



The Potential of Cloud Computing for Digital Libraries in Public Universities

¹James Kimutai*, ²Elizabeth Muli

¹Department of IT & Moi University, Kenya

²Department of Computer Science & Technical University of Kenya, Kenya

Abstract— *the demand for digital libraries to control large amounts of data requires a platform and an infrastructure that is economical and fast to deploy for public university libraries. With the digital revolution, there is rising information explosion and overload, and digital libraries need to implement integrated may data centre services to manage their library operations. Cloud computing offers digital libraries an attractive option for on-demand and scalable access to control their applications, services and data repositories thus reducing management complexity. This paper examines the architecture and application of cloud computing in the growth of digital libraries. It also discusses the challenges and prospects that public university libraries need to consider before adopting a quality cloud solution for their digital libraries.*

Keywords— *Cloud computing, digital libraries, ICT, cloud libraries*

I. INTRODUCTION

Cloud computing is a style of computing in which massively scalable and elastic information technology (IT)-enabled capabilities are delivered as a service to external customers using internet technologies [4]. Cloud computing can be categorized into four main types: infrastructure, platform, applications and service [5]. According to National Institute of Standards and Technology(NIST) cloud computing is a model for enabling convenient, on-demand network access to shared pool of configurable computing resources (e.g. network, servers, storage, application and services) that can be provisioned rapidly and released with minimal management effort or service provider intervention. The cloud infrastructure promotes availability and is composed of five essential characteristics, three service model and four deployment models [9].

In reality, a majority of people are using cloud computing services without recognizing it. These services include Google Docs, e-mail services, social networking sites like Facebook, Photo sharing networks like Flickr. Currently data availability, scalability, elastic service, and pay-per-use are attractive characteristics found in the cloud service model. There are several examples of public cloud storage, such as Amazon S3, Rack Space and Google Storage which offer high availability, fault tolerance, and services and administration at low cost [16].

On the other hand, digital libraries are organizations that provide access to resources enabling users to select, structure, interpret, distribute, preserve the integrity of, and ensure persistence of digital works to be readily and economically available for use by communities[3].With digital revolution, bursting digital content there is need for digital libraries in public universities have to find a reliable, fast and cost effective deployment platform for the delivery and storage of digital contents.

Recently, fifteen colleges were elevated to full universities bringing the total of public universities in Kenya to 22[11].Most public universities are already implementing open and long life learning platforms to further extend the equitable access to institutions of higher learning (IHE).Each public university would be required to operate a fully functional library to share informational and knowledge resources to the rising number of student enrolment in these institutions. One of the challenges faced by university libraries is to develop innovative ways of enhancing and adding value to their library services and operations. In the wake of shrinking public university library budgetary allocations, librarians have to seek innovative ways to support integrated library system to leverage on information and communication technologies (ICT) to provide a cost-effective platform. This will result to an increased web presence in the access of information resources through digital libraries.

Furthermore, there is a shift by users who prefer e-resources, books are now in electronic formats and librarians are tech-savvy. In addition, dynamic models of computing are creating exciting opportunities for new products and services. The landscape for automation systems are such that they are transitioning to deployments through cloud computing technologies.

As a result, public universities have a golden chance to rethink and realign their automation strategies with new technology enabling them to leverage on the available massive data sharing and efficiencies for their digital libraries. The biggest challenge for most digital libraries in public universities is to implement an integrated library system that simplifies library operations, reduces operation costs, increases access to resources and accommodates user requirements. Cloud computing services, therefore is an attractive choice that will provide transformational opportunities for digital libraries in public universities to run their operations more efficiently and effectively.

The Kenya Vision 2030 blueprint identifies economic, social and political pillars as growth areas for Kenya which involves a countrywide needs assessment and provision of infrastructure and ICT equipments [10]. As a result, Kenya is positioning itself as a knowledge based economy endowed with a workforce that possess a skill set that will enable her to leverage on the digital revolution. The Government of Kenya is at the forefront in digitization of its services through the e-government initiative where its citizenry can access essential services through the internet regardless of their geographical locations. Therefore, as the country prepares to transition to a knowledge based economy, public university libraries as citadels of intellectual repositories need to explore and invest in opportunities provided by cloud computing to offer quality services.

