

# Migration of a Research Library's ICT-Based Services to a Cloud Platform

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## ABSTRACT

*Libraries have been at the forefront in adopting emerging technologies to manage the library's operations and provide information services to the user community they serve. With the emergence of cloud computing (CC) technology, libraries are exploring and adopting CC service models to make their own services more efficient, reliable, secure, scalable, and cost-effective. In this article, the authors share their experience migrating some of the library's locally hosted ICT-based services onto the Microsoft Azure cloud platform. The migration of services to a cloud platform has helped the library significantly reduce the downtime of its services due to power or network or system outages.*

## INTRODUCTION

Established in 1909, the Indian Institute of Science is a leading advanced education and research institution in the sciences and engineering. Since its inception, the Institute has balanced an emphasis on pursuing basic knowledge with applying its research findings for industrial and societal benefit.

The Institute, which started with just two departments—General and Applied Chemistry and Electrical Technology—now has over 40 departments spread across six divisions: Biological Sciences, Chemical Sciences, Electrical Sciences, Interdisciplinary Research, Mechanical Sciences, and Physical and Mathematical Sciences.

The Institute's JRD Tata Memorial Library (<https://library.iisc.ac.in>) celebrated its centenary in 2011. Established in 1911, the library was one of the earliest central facilities created by the Institute to support teaching and research.

The library offers both conventional and contemporary services to its users. The library's traditional services include reference, referral, cataloguing and classification, circulation, inter-library loan, document delivery, weekly display of recent periodicals and books, and photocopying. Some of the library's current information and communications technology (ICT)-based services include digital repository services for the Institution's research publications and theses and dissertations, a faculty profiling system, a web-based online public access catalogue (Web OPAC), and Shibboleth-based federated access to the library's subscribed online resources. The library also facilitates information literacy services such as library orientations, workshops, seminars, demonstrations, invited talks, training sessions on subscribed resources, trial access to new products and services, and author workshops on the research publishing process.

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Until 2018, the library used its on-premises IT infrastructure to provide these ICT-based services. The library had dedicated computer servers for its email, institutional repository, library website, integrated library management system (LMS), and online journal publishing system. The Institution's faculty profiles system is part of the Indian Research Information System (<https://irins.org/irins/>), a web-based research information management service provided by the Information and Library Network (INFLIBNET) Centre.

The library's in-house servers were ageing, and they were even beginning to fail. Also, managing the in-house servers with limited human resources was increasingly challenging. As a result, the library contemplated moving some of its services to a cloud platform. Even smaller libraries had begun migrating their services to the cloud platform almost a decade ago.<sup>1</sup>

Around 2016, the Institution established the DIGITS (**D**igital **C**ampus and **I**nformation **T**echnology **S**ervices) office to conceive, plan, and create a best-in-class information technology and networking system and support operational excellence through agile IT and networking services. To date, the DIGITS office has, among other projects, successfully migrated more than 70 departmental email servers to a centrally managed cloud-based Microsoft Office 365 suite and developed and migrated the Institute's main website (<https://www.iisc.ac.in>) and more than 150 websites and 10 web portals of Institution departments, centres, and other facilities to the Microsoft Azure platform. The DIGITS office also creates and maintains virtual machines (VMs) on the Microsoft Azure cloud platform for the Institution's departments and offices.

Migration of locally hosted IT infrastructure to a cloud platform offers several benefits to the organization. These benefits include setting up virtual offices accessible from anywhere and at any time, avoiding capital investment in computing infrastructure, taking advantage of the cloud platform's elastic computing resources, avoiding the necessity of having a dedicated IT team, and, most importantly, minimizing downtime and loss of productivity and data. Moreover, a cloud platform offers easy scalability, redundancy, and security. Achieving these features in the traditional in-house hosting of computing infrastructure would be cost prohibitive.<sup>2</sup>

The library has configured three VMs on the Azure platform and has moved some of its ICT-based services to the cloud platform. Migrating ICT-based services to the cloud platform has helped the library significantly reduce the downtime of computer servers.

