Common inhibiting factors for technology shifting from physical to virtual computing

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ABSTRACT

Due to the rapid growth of cloud computing demands and the high cost of managing traditional physical IT infrastructure, virtualization technique has emerged as a foremost and key success factor for technology adopters to attain the intended benefits. However, the transition from physical to virtual computing is confronted with overwhelming adoption inhibitors rarely known to adopters. This paper examines inhibiting factors which have triggered to low adoption rate of virtualized computing infrastructure despite being the fastest growing and globally accepted technology. Survey results from 24 companies indicate that lack of relevant virtualization skills, security uncertainties, low computing demands and change management issues are the utmost inhibitors. In public entities, the slowness in the adoption process is highly caused by the low computing demands, lack of virtualization coverage in ICT policies, resistance to change, choice of technology and the lack of virtualization project priority in the ICT master plans. On the other hand, the use of open-source hypervisors and support and maintenance are specific inhibitors affecting the private sectors. This paper is useful for adopters who have virtualized their server resources or have a plan to virtualize in the near future.

Keywords: Server; Virtualization; Adoption; Hypervisor; Inhibitor
DOI: https://dx.doi.org/10.4314/ejst.v15i2.2

INTRODUCTION

Virtualization of server resources is one of the fastest emerging computing techniques globally and a key factor to accept and grow cloud computing. Virtualization process has revolutionized the way online services are managed

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within the IT industry by maximizing the use of server resources, application security and significant reduction in IT costs. The operational cost in IT sector is likely to double in the near future if companies do not virtualize their servers today.

A virtualization system is implemented when a physical host machine is divided into multiple execution environments called virtual machines (VMs). Each VM is created with its own virtual resources for CPUs, RAMs, HDDs and NICs. The number of VMs and the allocation of virtual resources is constrained within the physical specifications of the server machine, and are either fixed as static or varied as dynamic resource depending on the size of the computing workloads. To create virtualization environment, a special software called hypervisor should either be installed on the hardware for type 1 hypervisors or on the host operating system (OS) for type 2 hypervisors.

In a typical virtualized environment, computing resources are combined between multiple OSs so that each VM can access the required resources (Ameen and Hamo, 2013). This approach facilitates implementing heterogeneous architectures in the same physical infrastructure (Bays *et al*., 2015) where varieties of OSs can be installed in VMs.

It is evident that server virtualization brings tremendous benefits to adopters and clear economic values through optimization of IT savings if the adoption process is well structured and implemented (Uhlig *et al*., 2005; Infographic, 2014). This clearly explain why the adoption pace and usage rate at global level has rapidly expanded with high acceptability level (Padhy, 2012; Rudy, 2014; Biggs, 2015; Malla, 2017). With existing IT budget constraints in many developing countries (Bakari, 2007), virtual techniques have been considered as yardstick for implementing any cost-effective IT projects. To survive in a competitive environment, organizations with a restricted budget and limited resources must utilize opportunities provided by cloud computing (Zhang *et al*., 2021) based on virtual technologies. In Tanzania for instance, this approach has now become a national focus for both public and private sectors (Ally, 2018) after the establishment of a multimillion-dollar state-of-the-art tier-3 national Internet data center (MoCST, 2015) as one step towards becoming a middle-income country as guided by the national development vision of 2025 (NICTPP, 2016). The data center provides platform to utilize emerging ICT opportunities such as cloud computing as a critical factor for long lasting national socioeconomic development as recognized in the current national ICT policy (NICTPP, 2016). ICT contribution to the Gross Domestic Product (GDP) has increased from 1.5% in 2004 to 2.4% in 2013 (NICTPP, 2016) with no virtual techniques deployed. It is apparent that the percentage increase in the national GDP has been achieved when the average utilization of computing

resources is ranging between 5% and 15% in a non-virtualized server. This is due to the fact that virtualization techniques offer efficient resource utilization in physical servers to extraordinary levels through creating many VMs, each working as full-fledged computer with its own OS, CPU, RAM, HDD and NIC. Generally, virtualization trends in Africa are very promising with increasing number of data centers (Ojika *et al*., 2021) despite various challenges. The fact that the continent suffers unstable and unreliable electricity supply (Addo *et al*., 2019), virtualization process remains vital for adopters. By properly implementing appropriate methods for server virtualization, the average utilization rate of server resources can significantly be increased to the extent that adopters would noticeably achieve a remarkable GDP growth in the country.