II. OBJECTIVES

The objectives of this paper:

1. To identify a sustainable cloud computing deployment model for digital libraries in public universities.
2. To establish components that will make up an effective choice for cloud computing models.
3. To investigate the impacts of cloud computing adoption in enterprises.
4. To examine how cloud computing can enhance access to libraries resources in public universities.
5. To make recommendations on the rationale for adopting cloud computing technologies for digital libraries in public universities.

III. METHODOLOGY

This study adopts a documentary research method. This method is good and more cost effective than social surveys; in-depth interviews or participant interviews. The documentary research method is a technique used to categorize, investigate, interpret and identify the limitations of physical sources, most commonly written documents whether in the private or public domain[12].

Drivers for Adoption of Cloud Computing [15]

- Scalability: Users have access to vast resources that scales based on user demand.
- Elasticity: The environment transparently manages a user's resource utilization based on dynamically changing needs.
- Virtualization: Each user has a single view of the available resources, independently of how they are arranged in terms of physical devices.
- Cost: The pay-per-usage model allows an organization to only pay for resources they need with basically no investment in the physical resources available in the cloud. There is no infrastructure maintenance or upgrade costs.
- Mobility: Users have the ability to access data and applications around the globe.
- Collaboration: Users are starting to see the cloud as a way to work simultaneously on common data and information.
- Risk reduction: users can use the cloud to test ideas and concepts before making major investments in technology.
- Usability: The ease with which the user is able to configure and operate virtual resources.

Benefits of Cloud Computing

Cloud computing is a new technology model for IT services which every organisation and enterprises are adopting. As the uptake for cloud computing services by enterprises and organizations continues to increase, it is a matter of time before public universities transition to cloud computing services for their ever increasing digital repositories. The following are some of the key benefits of switching to cloud based services [18], [2].

- Flexibility: Digital libraries can benefit from instant increase in bandwidth and on-demand scalability of cloud-based services because of the vast capacity of the service's in remote servers.
- Disaster recovery plans: Organizations no longer need complex disaster recovery plans since cloud computing providers takes care of most issues in a faster way. According to a study by Aberdeen Group, businesses that used the cloud were able to resolve issues in an average of 2.1 hours nearly four times faster than businesses that didn't use the cloud (8 hours).
- Automatic software updates: Cloud computing suppliers do the server maintenance including security updates themselves freeing up their customers time to concentrate on their core business.
- Increased Collaboration: Cloud computing increases collaboration by allowing all employees wherever they are to sync and work on documents and shared applications simultaneously, and follow colleagues and records to receive updates in real time. A survey by Frost and Sullivan found that companies which invested in collaboration technology had a 400% return on investment.
- Telecommuting: With internet connection, employees can work from anywhere providing flexibility that impact positively on work-life balance and productivity.
- Security: The level of security offered by reputable cloud providers usually exceeds the level businesses, especially small businesses, can provide themselves.

- **Eco-friendly:** Organizations using cloud computing only use server space they need which decreases their carbon foot print. Using the cloud results in at least 30% less energy consumption and carbon emissions than using on-site servers. And the most benefit for small organizations, the cut in energy use and carbon emissions is likely to be 90%.
- **Document Control:** According to a study conducted by Forrester Consulting on behalf of Adobe[14], 73% of knowledge workers collaborate with people in different time zones and regions at least monthly. Cloud computing keeps all files in one central location where everyone works off one copy. This whole process makes collaboration stronger, which increases efficiency and improves an organizations bottom line.

Challenges of Cloud Computing

Like any piece of technology, there are challenges which organizations have to analyse before adopting it. The good news is that as technology evolves, more emerging issues are addressed and refined further creating a trust value in the technology.

A survey by KPMG of 650 senior executives in 16 countries found a number of top most common challenges in the use of cloud computing as summarized in figure 1 below [6].