## **CLOUD COMPUTING AND ITS SERVICE MODELS**

Cloud computing (CC) refers to computer hardware and software provided as a service by another company. The only requirement to access the cloud computing service is a device with access to the internet. Some leading CC service providers include Amazon Web Services (<https://aws.amazon.com/what-is-aws/>), Microsoft Azure (<https://azure.microsoft.com/en-in/>), and Google Cloud (<https://cloud.google.com>).

There are three service models in cloud computing: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). Service providers host software applications on their cloud platforms in the SaaS model. Examples of the SaaS model include Google Apps (<https://workspace.google.com/>) and Microsoft Office 365 (<https://www.microsoft.com/en-in/microsoft-365>). Clients opting for the SaaS model need not worry about installation, setup, running, and maintaining the applications. Service providers will do that for the clients.

PaaS provides a computing platform comprising an operating system, database, programming environment, and application programming interface. Examples of the PaaS model include Amazon Elastic Beanstalk (<https://aws.amazon.com/elasticbeanstalk/>), Windows Azure (<https://azure.microsoft.com/en-in/>), and Google Compute Engine (<https://cloud.google.com/compute>).

In the IaaS service model, clients can obtain computing infrastructure, virtual machines, networking, and storage components on demand and deliver them over the internet. Examples for the IaaS model include Google Compute Engine, Amazon EC2, and Microsoft Azure. In coordination with the DIGITS office, the library initially provisioned three VMs on the Microsoft Azure cloud platform to migrate some of its IT-based services. Table 1 shows the initial hardware configurations of each of the three VMs.

**Table 1.** VM types and their system configurations along with the cost

Virtual machine (VM)	VM type <sup>1</sup>	vCPUs & RAM (GB)	Cost / month (USD) <sup>2</sup>	OS disk (GB) & type	Secondary storage disk (GB) & type	Storage cost / month (USD) <sup>3</sup>	OS
VM1 (IR services)	Standard F4s_v2	4, 8	140	400 (SSD)	600 (SSD)	114	Cent 7.x
VM2 (ILMS)	Standard D4s_v3	4, 16	148	300 (SSD)	200 (SSD)	57	Cent 7.x
VM3 (website)	Standard F4s	4, 8	140	300 (SSD)	200 (SSD)	57	Ubuntu 18.x

<sup>1</sup>As of 2018 and subject to change with time.  
<sup>2</sup>Cost as prevalent in 2018.  
<sup>3</sup>Cost as prevalent in 2018.

A virtual machine (VM) is an on-demand and scalable computing resource available on CC platforms. VMs give better control over the computing environment without buying any underlying physical hardware.

The Microsoft Azure platform offers various VM options, each optimized for different workloads. For example, the D-series Azure VMs provide a combination of vCPUs (virtual CPUs), memory, and temporary storage to meet the requirements associated with most production workloads. Categories in the D-series of VMs include Ds-series, Dds-series, and Das-series. The F-series VMs feature a higher CPU-to-memory ratio, are equipped with 2 GB RAM and 16 GB of local solid-state drives (SSDs) per CPU core, and are optimized for compute-intensive workloads. F-series VMs are costlier than the corresponding D-series VMs (<https://docs.microsoft.com/en-us/azure/virtual-machines/sizes>).

For the secondary storage, apart from the standard hard disk drives (HDDs), VMs support Azure premium SSDs and ultra-disk storage, depending on regional availability. The premium SSDs are designed to support intensive input/output workloads. They are priced almost three times higher than the standard HDDs. The standard disk capacity of an Azure VM's OS disk is 30 GB, and it can be increased to the desired capacity. Apart from the OS disk, one can also have a required amount of secondary disk storage. The cost for the additional disk storage (both OS and data) is

independent of VM pricing, and it depends on storage type and capacity. A vCPU refers to a virtual central processing unit. A VM treats each vCPU as a single physical core.

