UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING & INFORMATICS

Application of the Design–Reality Gap Model to Enhance High Availability of Systems for Health Care Providers in Nairobi, Kenya

By

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A project report submitted in partial fulfillment of the requirements for the award of Master of Science in Information Technology Management of the University of Nairobi.

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DECLARATION

This project is my original work and to the best of my knowledge this research work has not been submitted for any other award in any University

Solomon Munene Chege: ______________________________ Date: _______________
(P54/64718/2013)

This project report has been submitted in partial fulfillment of the requirements of the Master of Science Degree in Information Technology Management of the University of Nairobi with my approval as the University supervisor

Christopher A Moturi: ______________________________ Date: _______________
Deputy Director
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DEDICATION

To Chege,

Greater works than this shall you do.

ACKNOWLEDGEMENTS

This work would not have been possible without the diligent supervision of Mr. Moturi of the School of Computing and Informatics, the University of Nairobi, as well as the valuable work of panelists Dr. Abade, Dr. Opiyo, Mr. Ogutu, and other members of faculty. Their feedback has greatly developed my capacity in this discipline. I also appreciate the contribution of ideas, encouragement and peer commentary from my fellows in the Information Technology Management class – Grace, Selina, Vivian, Pauline, Moses, Daniel, Kennedy and others. Thanks also to my family - Wanjiku, Chege, Muchoki and Mwangi for support and providing the motivation to make the work worthwhile. Finally to all my colleagues and systems administrators who participated, and all who made valuable contribution in the course of my studies. Thank you.

ABSTRACT

The health care sector continues to implement and rely on computer based information systems. In doing this, the providers install high end computing technology in hardware, software and network infrastructure imported from advanced countries. The success of these systems is degraded by various factors. This study applies the Design-Reality Gap model to understand and evaluate the dimensions affecting systems availability in the health sector in Nairobi, Kenya. The objective was to form the basis of improvement of the systems availability by appropriate mitigations. A qualitative study was conducted on a number of medium and large health care institutions, both public and private. It was apparent that various dimensions of the model are responsible for degraded availability. The study concludes that corporate objectives, staff skills and technology aspects present the strongest challenges, while other dimensions are observed in varying degrees.

Keywords: High Availability Systems, Health Information Systems, Design-Reality Gap Model.

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ABBREVIATIONS

CNO	Computer Network Operator
DOI	Diffusion of Innovation
FOSS	Free Open Source software
ICT	Information and Communications Technology
ICTD	Information and Communication Technology for Development
ICT4D	Information and Communication Technology for Development
ISP	Internet Service Provider
NGO	Non-Governmental Organization
OSS	Open Source Software
TAM	Technology Acceptance model
TOE	Technology, Organization and Environment Model
TPB	Theory of Planned Behavior
UTAUT	Unified Theory of Acceptance and Use of Technology
UPS	Uninterrupted Power Supply

DEFINITIONS

Availability A measure of system quality that indicates the degree to which the system continues to without failure over a period of time when it is required for usage.

Downtime: The time between the occurrence of a fault and the time the information system is restored to a functional state.

E-Government: The delivery of government services to the citizens aided by computer based information systems.

Ethernet: A widely used Local Area Network standard that utilizes copper twisted cable as communication medium.

Enterprise Resource Planning System: A business system comprising of several independent modules with standard functions, configurable for different client environments. ERPs have modules that are applicable to a large number of large businesses in manufacturing or process management.

Failure: A state of an information system in which it is not performing its function due to a fault.

Fault: A defect that causes the halting of the proper functioning of an information system

Fiber Channel: Optic fiber network media as implemented over short distances.

Gigabit A measure of network bandwidth denoting a billion bits per second.

Health Information System: An information system with functions for input processing and output of health information and patients health records in health care institutions.

High Availability Systems: Information systems that are required to be operational and in service to users 24 hours a day every day of the year, abbreviated as 24/365.

Maintainability, A measure of systems quality that indicates the ease of making correct changes to the system

Reliability: A measure of system quality that indicates the degree to which the system continues to function correctly without failure.

Uninterrupted Power Supply: A device or power installation designed to override power supply interruptions or overloads by storing electric power and supplying to target systems in a controlled manner

CHAPTER 1: INTRODUCTION

1.1 Background

As the dependence on information technology escalates in developing countries, there is need to enhance availability of successfully implemented computer based systems. This is one aspect of quality improvement. The nature of the digital divide is changing from absolute lack to getting less value from the systems implemented. Few countries remain in the 'third world' notion of 'developing countries'. Most are progressing to middle income countries and globalization is adding to the push of high technology from industrialized countries to developing countries (Hawari and Heeks, 2010; Bass and Heeks, 2011).

While the developing countries can quickly import finished technologies, the operational and organizational ecosystems in which they are applied is far from ideal. The design of the technologies and systems are so heavily influenced by the 'western' way of doing things that they become misfits in their destinations. Bass and Heeks (2011) note that there is little literature available on the failure of systems in the less developed countries. The Design – Reality Gap Model (Heeks, 2003) is adopted in this study as a theoretical basis for evaluation of computer based systems in use in developing countries. This study evaluates the gaps that exist in Kenya health care sector and which affect the availability levels attained by the installed systems. Infrastructural and environmental support systems are poorly developed in the sector, and they hamper the availability of the systems (Touray and Salminen, 2013).

Most institutions in the sector deploy imported information and communications technologies. Apart from the import nature, the technology is advanced and complex in many ways. Understandability of the ICTs has always been a challenge in the implementation and the sustenance. A lot of research has been done to address the disparities and the ensuing challenges. The Design-Reality Gap Model is one of the most widely applied models for understanding the gap between the design of imported ICTs and the reality of the destination contexts. Heeks and others have applied this model to explain and seek to mitigate failure of e-government projects. Early findings were put into three camps: Total failure, where the initiative was never implemented or was implemented but immediately abandoned; Partial failure where major goals for the initiative were not attained and/or there were significant undesirable outcomes and successes, where most stakeholder groups attained their major goals and did not experience significant undesirable outcomes. Putting these sources together, the following working estimates are produced for e-government projects in developing and transitional countries: 35% are total failures, 50% are partial failures, and 15% are successes (Heeks, 2003). This study was based on the reality that even when the gaps don't sink the project, the gap dimensions may present continuing degradation of quality, and for this study, availability, such that the true potential and usefulness of the system is not attained. The successful projects, therefore, require evaluation, with a view to improving their characteristics against the Design – Reality Gap Model.

1.2 Problem Statement

The challenges of high availability have been tackled almost as long as modern computers have existed. In running a business, managers set objectives to attain and maintain high levels of systems availability, commensurate with global standards of service provision in different sectors (Kumar and Kumar, 2013). However, at the end of a business reporting period, the availability attained is much lower than the target. The availability levels achieved in the developing counties are far lower than in developed nations. This degrades the value derived from the system. Although different researchers have looked at different aspects of this gap, further research needs to be done, especially on reliability aspects of the underlying technology and infrastructure. In the health care sector in Kenya, the quality of the successful systems keeps improving towards world class standards (Park and Pokharel, 2010). There is little literature available on the failure of systems in the less developed countries, except for a few cross sectional studies that lack the longitudinal follow up (Bass and Heeks, 2011). This is largely due to the unavailability of resources for the researchers in these regions to carry out comprehensive research on the subject.

1.3 Objectives

The main objective of the study was to apply the design – reality gap model to mitigate against the major factors degrading the availability of information systems in health care enterprises operating in the Nairobi, Kenya. In doing this the study sought to:

1. Find out the extent to which Design – Reality Gap Model dimensions are responsible for degraded availability.
2. Develop mitigation measures in line with the design – reality gap model.

1.4 Research Questions

The research sought to find the extent to which degraded availability of information systems in the sector is a function of design - reality gap factors. Appropriate mitigation measures available for the improvement of the achieved availability levels were sought out in line with the study model. In dealing with this question, the study sought to answer the following:

1. Are the dimensions of the Design – Reality Gap Model relevant to degraded systems availability?
2. What can be done to increase the systems availability in this context?

1.5 Significance of the Study

The business cost of unavailability, also referred to as cost of downtime, is high. This cost is rising per sector as dependency on computing technology and interdependencies increase. This study sought to gain more understanding of the problem. The results of the study lead to the development of a structured management approach towards achieving high systems availability. Organizations will find the results of this study valuable in developing or improving processes to manage information systems implementation. They will also help systems vendors identify improvement opportunities for achieving desirable systems benefits for their customers.

CHAPTER 2: LITERATURE REVIEW

2.1 Classification of High Availability Systems

Unavailability is the measure of computing systems downtime. Unavailability frustrates end users and increases the negative perception of the system in the organization. Systems have been installed and put to use with no plan for fault tolerance or fault management. This points to the need to give attention to the matter (Park and Pokharel, 2010).

Today's best systems are in the high-availability range. In developed countries, there are well developed support environment to attain the high nines of uptime as tabulated. That is not the case in developing countries. Adegoke and Osimosu (2013) concluded that cloud services outage have led to questioning the reliability of cloud environments to run mission critical applications. Amazon Web Services (AWS) was down for 49 minutes on January 13, 2013. Other major cloud service providers such as Google and Windows Azure have had their share of outages too. In implementing the kind of networks required for cloud era computing, numerous failure modes continue to present challenges (Ali, 2013).

Table 1: Classification of High Availability Systems

Type and Class	**Uptime (%)**	**Downtime (%)**	**Downtime Per Year**	**Downtime Per Week**
Unmanaged (1)	98	2	7.3 days	3 hrs 22 mins
Managed (2)	99	1	3.65 days	1 hr 41 mins
Well-managed (3)	99.8	0.2	17 hrs14 minutes	20 mins10 secs
Well-managed (3)	99.9	0.1	8 hrs 45 mins	10 mins, 5 secs
Fault-tolerant (4)	99.99	0.01	52.5 mins	1 mins
High-availability (5)	99.999	0.001	5.25 mins	6 secs
Very High-availability (6)	99.9999	0.0001	3.15 secs	0.6 secs
Ultra High-availability (7)	99.99999	0.00001	<1 secs	<0.3 secs

Adapted from Adegoke and Osimosu, 2013

The numeric metrics of availability can be rather abstract and cumbersome, so the concept of availability class is defined. High availability classes are defined from class 1 for the lower end managed systems to class 7 for ultra-high availability. As seen in the table, the higher classes are Fault-tolerant systems and then the high availability systems. Starting with class 4, the downtime per year is 52.5 minutes. That is just less than an hour per year. Classes 5, 6 and 7 are very close in terms of the seconds per year tolerated for downtime. Similar techniques and measures are applied to attain these levels of availability. These will include redundancy at all levels, real time replication with automatic failover, clustering among others. It also follows that they are more costly to implement and require a more thorough economic justification.

2.2 The Business Cost of Degraded Availability

In many cases, having a critical unplanned outage translates to whether a business continues or closes. This is more so in developed countries where dependence on the systems is very high. Some of the high costs that hit a business due to systems outages include: Tangible or direct costs as well as intangible or indirect costs: The cost that may be assignable to each hour of downtime varies widely depending upon the nature of the business, the size of the company, and the criticality of the IT systems to primary revenue generating processes (Schwartzel and Mnkandla, 2012; Trautman and Altenbaumer-Price, 2011). Whether planned or unplanned, outages can unleash a procession of costs and consequences that are direct and indirect, tangible and intangible, short term and long term, immediate and far reaching. Having a critical unplanned outage literally translates to whether a business continues or closes. (CA Technologies, 2010). Some of the high costs that hit a business due to systems outages include:

Tangible or Direct Costs: These include lost transaction revenue, lost wages, lost inventory, remedial labor costs, marketing costs, legal penalties from not delivering on service level agreements.

Intangible or Indirect Costs: These include lost business opportunities, loss of employees and/or employee morale, decrease in stock value, loss of customer/partner goodwill, brand damage, driving business to competitors, bad publicity. The cost that may be assignable to each hour of downtime varies widely depending upon the nature of your business, the size of your company, and the criticality of your IT systems to primary revenue generating processes. For instance, a global financial services firm may lose millions of dollars for every hour of downtime, whereas a small manufacturer that uses IT as an administrative tool would lose only a margin of productivity. (Vision Solutions, 2008)

Labor Productivity: Number of employees affected, Duration of outage, Average fully burdened labor rate, Percent productivity loss during an outage

Revenue: Direct loss, Compensatory payments, lost future revenue, Billing losses, Investment losses

Damaged Reputation and Loyalty: Customers, Suppliers, Financial Markets, Banks, Business Partners

Financial Performance: Revenue recognition, Cash flow, lost discounts, Payment guarantees, Credit rating, Stock price

Other Expenses: Regulatory and legal obligations, Temporary employees, Equipment rental, Overtime costs, Extra shipping costs, Travel expenses. (CA Technologies, 2010)

2.3 Factors Affecting Downtime

The factors of systems failure have been studied over many years since the deployment of computer systems in business. Different researchers have documented the following factors.

Operator errors: Operator errors eclipse other causes of failure and will occasionally cause an outage for several hours. They contribute more than a thousand minutes of outage per year in high availability systems (Liinasuo, et al, 2012). In a study of error factors in a network environment, respondents considered the impact of human errors on network failures as remarkable (Kumar and Kumar, 2013; Ogheneovo, 2014).

Software Upgrades and Repair: Scheduled software upgrades are normally done once a year. They are done more slowly and takes longer to close than normally planned. Besides, there are repairs that arise at random due to oversight in the setup, configuration and patching of the operating system, utility programs or applications. When certain runtime conditions come into being, the software experiences a failure prompting an unplanned repair for continued running.