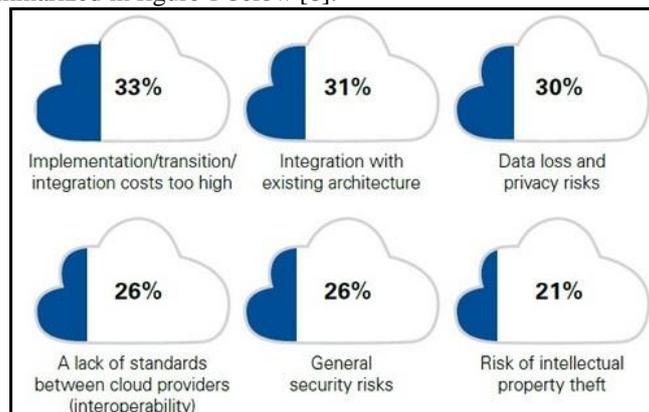


Fig. 1. Top challenges of cloud computing

Challenges in adoption of Cloud Computing

- **Control:** in a cloud solution, there is less control over software preferences, and businesses can no longer ask their IT staff to install software or make modifications to a software package to meet their needs.
- **Data mining:** some cloud solution providers own the data put into their “cloud” and are free to mine the data (particularly providers that provide the cloud solution for free or for a nominal fee). Businesses should ensure the data put into the cloud is owned by them, and that the service provider cannot mine that data.
- **Data storage location:** depending on where the provider locates their server/s, they may be subject to legislative requirements in that location that can impact access to information.
- **Functionality:** some functionality may not be available, or may be very different in “the cloud”. The performance on a cloud-based solution can also be very different to in-house systems. For example, computer functionality may be unavailable in a cloud solution (tasks such as video editing and other bandwidth-intensive tasks are best kept out of the cloud).
- **Knowledge of cloud service providers:** Many businesses lack knowledge about cloud service providers and hence may make mistakes in choosing the best service provider for their business.
- **Reluctance from IT staff:** A business’s IT staff may not be supportive of a move to cloud solutions as they may not have the required expertise and they may feel threatened by such a move.
- **Inadequate bandwidth:** Cloud solutions require continuous internet access. If internet access is down, intermittent or slow, it affects the availability of the cloud services.
- **Security and privacy:** With a cloud service provider, data is stored with a third party. It is necessary to sign service level agreements to ensure privacy and confidentiality of the data.
- **Technical issues:** In spite of cloud solutions being generally well maintained, often to a higher standard than in-house systems, there will be times when the system may not work as required for example when the fibre optic cables are damaged under sea.

Service Providers of Cloud Computing for libraries

The following are some of companies that provide library automation systems through the cloud [19].

- **Ex Libris:** Ex Libris is a cloud service provider based in USA. They provide various features like compatibility with Unicode font, flexibility, migration of data customization e.t.c. Ex Libris is available for all types of libraries.
- **Polaris Library Systems:** This Company provides standard acquisition and processing system for libraries. The system uses well known standards like MARC 21 for bibliographic data, XML, Z39.50 for retrieval, Unicode e.t.c

- **Dura Cloud:** Dura cloud is providing cloud solutions for digital library services. Dura Cloud is a collaboration of the Dspace digital library software and Fedora Commons. Fedora commons is a framework for digital repository which offers complete solution for digital libraries with standard software and hardware solution.

Cloud vendors can run their data centres at over 90% capacity and as a result, energy is saved because the carbon footprint of each unit of computing power is reduced. Therefore, digital libraries in public universities can become more greener by using cloud libraries thus reducing the overall energy consumption through the traditional investment of in-house ICT infrastructure. Cloud computing can lead to a transition of using low powered devices that connect to the cloud based computing services which is more economical.

IV. TECHNOLOGY DESCRIPTION

Cloud computing is categorized into three service models, four deployment models and five main essential characteristics [9].

