enterprise cloud storage platforms to enhance cloud security of research output. The paper contributes to the field of knowledge by developing a framework that supports an approach to understand security in cloud storage. It also enables actors in the library profession to understand the makeup and measures of security issues in cloud storage. By presenting empirical evidence, it is clear that university libraries have migrated research output into cloud infrastructure as an alternative for continued storage, maintenance and access of information.

**Keywords:** cloud computing, storage, security, research output, academic libraries, university libraries

## 1. Introduction

Despite the renewed interest in safeguarding research output, the changing storage carriers due to the fragility of storage carriers, lifespan, and handling practices are a cause of concern for the university libraries [1]. University libraries cannot avoid working in the cloud as they have become adaptive to inevitable and unpredictable changes occurring within the digital environment [1]. The university community places much emphasis on research and publication not only because it is presumed that research enriches teaching and the learning process, contributing to the body of knowledge, but also because it is a major determinant of institutional prestige and that of the nation at large [2].

Irrespective of the technological changes, stored research output in universities must be secured for future availability and accessibility [3]. Cloud storage has become an alternative for the storage of research output. According to Yuvaraj [4], university libraries have continued not only as only new technology adopters but rather cutting-edge IT users. Clearly, cloud computing as a cutting-edge IT platform proves to be a lasting technological innovation that continues to rise in usage [5].

However, owing to the technological age, university libraries are faced with new opportunities for innovative educational practices, hence providing electronic library services. Almost all university libraries are primarily concerned with enhancing teaching, learning, and research through the provision of timely information resources. On that basis, researches by Gabridge [6], Gold [7] and Jones [8] revealed the need for libraries to provide research data services. In providing timely information resources, modern libraries' digital collections must be stored for future use and as backups to ensure continuous accessibility by library users.

Witten and Bainbridge [9] explained that a digital library is a focused "collection of various forms of digital objects" such as text, audio, and video, as well as their methods for access, retrieval, selection, organization, and maintenance. Rosenberg [10] also reiterated that a digital library can refer to information resources which are accessed by and delivered to users electronically or via a network [11]. Primarily, in developing countries, microfilms, databases, CD-ROMS, hard disks, external drives have been the existing platforms for storing library digital information, though these come with major drawbacks. For instance, these storage devices are exposed to threats such as theft, inadequate storage space, virus attacks and unauthorized accessibility among others. These drawbacks have been a major concern for academic libraries' thus an ongoing debate and discussion on the new technology "cloud storage" as an alternative storage media.

To a large extent, studies confirm that modern university libraries have greatly shifted from traditional roles (paper-based services) to digital library services. This paradigm shift has paved the way for library services to be accessed and delivered via the web [12]. For university libraries, the issue of using cloud services to store digital collections is particularly important as technological changes have paved the way for library services to be accessed and delivered via the web [12]. As more data and information is generated and stored in the cloud, either by design or default, university libraries need to be confident of the security of the digital collections. There is a growing interest in the implementation of cloud storage services which exposes university libraries to a new set of threats and vulnerabilities. McLeod and Gormly [13] concluded that if cloud service providers are to be used, their security, viability, sustainability, and trustworthiness must be paramount.

Studies have demonstrated that that cloud computing in libraries has widely examined the rise of data-intensive services in academic libraries with less emphasis on cloud storage security [14, 15]. Most of these studies were based on individual

or small-scale survey data concentrated in one country. Owing to the extant gap in wide-scale exploratory studies, the present paper explored the risks associated with cloud storage services and how university libraries can ensure safe research output. In this light, the paper contributes significantly to the body of literature by unraveling new evidence from universities located in Ghana and Uganda on how academic libraries can secure research output with cloud services.

The following sections include research questions, related literature, theoretical framework, research methodology, results, a summary of key findings, conclusion and recommendation.

### 1.1 Research questions

i. What are the existing storage carriers/media for storing research output in university libraries?

ii. What are the reasons for university libraries moving research output into a cloud infrastructure?

iii. What risks are associated with cloud storage services for university libraries?

iv. In university libraries, how can research output store on the cloud service be secured?