However, shifting from physical to virtual computing is still not promising at a local level despite its huge benefits in technology, organization and management, and its high acceptance rate at global level (Tsai, 2016; Malla, 2017). Adopters need to consider multiple factors towards the adoption process of virtualization process for them to attain maximum benefits (Zhang *et al*., 2021). The slow adoption rate is mainly attributed to existence of various inhibiting factors. Deployment of virtualized IT infrastructures is a multidimensional change and it is a paradigm shift for both digital enabled and non-digital firms. Although adopters are determined and are striving to implement cost-effective IT solutions including server virtualization, there is a need to identify the inhibiting factors which hinder sufficient adoption and usage by adopters that prevent them from attaining maximum virtualization benefits. Therefore, this paper aims to identify the common inhibiting factors and their impact on the growth of virtualized server computing among public and private entities so that adopters can make informed decisions when shifting from physical to virtual computing.

METHODOLOGY

This study is based on empirical research (Lennart and Christine, 1997) for the exploration of adopter's level of virtualization, and in this study, we applied a case study approach to get in-depth explanation of adoption process (Alavi and Carlson, 1992; Silverman, 2010). The assessment items that have been used in this study are the constructs that can inhibit the adoption and usage processes when implementing server virtualization. Eleven constructs were extracted qualitatively from relevant literature. The set of constructs were deductively developed through an approach of thematic analysis (Braun and Clarke, 2006) to include the following: IT infrastructure challenges, cost of investment,

knowledge and skill level, virtualization software selection issues, clear policy statements, open-source issues in virtualization, support and maintenance, security uncertainties, resistance to change, extent of computing demands, and virtualization project priorities. This paper therefore uses these constructs to ascertain the most common inhibiting factors facing adopters in the process of shifting from physical to virtual computing.

Data collection methods and tools

Based on the nature of the study, a survey method was used for data collection by means of self-administered questionnaires (Kumar, 2011; Sekaran and Bougie, 2016), and a critical document review of 13 ICT policies, five ICT master plans, and six IT project reports to determine if virtualization aspects are covered and incorporated into the guiding documents of the adopters. For triangulation purpose (Eisner, 1991), a participant observation in 19 companies was also employed to assess adopters' level of virtualization (Yin, 1994).

Sampling selection

For a sensible and a meaningful sampling process, research respondents were selected purposively from a group of people who are responsible to oversee the day-to-day management of IT operations and services in the visited organizations. They include IT managers, IT directors or heads of ICT units. A non-probabilistic sample size proposed by Saunders *et al*. (2009) was used for the 24 organizations participated in the study. They include 13 organizations which have already implemented server virtualization projects, six (6) having plans to virtualize, and five (5) which are in the process of virtualization. The selected organizations come from various sectors such as banks and finance (FIN), telecoms/mobile companies (TEL), ICT/Software firms (ICT), Government ministries, authorities, agencies and departments (MDA), and Academia/Universities (EDU).

Considering that the virtualization state of most of adopters were unknown in the early research stage, a snowball sampling technique of Heckathorn and Cameron (2017) was applied to get data from 15 public and 9 private companies. Table 1 provides demographic profiles of respondents based on their economic sector and educational level. The majority of respondents were from finance and banks (29.2%), ICT firms (29.2%), and social services (25%). The majority were Masters graduates (71%), followed by Bachelor (21%) and PhD (8%) while there was no respondent with certificate or diploma qualification. Table 2 shows demographic profile of respondents based on years in service and years in using VMs.

Table 1. Number of respondents per group based on adopter's category.

SN	Adopter's Category	No. of Respondents		Education Level					
				Bachelor		Masters		PhD	
		N	%	N	%	N	%	N	%
1	FIN	7	29.2	0	0.0	7	29.2	0	0.0
2	EDU	2	8.3	0	0.0	0	0.0	2	8.3
3	TEL	2	8.3	0	0.0	2	8.3	0	0.0
4	MDA	6	25.0	3	12.5	3	12.5	0	0.0
5	ICT	7	29.2	2	8.3	5	20.9	0	0.0
	Total	24	100	5	20.8	17	70.9	2	8.3

Table 2. Experience in Years in Service and Years in using VMs.