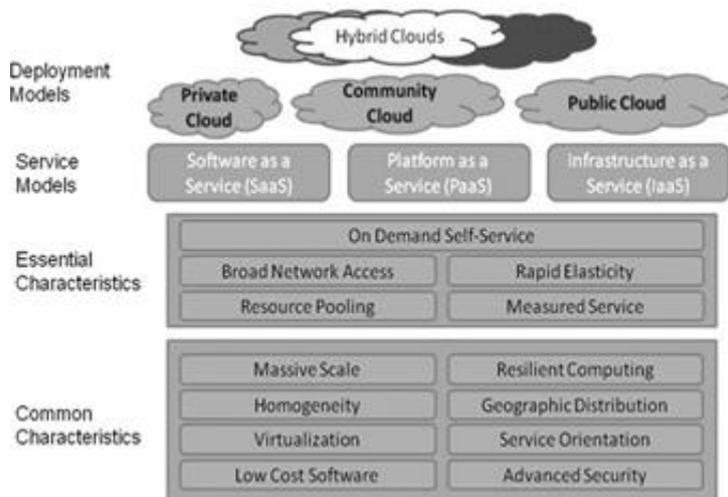


Fig. 2. cloud computing definition

Characteristics of Cloud Models

The five main essential characteristics include:

- **On-demand self-service:** A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.
- **Broad network access:** Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, tablets, laptops, and workstations).
- **Resource pooling:** The provider’s computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand.
- **Rapid elasticity:** Capabilities can be elastically provisioned and released, in some cases automatically, to scale rapidly outward and inward commensurate with demand.
- **Measured service:** Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service.

Service Models

- **Software as a Service (SaaS):** The capability provided to the consumer is to use the provider’s applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings. Examples include Salesforce.com, Google Docs, WebEx e.t.c.
- **Platform as a Service (PaaS):** The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquire applications created using programming languages, libraries, services, and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly configuration settings for the application-hosting environment. Examples include Facebook, Microsoft’s Windows Azure Platform, Yahoo pipes e.t.c.
- **Infrastructure as a Service (IaaS):** The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary

software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but controls the operating systems, storage, and deployed applications; and possibly limited control of select networking components (e.g., host firewalls). Examples include Amazon A3/S3, Amazon EC2, Bungee e.t.c

Deployment Models

The following are the four main cloud computing models [9],17]:

- Private cloud: The cloud infrastructure is operated by a single organization. It may be owned, managed and operated by the organization or a third party and may exist on premise or off-premise. (i.e. enterprise owned or leased).
- Community cloud: The cloud infrastructure is shared by specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policies, and compliance considerations). It may be managed, owned and operated by one or more organizations or a third party and may exist on premise or off premise. (i.e. shared infrastructure for specific community).
- Public cloud: The cloud infrastructure is made available to the general public. It may be managed, owned and operated by a business, academic, or government organizations, or a combination of them. It exists on the premises of the cloud provider.
- Hybrid cloud: The cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

Cloud Computing Architecture for Digital Libraries

The architecture behind cloud computing is a massive network of “cloud servers” interconnected as in a grid running in parallel, sometimes using virtualization could be used to maximize the utilization of the computing power available per server, e.g. to better match the overall workload [20]. The following figure 3 shows the architecture of cloud computing in a digital library.

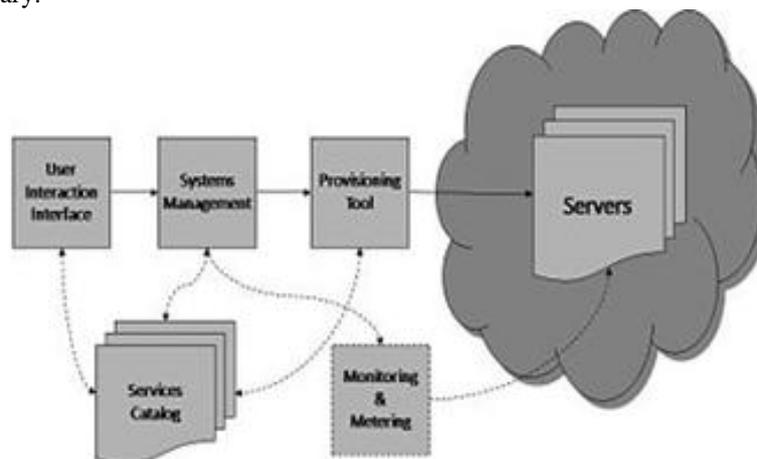


Fig. 3. Cloud Computing Architecture for Digital Library

A front end user interface such as a portal allows a user to select a service from a catalogue. This request gets passed to the system management which finds the correct resources and then calls the provisioning services which allocates resources in the cloud. The provisioning service may deploy the requested software stack or application as well, e.g. via licensing on- demand [20].