## 2. Related literature

### 2.1 Storage media in university libraries

Libraries use several types of media in storing digitized content or information (audio, video, text, images etc.). Each of the media suffers disadvantages with regard to reliability, high lifespan, ease of access and validation plus various costs. Enakrire and Baro [16] argued that these media include;

i. **Magnetic disk drives** are disk drives which are mostly mounted on computers. They are inexpensive, of very high-density, fast to use, and multiple user connectivities to the server are possible.

ii. **Magnetic tape**, which comes in various formats and can only be effective for duplicate or backup copies. However, they are not recommended for primary storage.

iii. **Optical disks**, for example, CD-R and DVD-R cost less, use low energy but exert high labor costs, poor accessibility, a periodic verification is not cost-effective and low density by today's standards. Others are CD-RW and DVD-RW these are recommended for individual and day-to-day use but are not recommended for data preservation [17].

### 2.2 Cloud storage services

Until recently, evidence from the pool of literature shows that the concept of cloud is of the growing research area. Indeed, a lot more storage capabilities exist in the cloud. According to Mavodza [18], cloud computing is the delivering of hosted electronic services over the internet. Scale [19], opines that it is: "the sharing

and use of applications and resources of a network environment to get work done without concerns about ownership and management of the network's resources and applications, data are no longer stored on one's personal computer, but are hosted elsewhere to be made accessible in any location and at any time". Gosavi et al. [20] iterated that cloud computing harnesses the capabilities of resources like storage, scalability, and availability, which are accessible to university libraries as clients. Hence, depending on the needs of the clients, the infrastructure can be scaled up or down.

In developed or developing countries, cloud storage provides promising advantages to university libraries. According to Li [21], cloud storage reduces the cost of hardware and software, and it makes the storage and management of data on the internet possible. It also reduces the work of Information Technology (IT) professionals as most of the system's work is performed by the hosting company. Payment for the cloud storage service is by pay-as-you-go, which is convenient for organizations such as academic libraries which have budget restraints. Han [22] enumerates cost-effectiveness, flexibility, and data safety as a rationale for cloud storage in academic libraries. Han [23] alludes the advantages that cloud storage has over traditional storage to "availability, scalability, off-site storage, on-demand, and multi-tenancy" which allows different applications or different users to access the same resources to fit their needs. Han further states that data stored in the cloud can be easily transferred and duplicated globally to minimize data loss due to natural disasters.

Haris [24] also gives an analysis of the benefits of cloud storage especially for libraries and these include high performance, an avenue for collaboration, less "need for in-house technical expertise, cost savings, and more timely access" to the latest IT functionality. Haris further states that the cloud also provides a better workflow, "automated software updates, redundancy", and backups. Cloud storage provides collaboration, particularly for academic and research libraries. Through the use of cloud technology, a collaboration between libraries, researchers, and students is promoted. The cloud also enables remote access to a wide range of research materials.

### 2.3 Reasons for cloud computing in university libraries

In this section, the role of cloud computing in university libraries, specific cloud storage platforms and the risks associated with cloud storage are reviewed.

Kaushik and Kumar [25] contend that cloud computing can offer many interesting possibilities for institutions such as libraries. Cloud computing is quite significant as it reduces technology cost, increases capacity reliability, and storage performance for some type of automation activities like library services. In recent times, cloud computing has made strong inroads into other commercial sectors and is now beginning to find more of its applications in the library and information environment.

After the personal computer and the internet, cloud computing also known as the third revolution is completely new in terms of technology. Potentially, cloud computing is an unraveled technology in university libraries as digital content can be stored in the cloud. Mobile devices are enabled using cloud computing by taking out an item or scanning a barcode [26]. Gosavi et al. [20] argued that when using cloud computing, users can be able to browse a physical shelf of books located in the library, choose an item or scan a barcode into his mobile device. More so, heritage materials or documents can be digitized, searched and accessed by library patrons. The new concept of cloud libraries includes OCLC, Library of Congress (LC),

Exlibris, Polaris, Scribd, Discovery Service, Google Docs/Google Scholar, WorldCat and Encore [27].

Nowadays, studies appear to be emerging in cloud computing. For instance, a paper presented by Saleem et al. [27] indicated that university libraries have adopted cloud computing technology to enhance library services by adding more values, attracting users and cost-effectiveness. In the cloud computing environment, clouds have vast resource pools with on-demand resource allocation and a collection of networked features. The new concept of cloud and libraries has generated a new model called cloud libraries.