Database updates: These are like software upgrades; they may go through the same challenges. They are performed to provide for new types of information in the system. These are like software upgrades; they experience the same challenges. Sometimes, the upgrades cause unplanned downtime in the days following, due to unforeseen problems that have to be resolved.

Environmental faults: Fire, flood, earthquake, power failure, sabotage radiation and electromagnetic interference. Geographic location and the stability of the environment around the location has a significant effect on this. The design of the system environment should have such a broad consideration as to factor in these and thereby reduce the probability of failures related to environmental factors.

Electrical power failure: This causes more than a thousand minutes of downtime per year in managed systems installations. All the electronic computing installations must constantly have high quality of power for input. Uninterrupted Power Supply (UPS) system’s commonly suffer from neglect of maintenance and are therefore prone to failure. The management and control of power supply and quality systems to the computing environment is one of the biggest contributors of failure or success of reliability mechanisms.

Component defects and hardware faults: These cause the common hardware failure (Kumar and Kumar, 2013). Components with moving parts such as hard disk drives are more prone to this kind of failure.

Specification Mistakes and Design faults: These are design errors in hardware and software. Large software systems have many latent elements of incorrect algorithms. In the long term operation, the effects of these come to light as malfunctions and failures (Ogheneovo, 2014).

Increased Complexity: Systems administrators operate on more complex systems and this makes their work a high risk engagement. Greater complexity increases the possibility of errors, because no one really understands all the interacting parts of the whole or has the ability to test them. (Ogheneovo, 2014) It has been acknowledged to be impossible to thoroughly test software that is large in size. In implementing ERPs, which are by nature very large in size, the authors noted that it is complex, expensive, and difficult to implement (Bhatti & Khan, 2010, Hawari and Heeks, 2010).

In addition, during the implementation of cloud computing infrastructure, a number of failure modes have been documented. Adegoke and Osimosu (2013) noted that assuring uninterrupted availability of cloud services is still a challenging issue for cloud service providers. Recent cloud outages have questioned the reliability of cloud environments to run mission critical applications. Amazon Web Services (AWS) was down for 49 minutes on January 13, 2013. Other major cloud service providers such as Google and Windows Azure have had their share of outages too. These services are operated by the most capable and most advanced technology companies existing, yet they have not attained the holy grail of availability. (Ali, 2013) notes availability of cloud services as one of the arising challenges as computing shifts to client-cloud systems. In implementing the kind of networks required for cloud era computing, (Afergan, LaMeyer & Wein, 2011) note that numerous failure modes present challenges. Some of them are outlined as follows:

Path Failure: Various problems can degrade or destroy connectivity between any two endpoints in the Internet. A common mode is the breakage or cutting of undersea fiber cables.

Machine Failure: Servers fail for a variety of reasons, from hardware failure to cable disconnects.

Region / Rack Failure: The cause may vary such as a switch fails. It may also be outside cause, such as a rack losing power, failure of an upstream router, or datacenter maintenance.

Multiple Rack/Data Center Failure: Multiple racks within a datacenter or even an entire datacenter can fail, for reasons ranging from operational error in the host network.

Network Failure: ISP-internal failures can affect a subset of datacenters or even the core of a particular network.

Multi-Network/Internet-wide Failures: We continue to see issues including trans-oceanic cable cuts, Internet scale worms (e.g., SQL-Slammer), peering problems, and BGP operator errors. The impact of these incidents can vary from significantly higher latency or packet loss to complete disconnection.

2.4 Models: Measuring Failure and Success of Systems

Several models have been developed and applied in the measurement of success and failure of information systems. The Technology Acceptance model (TAM) has two main components; Theory of Reasoned Action and the Theory of Planned Behavior: The Theory of Planned Behavior influences, or is influenced by the perceived ease of use of the system. This model, like the several others considered, focuses on measuring success in terms of the satisfaction with usage and functionality. The DeLone & McLean Model of Measuring Success of Information Systems is to a great extent a development of the Technology Acceptance Model. It has six dimensions namely Systems Quality, Information quality, Service Quality, System Use, User Satisfaction and Net Benefits (Hawari and Heeks, 2010). The model also is orientated to measuring success in terms of the satisfaction with usage and functionality.

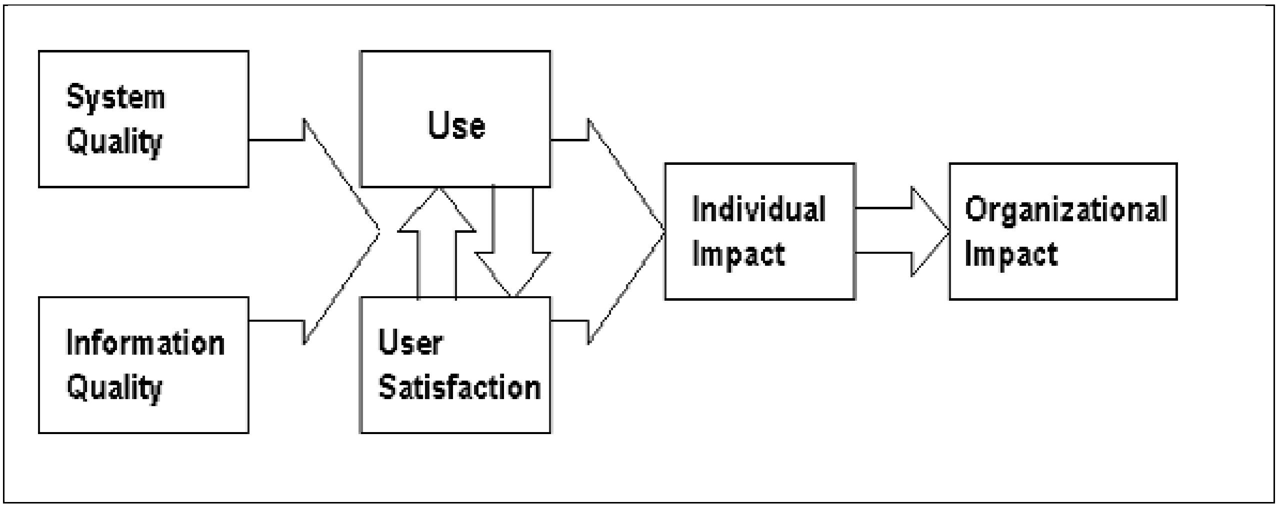

Figure 1: DeLone & McLean Model

(Adapted from Hawari and Heeks, 2010)

Hawari and Heeks (2010) correctly argue that the use of DeLone & McLean model is suited to measure and determine if the particular system is a failure or a success by usage or by acceptability with the user community. Beyond understanding user acceptance and usage, they sought to explain the causes that led to the failure of the system in the intended operational environment. In seeking to find the root causes of failure, the DeLone & McLean model is not particularly suited because it does not make a comprehensive look backwards for into the development process (Al-Haddad, Hyland and Hubona, 2011). A model that addresses there causative factors of the subject matter was sought. This study is in the context of a developing country, and the technology being evaluated was designed, and mostly used first in advanced nations. The Design-Reality Gap Model was found to have the dimensions and components to frame the answers to the research questions arising (Hawari and Heeks, 2010).

The Diffusion of Innovation (DOI) and the Technology, Organization, Environment Model (TOE) Models have also been considered in this study. The DOI and the TOE frameworks have also been considerably evaluated in various studies. The latter two are applied at the organization level. In their application, the behavioral characteristics of the organization are the primary focus. This is so as relates to the organizations receptiveness and capacity to adopt new technology, or hinder the progression of the same. The Technology Acceptance model (TAM), Theory of Planned Behavior (TPB) and Unified Theory of Acceptance and Use of Technology (UTAUT) are at the individual level. It is noted that the DOI model does not seek to explain the causes of failure or success of a technology. Instead it identifies five categories of individuals who participate in the adoption and spread of a technology or in our context, usage that leads to success of the system. The five participants being innovators, early adopters, early majority, late majority and laggards. The innovation process in organizations is much more complex. It involves a number of individuals, including both supporters and opponents of the new idea, each of whom plays a role in the innovation-decision (Oliveira and Martins, 2011). The TOE framework identifies three aspects of an enterprise's context that influence the process by which it adopts and implements a technological innovation: technological context, organizational context, and environmental context. Some of the elements of the TOE framework may be loosely related to the dimensions of the Design-Reality Gap Model.

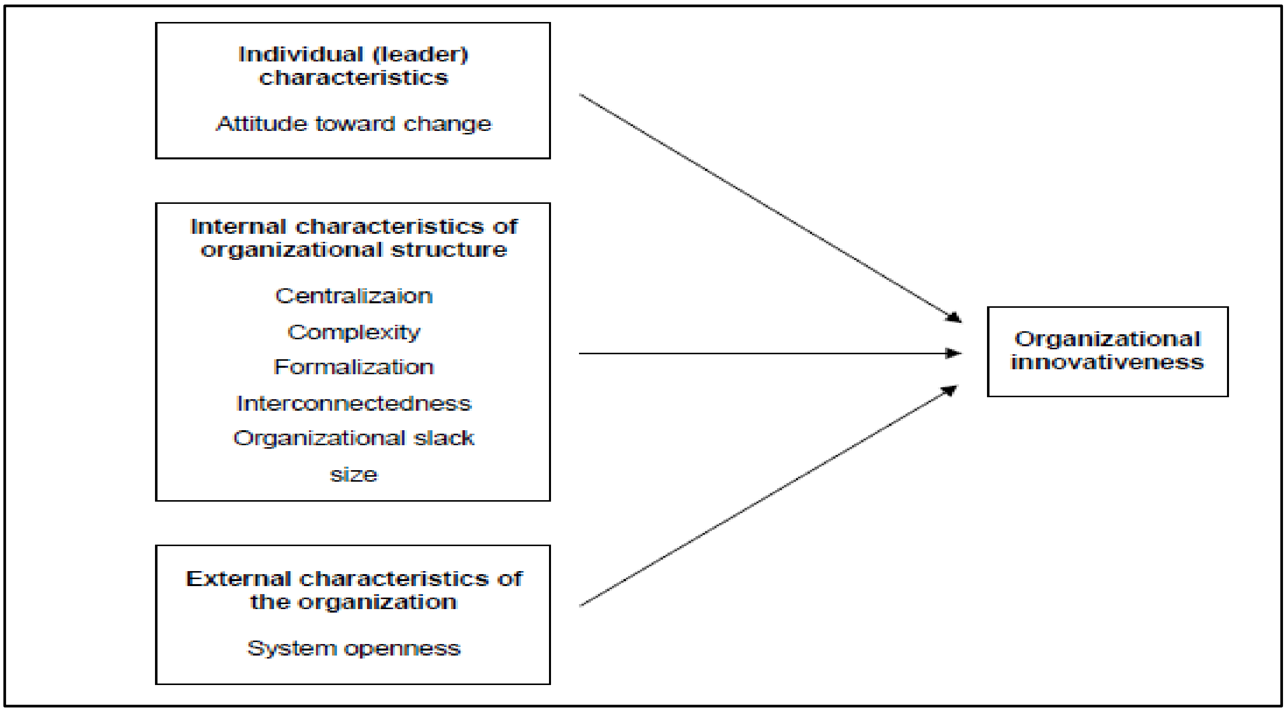

Figure 2: The DOI Model.

(Adapted from Hawari and Heeks, 2010)

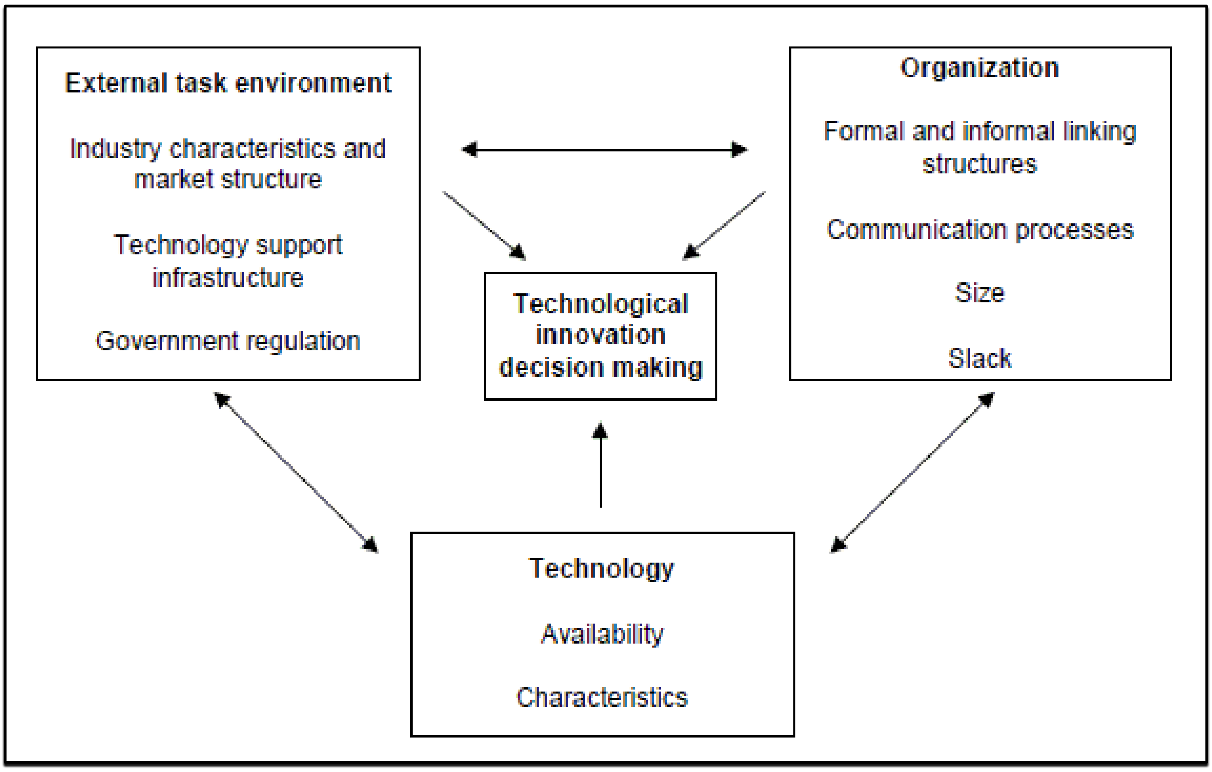

Figure 3: The TOE Framework

(Adapted from Hawari and Heeks, 2010)

The ICU – P Model is an enhancement on the DeLone and McLean: Based on the benefits users receive and their satisfaction with a system, they form beliefs about whether they can rely on the system for future use. This is described as developing trust in the system. Based on the outcome they will decide whether or not to continue using it. The authors of the ICU-P model extend the DeLone and MacLean model by adding trust as the immediate predecessor of intention to continue using the system (Abouzahra and Tan, 2014).