- User interface :This enables users to request services;
- Services catalogue: This is the list of services that a user can request;
- System management: This is the piece which manages the available computer resources;
- Provisioning tool: This tool allocates the systems from the cloud to deliver the requested service. It may also deploy the required software;
- Monitoring and metering: This optional piece tracks the usage of the Grid to ensure that resources used can be attributed to a certain user;
- Servers: The servers are managed by the system management tool. They can be either virtual or real.

Cloud computing is not a magic silver bullet technology but considerations have to be made based on university digital library requirements before investing in any of the four deployment models. The challenge for most public university libraries is to integrate both an in-house system and a hosted system from multiple vendors. This problem is further compounded by the capacity of public university libraries who may incur huge expenses to manage and maintain sophisticated ICT systems for their digital library operations.

The solution is to adopt a quality cloud based library service platform to run library applications and services. The cloud based library service should run a service level that anchors above PaaS and employs a hybrid cloud for its deployment. The resultant hybrid library service platform will combine both commercial library services such as discovery services, catalog services, vendor interfaces e.t.c and in-house library services such as institutional repositories, custom applications e.t.c.

V. DEVELOPMENTS

Case Studies on the use of Cloud Computing in Libraries

Emory university library teamed with a commercial firm to develop a prototype system using Amazon's Elastic Compute Cloud (EC2) [14]. Amazon EC2 is a web service that provides resizable compute capacity in the cloud. Amazon's EC2 simple web interface provides complete control over computing resources and it leverages on proven computing environment to quickly scale up capacity as computing resources changes [1]. The study at Emory University to use Amazon's EC2 was to assess whether Amazon's EC2 successful deployment strategy in commercial environments would similarly be adopted in the academic environment. The areas of assessment included cloud configuration and deployment costs; test preparation and analysis, and overall feasibility of the Amazon's EC2 approach. The findings ascertained significantly lower user levels, lower deployment cost and a return on investment (ROI) though not immediate. The study demonstrated that the deployment of digital libraries was worthwhile as an investment based on two conditions (a) where there are significant repercussions from under-sizing a newly deployed digital library and (b) availability of sufficient engineering staff to develop and debug the deployment scenarios [14].

Another survey conducted based on data collected from 72 academic, public and special libraries in USA, Canada, Australia and the UK found that 15.38% of libraries with budgets between \$750,000 and \$5,000,00 used server space rented from cloud computing services. Interestingly, 63.04% of libraries categorized Google as trustworthy, 8.7% as highly trustworthy and none consider it untrustworthy. The level of trustworthiness could be a reflection on Google's growth in cloud computing services such as Google Apps, Google drive and Google email among others. Consequently, 16.9% of libraries have adopted Google Apps as their default means of word processing. In addition, 2.82% of the libraries surveyed considered using cloud services provided by RackSpace in the future.

OCLC conducted a survey on 300 librarians out of 2700 in March 2011 and found that [22]:

- 5% have started cloud computing (AmazonEC2; VMWare; Vcloud Express)
- 13% use cloud computing as Stage and Backup (Dropboxetc)
- 55% used cloud computing Applications (with leaders being Google Docs, Google Calendar & Gmail).
- 66% using cloud based sharing Applications with leader being Facebook; Twitter, Flickr and You tube.
- 19% had created Library related Applications' using Cloud services?

VI. RESULTS

Today cloud computing vendors can provide more computing power in a cost effective way than what is currently provided for by traditional in-house ICT departments. Furthermore, mobile computing is changing the architecture and landscape for ICT.

As a result, the case studies and literature discussed in this paper provides a compelling rationale and an opportunity for public universities to rethink and realign their automation strategies for implementation digital libraries as deployments on cloud computing technologies.