In the work of Zainab et al. [28], it was reported that the first reason of shifting research report into cloud computing is to reduce the total cost of ownership and maintenance of the cloud infrastructure. Secondly, scalability of the cloud service system is another objective, so that it is able to handle increased traffic. Due to the rapid expansion of the user group, we need to redesign the back-end web server with scalability in mind, such that it is able to accommodate an increasing number of concurrent users.

Based on the web traffic statistic, the average visit per month for the year 2012 is approximately 87,000 users and we expect the numbers will grow in the coming years as resources in the repository also grew. The high volume of transaction is causing The server to behave extremely sluggish and crashes frequently [28]. On the hand, migration is necessary in order to meet the increasing demand for storage space for full-text digital resources. File sizes of some digital resources are extremely large especially audio, video and images. Besides, as more users' access and upload articles to the magnetic hard drives, university libraries face problems in fulfilling the storage space demand. The cloud storage service which promises and contributes to about 13 terabytes of storage space, can store over 12 million digital files of research output. Thus, it is very obvious that without a long-term plan, university libraries would not able to sustain the present storage demand from users in the future until alternative storage is assessed.

It is expected that migration of digital files would reduce downtime when scheduled backup and indexing, as well as site traffic, occur simultaneously. The previous system backup was very laborious and time-consuming. Often scheduled jobs would cause unnecessary downtime of the magnetic and optical systems. System downtime is unavoidable because the system was hosted without a redundant server.

## 2.4 Enterprise cloud storage platforms

**Amazon S3:** Amazon Simple Storage Services (Amazon S3) provides a secure, durable, highly-scalable object storage (Amazon, 2015). It uses a web service interface to store and retrieve any amount of data. It is a pay as you use service. There are different storage classes designed for different uses; Amazon S3 standard, Glacier for long-term archive. The services include backup and archiving, disaster recovery, and big data analytics [29].

**Google cloud storage:** Allows storage and retrieval of any amount of data at any time. It facilitates the storage of data on Google's infrastructure with high-reliability performance and availability (Google, 2015) [29]. The services include data storage, large unstructured data objects, uploading data, and managing data. The lowest storage class is $0.01 GB/month.

**Microsoft Azure:** Azure supports the selection of wide services including operating systems, frameworks, tools, and databases. It's typically a platform-as-a-service and software-as-a-service. It provides secure private connections, storage

solutions, and data residency and encryption features (Microsoft, 2015). It provides scale-as-you-need, pay-as-you-go service plan, and strong data protection security.

**Other cloud storage platforms include** Dropbox, SkyDrive, Box**,** Google Drive**,** Flickr**,** Google music**,** Apple iCloud, and Amazon cloud player.

## 2.5 Associated risks and possible solutions for cloud storage

Lili and Buer [30], highlighted that advancement in technology may not necessarily transform the cloud services into mainstream technology in academic libraries. A scan of literature [31–33], revealed that cloud security, interoperability, and regulatory perspectives are worrying. In addition, academic libraries may or may not completely lose control over IT and data. Sometimes, trust in the service provider, data portability, migration, copyright issues, and privacy is a big risk when it comes to adopting cloud computing technology.

### *2.5.1 Policy issues*

Policies guide institutions and operations on what to do and not to do. Cloud storage and applications are valuable resources that allow academic libraries to store large amounts of information and perform collaborative tasks more effectively. However, there are risks associated and that must be mitigated in order to properly secure the research assets placed into the cloud [32]. In this light, it is purposeful for the policy to provide the framework within which the libraries will be expected to operate for storage and process information in cloud environments. Basically, the policy should encompass the scope of work, software, research information, human resource, users, copyright and many more.

### *2.5.2 Unauthorized accessibility*

Once a digital collection (scholarly works, publications/collections, and historical documents) is put on the cloud, it becomes available for all groups of users and this can be exposed to unauthorized access to data centers. "*Cloud operators can dictate the manner in which users can access, use and reuse content or information via specific online services or applications. That is, the user interface ultimately dictates what can or cannot be done by end-users, regardless of what they are theoretically entitled to under the law*" [34]. So, the question is whether academic libraries can allow such law to be overridden on as it has already fallen in the public domain. This indeed is likely to impact on copyright law in the context of online applications.