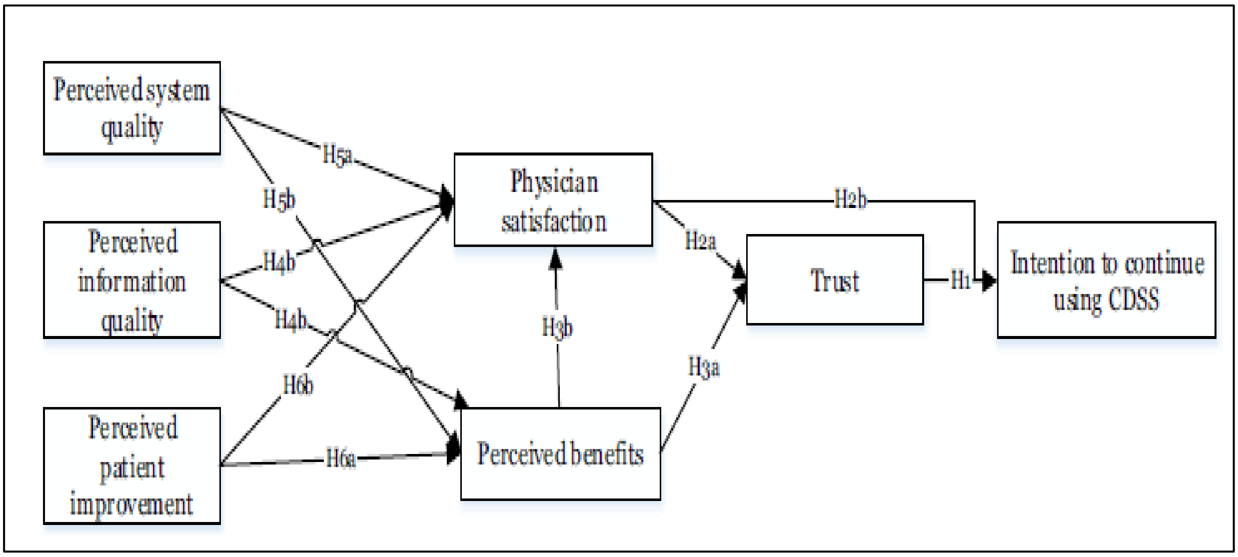

Figure 4: ICU-P Model.

(Adapted from Hawari and Heeks, 2010)

2.5 Design - Reality Gap Model

The Design – Reality Gap Model has been widely applied to analyse and explain the success and failure of ICT4D projects in developing countries. It has also successfully applied outside this domain. Hawari and Heeks (2010) applied it to explain the failure of ERP implementation project in a large, private sector manufacturing firm. It has also been applied to evaluate computing degrees curricula in 12 universities in Ethiopia (Bass and Heeks, 2011). Based on analysis, the larger the design-reality gap assessed in any aspect of the project, the greater the risk of project failure (Hawari and Heeks, 2010). Conversely, the smaller the gap the greater the chance of success.

The dimensions of the Design-Reality Gap Model are as follows:

Objectives and Values: These concern the formal strategies, culture and informal goals of an organization. In many organizations in developing countries, there are many underlying and undocumented objectives, socio cultural influences and political agenda, which can greatly influence the support available in the systems area, influencing their success or failure (Kemppainen and Tedre, 2014).

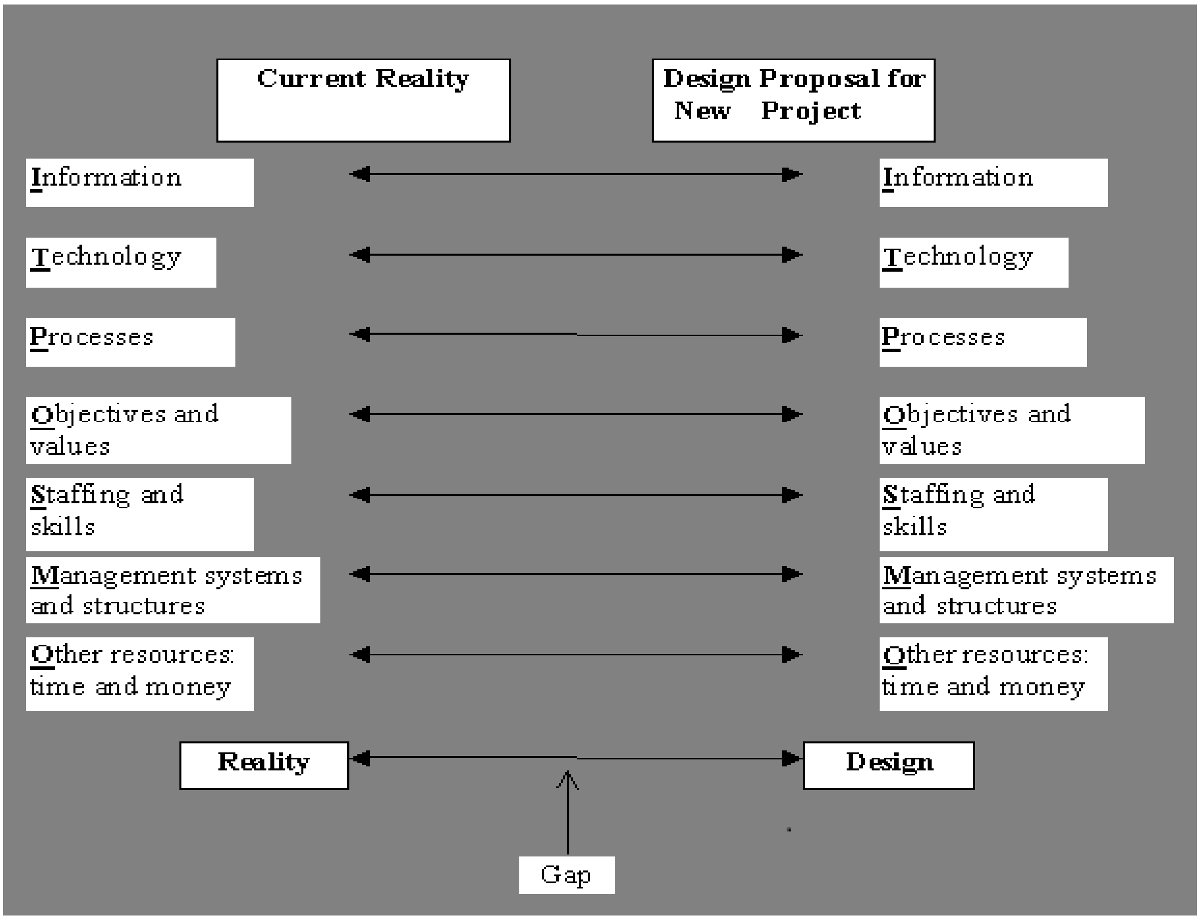

Figure 5: The Design—Reality Gap Model

(Adapted from Hawari and Heeks, 2010)

Processes: From individual tasks up to broader business processes. A system may be designed with the assumption of a rational, well-structured and optimized decision making and business process while the organization uses a semi-structured and quite informal decision making process that may not be mapped to the information systems. Where the processes and management style are more formal, and more so where controls including internal audit or other function with similar control and monitoring role exists, the quality of administration can be higher, resulting to better outcomes for systems deployed.

Technology: Implementers of complex high reliability systems in developing countries assume the availability of high end local area networks, fiber channel links or gigabit Ethernet, high quality electrical power supply among other technologies. In reality such are not always available (Hawari and Heeks, 2010; Mutula and Mostert, 2010; da Silva and Fernandez, 2013). Maintainability, and therefore the sustainability of the systems can depend on the vendor as well as their willingness to adapt their solutions for local context (da Silva & Fernandez, 2013). Besides, technology as a social construct (Gardstedt, Julin & Tornqvist, 2013), implies that technology that is injected from outside, to a society that is not advanced to that level, will fail.

Information: One of the major gaps in information affecting availability is the lack of documentation related to best operation and recovery of systems when they go down (Kumar and Kumar, 2013). The situation improves as access to web based material becomes more accessible to systems administrators, but the gap remains for the more specialized and bespoke systems. Loss of information also occurs as the administrators who have had direct interaction with a long absent implementation team leave the organization.

Management Systems and Structures: Bass and Heeks (2011) noted that the contribution of ICTs in a sector requires a broad range of competencies and skills. They enable the formation of a pool of knowledgeable people that call on each other's knowledge and experience for successful implementation and operation of complex systems and networks (Liinasuo, et al. 2013; Bass and Heeks, 2011). In Hawari and Heeks (2010), a major management decision by a Jordanian manufacturer was based on imitating an American corporation. This disregarded the enormous gaps in the supporting structures and environments between the two regions. The recognition of such disparities is also highlighted by Touray and Salminen (2014).

Staffing and Skills: Dearth of relevant skills is chronic, especially in hardware and network domain areas (Mow, 2014). The very design of advanced systems such as ERPs, assumes the existence of 'a balanced multifunctional team' drawing skills and knowledge from a variety of areas (Hawari and Heeks, 2010). In reality, the client organization business managers may not even be fully aware the level of skill and knowledge required to successfully and sustainably operate the system.

Milieu (Other): The external political, economic, socio-cultural, technological and legal environment. Social cultural factors influence the level of attention and importance attached to the high availability of the systems by the senior management, systems administrators and external support teams (Bass and Heeks, 2011). It also encompasses language barriers, societal attitudes towards ICTs and the scarcity of local ICT content, and telecommunications infrastructure, investment resources: Particularly time and money (Touray and Salminen. 2013).

2.6 Gap Analysis

The disparity between the design of the system and the reality of the context in which it is applied is the measured gap. The measurement of a qualitative nature. Taking gap values from 1 to 10, and considering the 7 dimensions, the highest score of gap measured would be 70 gap points. Accordingly, on a scale of 1 to 5, the highest gap score will be 35. In the following table, five bands of gap ranges are presented. The likely outcomes of systems projects whose gap measurements match the different ranges are indicated. Interventions in the different dimensions may move the project from one likely outcome to another. In table 2, the observed values of gap for different dimensions are presented. These figures are developed pre-implementation. Different players are expected to put in place various measures and actions, to close the gaps, or reduce them to levels that pose little risk of failure. For management, this can be a project saving mitigation application of the model. On a scale of 1 to 10, the following scale gives an indication of the risk of failure associated with each level of reality gap. This scale may be translated to a 1 to 5 gap level measurement, which is applied in the design of this study.

Table 2: Design—Reality Gap Predictive Values

Dimension	**Gap Score**	**Likelihood as Cause of Failure**
Information	8	Likely
Technology	8.5	Very Likely
Processes	8	Very Likely
Objectives & Values	9	Very Likely
Staffing & Skills	8.5	Very Likely
Management Systems & Structures	8	Likely
Other Resources	5	Possible

(Adapted from Hawari and Heeks, 2010)

Based on the scale, each of the seven dimensions is assigned a score, after the assessment of the project being evaluated. The worst possible score would be 70. For any single dimension, a score of 8 or more would mean the project is in high risk of failure, in which case the other dimensions may not adequately compensate for the deficiency. When multiple dimensions have high scores, it almost determines the complete failure of the project in the very early stages. This is so because the users and stakeholders soon come to see that the implementation is a misfit for the target group.

Table 3: Predicted Project Outcomes

Design—Reality Gap Score (Overall)	Likely Project Outcome
57 – 70	Project will almost certainly fail unless action is taken to close design—reality gaps
43 – 56	Project may well fail unless action is taken to close design—reality gaps
29 – 42	Project might fail totally, or might well be a partial failure unless action is taken to close design—reality gaps
15 – 28	Project might be a partial failure unless action is taken to close design—reality gaps
0 – 14	Project may well succeed

Adapted from Hawari and Heeks, 2010

During the implementation, it is possible to make changes to the different areas that are evaluated by the different dimensions. Management may evaluate the whole organization and decide to make adjustments in line with the objectives of the systems project. In cases where the project impacts the work of the entire organization, this can be critical. It may mean renewal of the organization in aligning it to a renewed way of doing things with the new system.