### **MIGRATION OF THE LIBRARY'S ICT-BASED SERVICES TO MICROSOFT AZURE CLOUD PLATFORM**

Libraries have always been at the forefront of adopting emerging technologies. It is true with CC technology as well. In an interview at the American Library Association annual meeting in Anaheim, California, in June 2012, Clifford Lynch traced 30 years of interactions between libraries and new technologies.<sup>3</sup> With the evolution of CC technologies, libraries have been using CC's SaaS and IaaS service models since 2009 to host their websites, library management system (LMS), and digital repositories. Libraries have been using the CC mainly for SaaS and IaaS services.<sup>4</sup>

As a first step, during mid-2017, the DIGITS office began migrating all the 70+ individual departmental email servers, including the library's, to a centrally managed, cloud-based mailing solution using Office 365 (now Microsoft 365) Exchange Online. After the successful migration of all the email servers, the library shut down its email server. Next, the library decided to migrate some of its locally hosted ICT-based services to the cloud platform in a phased manner.

#### ***Planning the Migration Process: Considering a Single VM or Independent VMs for Each Application***

Before undertaking the migration process, libraries need to consider what types of projects are good candidates for the cloud and what types are not.<sup>5</sup> In the first phase of the cloud migration, the library decided to migrate the following services: (1) institutional repository services, (2) the library management system, and (3) the library website.

Before the cloud migration, the library used three independent on-premises servers to host the above services. A Sun Fire computer server with Intel Xeon processor, 4 GB of RAM, and 2 TB of secondary storage hosted the institutional repository service for research publications using EPrints software and the electronic theses and dissertations service using DSpace software. The LibSys library management system was hosted on an IBM server with Intel Xeon CPU E5-2620 v2 @ 2.10GHz processor, 16 GB RAM, and 1 TB of secondary storage. The library website was hosted on an IBM ThinkServer TS150 server with Intel Xeon CPU E3-1225 v5 @ 3.30GHz processor, 8 GB RAM, 1 TB of secondary storage.

All three computer servers had been in use for nearly 10 years and were long overdue for replacement. As the library contemplated upgrading its ICT infrastructure, provisioning VMs on the Azure cloud platform through the DIGITS office was a stimulus. Next, the library had to decide whether to go with a single VM with robust hardware configuration to host all three applications or to provide independent VMs for each service.

Based on the experience gained from hosting two IR services on a single server, the library decided to go again with a single VM with robust hardware configuration to host the IR services. The LMS is a critical application for managing all library functions; therefore, the library decided to host it on a separate VM. A third VM is used to host the library website. As the library eventually plans to move its other ICT-based applications to the Azure platform, it could migrate and distribute those applications on the existing three VMs based on the utilization and load on each of the three VMs.

Initially, the library opted for two VMs in the F-series and one in the D-series with premium SSDs for all three VMs. After observing performance and price for about three months, the library had

one of the two VMs (VM3) moved from F-series to D-series and downgraded the OS and data disk types of all the three VMs to the standard disk drives. The data disk on VM3, hosting the library website, was dropped as the OS disk capacity was more than adequate to run the service. Table 2 shows the revised VM types and their configurations.

In April 2020, most of our students and faculty members started working off-campus because of the onset of the COVID-19 pandemic. To facilitate seamless access to licensed online resources from off-campus, the library set up federated access through Shibboleth SSO.<sup>6</sup> The library provisioned a new virtual machine (VM4) with a system configuration as indicated in table 2.