### *2.5.3 No interoperable cloud standards*

Cloud storage service providers are not guided by standard regulations. As a result, some service providers are tempted to offer low-quality services to developing countries in Africa thus creating loopholes for cybercriminals to take advantage. As an emerging trend, this issue of no interoperability is of concern, if research assets can be secured on the cloud. Interoperability refers to the ability of a collection of communicating entities to share specific information and operate on it according to agreed-on operational semantics [35]. Even though the clients (academic libraries) desire standards for cloud interoperability, the reality currently is that standard efforts only focus on portability, which is the ability to migrate workloads and data from one provider to another.

Librarians cannot sit unconcerned in this matter since the open access (OA) repositories are also part of collections of the library [36]. Though the OA

repositories facilitate sharing of resources in educational research through portals that are modeled as gates to several repositories, it is a challenge because data synchronization is an issue when components in different clouds or internal resources work together, whether or not they are identical. Communication between clouds typically has a high latency, which makes synchronization difficult. Also, the two clouds may have different access control regimes, complicating the task of moving data between them [37].

Thus, interoperability is required, not just between different components, but between identical components running in different clouds [38]. Such components often keep copies of the same data, and these copies must be maintained in a consistent state. The design approach must address management of "system of record" sources, management of data at rest and data in transit across domains that may be under control of a cloud service consumer or provider and data visibility and transparency.

Nurnberg et al. [39] argued that full interoperability includes dynamic discovery and composition: the ability to discover instances of application components and combine them with other application component instances, at runtime. Application interoperability requires more than communications protocols. It requires that interoperating applications share common processes and data models. These are not appropriate subjects for generic standards, although there are specific standards for some particular applications and business areas.

### 2.6 Cost

Obviously, the cost is a challenge for academic libraries. More especially, enterprise cloud storage platforms such as Amazon S3 and Microsoft Azure are paid for as you use the cloud services. Unfortunately, libraries that find it difficult to fund basic services will see that as an extra cost inhibiting them to withdraw from the cloud service. The cost comes with human resource and sometimes maintenance of servers.

## 3. Theoretical framework for cloud storage security

The paper adopts the development of a Cloud Storage Security Framework (CSSF) to support an integrative approach to understanding and evaluating security in cloud storage in university libraries. The framework enables understanding

| Factor | Item |
|---|---|
| 1. **Cloud Storage Security** | 1. Cloud Storage Security Policies |
| | 2. Cloud Storage Security Procedures |
| 2. **Confidentiality** | 3. Identification of cloud storage user |
| | 4. Authorisation to access data |
| 3. **Integrity** | 5. Accurate ownership of data |
| | 6. Encryption of data |
| 4. **Availability** | 7. Accessible to the data |
| | 8. Up-to-date available data |
| 5. **Non-repudiation** | 9. Accurate time-stamping of accessed data |
| | 10. Assurance with user signature |
| 6. **Authenticity** | 11. Verified data based on authentication |
| | 12. Synchronised data in the storage |
| 7. **Reliability** | 13. Consistency of cloud service |
| | 14. Valid service |
| **Factors: 7** | Items: 14 |

**Figure 1.**
*CSSF. Source: Yahya [40].*

of the makeup of cloud storage security and its associated measures. Drawing upon CSSF, it indicates that security in cloud storage can be determined by seven factors: (1) security policies implementation in cloud storage, security measure that relates to (2) protecting the data accessed in cloud storage; (3) modifications of data stored; (4) accessibility of data stored in cloud storage; (5) non-repudiation to the data stored; (6) authenticity of the original data; (7) reliability of the cloud storage services.

The framework is summarized in **Figure 1**.

In applying the framework to the current research, security of research output in the cloud infrastructure can be determined by ensuring that all the seven factors are met by the university library.