Table 4: Gaps as Likely Causes of Failure

Dimension	Gap Change	Gap Score	Likelihood as Cause of Failure
Information	-1.5	6.5	Likely
Technology	-2.5	6	Possible
Processes	-2	6	Possible
Objectives and Values	0	9	Very Likely
Staffing and Skills	-1	7.5	Likely
Management Systems & Structures	-1.5	6.5	Likely
Other Resources	0	5	Possible

Adapted from Hawari and Heeks, 2010

More gradual change may even be possible during the actual long term usage of the system, it is possible to change the gap sizes of different dimensions. Managerial and Staff capacity, while expensive, can be changed. So is information and technology. The efforts put into bridging gaps may yield some results. For this model, changing the design of the system proposed is a major approach to bridging the gaps. The following table shows an example of the results of efforts applied to close the gaps, and what the results indicate. The results of such efforts may just move the system in question, or its implementation from the may fail category to likely to succeed with further efforts. The failure to close some important and large gaps at all, either during design, implementation, or operation may keep the system in the dire category.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Research Design

The research project was situated in Nairobi, Kenya. It focused on health care organizations that run computer based systems that are required every day and night of the year. These institutions are in different levels of maturity in adopting advanced computer based systems. The respondents were systems administrators and Information Technology managers in various medium and large sized health care institutions, both public and private. A cross-sectional qualitative study was conducted. The research involved collection of primary data. This was carried out by the use of structured questionnaires. It involved having participants, who are professionals in the area of systems administration to complete them as fully as possible. These questionnaires had sections with open ended questions. For these, the answers were highly dependent on the unique experiences and the unique contexts of the systems the administrator worked with. For these components of the study, an interview approach was used. This was especially in seeking to understand the human elements of systems success or failure. The human factors are significant as implied by the model being applied. A degree of iteration was accepted where the researcher went back to ask several interview questions after having received a completed questionnaire. At the same time, for the sake of objectivity and analysis, structured data collection and analysis techniques were applied. The study was qualitative in nature. While some data was quantitative in nature, it was limited.

3.2 Data Collection and Analysis

The Nairobi County has 59 hospitals with inpatient departments and 24/365 operations. 53 of these were reached for participation in the research study. The other six were not reached due to logistical constraints. Of those reached, 8 institutions formally declined to participate. It was noted that these were affiliated to two sponsoring agencies. Another four declined informally. The researcher was able to interview and gather data from 41 health care institutions. Interactions for data collection involved 49 individuals. Starting with the occurrences of systems failure, the researcher sought to extract each respondent’s unique experiences and insights, being sensitive to the context and the factors that may affect one specific setup. The very large institutions, with over 500 systems users and over 1000 employees, were compelling candidates for case study research. However, it was untenable to carry out case study of these few and combine the findings with the smaller organizations. It was the intention of the research to capture the factors from a broad range of institutions as an indication of what may affect a much larger scope.

The unit of study was the systems installed in the health care institutions. Each institution, represented by at least one respondent had one or more systems subjected to the study. A systems administrator was in a position to provide detailed information for two, and for some, three systems in the institution in which they work. The systems administrators were asked to fill structured questionnaires. The sampling method was non-probabilistic. The number of potential respondents was 59. Being scoped in the Nairobi city area, it was possible to reach almost the whole population for data collection.

Due to scope constraints, representatives from 41 health care institutions were interviewed. It was possible to do several interviews with 11 of the respondents. These were based on the questions in the data collection too. Another 19 of the respondent answered the unstructured interview questions during one to one meeting the researcher. The other 11 filled the answers in the printed forms. Some less used or partly used systems and applications in the same institution were not studied but were excluded from the study. They did not meet the criteria to be counted as high availability systems.

A questionnaire was administered to capture the otherwise unstructured data. This provided structure and to render it easier to analyze. The first part of the data collection tool had some open ended questions about the system being studied. A large part of the data collection tool consisted of questionnaire type questions. These were well structured to facilitate quick gathering of pertinent information about the system. The segments of the questionnaire component were derived from the dimensions of the Reality – Gap Model, so that each is represented. The items in the questionnaire consisted of over 28 points. These are structured along the 7 dimensions of the Design – Reality Gap Model. There is also sections that document the characteristics or measurable aspects of the system being evaluated. Descriptions of the contexts of the systems were made by the respondents. In this case, the questions were be open – ended in nature. In a few cases, numeric information was elicited such as the number of occurrences of failure. The questionnaire is attached as an appendix. The results are presented in a textual and narrative structure, illustrated with charts to demonstrate the variations. This table represents the type of systems that were evaluated in the study.

3.3 Limitations of the Study

This study was focused on medium and large health care institutions both public and private, operating in Nairobi, Kenya. For this study, administrators from 41 organizations were involved, representing over 87 operational computer based systems. The field studies were conducted on systems administrators. The study did not involve users. It was the view of the researcher that the systems in question are successful and accepted by the user community where they are in use. The study focused on various factors that contribute to degraded system availability; that is, causing the system to be down or unavailable in any way to all or a large section of the users at the same time.

Table 5: Types of Systems Studied

Type	**Description**
Enterprises Resource Planning Systems	ERP are adopted in the larger institutions that have larger budgets and complex operational processes that demand the level of integration they provide
Electronic Medical Records (EMR) Systems	These are mostly have to be integrated with HMIS or ERP. They may be acquired separately
Health Information Management Systems (HMIS):	Most of the HMIS come with EMR components while some don't and have to be interfaced with the EMR system
Radiology Information Systems and Picture archiving Systems (RIS / PACS)	These systems capture radiology images from diagnostics machines and store them in electronics format for reporting, storage and retrieval
Email systems	Many institutions did have their own email server systems hosted internally. Their availability was evaluated

The time when this happens is referred to as downtime. For a more comprehensive study of this subject, the management needs to be addressed. The administrators may not have the mind of the manager, and may therefore have some bias in matters that the management may have better judgment of. As well, it is important to reach the Board level management to understand the objectives and values of the organization. It was not possible to have the detailed interviews that might yield better quality of data and knowledge specific to contexts as would be good. The need to interview many respondents in a limited time schedule led to compromises as to what is critical.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Research Findings

The study assessed the availability levels attained for the various systems in different institutions. Most systems lag behind the 99.x % availability classes, they were classified in the 9x% availability level. Table 5 illustrates the availability attained for the systems assessed.

Table 6: Reported Systems Availability

Availability Recorded	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85 or Less
Count of Systems	6	12	7	7	4	4	6	9	6	6	3	3	2	4	8

This performance is far below the global standards of measurement of availability that ranges between 99.0% and 99.999%. According to the Classification of High Availability Systems (Adegoke and Osimosu, 2013), the best of the studied systems are in the Unmanaged (Class1), Managed (Class 2) and Well-managed (Class 3) categories.

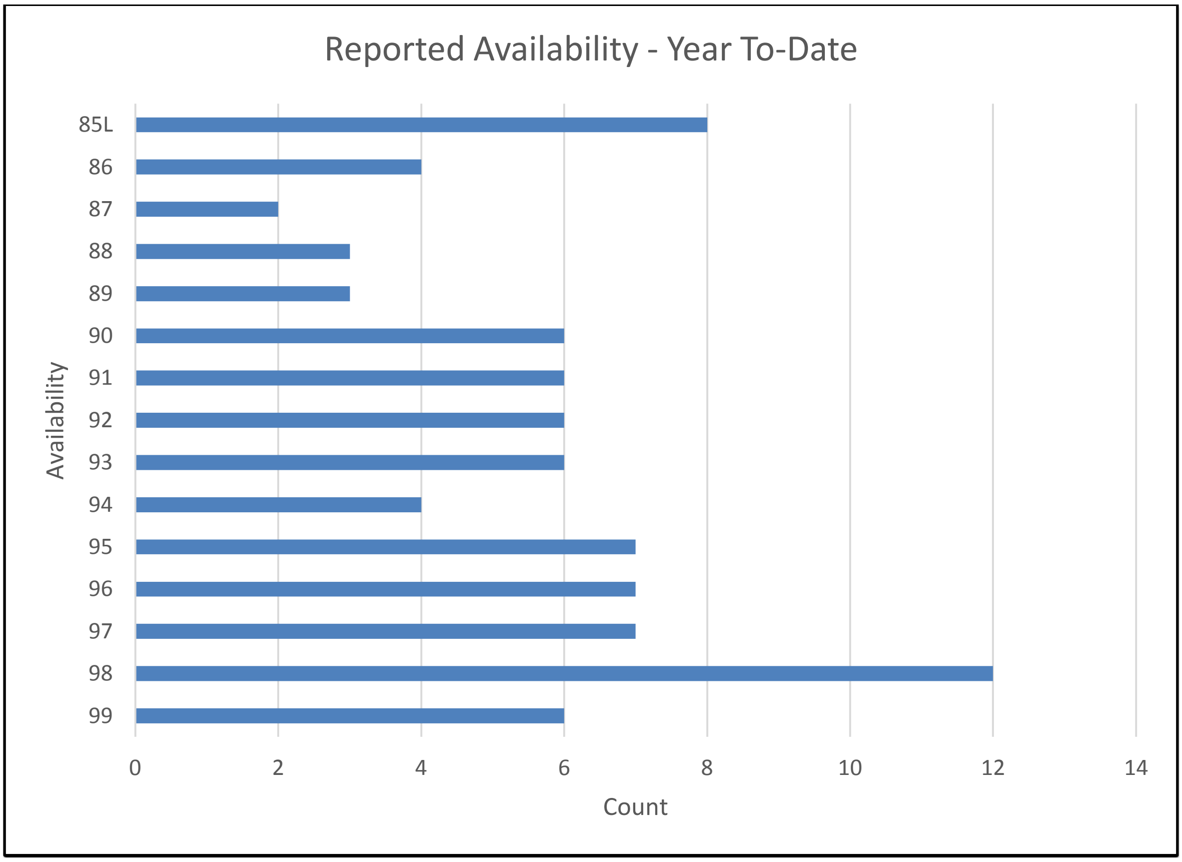

Figure 6: Reported Availability: Year To-date

The following is a distribution graph of the prevalence of each cause of downtime for the systems that were studied.

Table 7: Identified Causes of Failure

Factors Causing Failure	Occurrences	Percentage
Power and Cooling	48	27
LAN, WAN Device Failure	23	13
Disk / Controller /Capacity	6	3
Hardware Failure	14	8
OS and Application Software Changes	26	15
Database Changes Failure	9	5
Backup Failure	18	10
Virus and Malware	11	6
Sabotage and Hacking	3	2
Operator Errors	19	11

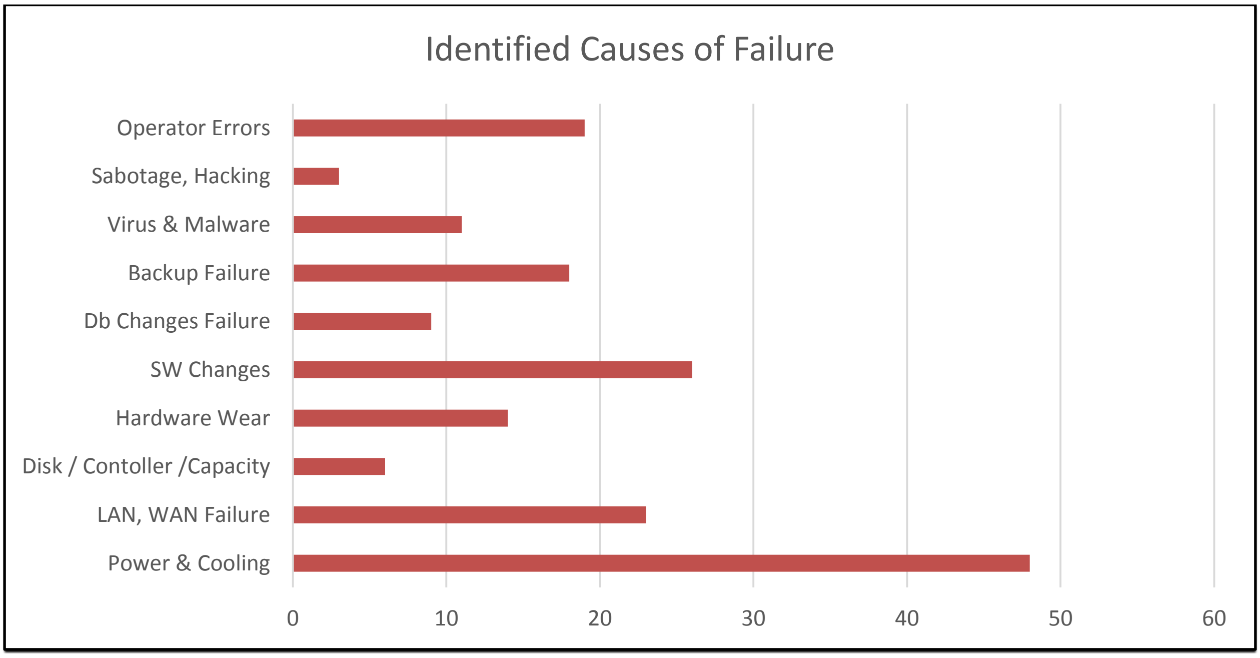

Figure 7 : Identified Causes of Failure

According to the findings, the four major causes of failure are power and cooling issues which come related. Second is Operator errors. This is close to the findings of other studies except that the power related failures in this study exceed this first rated factor. Third comes software changes both in operating system and the applications. For application software changes, these are sometimes frequent where the vendor is still very active with the client, or where the institution feels the need to keep empowering the users with new features, in pursuit of greater utilization of

ICTs. The environment rife with changes presents many opportunities for defects to reach the production environment, and cause failure affecting some or all the system users.

4.2 Gap Measurement and Analysis

On a scale of 1 to 5, the gap between the desired level (worst value is 5) and the current level of achievement in the specific dimension is measured. The most inadequate areas have high gap levels and the better covered areas have lower gap levels.