SN	Experience	No. of Years		
		Min	Max	Mean
1	Years in Service	3	20	9
2	Years in Using VMs	2	8	5

The average number of years in service for the respondents is 9 years while the average years of experience in using VMs is 5 years ranging from 2 to 8 years. These years of experience in using virtualization systems is vital and sufficient to determine common inhibiting factors for shifting from physical to virtual computing. Data were analyzed using descriptive statistics and correlation analysis. For the allocation of virtual resources among adopters, a two-way ANOVA was used as a statistical computation to analyze the size of vRAMs and vHDDs based on the adopter's type and service sectors. To find the correlation between years of personnel in-service and their experience in the virtual computing, a Pearson's correlation analysis was conducted from all responses.

RESULTS AND DISCUSSION

Leading inhibiting factors

The overall ranking of all inhibiting factors for the adoption of server virtualization is summarized in Table 3. Findings show that the lack of the required skills and security uncertainties in virtualization followed by low computing demands and the change management issues were the most significant inhibiting factors facing adopters from shifting from physical to virtual computing. Figure 1 shows agreement level of inhibitors:

The challenges related to IT infrastructure is the least considered as inhibiting factor that hinders adoption process despite experiencing unreliable power supply, Internet accessibility and bandwidth size that persist as major issues for

efficient IT infrastructure (Figure 1). This finding confirms that the non-virtualized physical server resources are heavily underutilized at 15% maximum.

Although shifting from physical to virtual computing promises a drastic and significant reduction of IT cost (Infographic, 2014) throughout its entire virtualization life, yet the initial cost of investment remains to be a vital deciding factor for the shift.

Table 3. Ranking of virtualization process inhibiting factors.

SN	Missing catalyst for virtualization adoption	Inhibitor code	Adopters (*N=24*)				Total (*N=24*)	
			Public (*N=15*)		Private (*N=9*)			
			N	%	N	%	N	%
1	Security uncertainties in virtualization	SUV	15	100	9	100	24	100
2	Knowledge and awareness level	KAL	15	100	9	100	24	100
3	Change management challenges	CMC	11	73.3	4	44.4	15	62.5
4	Low computing demands	LCD	12	80	3	33.3	15	62.5
5	Lack of clear policy statements	CPS	12	80	0	0	12	50
6	Low virtualization project priority	VPP	9	60	3	33.3	12	50
7	Virtualization software selection issues	VSS	11	73.3	0	0	11	45.8
8	Open-source issues of hypervisors	OSI	5	33.3	4	44.4	9	37.5
9	Support and maintenance	SMI	5	33.3	4	44.4	9	37.5
10	High cost of investment	HCI	6	40.0	3	33.3	9	37.5
11	IT infrastructure challenges	IIC	5	33.3	2	22.2	7	29.2

Discussion of common inhibiting factors

Security uncertainties in virtualization

Security uncertainty is a serious hurdle when shifting from physical to virtual computing. This is simply because VM is just a computer file which can corrupt, dislocate, or get lost. Furthermore, all VMs are physically surrendered into one server which when the host is compromised, all VM files can be exploited to open door for the attack at application level. Being a top ranked adoption inhibitor, the result concurs with Singh *et al*. (2016) who claimed that about 74%

of all adopters are uncertain about virtualization security enough to create a fear factor in the transformation process. Thus, security remains as a vital decision-making question in the virtualization process.

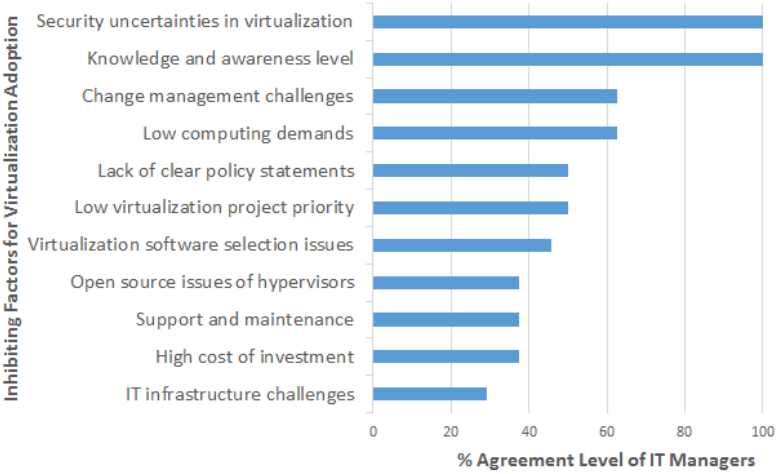

Figure 1. Results of virtualization process inhibiting factors.