## 4. Research methodology

This study aimed to explore security issues considered in migrating research output to the cloud service as input into the development of preservation or storage systems within the library environment. This section described an approach followed in the study. This included the research approach, purpose, instrumentation, and sources of data. Our paper adopted the qualitative approach to explore cloud computing in university libraries in the sub-Saharan Africa. Using a wide range of evidence and discovering new issues, the purpose of the paper was to explore the risks associated with cloud storage and security implications. The exploratory design was significant as the authors became more familiar with basic facts, settings, concerns, and generating new ideas. In this study, interviews were conducted with respective librarians in charge of research output within the (4) universities. Hence, the research sites were purposefully selected to ensure that they provided sufficient opportunities to test available infrastructure for storing research output. Again, since the paper was interested in only libraries with repositories, the institutions without OA repositories were excluded.

An interview schedule on the research questions was presented to 4 librarians from the universities. Thus, participants for the investigation were made up of librarians in charge of institutional repositories. These four university libraries selected were; Balme Library, (University of Ghana—Legon), Kwame Nkrumah University of Science and Technology—KNUST library (Ghana), HamuMukasa Library, (Uganda Christian University), and The Iddi Basajjabalaba Memorial Library, (Kampala International University—Uganda). The thematic content analysis was used to analyze the qualitative data. The authors further reviewed scholarly research articles, explored in the context of research data storage in and outside Africa.

## 5. Results

This section draws reference from respective university libraries in the context of cloud storage security for research data.

### 5.1 Balme Library, University of Ghana, Legon

The University of Ghana (UG), the premier university and the largest university in Ghana was founded as the University College of the Gold Coast by Ordinance on August 11, 1948, for the purpose of providing and promoting university education, learning and research. The vision of the university is "to become a world-class

research-intensive University over the next decade". To achieve the vision, it "will create an enabling environment that makes the University of Ghana increasingly relevant to national and global development through cutting-edge research as well as high quality teaching and learning" (http://ug.edu.gh). To achieve this mountainous vision in the next decade, the Balme Library, the central library of the university plays a crucial role.

Established in 1948, the Balme Library is the main library of the University of Ghana. In addition to the Balme Library, there are other libraries in the various Schools, Institutes, Departments, Halls of Residence and the Accra City Campus which form the University of Ghana Library System (http://balme.ug.edu.gh).

In UG, research assets (theses, journals, newspapers) in the form of PDFs, word files, conference papers, videos, and audio have been generated. In the context of this study, the existing storage media for storing research data include CDs, DVDs, external drives, servers, hard drives, microfiche, and microfilms. Others include networked drives, Google drive and Dropbox used by researchers and the library in storing research assets.

The interviewee indicated that digital storage and backup is important because;

> *"Data may need to be accessed in the future to explain or augment subsequent research. Other researchers might wish to evaluate or use the results of previous research outputs as precedence to conduct other similar or extended studies".*

Agrawal and Nyamful [41] corroborated the findings in the present study. Accordingly, they reported that storage devices which stores and maintains large sets of data over time play an important role in mitigating big data challenges. Factors such as capacity, reliability, performance, throughput, cost, and scalability are involved in any ideal storage solution system. They argued that reliability is basically the retrieval of data in its original form without any loss. The issue of reliability takes into account both internal and external system failures and vulnerabilities. With the scale of data, the probability of losing some data during retrieval can be very high. In order to ensure continuous accessibility of data, storage is very necessary.

It was revealed by the interviewee that

> *"there is no robust or enough backup plan when the primary server goes down. With an average of 3000 visits per day on the Institutional Repository (IR), we wish to keep The website availability as high as possible. To solve the problem, the IR team decided to move digital files to a cloud environment using virtualization technology".*

A study by Ji et al. [42], revealed a compelling need for storage and management of research output. Given the current development of data (text, audio, video, images, etc.), university libraries are employing techniques such as data compression, deduplication, object storage, and cloud storage.

The Librarian in charge of research data opined that

> *"Unauthorized accessibility, physical damage, theft, and hacking are particular concerns with electronic data. Many research projects involve the collection and maintenance of human subject's data and other confidential records that could become the target of hackers and thus integrity must be maintained. The costs of reproducing, restoring, or replacing stolen data and the length of recovery time in the event of a theft highlight the need for protecting the computer system and the integrity of the data".*

The Librarian iterated that several issues are associated with storing research data on the cloud.