4.2.1 Information Gap

Table 7 represents the aspects of systems administration and management that contribute to inadequate information to support high availability. The four aspects considered were the availability of system specific documentation to the administrators, the adequacy and presence of current vendor support, specific training available to the current administrators as a means of transferring knowledge and information, as well as availability of knowledge resources.

Table 8: Information Gap

Gap Level	No System Documentation	Inadequate Vendor Support	Inadequate Staff Training	Off / Online Support
Very Low	3	7	4	6
Low	19	20	15	23
Medium	37	47	53	50
High	24	11	13	5
Very High	4	2	2	3

By count, most of systems was found to have medium levels of deficiency as far as the information required to run them effectively was concerned.

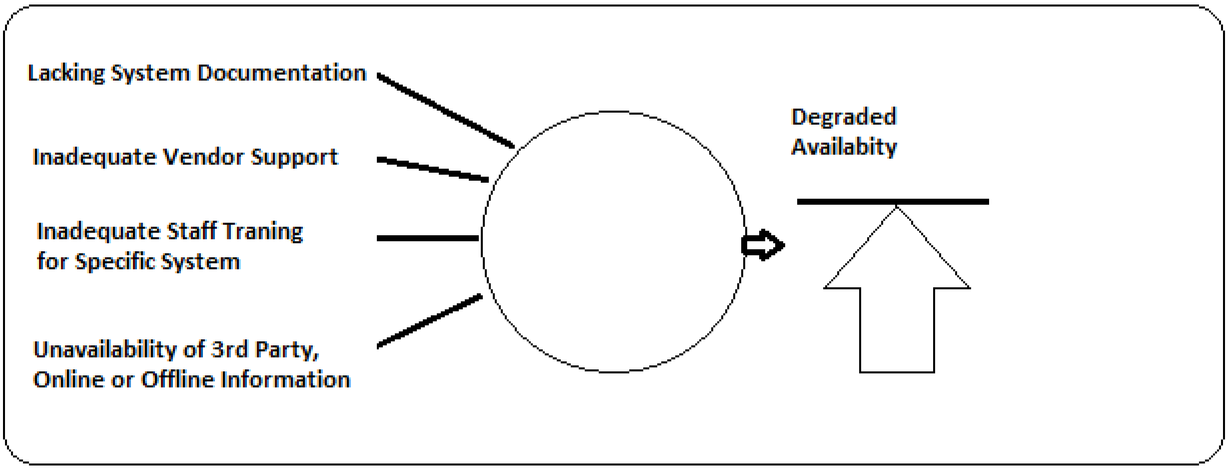

Figure 8: The Information Gap

Lack of information to facilitate high availability is indicated by the lack of documentation, lack of specific training for the system and the lack of vendor collaboration. Training was rarely not done. Collaboration was low. Most respondents indicated an average or medium availability levels of the information required. It is left to the administrators to seek this information out on their own or to learn on the job. In lease arrangements, the vendor retains almost total control and information, but the availability levels can be very high due to high specialization of the vendor in implementing, operating and maintenance of the specific or range of systems.

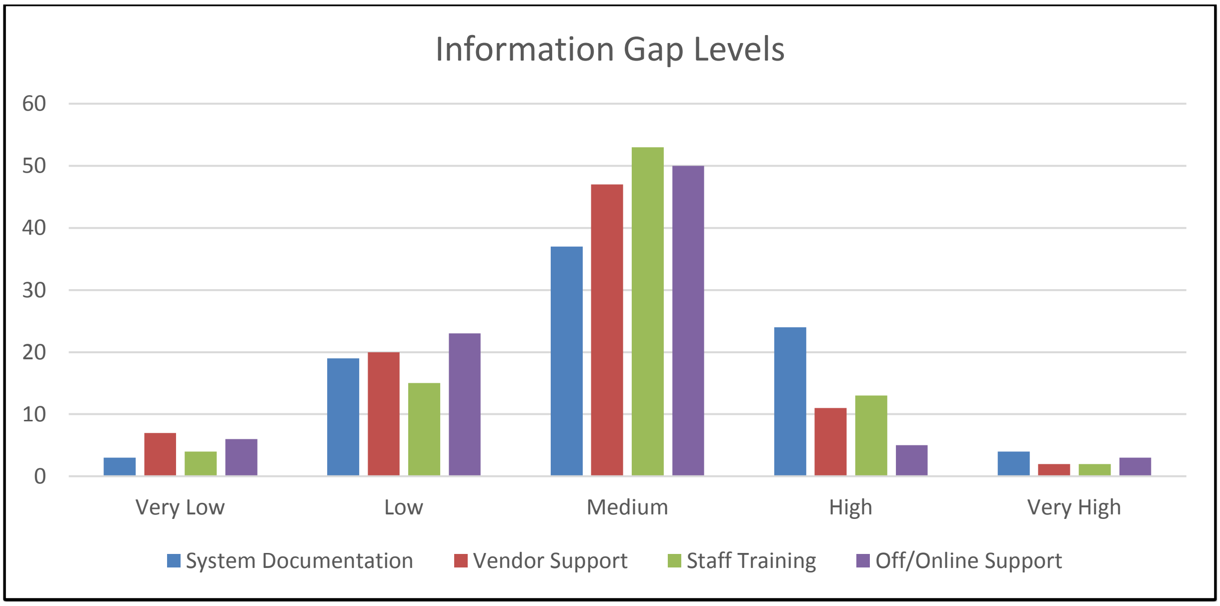

Figure 9: Information Gap -Chart

4.2.2 Technology Gap

Table 8 represents the aspects of technology that offer challenges affecting high availability of the systems. Advances in hardware and software technologies at the global level are unrelenting and require constant effort to keep up to. The installation and application of the technologies in new areas where the operating environment is not well adjusted degrades the total quality of the system. The aspects that were analyzed were hardware failure, software failure during changes, power and cooling systems failure and the condition of backup and recovery systems.

Table 9: Technology Gap

Gap Level	**Hardware, Network Failure**	**Software Change Failures**	**Power and Cooling Failures**	**Backup, Recovery Systems**
Very Low	11	3	0	1
Low	20	11	7	8
Medium	32	18	47	37
High	19	38	27	37
Very High	5	17	6	4

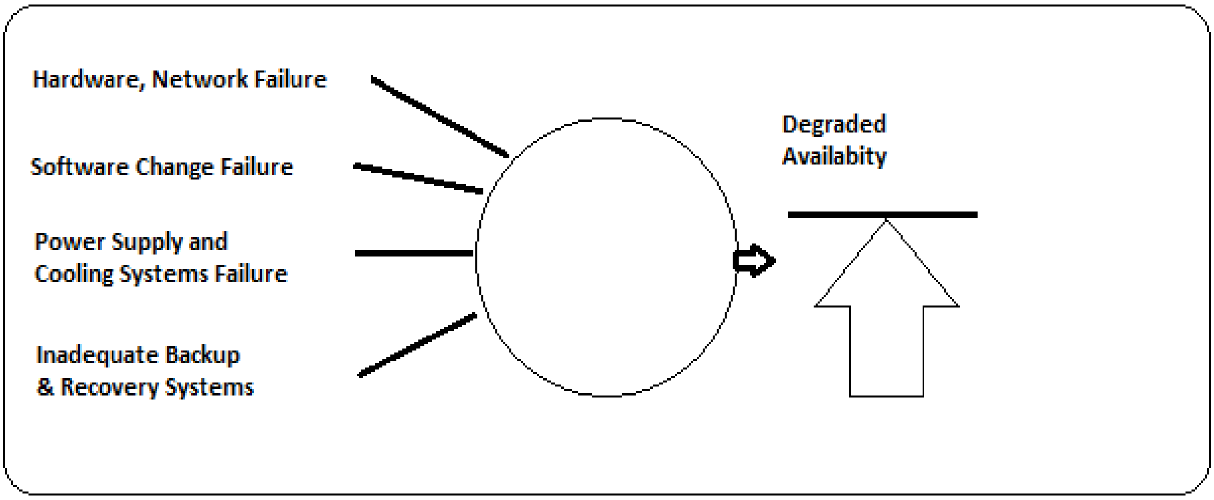

Figure 10: The Technology Gap

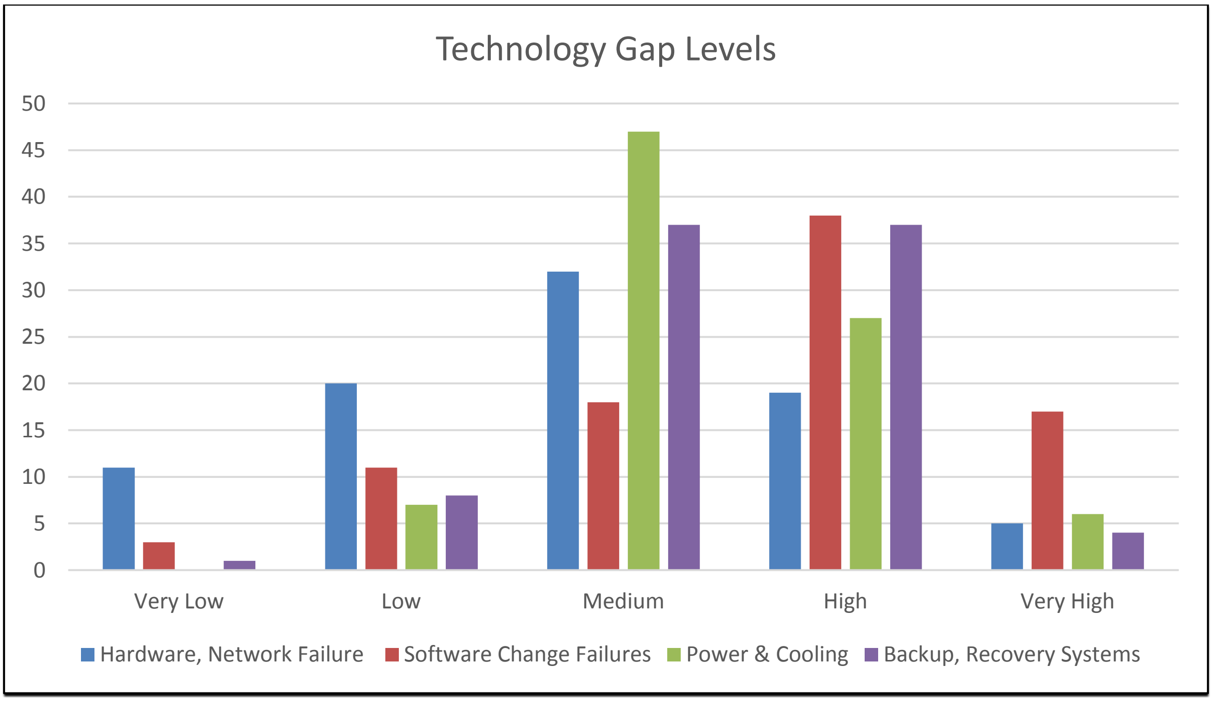

Figure 11: Technology Gap - Chart

Measuring the technology gap has many facets. Complexity of software, operating system configurations, server hardware, network gear configurations and related issues. Understanding of the hardware, software and the ability to change and configure it in an error free manner remains a big challenge to the administrators. It was noted that some PACS systems have very high availability, where they are fully managed by the vendors in a lease contract. This is a financially expensive choice. The vendors charge premium rates for the lease operation. It is also noted that hardware failure is much lower in frequency than other technology factors. It is acknowledged that in the absence of other interfering factors, modern computer hardware is more reliable than in previous decades.

4.2.3 Processes Gap

Processes refer to documented and adopted procedures and standards of carrying out business activities. They are supposed to be put in place and implemented by management for effective business operations. The collective lack of effective processes, procedures and controls in the administration of systems for high availability was assessed. The factors as monitoring mechanisms, process visibility in the organization, operational controls and their enforcement, and the effectiveness of the maintenance schedule were all assessed.

Table 10: Processes Gap

Gap Level	Poor System Monitoring	Poor Process Visibility	Lacking Operational Controls	Poor Maintenance Schedules
Very Low	1	3	2	2
Low	7	16	15	12
Medium	43	32	41	30
High	35	29	23	31
Very High	1	7	6	12

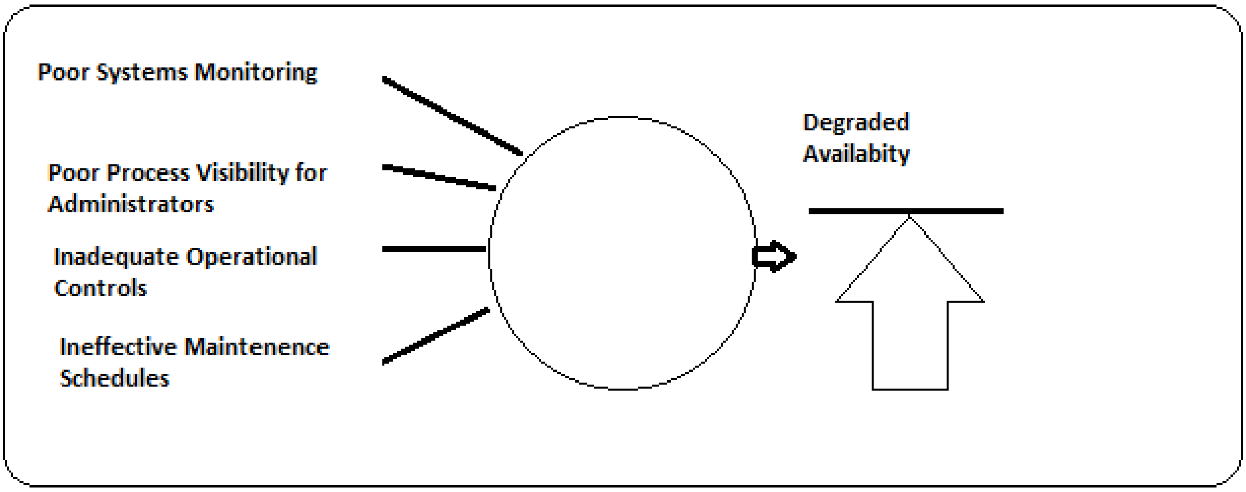

Figure 12: The Process Gap

The existence and visibility of formal operating procedures, documented internal standards, mechanisms for enforcement were assessed. In few cases, a strong audit with a management that is able to implement changes was in place to ensure high standards of compliance. Most respondents however, indicated that management controls are poorly defined, and poorly implemented. There was a large number of respondents who indicated that the processes for effective systems controls were very poor or non-existent. This in turn means that the operations in systems departments are in many cases ad-hoc. It further points to deficiencies in top management agenda (objectives and values), and management quality in the whole organization.