Recommendations

The following are recommendations of this study:-

- The management of public universities should support libraries in the implementation of a digital services program as a milestone towards cloud libraries.
- As a measure of quality of services provided through cloud computing technologies, information technology and infrastructure library (ITIL) should be used to align IT to the digital library services requirements.
- The Government should support all public universities by subsidizing and providing high speed internet bandwidth to support implementation of digital libraries deployment on the cloud and increase access.
- The management of public universities need to support librarians fully by implementing computer labs to enhance access to digital repositories.
- Public university libraries should develop a digital library policy to guide the growth of dynamic changes in ICT by realigning new technology with its digital library services requirements.
- Digital literacy is an important element in the use of digital libraries. Periodic training for both users and library staff should be conducted to equip them with skills to access and explore new applications and services offered by digital libraries deployed on the cloud.
- Public universities need to invest in staff development training programs to stay abreast with the dynamic technology.

Perhaps the best illustration of the importance and encouragement to libraries to transition to cloud libraries is by Taiga provocative statements of 2011[21], that within five years all library collections, systems and services will be driven to the cloud.

VII. BUSINESS BENEFITS

Public university libraries need to remain relevant and competitive by enhancing how users access digital library services and information resources. Consequently, the acceleration of digital revolution is pushing public university libraries to invest in digital libraries that can increase their foot prints on how information users access digital content. Therefore, cloud computing provides a competitive and economical model for digital library services though a "cloud library".

The following gives a snapshot of general problems inherent in public university libraries and identifies beneficial areas in which library services can leverage from cloud computing services [5]:

The Challenges of Public University Libraries

- Most library computer systems are built on pre-web technology
- Systems distributed across the .NET using pre-web technology are harder and more costly to integrate
- Libraries store and maintain much of the same data hundreds and thousands of times.
- With library data scatter across distributed systems the library's web presence is weakened
- With libraries running independent systems collaboration between libraries is difficult and expensive.
- Information seekers work in common web environments and distributed systems make it difficult to get the library into their workflow.
- Many systems are only used to 10% of their capacity. Combining systems into a cloud environment reduces the carbon footprints, making library greener.

Library Services that can benefit from cloud computing services

- Acquisition:- Librarians need to manage increasingly diverse collections
- Cataloguing: - Librarians are seeking to manage an ever increasing body of knowledge and information resources.
- Serials: Librarians are working to maintain and control access to collections spidered across the web.
- Electronic resource:- Librarians are managing burgeoning collections, and ever-changing list of vendors.

It is evident that cloud computing is essential and can ensure that digital libraries in public universities become greener, competitive and provide an environment for innovation. Consequently, cloud computing provides an opportunity for IT departments in public university libraries to assist users to leverage on new products and services available on the cloud.

VIII. CONCLUSIONS

Scalability, collaboration, virtualization and cost reduction among others as driving factors have led to the wide adoption of cloud computing technologies by organizations and academic libraries in universities. Digital libraries in public universities have an opportunity to transform how they balance resources, support and engage information users. Cloud computing is an attractive choice for moving into the future. Not only is deployment of cloud computing technologies cheaper but can be more collaborative, intelligent and available.

Through the adoption of cloud based library services, public universities will invest in a platform that provides a balanced delivery and allocation of digital library resources. Cloud computing therefore, provides computing resources as a service rather than a product where the emergence of "Cloud libraries" services can be accessed on-demand as pay-for-service. However, public universities can tremendously benefit from greater flexibility and economies of scale from the adoption of a quality cloud solution that meets its digital library requirements. Ex-Libris, Dura Cloud, Amazon EC2, Google, Dspace and Polaris Library Systems are among some of the available cloud services for university digital libraries.

With the right environment for reliable and fast network bandwidth, digital library policy, university management support and continuous digital literacy training, the most suitable and sustainable cloud computing model for digital libraries in public universities is the hybrid model which combines both commercial and in-house library services. However, cloud computing has its merits and demerits and universities need to consider its digital library requirements before moving to the cloud.

Early adopters of cloud libraries by digital libraries in public universities will benefit a great deal from integrated and automated library systems that affords its information users an intelligent collaborative network of shared information resources and give users a global foot print. Digital libraries in public universities, therefore, cannot ignore the winds of change in the form of cloud revolution. For most digital libraries in public universities, the only option is to become part of the cloud computing community.

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