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An Analysis of the Best Practices for the Implementation of Data Centers in Zambia

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***Abstract*—The purpose of this study was to assess the best practices in the implementation of the data centres in Zambia. For this reason, a total of 120 respondents were randomly selected from various institutions to participate in the study. The results shows that the impact of new hardware technologies on the infrastructure of the data center facility in Zambia will result in speedy access to data. The results also shows that the location of the Data Centre can be a critical design considerations and best practices in the site selection and design of data center in Zambia. It was observed that availability of power and also security can be a critical design considerations and best practices in the site selection and design of data center in Zambia. In addition, the study showed that human capital is the most common cost elements associated with different levels of data center reliability and fault tolerance in Zambia among others. Based on these recognitions, the following recommendations were made: that deliberate measures should be put in place to acquire new hardware technologies for the data center facility in Zambia to ensure speedy access to data. It was further recommended that in trying to design new data centers, the selection of the location should be a critical consideration. Furthermore, it was revealed that the management of data center facility in Zambia should also be organized through capacity building.**

***Keywords*-- Performance, public sector, data center, server. LANs, database, flexibility; security aspects, design consideration, data;**

1. Introduction

According to Bell [14] the key to a successful data center facility is to have one that is sustainable in the long term and is to consider it as a receptacle for equipment and operations, as well as an integrated system, in which each component must be considered in the context of flexibility and scalability [1]. Despite these requirements, Data centers seldom meet the operational and capacity requirements of their initial designs. The principal goals in data center design are flexibility and scalability, which involve site location, building selection, floor layout, electrical system design, mechanical design and modularity.

In the recent past, Zambia like many other countries in the region has embraced the use of Information and Communication Technology (ICT) in almost every sphere of its economy. The year 2011 saw the government enforcing a number of policies to promote ICT usage in government departments [17]. However, despite the attempt to implement a data center, most requirements pertaining to the creation of the data center have been almost unattainable making the process to take long.

In other countries, the advent of Data Centre Consolidation has brought efficiency both in the design and management of Information Communication Technology (ICT) infrastructure resources. It has also significantly reduced Data Centre Information Technology (IT) costs. In the United State of America for instance, the Government has witnessed an increasing demand for IT that has led to a dramatic rise in the number of its Data Centres (Zambia Business Review, Report, and 2016 Edition). The report added that operating such a large number of Data Centres with heterogeneous devices was inefficient and expensive. Nevertheless, the introduction of Data Centre consolidation in the Zambian Public Sector is inevitable. In addition, it represents one of the available solutions to most Data Centres challenges in the areas of design and management of ICT infrastructure resources. It is against this background that this study attempts to analyse the best practice of the implementation of the data center in the country to consolidate the data from one central location.

According to Computer Economics Report (2016), Data Centre Consolidation is defined as a physical combination of two or more Data Centres into a single facility with the goal of reducing costs or improving performance. In addition, the report explained that consolidation may simply be a physical relocation of moving computer hardware and support personnel

to a single location. Furthermore, the report indicated that it might be `a more aggressive effort with other types of consolidation which include servers, applications, databases, storage, networks and operating systems. Based on the above definition and the potential benefits that consolidation would bring, this study is proposing the creation of Data Centres for the country to consolidate the data management across ministries. These Data Centres are expected to be exclusively customized for the Zambian Public Sector to enhance the design and management of ICT infrastructure resources to enhance improvement in performance as well as reducing operational cost [3].

In the current study, it is observed that, despite the fact that Zambia has proposed data centres for the purpose of consolidating data from across the ministries, the implementation process has not been a success (Zambia Business Review Report, 2016). The organizations that are tasked with the implementation of this new technology in the country include: ZICTA, SMART Zambia, CIDZ among others and all have raised issues regarding the implementation of data centres in the country. According to Zambia Business Review Report (2016), the advent of new technologies, such as blade servers, that require substantial incremental power and cooling capacity; the pressure to consolidate multiple data centres into fewer locations; the need for incremental space; changes in operational procedures; and potential changes in safety and security regulations converge to impose constant facilities changes on the modern data center are still yet to be addressed in the initial plan of the data center creation[2].