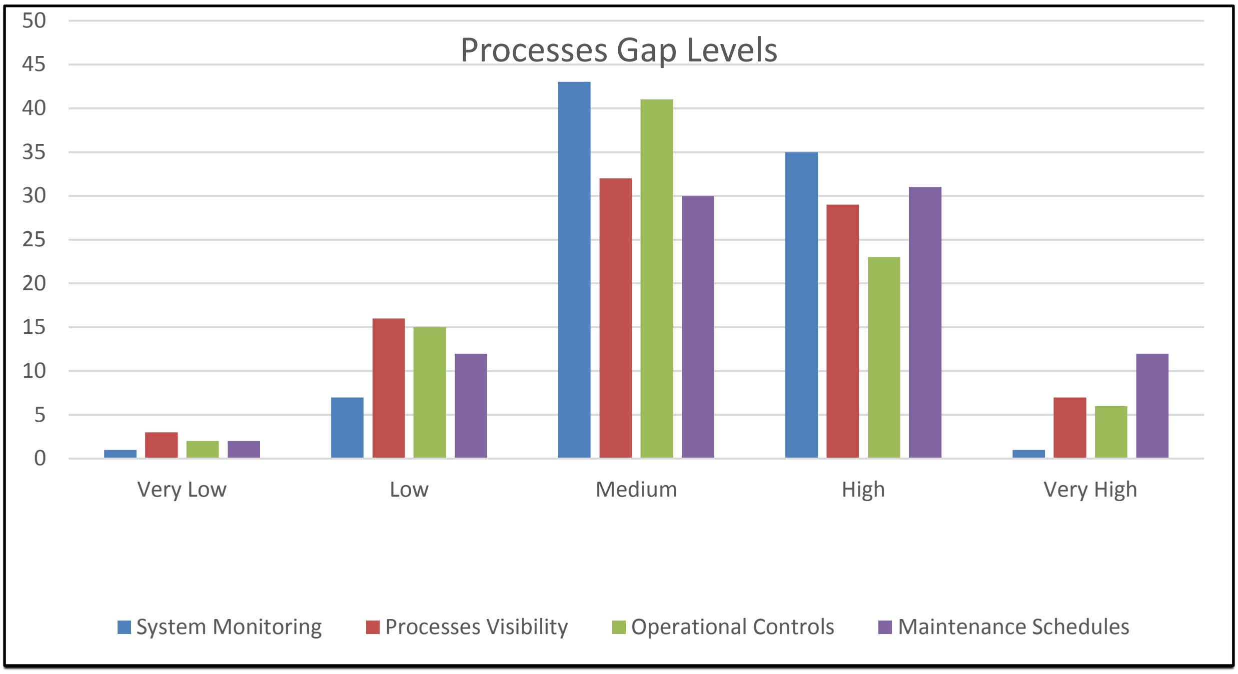

Figure 13: Processes Gap - Chart

4.2.4 Objectives and Values Gap

This refers to the direction and priorities of the senior management and the extent to which they propagate them to the rest of the organization. They refer to the core driving forces of the organization. The driving forces are driven by the specific aspirations of the business leaders. When the aspirations are tied to effectiveness of systems reliability and availability, then the drive to ensure proper administration for availability is available and is made known to the systems administrators. They in turn seek the measures and resources necessary to achieve the desired goals in line with the goals of senior management.

Table 10: Objectives and Values Gap

Gap Level	**Support By Management**	**Investment in ICTS**	**Assigned Importance by Management**
Very Low	6	5	12
Low	27	16	21
Medium	32	32	44
High	21	27	10
Very High	1	7	0

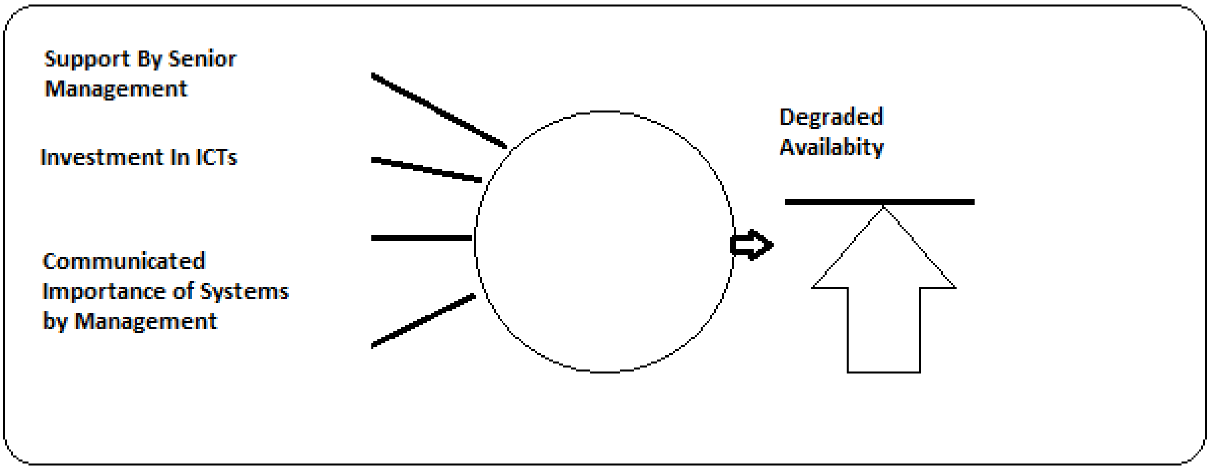

Figure 14: The Objectives and Values Gap

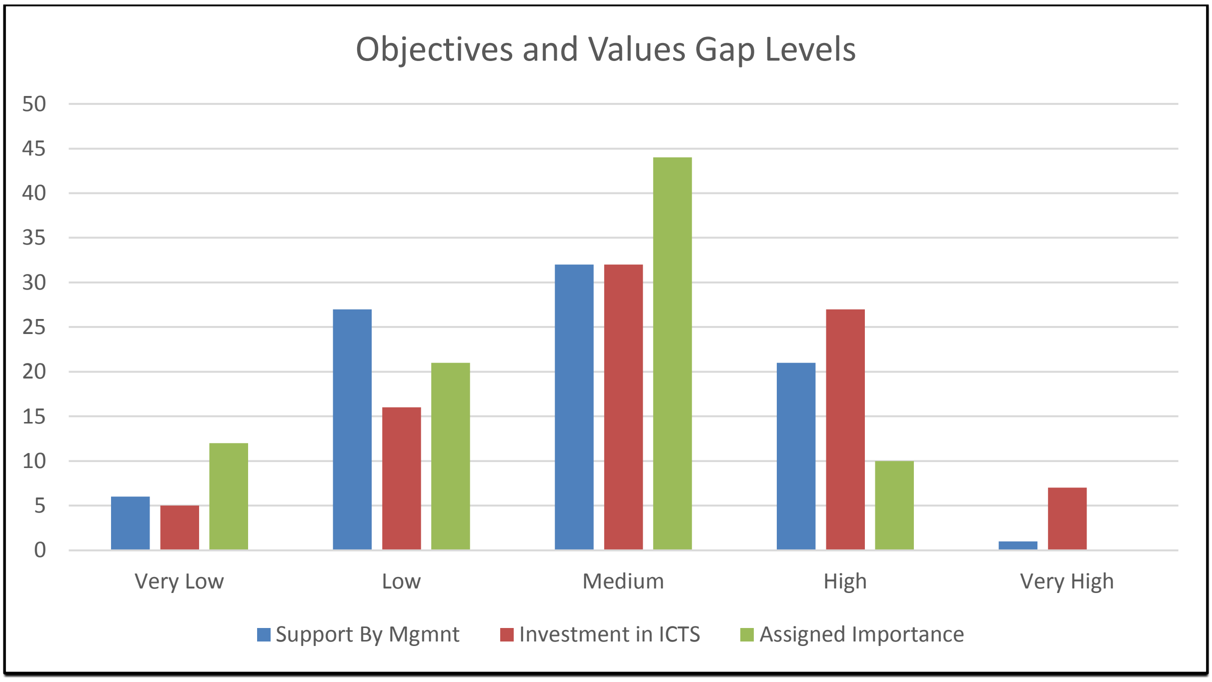

Figure 15: Objectives and Values Gap - Chart

The perception of management's interests and their commitment to high availability of the systems was assessed. The communication and effective emphasis on the value of systems by top management was assessed. In six organizations, it was found that the effectiveness of the systems, the quality of systems and the availability was a high priority. In these, the investment in ICTs was large. This investment includes the extra systems components that are implemented to install redundancy, failover and recovery systems. Another indicator assessed was the investment in power supply and control systems. The management commitment may be seen through their willingness to spend in eliminating the number one cause of failure – power outages. Another strong indicator was the tolerance of manual processes instead of the computer based system. Tolerance for manual interventions was indicative that high availability of the automated processes was not given a high priority.

4.2.5 Staffing and Skills Gap

Table 12 shows the aspects of staffing and skills that affect the success of high availability systems covered in the study. Cost of the certification training for the relevant skills, failures during software change implementation, operator errors especially during uncommon tasks and lack of the right tools or the rights skills to operate the tools were the factors that were considered.

Table 11: Staffing and Skills Gap

Gap Level	Lack of Certified Administrators	Software Change Failures	Operator Errors	Lack of Advanced Admin Tools
Very Low	2	4	3	1
Low	4	11	6	7
Medium	29	28	26	39
High	38	39	45	34
Very High	14	5	7	6

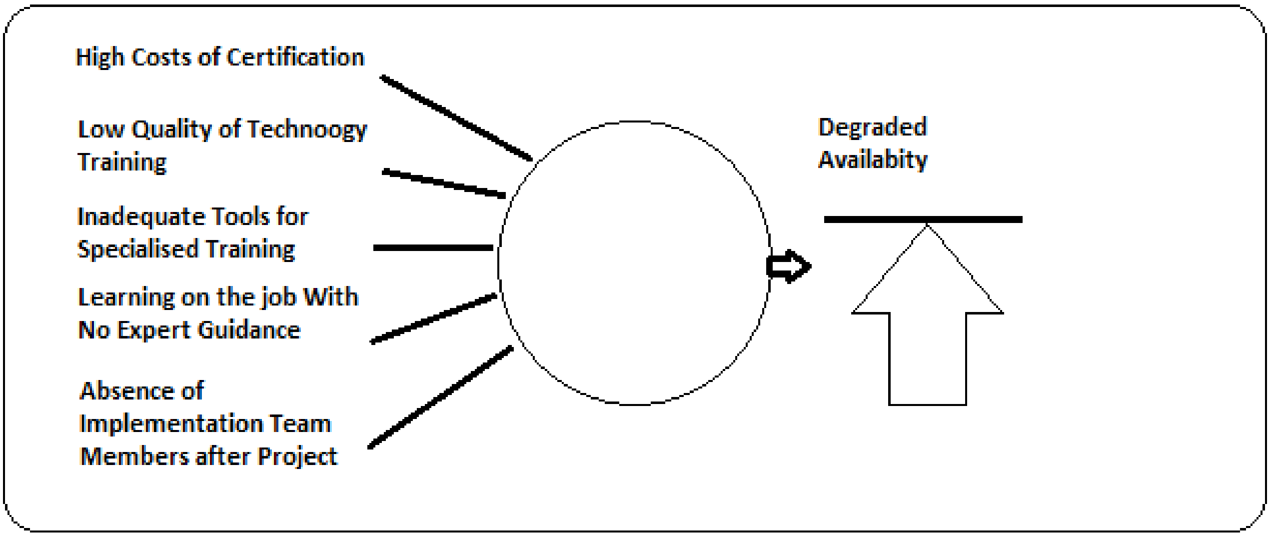

Figure 16: The Staffing and Skills Gap

Operator errors, the second largest cause of failure can be partially tackled by hiring staff that have better knowledge of the systems they work with. One of the indicators of qualification is certification of administrators by the original equipment manufacturers. Lacking the right skills internally increases the time it takes to restore a system on average (MTTR) and thereby decreases the availability. Where the staff are highly skilled, it indicates the commitment of management to the objectives of high systems quality and availability. A number of the respondents indicated that they learn the technology on the job. For most, it's the first experience with this particular system, server or network technology.