**Table 2.** Revised VM types and their system configurations along with the cost

Virtual machine (VM)	VM type <sup>4</sup>	vCPUs & RAM (GB)	Cost/month (USD) <sup>2</sup>	OS disk (GB) & type	Secondary storage (GB) & type	Storage cost / month (USD) <sup>3</sup>	OS
VM1 (IR Services)	Standard F4s_v2	4, 8	147	400 (SSD)	600 (HDD)	39	Cent 7.x
VM2 (ILMS)	Standard D4s_v3	4, 16	148	300 (SSD)	200 (HDD)	21	Cent 7.x
VM3 (Website)	Standard D2s_v3	4, 8	81	300 (HDD)	None	Nil	Ubuntu 18.x
VM4 IdP Server	Standard F2s_v2	2, 4	71	300 (HDD)	None	Nil	Ubuntu 18.x

<sup>1</sup>As of 2019 and subject to change with time.  
<sup>2</sup>Cost as prevalent in 2019.  
<sup>3</sup>Cost as prevalent in 2019.

## THE CLOUD MIGRATION PROCESS

Cloud migration is the process of moving applications and data from an organization's on-premises computers to a cloud platform. Before undertaking the migration process, the requisite software applications must be installed and configured on the VMs. Then, the data corresponding to each application must be backed up on the on-premises system and moved to the corresponding VMs. Coordination with the campus network support team is essential to ensure the VMs are accessible on the internet with all the security measures in place. So, every application migrating to the cloud platform has to go through a cloud migration process.

In the following sections, the authors briefly describe the library's migration process to migrate three of its ICT-based services to the Azure cloud. The library completed the entire migration process in about three months.

### ***Migration Process for the Research Publications Repository***

ePrints@IISc, the Institute's institutional repository (IR), was established in 2002 and holds nearly 55,000 publications. It is one of the earliest repositories in this part of the world.<sup>7</sup> The IR runs on EPrints (<https://www.eprints.org/uk/>), the world-leading open-source digital repository platform. Developed at the University of Southampton for over 20 years, EPrints has provided stable, innovative repository services across academia and beyond. EPrints is a stable, flexible,

reliable software and ideal for maintaining institutional repositories. Before the migration, the library hosted the publications repository on an on-premises server for almost 17 years.

EPrints software depends on other software, including Apache web server with mod\_perl (<https://httpd.apache.org/>), MySQL/MariaDB (<https://mariadb.org/>) relational database management system, Perl programming language, and several Perl modules. EPrints software bundles many required Perl modules, but some are installed depending on the underlying operating system (OS). For example, for the ePrints@IISc repository installed on a VM running the Cent OS, the library has installed Apache web server with mod\_perl, MariaDB relational database management system, and a few missing Perl modules. After installing all the dependent software, the library followed the steps listed below to migrate the publications repository to the VM on the Azure cloud platform:

1. Installed the latest version of the EPrints (3.4.1) software on the VM and incorporated all the local customizations done at the configuration and code levels.
2. Created a new repository and retained the existing repository name.
3. Created a new MariaDB database and assigned appropriate grant permissions to the database.
4. As the database structure had changed in the latest version of EPrints, executed the necessary scripts built into the EPrints software to update the EPrints database structure.
5. Imported customized Institute-specific subject headings to override the default ones.
6. Moved the database and full-text backup files to the VM using WinSCP—an open-source, free FTP client (<https://winscp.net/eng/docs/introduction>).
7. Restored the backups comprising EPrints MySQL database and full-text files on the VM to the corresponding locations on the file system and uncompressed database and full-text files.
8. Imported the MySQL database into the new MariaDB database on the VM.
9. Regenerated all the static pages of the repository, abstracts of all the records, and browse views for the year, author, document type, and subject categories on the VM.
10. Enabled hypertext transfer protocol secure (HTTPS) for log in and account creation links.
11. Configured postfix (<http://www.postfix.org/>). Postfix is a free and open-source mail transfer agent that routes and delivers electronic mail.
12. Coordinated with the Institute's network support team to make necessary changes in the DNS entries to reflect the VM's new public IPs and enable the VM to send and receive emails.
13. Created crontab entries on the VM to run the cron jobs. A cron job is a time-based job scheduler in a Unix-like computer operating system. Some of the cron jobs include updating the latest records added to the repository, displaying the latest count of records in the repository, and updating the browse views of the repository.