One interviewee pointed out that;

> *"Risks associated with cloud storage are crucial for the Balme Library. Storing research assets online via the Dropbox, mozy.com, Box.net, Adrive.com, Carbonite.com have proven the best alternative. However, a few associated risks include issues regarding property rights, copyright, data protection licenses or privacy. Other issues to consider is the fact that in the event of restoring data, it may be a bit slow and the service provider (Google Reader) could go out of service".*

## 5.2 KNUST

KNUST Library has realized the need to digitize and store documents and research data generated by staff and students of the University, hence the decision to create the online Institutional Repository. The online repository showcases the intellectual output from the KNUST. In the earlier 2010, a server and scanners were acquired to support digitization processes. Since then, postgraduate thesis, reports, and few research articles have been uploaded unto the repository. Increasingly, the project has continued to receive acclamation internationally due to robust IT infrastructure in the library.

The librarian for KNUST responded in this manner,

> *"Currently, the KNUST uses non-web based storage media to store data. There are two servers; one for the Library's catalogue and another for the Institutional Repository. The library also uses an external hard drive as a backup, but both media are located in-house".*

Reed et al. [43] asserted that "data backup plays an indispensable role in the computing system. Backup is one way to ensure data protection. By keeping copies of production data, backup protects data from a potential loss such as hardware and software loss, human errors, and natural disasters. The huge amount of data needing backup and archiving has reached several petabytes and may soon reach tens, or even hundreds of petabytes. The massive amount of data in today's library environment may consume much storage."

Furthermore, it was reported by the interviewee that

> *"The challenge faced with this kind of storage media is frequent memory crash, lack of expertise to manage the storage media, lack of space – the servers have low memory space, an interrupted power supply which uninterruptible power supply (UPS) is not even able to solve. Then finally, remote access to the information is denied because data is not online". Thus, the need to seek cloud storage.*

It was evident from the interviewees that cloud computing environments are easily scalable and backup recovery is very easy in Infrastructure as a Service (IaaS) Providers, hence there is efficient incident response whenever data needs to be recovered.

The authors sought to find what risks were associated with cloud storage. Cost and data security were concerns raised by the managers of the repositories. Agrawal and Nyamful [41] argued that the state of preventing a system from vulnerable attacks is considered as the system's security. Security risks involved

with the use of cloud computing have various risk factors for the library environment. Seven important identity factors for risk in a cloud computing model are access, availability, network load, integrity, data security, data location, and data segregation.

### 5.3 Hamu Mukasa Library, Uganda Christian University Library

Uganda Christian University has been in existence for 11 years having only one library which uses traditional devices. In the year 2015, the library launched its institutional repository. The storage media for storing research data in Uganda Christian University library is examined as follows:

Uganda Christian University has both traditional and modern storage devices. Traditional storage includes CDs, flash disks, card catalog and later introduced modern storage like creating an institutional repository where dissertations and research papers are kept safely for future use.

The Librarian in charge of the research data output of the Uganda Christian University observed that;

> *"For modern storage devices, Google drive is currently used to store documents such as student Theses works, proposals, and the day to day statistics. This started early last year when the learning commons was opened. This is used because it is cheap and can be accessed easily by staff and students while doing their work".*

In this twenty-first century, information is not just in print but digitally created and reused by researchers and patrons within academic institutions. There is a need for digital information storage at Uganda Christian University because of the advantages. Prior to cloud storage, institutions invested heavily in data centers and servers even though they may not have used its storage space. The cloud storage allows institutions' (academic libraries) only pay for computing resources they use. By using cloud storage one can achieve a lower variable cost than can be gotten on the traditional storage devices.

However, using cloud storage by Uganda Christian University academic library has some risks. Lack of internet access or less bandwidth is a major issue. Specifically, when the internet is down its difficult for data to be retrieved thus inconveniencing the patrons. Secondly, sensitive information for the institution can be disclosed accidentally or deliberately in cloud services if not handled well especially when demand grows. Thus, the inappropriate accessibility of the institution data can be compromised.

For an institution like Uganda Christian University Library to ensure the safety of its research information in the cloud, the following must be considered.

- avoid unauthorized accessibility of research data using strong passwords.
- Privacy policy services settings must always be checked by appropriate management.