Critical interpretation is that adopters have been essentially operating at a very high security risk for almost all five years in managing virtualized servers due to lack of in-house expertise. To fill the gap, adopters depended on security outsourcing. This is in consistent with Sandanayake and Jayangani (2018) who confirmed security as a major security challenge in cloud systems due to lack of awareness. Very little is known about virtualization security (Tsai *et al*., 2012). Although security trust is based on VMs isolation (Madnick and Donovan, 1973; Kirch, 2007), the increasing cloud attacks (Higgins, 2007; Jennifer, 2013; Moghadam, 2013; Kanoongo *et al*., 2014; Nazir and Lazarides, 2016; Thales, 2018) convey a simple message that adopters should remain worried about security uncertainty. The study conforms precisely with Wueest (2014) who stated that the security challenges are based on threats, attacks, and virtual-based intrusion detection and penetration tools. Security failures due to adopter's misconfigurations is much superior than software design weaknesses (Arif and Shakeel, 2015) implying that knowledge is a key gap. Some of the key security issues which prevents a shift from physical to virtual computing include capacity of the software from responding to web attacks, isolation level, risks due to open-source innovation, patching process, untrusted software maturity state, and support.

Knowledge and awareness level

Lack of relevant virtualizations skill was found a major and utmost barrier amidst adopters which forbid them from shifting from physical to virtual computing (Figure 1). In view of the respondent's profile where over three quarters have Masters level in IT and computer science discipline with average of nine years of experience, an imperative inference of the findings advocates to serious lack of enough coverage of virtualization topics in academic curricula as well as relevant in-service training programs. This is justified by a Pearson's correlation coefficient which was found with a weak positive relationship of $(r(152) = 0.104, \rho < 0.01)$ between experience in virtualization technologies and education level as well as relationship of $(r(152) = 0.275, \rho < 0.01)$ between employment years and education level. These values can be interpreted that majority of IT personnel gain virtualization skills from the field rather than from the academic environment.

This statistical finding conforms with the real situation in most developing countries where the coverage of systems virtualization in computer science curricula is very limited or not at all. The interpretation coincides with Brooks *et al*. (2018) who found that recruiters put much focus on years of experience one has spent in employment tenure instead of appropriate skills when advertising job ads. A need for integrating and harnessing virtualization courses in IT and computer science curriculum to have dynamic academic programs which cater the change of market needs, technologies and computing techniques is imperative. Integrating new topics in existing curriculum to satisfy the computing needs is in line with recommendations by Furfaro *et al*. (2016) and Soceanu *et al*. (2017).

Furthermore, lack of virtualization knowledge related to threat sources, attack types, and intrusion detection and prevention system tools imply that majority of adopters operate in a very high risk to counter security attacks, thus a need to invest in enhancing personnel skills is inevitable.

Change management challenges

The complexity of shifting from physical to virtual computing is also associated with readiness of people in the organization. Users are motivated when they are involved throughout the entire adoption process. Due to newness of virtualization techniques, it was found that almost half of adopters depend on the involvement third-party experts through outsourcing process. However, for data sensitive systems which require high security level, outsourcing approach is not practical. Thus, lack of inhouse expertise and motivation among key IT staff as well as

outsourcing risks together have resulted into the adoption deadlock. The fear factor among IT personnel from losing their jobs have scaled up to change management issue because in virtualized environment only fewer IT personnel would be required for server administration purpose, thus leading to job redundancy and idleness. Thus, it is vital to get IT people on board in early stages by ensuring that they acquire the relevant skills required in order to be in pace with rapid change of virtualization technologies in the IT world.

Low computing demands

Low computing demands among several adopters contribute to slow the adoption process. Number of applications and size of data transacted per second is still very low in public entities especially those in education sector and government ministries and departments. A perfect interpretation of low computing demands among adopters without service disruptions indicates that adopters rely on *ad hoc* practices for the allocation of server resources for processing (virtual CPUs), memory (virtual RAMs), storage (virtual HDDs), and networking (virtual NICs). With the *ad hoc* practices, adopters may be forced to go virtual in the very near future due to constant increasing of computing workloads and the rise of big data aspects. Thus, adopters will no longer suffer the underutilization of hardware resources between 5% to 15% as prescribed by Golden (2011), instead more viable virtual storage techniques will be required by the adopters. This is already the case in most private sectors where majority of the adopters are from the telecoms, finance, banking, and mobile companies.