### ***Migration Process for the Electronic Theses and Dissertations Repository***

Established in 2005, ETD@IISc, the Institution's electronic theses and dissertations repository, is one of the earliest ETD repositories in this part of the world.<sup>8</sup> The library uses DSpace software (<https://duraspace.org/dspace/>) to maintain the ETD repository. To date, the repository holds nearly 6,000 of the Institute's ETDs. Before the migration, the library hosted the ETD repository on an on-premises server for almost 13 years.

DSpace software is dependent on several third-party software applications and tools, including Java JDK, Apache Maven (<https://maven.apache.org/>), Apache Ant (<https://ant.apache.org/>), PostgreSQL (<https://www.postgresql.org/>) or Oracle (<https://www.oracle.com/in/database>) relational database management system, and Apache Tomcat Servlet Engine (<http://tomcat.apache.org/>).

The library followed the steps listed below to migrate the ETD repository to the VM on the Azure cloud platform:

1. Installed all the DSpace-dependent software packages and the latest version of DSpace software (version 6.3).
2. Configured the DSpace software to incorporate the native customizations.
3. Created communities and collections to reflect the divisions and the corresponding departments and centres of the Institute using Java Script.
4. Set the access permission for each collection of the repository based on the users and groups belonging to the collection.
5. Modified the metadata of the ETDs from the on-premises version using a script. The modified metadata was imported into the latest version of DSpace.
6. Copied and moved ETD items comprising PDF files from the on-premises server to the VM.
7. Enabled hypertext transfer protocol secure (HTTPS) for the ETD site.
8. Customized the default ETD site for a better look and feel.
9. Created crontab entries on the VM to run the cron jobs to take incremental backup and display the ETD count on the landing page.

The new version of the DSpace user registration system was modified to enable only people with an Institute email id to register with ETD@IISc. In addition, the registration process captures the registrant's department and the division, which helps automate the process of assigning the registrant to a specific collection of the repository. Therefore, a user will submit an ETD only to the designated collection.

#### ***Migration Process for the LibSys Library Management System***

The library has been using LibSys (<https://www.libsys.co.in/>), a commercial LMS, for over 25 years. LibSys is dependent on several other software applications, including WildFly application server (<https://www.wildfly.org/>), Java JDK, and MySQL (MariaDB) relational database management system. The steps involved in migrating LibSys to the cloud (VM2) are listed below:

1. Installed all the LibSys-dependent software components and the latest version of the LibSys software on the VM.
2. Restored the MariaDB database backup.
3. Made required changes in the LibSys configuration files.
4. Installed and configured postfix email transfer agent for email communication.
5. As the LibSys service and the OPAC run on nonstandard ports, the library coordinated with the network support team to open the required communication ports on the VM.

### ***Migration Process for the Library Website***

The library uses Drupal (<https://www.drupal.org/>), a content management system, to host its website. The steps involved in the migration process are listed below:

1. Installed all the Drupal-dependent software, including Apache web server, MariaDB, and PHP (<https://www.php.net/>), on the VM.
2. Installed one of the latest versions of Drupal using its web-based installer.
3. Installed the required Drupal plugins and the Drupal theme.
4. Restored Drupal database backup on the VM.
5. Installed and configured postfix email transfer agent for email communication.

After completing migration processes, the library coordinated with the network support team to make changes in the domain name system (DNS) to enable access to all the three VMs on the internet.

### ***Monitoring the Azure Virtual Machines***

Azure Monitor (AM) for VMs includes a set of performance charts that target several key performance indicators to determine how well a virtual machine performs. The graphs show resource utilization over a period to identify bottlenecks and anomalies or switch to a perspective listing of each VM to view resource utilization based on the metric selected. While there are numerous elements to consider when dealing with performance, Azure Monitor for VMs monitors critical operating system performance indicators related to the processor, memory, network adapter, and disk utilization. Performance complements the health monitoring feature and helps expose issues that indicate a possible system component failure, support tuning and optimization to achieve efficiency, or support capacity planning (<https://docs.microsoft.com/en-us/azure/azure-monitor/insights/vminsights-performance>).