### 5.4 The Iddi Basajjabalaba Memorial Library, Kampala International University-Uganda

The Iddi Basajjabalaba Memorial Library (The IBML) is an integral part of Kampala International University (KIU). It is the intellectual hub of the university that supports the study, teaching, research and social information needs of the university. The IBML has grown over the years from one small room in 2001

manned by one member of staff and serving 700 users to an eight ultra-modern building serving over 20,000 users. The IBML system has evolved over time from the manual system providing print information resources to automated circulation services and digital information resources. In 2014, The IBML set up a digital repository to capture, store, and disseminate the intellectual content of the university. The digital content includes research articles, papers written by university staff, PhD theses, and other university publications. DSpace software was used for this project and it is hosted locally on a networked server. The repository data is backed up on an external hard drive with several terabytes of storage capacity.

The IBML has not ventured much into cloud storage because data is still stored locally. Researchers, academic staff, and students typically use external hard drives, flash disks, CDs, DVDs, emails and Google Drive to store their data. Not many use Dropbox, OneDrive, and other Cloud storage media. However, this trend is risky because the library faces several challenges especially power outages that lead to a computer crash, theft of computer hard drives, and other storage media. There is also a danger of data breaches by unauthorized persons since the repository server is not within the confines of the library. Therefore, cloud storage is an important choice for the library to use in order to mitigate the danger of data loss.

**Figure 2** depicts how university libraries provide library services via cloud services. Due to the unreliability of non-web based storage media, university libraries have refocused attention to an alternative; cloud service which is web-based. In providing library services to university faculty, students and researchers; research assets in the form of electronic theses/dissertation, articles, research datasets, research reports are stored in the cloud. It is important to note that cloud services provide advantages like large storage space, data back-up among others which non-web based media does not have. However, alternative storage media (cloud computing) appears to accommodate the concerns of university libraries. Putting in place, security of content, defining accessibility levels, adherence to copyright and legal issues, cloud storage policy, among others, safety of research assets on the cloud service is safer.

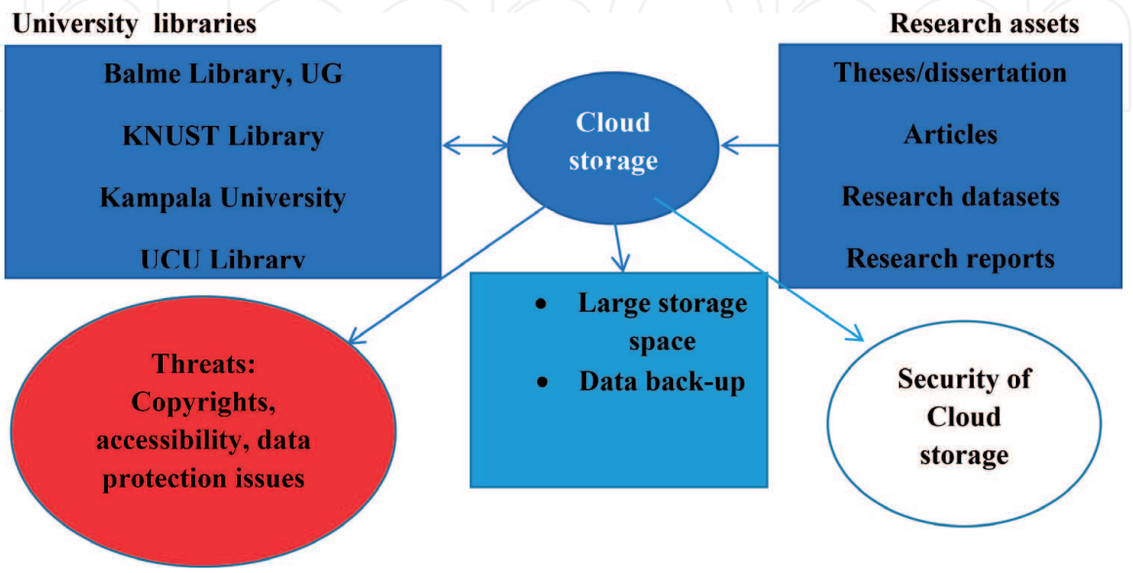


**Figure 2.**
*Cloud computing in university libraries.*

## 6. Summary of key findings

The paper discovered pertinent and important findings which were very vital for drawing a conclusion and informing policy makers.