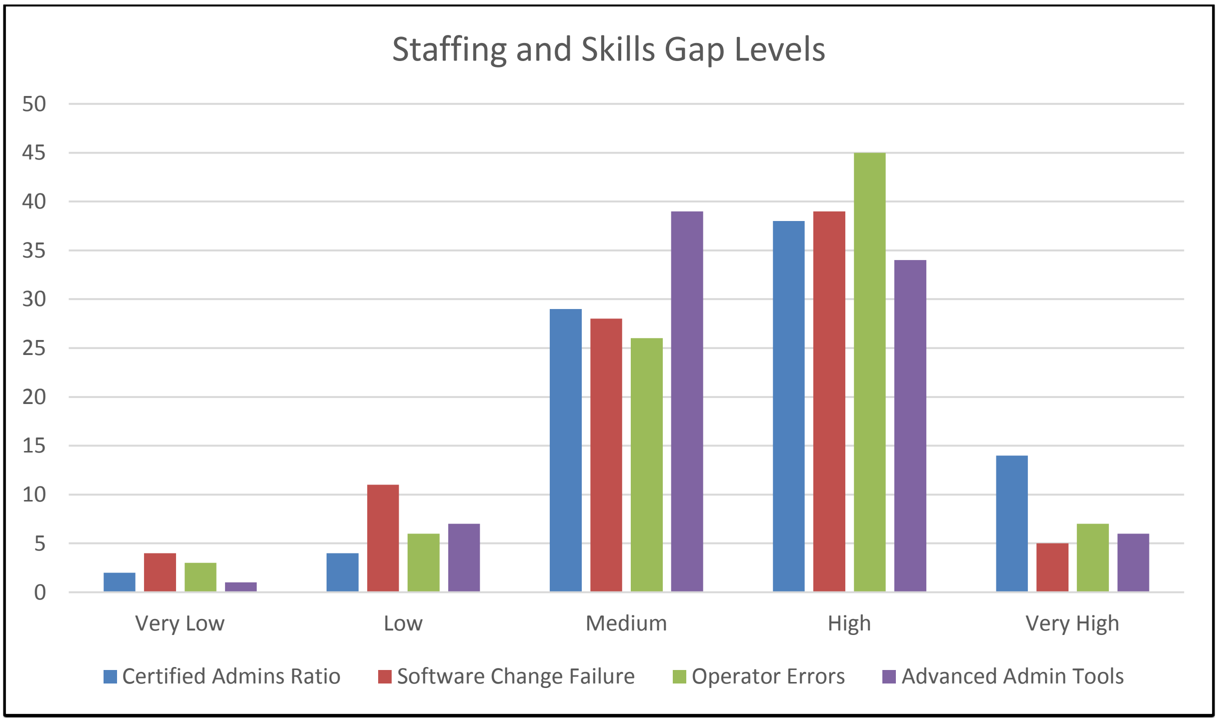

Figure 17: Staffing and Skills Gap – Chart

This leads to reluctance to perform complex recovery or maintenance tasks, and errors of configuration or changes as well as on dependence on vendors.

4.2.6 Management Gap

This relates to the capacity of managers and the effectiveness of their actions in relation to the management of high availability systems.

Table 12: The Management Gap

Gap Level	**Ineffective Actions**	**No Enforcement of Standards**	**Dependence on External Experts**	**Inactive Vendor Support, SLAs**
Very Low	7	1	3	3
Low	11	16	18	13
Medium	20	34	33	35
High	33	25	25	27
Very High	16	11	8	9

Management gap was measured by the enforcement of effective measures and procedures to ensure high availability. It was assessed by the enforcement of internal standards, where they existed, that are geared to systems availability. Availability of active and effective Service Level Agreements (SLAs) with vendors and support contracts with external experts for key systems indicated the commitment to their availability and overall health of the system.

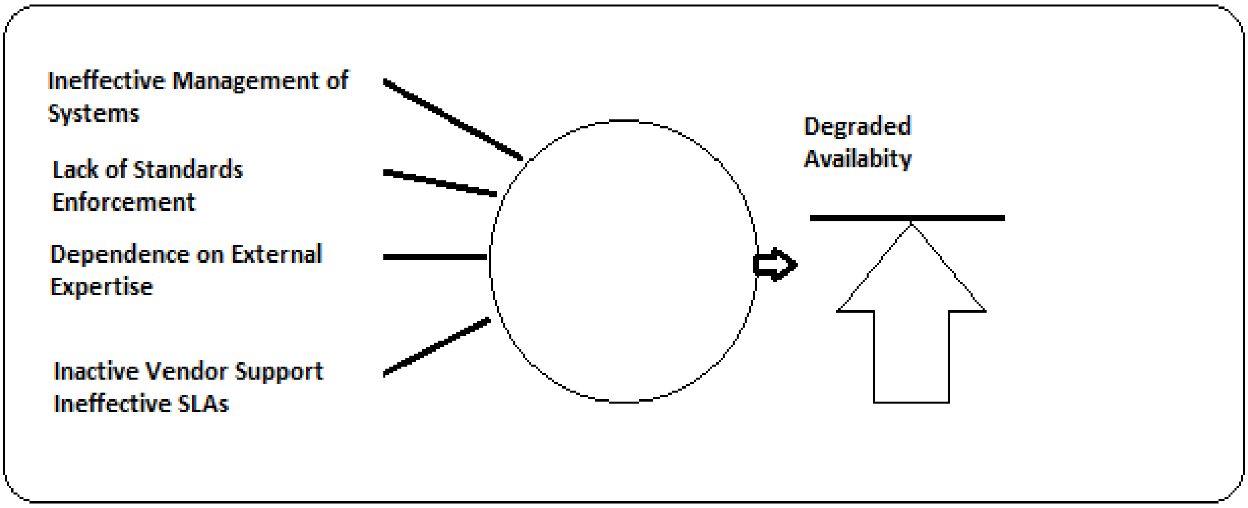

Figure 18: The Information Gap

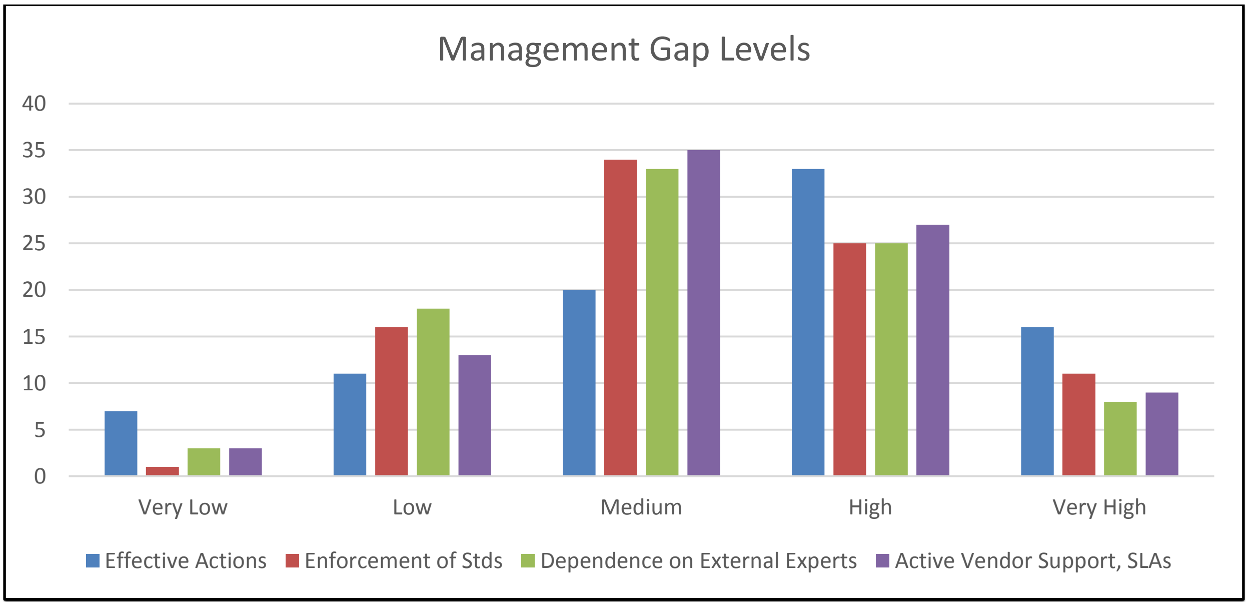

Figure 19: The Management Gap - Chart

In well managed institutions, there is a dedicated ICT Manager. The existence of a well-trained and experienced individual for this role is an indicator of the commitment to systems quality and availability. In smaller institutions, by number of users, the management of information systems has been delegated to business professionals, or to systems administrators, each being unsuited for the job for different reasons. In such, the role of the ICT manager is not clear or defined. The effectiveness of the manager is further affected by poorly defined roles of the staff and poorly developed or non-existent processes to work with.

4.2.7 Gap in Other Factors

A milieu of other factors affects the effective availability of the systems covered in the study. Table 13 is representative but not exhaustive. While many of the factors are common, there are many that are unique to each installation, due to history, vendors, management style, resources availability and other contributors.

Table 13: Gap in Other Factors

Gap Levels	Inadequate End user Skills	Inadequate Investment Capacity	Weak Internal Audit
Very Low	1	2	1
Low	7	12	8
Medium	43	30	37
High	35	31	37
Very High	1	12	4

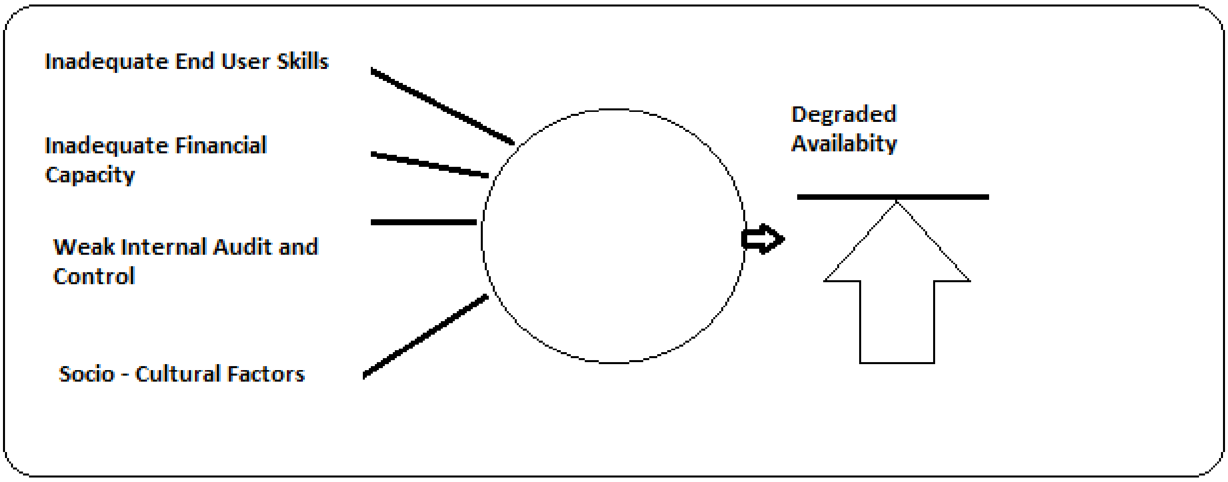

Figure 20: The Management Gap - Chart

Other factors such as the availability of resources for the investment in ICTS, the knowledge and expectations of end users, the pull demand from customers play a role. It was observed that the external influences are not strongly demanding for high availability. Except for a few providers who cater for more elite clients, others serve a population that is more tolerant of various aspects of downtime.

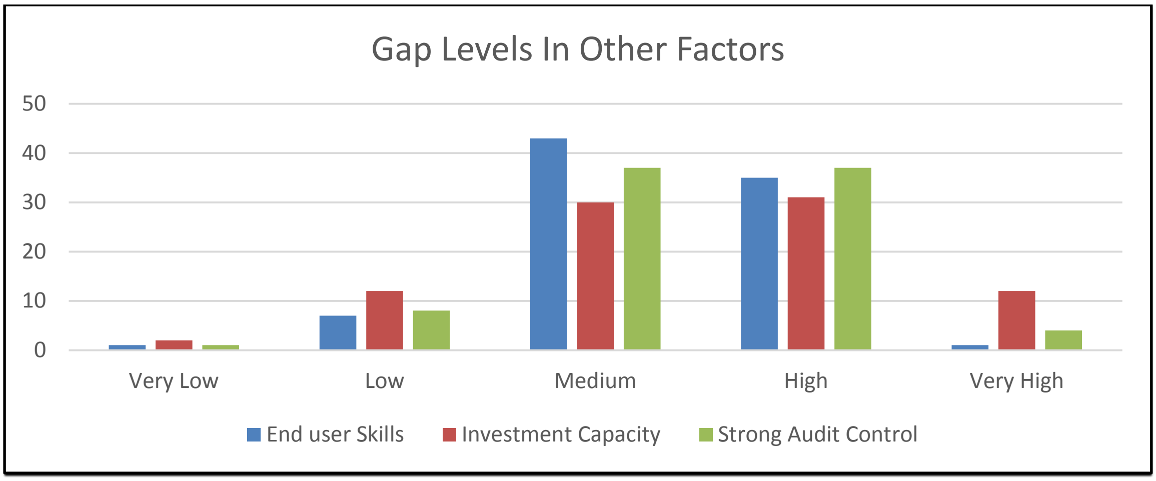

Figure 21:Gap in Other Factors - Chart

4.3 Mitigation Measures

The following sections enumerate the various remarks concerning mitigation from the respondents. Systems administrators responding to the research tools and in discussions related had these to say regarding lack of information on the systems they were required to support. It would fall on the management of an individual organization to evaluate again the effect and weight each is having in their specific environment and address it accordingly. Conversely it would be wise to ignore such as don't apply to their specific context.