The overarching rule in data center facilities is to design for flexibility and scalability. This rule embraces several key principles in the site location, building selection, floor layout, electrical system design, mechanical design, and the concept of modularity that enables the data center facility to change and adapt as needed, with minimum renovation and change to basic building systems (Michael A. Bell, 2015), it is based on this background that the study was conducted to determine the best practices to the implementation of data centre in Zambia. The following research questions are explored in this work:

- What is the impact of new hardware technologies on the infrastructure of the data center facility in Zambia?
- What are critical design considerations and best practices in the site selection and design of data center in Zambia?
- What cost elements are associated with different levels of data center reliability and fault tolerance?
- How should the management of data center facility in Zambia be organized?

2. Literature Review

The study by Dai et al., (2014) focussed its attention on the equipment of the data centres. It was established that a data centre consists of four main parts: power equipment such as power distribution units and batteries, cooling equipment (chillers and computer room air-conditioning (CRAC) units), IT equipment (servers, storage and network), and miscellaneous component loads (lighting and fire protection systems) [27]). Electronic component systems that arrange processing, storing and transmission of data is the main part of the data centre, according to [6] all of which and create a large amount of heat, which must be removed from the ICT components at a rate sufficient to avoid serious overheating problems and system failures. More than 30% of the heat removal costs of a typical data centre is used in IT equipment and cooling equipment.

Similarly, a study by Linda (2015) focused on security aspects of the data centres. Linda stated that securing the Data Centre against vulnerabilities and attacks had grown in importance in the past several years. However, he said many Data Centre modernisation initiatives had missed on the opportunity to improve security and reliability while pursuing cost-reducing IT objectives. Varcoe (2015) added that security ranks highly on any Data Centre Manager's list of priorities especially when considering the devastating impact that downtime or data theft can have on a business. In support of the above authors, there were also security challenges due to thousands of diverse ICT resources such as servers, switches, routers, networks, storage devices and applications hosted at various Government Data Centres in Namibia [1].

In a related study, McNamara [27] outdated approaches have left a gap between the management of data and the management of storage. Further, he stated that this has resulted in inefficient operations, with considerable duplication of effort and with frequent interruptions to the activities of highly interdependent administrative groups. In favour of the author, outdated methods in the operations of Data Centres have also left a gap which resulted in the inefficient management of ICT resources and regular disturbances to critical services in the Namibian Public Sector. Therefore, introducing Public Sector Data Center Consolidation (PSEDCC) would consider replacing outdated methods with new and efficient methods. As result, frequent interruptions would be decreased.

On the other hand, [8] described decision-making process within the public sector as one of the challenges that hinder most Governments from stopping Data Centre infrastructure sprawl. He argued that this is because the decision-making process can be complicated and lengthy. He further added that in many agencies it was not unusual to have up to fifteen (15) or twenty (20) people signing off on a decision. In support of the author, the situation is exactly the same in Namibia where the decision-making process on anything related to ICT management and operations projects is lengthy and complicated. In other words, it is difficult to identify participants in the Government decision-making process. As a result, time and game changing opportunities that could

transform Data Centre management and operations would be frequently missed.

Despite having adequate resources at their disposal, major companies had incorporated Data Centre consolidation as their strategic weapon for saving costs and improving service delivery. The above remark is supported by Computer Economics Report of 2015 which recognized that major organisations were already reaping the benefits of consolidation. The Report further provided a list of some corporations and how they had consolidated their Data Centres and services.

Lui as cited by Matthews (2017) proposed that typically, a Data Centre is served by dedicated mechanical, electrical and fire protection infrastructure that was independent from the systems that served other portions of the building. He further stated that similar to other building types, Data Centre infrastructures were designed to meet local, state and federal building codes, as well as design standards and guidelines set forth by industry organizations. In addition, he said Data Centre design was often required to meet certain levels of redundancy, reliability, maintainability, fault tolerance, scalability and flexibility. Similarly, (PSEDCC) would meet the above characteristics by establishing a consortium of O/M/As devoted to maximising uptime for the consolidated Data Centre.

Another study by Rose Welington (2019) stated that running a data center is a complex undertaking. In addition to maintaining the strict physical security measures and logical security protocols needed to secure customer data, facility personnel face an ongoing challenge of optimizing IT infrastructure to improve power efficiencies and maximize cooling capacity. Quality data center operations are a key differentiator for colocation customers and managed service providers (MSPs) looking for the best possible partner to house and manage their IT infrastructure solutions (Rose Welington, 2019). This makes it critically important for a facility to implement a variety of best practices to improve its data center operations.