AM is accessible only to the cloud administrator. Based on the AM charts, the library's inference has been that the IR server (VM1) hosting publications and ETD repositories needs capacity planning. CPU utilization is reaching maximum capacity quite frequently. Therefore, the library plans to move the ETD repository to an independent VM.

The utilization of the ILMS server (VM2) is less than optimal. Therefore, the library decided to migrate publication of the Institution's *Journal of the Indian Institute of Science (JIISc)* from on-premises hosting to the ILMS server (VM2) on the Azure cloud.

For hosting *JIISc* on the Azure cloud platform, the library uses the Open Journal System (OJS) platform (<https://pkp.sfu.ca/ojs/>). OJS is open-source software for the management of peer-reviewed academic journals. OJS is dependent on other software and tools, including Apache web server, MySQL or PostgreSQL, and PHP.

The library used the virtual hosting concept to host multiple sites on a single VM (VM2). Virtual hosting is a method of hosting multiple domain names on a single server.



## **BENEFITS OBSERVED OF MIGRATING TO THE CLOUD**

Moving some of the ICT-based services of the library to the Azure cloud platform has resulted in the following benefits:

1. Service reliability has improved significantly as the reliance on the in-house ageing servers has been done away with.
2. Cloud migration has made the library's computing infrastructure more flexible. It can be scaled up or down as per the library's requirement.
3. Operational logs and usage metrics are easy to obtain.
4. Set alert rules are based on VM metrics.
5. The cloud hosting company's managed services include periodic backups, ensuring that data is secure.
6. Users can now quickly move between the library and home (or any other location) and access all their research.
7. Another significant benefit to cloud computing for library users is sharing information easily. Libraries provide collaborative spaces within the building, but patrons also can use collaborative online spaces. OneDrive provides access to online storage and allows sharing of files and folders among approved users.<sup>9</sup>

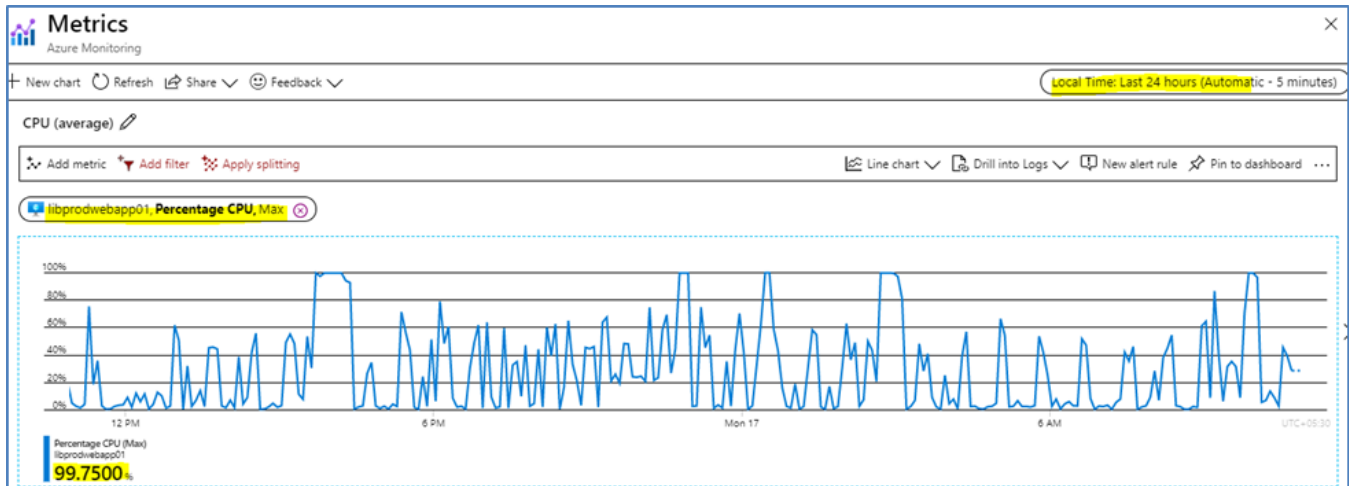
## **LESSONS LEARNED DURING AND AFTER THE MIGRATION PROCESS**