Lack of clear policy statements and low virtualization project priority

Lack of virtualization coverage and priority in the institutional ICT policies and IT projects has been found as one of the inhibiting factors towards the adoption of virtualization techniques. Three quarters of the adopters were found to have ICT guiding policies but only 25% of them have their ICT policies with limited virtualization coverage. This implies that three quarters of the adopters have experienced a blind shift from physical to virtual computing due to lack of guiding policies. Technology adoption without clear guiding policy is very risky as it opens up a door for adoption malpractices among IT people. The findings show that the missing virtualization coverage in ICT related policies and projects are due to lack of pace with growing virtualization trends and awareness among IT executives. Thus, with missing clear guidance, the IT personnel commit *ad hoc* practices and are left with the most privilege which may influence critical decisions within organizations.

Virtualization software selection issues

Selection of appropriate virtualization software is very tricky because vast options exist in the market. Regardless of the server capacity, the performance of the virtual machines depends heavily on the type of the installed software. Virtualization software differ in terms of security, isolation level between virtual machines, the maximum possible number of created virtual machines, size of the computing resource allocation for the virtual CPU, virtual RAM, virtual HDD, and virtual NIC and compatibility aspect to accommodate homogeneous and heterogeneous computing infrastructure. Thus, the type of a chosen virtualization software is a key for adopters to attain intended benefits. The same was argued by Oljira (2020).

Software selection is mainly done by server the administrator followed by third-party consultants through outsourcing process in most adopters due to lack of clear guidelines on the virtualization process (Table 4). This has resulted into a lot of inconsistencies on the number of virtual machines, allocated resources, file formats, and nomenclature system.

Table 4. Adopters' decision process for software virtualization.

Sn	Adopters' decision process	Rate (%)
1	Server admin	90
2	Consultant/outsourced	60
3	ICT steering committee	50
4	Stated in ICT policy	20
5	Experience from other organizations	20

Other huddles towards software selection include restrictions on use of specific server brands (HP blade, Dell, Huawei, IBM) which was mainly found in data sensitive sectors such as in banks, finance, telecoms, and mobile companies. Main issue here is adopters do not bother existence of inbuilt hardware virtualization capabilities such as Intel VT-X or AMD-V. Thus, some of the organizations found it difficult to shift from physical to virtual computing because legacy systems without inbuilt virtualization capabilities existed.

Other inhibiting factors in virtualization process

Other factors were found to have a very low impact to be considered as inhibiting factors towards adoption of server virtualization. These are the IT infrastructure challenges, support and maintenance, high cost of investment, and open-source issues. Most of the adopters were found to have substantial IT infrastructures. This is supported by the fact that the utilization ranges between an average of

10% and 15% of the total server capacity in most organizations. Although a general result shows that IT infrastructure is not a serious inhibiting factor, however among the issues associated with IT infrastructure such as space, power, performance, storage, control and management, power supply has been noted as major issue that hinder infrastructure performance.

For the support and maintenance, it was found that three quarters of the adopters receive support from vendor through direct support and trusted vendor website. Other support sources include use of public internet discussion forums and open mailing lists. Support and maintenance are the key factor on the choice of the low-cost open-source software. Adopters require assurance of the software maturity level in order to use it. Results show that most of data sensitive firms such as telecoms and finance companies depend heavily on vendor support while ICT firms and public organizations depend on the public internet forums. The open-source software are freely released as prototypes and previews intended for market and expert feedback. The results show that the open-source prototypes are released without reaching a functional maturity stage. One-third of adopters are not able to perform the premature analysis of the adopted software before using it. This can result into the software installation with lots of security bugs.

Comparison between public and private adopters

A comparative analysis was conducted to rank adoption inhibitors between public and private entities (Table 3). Both public and private sectors were found to be highly influenced by the utmost and top adoption inhibitors which are the security uncertainties in the virtualization process and the knowledge and awareness level among adopters. Apart from these two leading adoption inhibitors, other inhibitors in the public sectors include low computing demands and lack of clear virtualization coverage in the policy statements, each with 80%, followed by change management issues for IT personnel and virtualization software selection issues each with acceptable level of 73.3%, and the low virtualization project priority in the ICT master plans by 60%. Unlike in public entities, the issues related to change management and low computing demands are less significant to be considered as major inhibitors for the virtualization adoption for private sectors. Furthermore, lack of clear policy guidelines and software selection issues are not problems at all in private sectors.