Rose (2019) further added that few things are more critical to data center operations best practices than an effective data center infrastructure management (DCIM) platform. Managing a data center without DCIM software is like trying to sail a boat in complete darkness (Rose Welington, 2019). It's nearly impossible to know what's happening in the moment and even minor problems can be extremely disruptive because they take the facility by surprise. Implementing DCIM tools provides complete visibility into the facility's IT infrastructure, allowing data center personnel to monitor power usage, cooling needs, and traffic demands in real time (Rose Welington, 2019). They can also analyze historical trends to optimize deployments for better performance. With a DCIM platform in place, IT support tickets can be resolved quickly and customers can communicate their deployment needs without having to go through a complicated request process [5].

The study conducted at Phenomon Institute (2016) establish that Data centers necessarily use quite a lot of cable. Whether it's bulky power cables or fiber-optic network cables, the facility must find ways to manage all that cabling effectively to make sure it all goes to the proper ports (Phenomon Institute, 2016). While messy, unstructured cabling might be a viable solution for a very small on-premises data room in a private office, it's completely unsuitable, and even dangerous, for even the smallest data centers. Cabling used in scalable infrastructure must be highly structured and organized if IT personnel are going to have any hope of managing it all.

Poorly organized cabling is not only messy and difficult to work with, but it can also create serious problems in a data center environment. Too many cables in a confined space can restrict air flow, putting more strain on both computing equipment and the facility's cooling infrastructure ([7] Inefficient cabling can also place unnecessary restrictions on deployments, which can make power distribution inefficiencies even worse.

Other studies established that there is fundamental conflict between the desire to reduce operational expense (OPEX) and the lack of implementation of higher cooling temperatures and the resulting benefits Keith (Klesner, 2017). The goal of the study was to give data center managers the tools to reduce the mechanical cooling power consumption through more efficient use of cooling units. Improving airflow management will allow for elevated return air temperatures and a larger across the cooling unit resulting in increased capacity of the cooling unit. This allows for the cooling to be performed by fewer cooling units to reduce mechanical energy consumption. Further cooling system best practices are discussed, including transition to supply air control, increasing chilled water temperatures, and refurbishment or replacement of fixed speed cooling units with variable speed capability.

Uptime Institute has consistently found that many site managers are waiting for the 'next big breakthrough' before springing into action (Klesner, 2017). The dramatic OPEX, subsequent environmental and cooling stability benefits of improved cooling air management, increased operating temperatures, variable speed cooling fans and other best practices are not being exploited by the data center industry at large.

3. Literature Review Theoretical

For the purpose of this study, the researcher used the Technology Acceptance Model (TAM). According to Davis (2015), TAM is a theoretical model aiming to predict and explain ICT usage behavior, that is, what causes potential adopters to accept or reject the use of information technology.

Theoretically, TAM is based on the Theory of Reasoned Action (TRA). In TAM, two theoretical constructs, perceived usefulness and perceived ease of use, are the fundamental determinants of system use, and predict attitudes toward the use of the system, that is, the user's willingness to use the system. Perceived usefulness refers to "the degree to which a person believes that using a particular system would enhance his or her job performance", and perceived ease of use refers to "the degree to which a person believes that using a particular system would be free of effort.

Another theory that will be considered is the Theory of Reasoned Action (TRA). The theory originates from social psychology, and it is a special case of the Theory of Planned Behavior (TPB) [27] developed TRA to define the links between the beliefs, attitudes, norms, intentions, and behaviors of individuals. The theory assumes that a person's behavior is determined by the person's behavioral intention to perform it, and the intention itself is determined by the person's attitudes and his or her subjective norms towards the behavior. The subjective norm refers to "the person's perception that most people who are important to him think he should or should not perform the behavior in question". The authors state that TRA is applicable, for example, when studying consumer behavior, women's occupational orientations, or family planning behaviors.

From the Theoretical Framework and literature review, the researcher formulated the conceptual frame showing relationship of variables, where the independent variables included availability of new hardware technologies, site selection, cost elements and management of the data center facility and the dependent variable was the successful implementation of the data center. The conceptual framework is shown below:

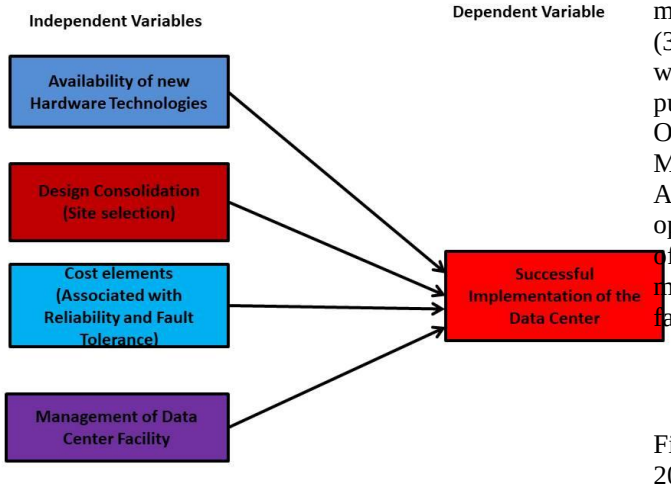

Figure 1.0 Conceptual Framework

4. Methodology

4.1 Overview

The study made use of a mixed-method research approach, where both qualitative and quantitative methods are considered. Quantitatively, a structured questionnaire was used to explore the current state of Data Centre best practices in the Zambia Public Sector. Qualitatively, an interview schedule was also used to find in-depth information on the operations, designs and management of Data Centre ICT infrastructure resources in the public sector.

4.2 Study population

According to Mwion (2015) a population is an entire group of individuals, events or objects with some common observable characteristics. The study took into account employees of at least 12 ministries, at their head office to determine the implantation strategies. The population was approximately 870 employees. The sample size was 120 respondents drawn from various ministries. The sample size was calculated using Raosoft sample size calculator accessed on www.raosoft.com.

4.3 Methods of Data Collection

For the purpose of this study, the researcher used both primary and secondary data. Secondary data gathered from different published reports by government sources, and other countries that have managed to successfully switch from analog to digital broadcasting. Primary data was collected using questionnaires and unstructured interviews.

4.4 Sampling Size

Argyrous (2005) described a sample as a set of cases that does not include every member of the population. The sample of this study consisted of fifteen (15) (randomly selected) and two (2) (purposely selected) Data Centres. Furthermore, the study was made up of thirty four (34) respondents in total, of which thirty (30) represented fifteen (15) randomly selected Data Centres while four (4) out of thirty four (34) was from two (2) purposely selected Data Centres at the headquarters in Lusaka. Of these respondents, seventeen (17) included IT Managers/representatives and seventeen (17), System Administrators/IT operators who overseeing Data Centre operations in the public sector. In short, the study was made up of thirty four (34) participants and 17 Data Centres of different ministries-these included randomly and purposefully selected facilities. The total sample was 120 respondents.

4.5 Methods of Data Analysis

Field data was analysed with the help of IBM SPSS Version 20.0. Further Mega statistics software was used to test the hypothesis. Data was organized according to the stated objectives and checked for errors before it could be analysed. One sample t-test was the statistical method used to test the hypothesis. An assumption of the t-test was that, data is coming

from normally distributed populations. The data on the variables was evaluated for normality using means, standard deviations, skewness and kurtosis statistics. More importantly skewness and kurtosis values within the range -2 to +2 were used to indicate no serious deviation from normality. Regression analysis was used to identify the relationships between variables of the study.

In addition the literature analysis revealed a variety of designs of both physical and logical architectures of data centers as depicted in figure 2.0 and figure 3.0 respectively.

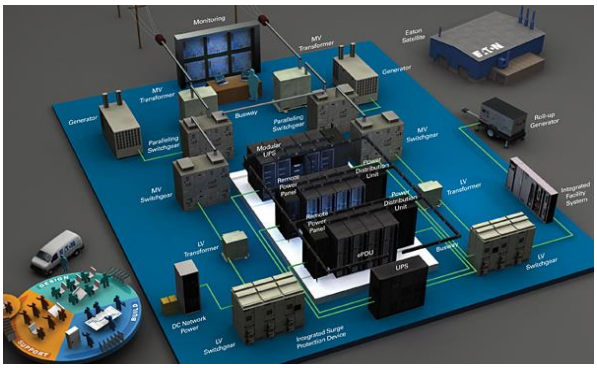

Fig 2.0 Physical Design of Data Center (source https://www.apecus.com/solutions)