Initially, the library opted for two VMs on Azure's F-series and one in the D-series with the SSD storage devices for all three VMs. As stated above, the pricing of the Azure VMs depends on the hardware configuration of a specific type of VM series. For example, the F-series with a particular hardware configuration and SSD costs more than its counterparts on the D- or B-series with the same hardware configuration with a standard HDD. Libraries should, therefore, have a clear understanding of the VM types and the corresponding costing aspect. After observing VMs performance and the cost aspect for a few months, the library moved one of the two VMs from the F-series to the D-series and switched to standard hard disk drives for all three VMs. The changeover did not result in any performance degradation, but the cost of the secondary storage came down by about one-third.

The library maintains two institutional repositories, one for research publications using the EPrints application and the other for theses and dissertations using the DSpace application. The library decided to migrate both the repositories to a single VM. However, it turns out that this decision was not a prudent one, for the Tomcat server running EPrints crashes, often resulting in downtime for the ETD service.

The VM usage metrics reveal that the DSpace application often utilizes nearly 100% of CPU capacity, which leads to the freezing of the Tomcat server, resulting in ETD service becoming unresponsive. The library contemplates upgrading the hardware configuration or setting up the two repository applications on two VMs. The library is checking to understand if the issue is with the Tomcat server configurations.

The graph shown in figure 1 is the screenshot of Azure's metric monitoring of the VM1 running EPrints and DSpace applications. The peaks in the graph represent the CPU usage by the DSpace application. It is evident from the graph that quite frequently, the CPU usage of the DSpace application is reaching 100%, which eventually leads to the freezing of the Tomcat web server.



**Figure 1.** Screenshot representing the CPU usage of EPrints and DSpace applications.

The professional library staff administered and managed the on-premises ICT-based services of the library. Therefore, the library did not encounter any technical challenges during and after the cloud migration process.

Other libraries that intend to migrate their services to a cloud platform should ensure that the library staff entrusted with the migration process are comfortable working with the command prompt, especially in the Linux operating system environment.

## CONCLUSIONS

It has been more than two years since some of the library's ICT-based services migrated to the Microsoft Azure platform. To date, the library has not experienced a single instance of its servers being down because of a power outage, network issue, or crashing of the VMs. However, there have been issues with specific services like the Apache Tomcat Servlet Engine or the Apache web server crashing, resulting in the corresponding application being unresponsive. Such behaviour can result because, at times, the system resources, especially the CPU and RAM, may be used to their capacity. Restarting the specific service will ensure that the corresponding application comes up. Therefore, it is essential to keep track of the RAM and CPU usage of the VMs and upgrade them if the situation warrants such an action. The rapid elasticity characteristic of cloud computing facilitates organizations to configure optimal computing resources based on actual requirements.

Based on the library's initial experience running the ICT-based services on a cloud platform, the authors suggest that deploying two different institutional repository software platforms like EPrints and DSpace on a single VM may not be a good idea. The Tomcat instance powering the DSpace site runs with higher CPU usage, swinging up to 100% and at times going beyond 100% CPU usage. The high CPU usage by the Tomcat instance can eventually lead to its freezing, resulting in the corresponding service being inaccessible.

Working with the VMs demands some degree of familiarity in working in the command prompt. Library staff who are not comfortable working in the command prompt will require additional training in getting used to the VM environment. In our case, the training was not necessary as the authors had adequate experience working in the Linux operating system. Also, library staff managing the cloud infrastructure need to coordinate with the organization's networking and

email support staff to configure the VMs to be accessible on the internet, email communications, and enforce security measures.

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## ENDNOTES

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