Both public and private sectors are faced with adoption challenges related to open-source issues, hypervisor support and maintenance, cost and IT infrastructure in a moderate level.

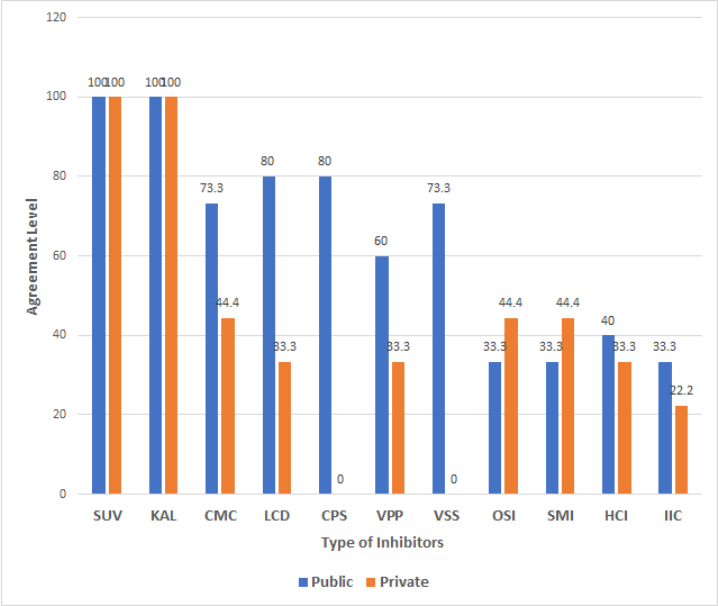

Figure 2. Comparison of inhibitors between public and private sectors.

Number of created virtual machines in a single host is smaller for public sectors than in private sectors (Table 5). This explains why in public sectors the low computing demands is considered as adoption inhibitor. Furthermore, allocation of virtual computing resource for vCPU, vRAM and vHDD needs to be managed efficiently to avoid security vulnerabilities. As indicated in Table 5, the resource allocation is not controlled and is based on *ad hoc* practice, thus creating possibility of virtual machine starvation. For instance, a huge difference was found for the maximum permissible virtual HDD for a given single virtual machine between public and private. A two-way ANOVA was used for statistical computation to find out if there are any differences in allocation of virtual computing resources for virtual HDD (in GB) and virtual RAM (in MB) among public and private adopters based on the five categories of the service sectors including finance/banks, education/academia, telecoms/mobile, ministry and departments, and ICT firms. The interaction, between the organization type and organization service was found to be insignificant for both virtual HDD ($F(2,27)=3.367$, $p>0.05$) with value of $p=0.056$ and virtual RAM ($F(2,27)=2.686$, $p>0.05$) with value of $p=0.094$. The clear interpretation of this is purely an *ad hoc* allocation of computing resources by server admins. Thus, resource allocation depends on the will, determination and self-competency of server admins. The *ad hoc* performance in resource allocation justifies adoption

inhibitors related to lack of knowledge, security uncertainties, lack of virtualization coverage in ICT policies, and existence of low computing demands.

Table 5. Comparison between public and private adopters.

SN	Comparative Aspect	Public Sector			Private Sector		
		Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
1	Number of virtual machines per host	9	4	20	31	7	100
2	Virtual storage (vHDD) allocation in GB	7065	13	64000	2038	20	9000
3	Maximum permissible virtual HDD size in GB	3000	1000	20000	30000	1000	128000
4	Virtual memory (vRAM) allocation in GB	23.106	0.7	122.88	25.394	4.048	128
5	Number of virtual processors (vCPU) per virtual machine	6	32	2	29	128	4

CONCLUSION AND RECOMMENDATIONS

This study shows that lack of skills and security uncertainty are the utmost inhibiting factors that hinder virtualization process among institutions in Tanzania. Other factors which have the potential to slow the physical to virtual migration process are the change management issues among IT people, low computing demands, and lack of virtualization coverage and priority in the ICT policies and IT projects.

The results call for further study to evaluate the performance analysis between virtualized and non-virtualized entities in Tanzania and to study a root cause analysis of inhibiting factors found in this study. The IT executives, policy makers, server admins and other stakeholders may use the results of this study to measure the pace of virtualization process in their institutions in order to maximize IT profits.

CONFLICT OF INTEREST

The author declares no potential conflict of interest in relation to this article.

ACKNOWLEDGEMENTS

We would like to acknowledge the Open University of Tanzania for financing this work.

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