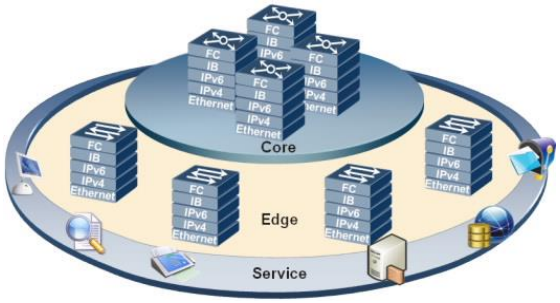

Fig 3.0 logical design of data center (source https://e.huawei.com/es/tech-topic/en/hw_133535)

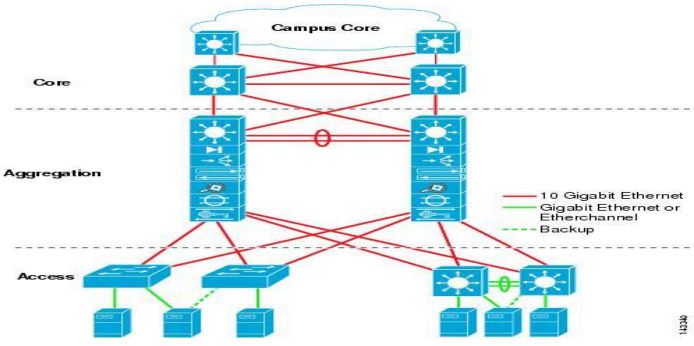

Fig 4 data center network design (source https://www.cisco.com/c/en/us/td/docs/solutions/Enterprise/Data_Center/DC_Infra2_5/DCInfra_1.html

5. Results

The results obtained from the field study are represented using mean, Standard Deviation and Skewness. The results are presented using research questions.

1. **Question one:** What is the impact of new hardware technologies on the infrastructure of the data center facility in Zambia? Table I below shows the results of this question.

TABLE I. NEW HARDWARE TECHNOLOGIES

	Mean	Standard Deviation	Skewness
The impact of new hardware technologies on the infrastructure of the data center facility in Zambia will result in speedy access to data	1.18	0.389	1.658
The impact of new hardware technologies on the infrastructure of the data center facility in Zambia will result in Improved Storage of Data.	1.28	0.449	1. 021
The impact of new hardware technologies on the infrastructure of the data center facility in Zambia will result in Improved Data Redundancy.	1.27	0.444	1.074

2. **Question Two:** What are critical design considerations and best practices in the site selection and design of data center in Zambia? Table II and III shows the results.

TABLE II. RELIABILTY FAULT TOLERANT

	Mean	Standard Deviation	Skewness
Acquisition of New Equipments is the most common cost elements associated with different levels of data centre reliability and fault tolerance in Zambia.	2.12	1.144	1.348
Human capital is the most common cost elements associated with different levels of data centre reliability and fault tolerance in Zambia	3.14	1.243	-.060
Internet connectivity is the most common cost elements associated with different levels of data centre reliability and fault tolerance in Zambia.	2.11	1.012	1.739
Cost of servers' acquisition is the most common cost elements associated with different levels of data centre reliability and fault tolerance in Zambia.	1.51	.502	-.056
Availability of security can be a critical design considerations and best practices in the site selection and design of data center in Zambia..	3.22	1.696	-.086

TABLE III. BEST PRACTICES

	Mean	Standard Deviation	Skewness
Location of the Data Centre can be a critical design considerations and best practices in the site selection and design of data center in Zambia	1.85	.791	1.296
Availability of power can be a critical design considerations and best practices in the site selection and design of data center in Zambia.	2.12	1.078	1.567

3. **Question Three:** What cost elements are associated with different levels of data center reliability and fault tolerance?

TABLE IV. MODEL SUMMARY

Model	R	R Square	Adjusted R Square	Std Error of the Estimate	Change Statistics				
					R Square Change	F Change	dff	df2	Sig. F Change
1	7302	.533	.519	.270	.533	39.875	3	105	.000

6. *Evaluation of the Assumptions of Regression Analysis*

The assumptions of regression analysis were evaluated using normal probability plot that were obtained from the SPSS output as shown below:

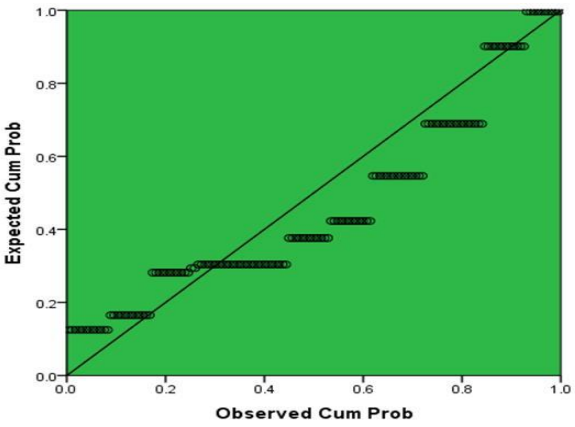

Fig 5 Normal Probability Plot

7. *Results Discussion*

The study sought to determine whether the impact of new hardware technologies on the infrastructure of the data center facility in Zambia will result in speedy access to data. According to the results obtained and as depicted in Table IV above, the statistics from the data on this variable were very close to the mean as reflected by a mean of 1.18. Showing that most of the respondents strongly agreed that the impact of new hardware technologies on the infrastructure of the data center facility in Zambia will result in speedy access to data. These results are supported by McNamara [16] who also established outdate approaches to data center have left a gap between the management of data and the management of hardware storage.

With regards to whether the impact of new hardware technologies on the infrastructure of the data center facility in Zambia will result in Improved Storage of Data, statistics from the data on this variable were slightly above the mean as reflected by a mean of 1.28. This means that majority of the respondents were agreeing that the impact of new hardware technologies on the infrastructure of the data center facility in Zambia will result in improved storage of data at the data centers countrywide. Based on the findings, it can be deduced that, new hardware technologies can results in improved storage of data.

Conducted tours at Kitwe Zambia National Data Center (ZNDC) were data centers has been actualized revealed quite much in terms of design considerations. The focus was to assess whether the best practices have been adhered to in these initial implementations. It was observed that indeed much has been done in terms primary power and backup power, security from eventualities such natural disasters. However it has not been established yet whether reliability concerns will stand the test of time in terms of upgrading the hardware should the current become obsolete.

In a case of design consideration, the respondents revealed that the location of the Data Centre can be a critical design considerations and best practices in the site selection and design of data center in Zambia. For this reason, the respondents indicated the data centers are best suited to be located along the line of rail with better access to electricity and communication lines.

In addition, the study sought to determine whether or not the availability of security can be a critical design considerations and best practices in the site selection and design of data center in Zambia. According to the results obtained, the mean value of the response rate from the respondents was 3.2, indicating that the respondents could not state their position as to whether or not the availability of security can be a critical design considerations and best practices in the site selection and design of data center in Zambia.

Linda (2015) also stated that securing the Data Centre against vulnerabilities and attacks had grown in importance in the past several years. However, he said many Data Centre modernization initiatives had missed on the opportunity to improve security and reliability while pursuing cost-reducing IT objectives.

The researcher also wanted to determine whether the acquisition of New Equipment is the most common cost elements associated with different levels of data center reliability and fault tolerance in Zambia. Statistics from the

data on this variable were slightly above the mean as reflected by a mean of 2.12. This means that the respondents agreed that the acquisition of New Equipment is the most common cost elements associated with different levels of data Centre reliability and fault tolerance in Zambia.

8. Conclusion

Based on the results and the discussions provided above, the following conclusions were made:

- That the impact of new hardware technologies on the infrastructure of the data center facility in Zambia will result in speedy access to data.
- That the location of the Data Centre can be a critical design considerations and best practices in the site selection and design of data center in Zambia.
- That the availability of power can be a critical design considerations and best practices in the site selection and design of data center in Zambia.
- That the acquisition of New Equipment's is the most common cost elements associated with different levels of data center reliability and fault tolerance in Zambia.
- That human capital is the most common cost elements associated with different levels of data center reliability and fault tolerance in Zambia.
- That providing for maintenance bypass and emergency shutdown to the data center can be the starting step in management of the data Centre facility in Zambia.
- That determining if equipment requires single phase or three-phase power to the data center can be the starting step in management of the data Centre facility in Zambia.

Recommendations

- That deliberate measures should be put in place to acquire new hardware technologies for the data center facility in Zambia to ensure speedy access to data.
- That in trying to design new data centers, the selection of the location should be a critical consideration. In addition, the availability of power is also another critical design considerations and best practices in the site selection and design of data center in Zambia.
- That reduction of cost associated with Acquisition of New Equipment, human capital and Internet connectivity should be reduced automating certain processes and this will in-turn ensure reliability and fault tolerance data Centre.
- That designers of data centers should strive to assess the overall power requirements to manage the data Centre facility in Zambia
- That there should be multiple utility feeds to the data center as a measure to manage the data Centre facility in the country

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