### 6.1 Existing storage media for research assets

From the study, it can be concluded that all the sampled academic libraries used magnetic disk drives (hard disk drives) for storing research outputs and assets and optical disks (CD-R and DVD-R).

### 6.2 Need for digital information storage

From the empirical evidence, it is concluded that information enhances knowledge, which affects behavior, and leads to development warranting its preservation. University libraries have the digital format as text, audio, video, and image which facilitates easy sharing of information. Storage is needed for current and future generation of researchers and academia as a whole. In addition, digital storage makes information easily accessible to users as compared to "analog items". This is due to the ability to easily copy the information on storage devices and carry around. Furthermore, digital storage facilitates the easy sharing of information.

### 6.3 Risks associated with cloud storage in university libraries

Specifically, copyright law infringement, unauthorized data accessibility, policy issues, the security of content, no interoperable cloud standards were identified as the risks associated with cloud storage in academic libraries.

### 6.4 Conclusion

Cloud computing offers university libraries improved storage solutions. In the era of IT, the library and information environment face numerous challenges including constant change of storage platforms. Notably, the storage of research output is primary to the functions of university libraries. Thus, there is a need for storage security; as it is a reality in the current technological environment.

In the developed world, some university libraries have already built and managed their own research data centers comparable to the developing world. Indeed, to avoid loss of data integrity, large digital storage in the cloud must be backed up, maintained and re-produced to avoid stress on the local server infrastructure. In conclusion, the opportunities offered by cloud computing via its storage services could ensure that university libraries gain more control over research output.

University libraries must consider investing in cloud infrastructure as it assures large savings or cost effectiveness in operational cost and tech-start-ups [44], paying for what you use and risk transfer and availability [45], scalability, accessibility [4], on-demand service, access to a large network, rapid elasticity and resource sharing [46]. Above all, Gosavi et al. [20] pointed out that libraries are likely to benefit from cloud storage in the area of self-healing, multi-tenancy, linearly scalable, service-oriented, SLA driven, virtualized and flexibility of services.

The paper contributes to knowledge by protecting research data in cloud storage systems. Furthermore, the implication of the findings gives significant input to policymakers, information professionals and future researchers. Finally, with qualitative data, the adopted framework indicates how the security of cloud storage can be implemented successfully.

## 6.5 Recommendation

The authors recommends the following; security/confidentiality of content, the resilience of librarians, determining access levels and enterprise cloud storage platforms if research output can be secured on the cloud;

### *6.5.1 Security of content*

Content concerns raised by Cave et al. [47] and Genoni [48] require consultation with legislation or the legal office of the academic institution. This is to say that the type of records and length of time for keeping research output must be determined, and policy put in place. In a fast-changing library environment, the technology for storage of research output suffers from obsolescence hence the need for regular back-ups to avoid data loss. Whichever way one considers the issue, storage and access concerns are central, leading to the consideration to make the cloud a viable option.

### *6.5.2 Resilience of librarians*

There is a need for university librarians to maintain the character of resilience and also be adaptive to inevitable and unpredictable changes that occur at an accelerated pace. It is therefore required of librarians to provide a wide variety of information from an equally varied selection of sources and formats through teams (working together) and particularly with the prevalence of cloud use. Since cloud computing enables almost a new streamlined workflow, cooperation through team building or network can be very laudable.

### *6.5.3 Determining access levels*

To overcome the enumerated challenge of unauthorized access to data centers, academic libraries must be concerned with the levels of accessibility; ranging from completely open access to highly private. In securing the content of the research assets on the cloud, different levels of accessibility or privileges must be assigned to the different users within the network. For instance, students, researchers, librarians, users outside the university community must be assigned roles as such.

### *6.5.4 Enterprise cloud storage platforms*

The authors highly recommends the enterprise cloud storage platforms such as Amazon Simple Storage Services (Amazon S3), Google cloud storage and Microsoft Azure. This is because they provide secure, durable, highly-scalable object storage, allows retrieval of any amount of data at any time and high-reliability performance and wide services including operating systems, frameworks, tools, and databases.

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