Table 14: Recommendations per Gap Analysis

Information	**Have vendors train the administrators**
	Vendors to be more available to clients
	Online, offline documentation be availed by vendors
	Clients to choose systems that are readily documented
	Change the Vendor (and system)
	Use Open Source Software whose information is more readily available

Regarding technology, different mitigation factors were cited. Reliability of power supply fell in the same category as the availability of technical documentation for procured software. Besides, administrators favor software that has publically available support and documentation as opposed to that tied to one vendor. Where the vendor support is excellent, this may seem counter-intuitive, but when the support is broken, administrators would seek to go to the public domain and online community.

Table 15: Recommendations for Technology Gap

Technology	Mitigation Measures
	Deploy reliable automatic failover standby power generator
	Acquire right capacity of UPS systems
	Procure readily documented and stable Software
	Implement simplified and stable networking solutions
	Use virtualized servers to simplify server management
	Copy the setups of other institution that works efficiently
	Install More locally serviceable, sustainable hardware

In most of the cases, administrators were not strictly required to follow procedures. The exceptions were the institutions where a strong internal audit was in place. In such a case, governance accountability to the senior management and especially to the Board or equivalent, ensured that some degree of conformity to procedures was observed. Even then, the undoing was the lack of induction of often new staff to the correct and procedural way of carrying out administration of systems. The effectiveness of the processes seemed to be under threats from ever exiting staff and lack of championing of the processes.

Table 16: Recommendations for Processes Gap

Processes Gap	Mitigation Measures
	Develop effective and efficient processes
	Enforce procedures for software changes
	Control the changes by the vendor to maintain understandability
	Develop and implement effective maintenance of power systems
	Develop and implement effective software change procedures
	Develop and implement effective early warning monitoring systems
	Provide and train administrators in use of effective tools

Some organizations have very sharply defined business objectives for the systems installed. The business cases are well developed, the systems and the vendors are carefully selected, the installations is carefully and effectively carried out and most importantly, governance and operational structure is put in place, with effective processes and procedure and controls to ensure that the systems are sustainable and that they continually deliver the intended results for the business. This is the case there the management has determined that there must be material business outcomes that can only be realized by effectively run ICT systems. If for any reasons this is not the case from the start, or falls by the wayside over time, then the running of the systems is let to deteriorate and is neglected. This is an indication that the objectives of the business are no longer tied to the effectiveness of the systems, or that the business management has deteriorated to the extent that success is not the critical and main objective. In non-ethical business circles, this can be the case since a breakdown of the systems management may provide loopholes and leeway for selfish objectives.

Table 17: Recommendations for Objectives and Values Gap

Objectives and Values Gap	**Mitigation Measures**
	Change Management
	Invest more in systems, and in systems quality
	Educate management and owners on the value of systems
	Place managers who are capable of applying systems in business operations

The Staffing and Skills was found to be a very dynamic area. Skills were being acquired on the job all the time, many times without a guide or mentor. The administrators had in many cases to work their own way to gain a skills set required for a particular environment. Again, only the organizations that had investing capacity could afford the highly skilled individuals to man the advanced systems. Even these however seemed under constant threat of losing the skills to other organizations due to the demand for experienced staff for more advanced positions.

Table 18: Recommendations for Staffing and Skills Gap

Staffing and Skills Gap	**Mitigation Measures**
	Change to a more effective vendor or service provider
	Deploy sustainable systems that won’t require rare skills
	Effect administrators training by the vendor or certified provider.
	Hire certified and experienced administrators
	Purchase applications systems that are well understood
	Retain the trained administrates by paying them better

Business managers’ understanding of the ICT administrator success factors needs to increase. This in many cases increases with the increase in quality of management in the overall organization, especially with increased understanding of modern organizations and doing business in a technology driven economic environment. It is therefore critical that top management itself is well versed with technology issues. After that, they are able to determine the effectiveness of ICT manager or systems administrators in properly supporting the business. In such, they can decide to make changes of the systems management staff, as well as make the necessary changes in the technology itself. Of equal importance they will be able to cause to be placed the right and effective systems, and the effective controls and measures of effectiveness, in total creating a better result from the ICT installations.

Table 19: Recommendations for Management Gap

Management Gap	**Mitigation Measures**
	Apply better management practices
	Improve the quality of managers : Hire or Train
	Enforce procedures for backup and for preventive maintenance
	Put in place effective procedures and controls
	Pay Administrators more to retain skills
	Hire administrators with balance of skills for the installed systems

There are other factors that do not fit in the six previous categories. These brought out also a myriad of comments from the respondents.

Table 20: Recommendations for Other Factors

Other Factors	**Mitigation Measures**
	Put in place strong internal audit
	Invest in ICTs at par with other areas of the organization
	Hire users with adequate computer literacy

4.4 Discussion

The different dimensions feed into each other and are inter-dependent. Poor corporate objectives and values lead to the placement of inadequate management and technical staff. It also accommodates lack of management processes and leaves the staff to operate in an ad-hoc manner. All these result in unmanaged systems availability and the result can only be poor. With regard to information, a strong relationship with the vendor of the system is necessary. This will ensure that the knowledge necessary for the proper operation of the system is always and readily available to the institution. Those investing in new systems should consider utilizing high availability hardware with virtualization. Processes should be well developed, and well enforced by managers to ensure that operations and maintenance are carried out in a professional, sustainable and effective manner. More importantly, the objectives and values of the institutions highest management organs should take recognition of high availability of systems as an important contributor to business process efficiency.

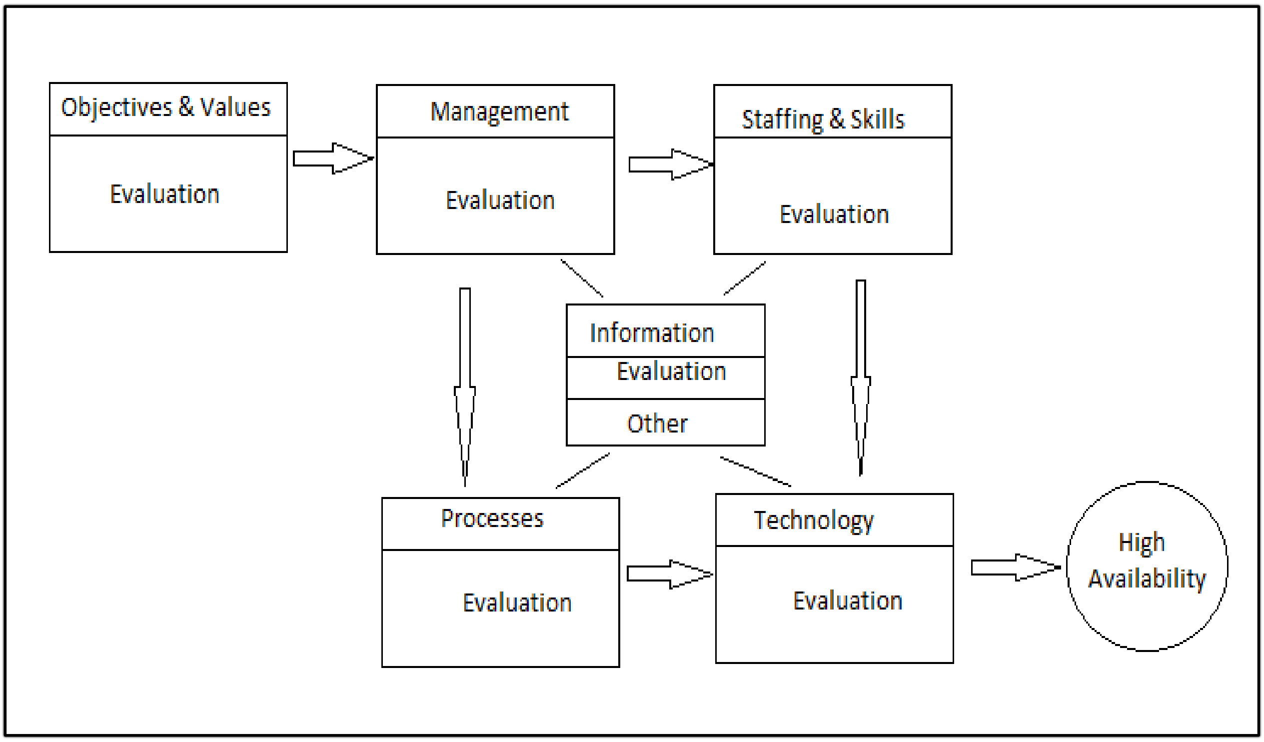

Figure 22: Proposed Availability Enhancement Graph

Managers should not leave the recommendation for hardware and software to vendors, who are likely to offer what is available or most profitable to them. High availability can be affordably attained by a high capacity server with virtualization, allowing for creation of multiple virtual servers to meet the needs of the organization. More importantly, failure of one dimension can infuse negative input into other dimensions and cause an aggravated degradation of systems availability.

Figure 23 shows the interactions among the seven dimensions of the Design-reality Gap Model in the factors that influence the availability of the computing systems in the study. This presentation does indeed present a basis for further evaluation of these factors. It is also a quite comprehensive view for management. It offers management at least two views, the causes, and the targets for mitigation measures.

Because management has to contend with limited resources, they can from this view determine the hot points and assign their investment in select areas in the overall environment.

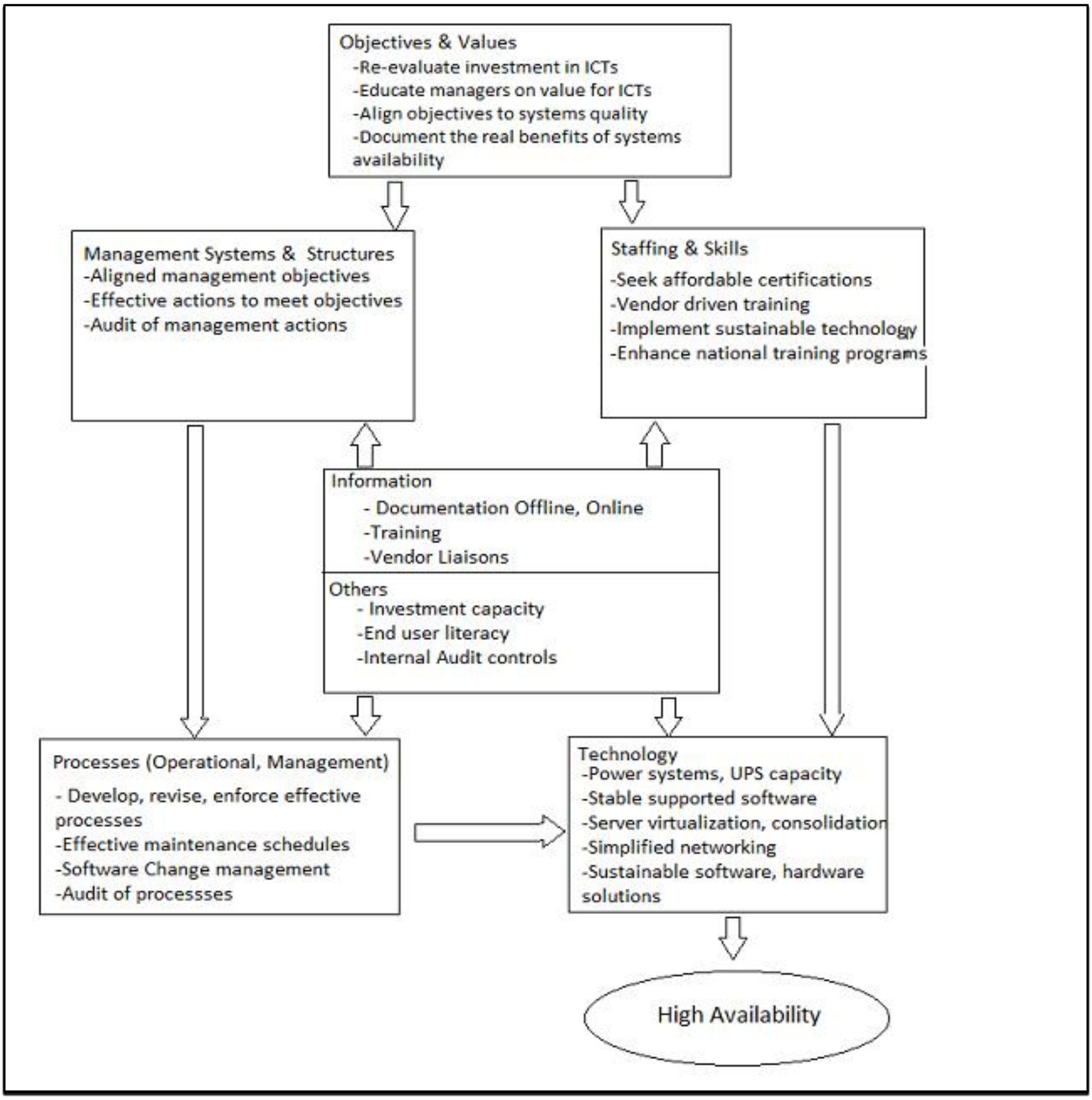

Figure 23: Availability Enhancement Graph Evaluation Criteria

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Achievements

In this study the researcher has succeeded in aggregating the common causes of failure in systems within the health care providers in Nairobi, Kenya. Poor qquality of power supply, and the control mechanisms implemented to improve it have a bad effect on systems availability. This is quite different from the economies where power supply quality is very high. Consistent with other studies, skills gap and technological gaps also influence largely the availability of systems. These manifest in operator errors and failures during planned software or hardware changes. The study has also illustrated that the factors causing failure interact with each other. They are grouped in the seven dimensions of the Design – Reality Gap model. When the elements of one dimension are deficient, others aspects also suffer. The cornerstone of this is the objectives and values of the organization. These strongly influence management, processes, staff and technology.

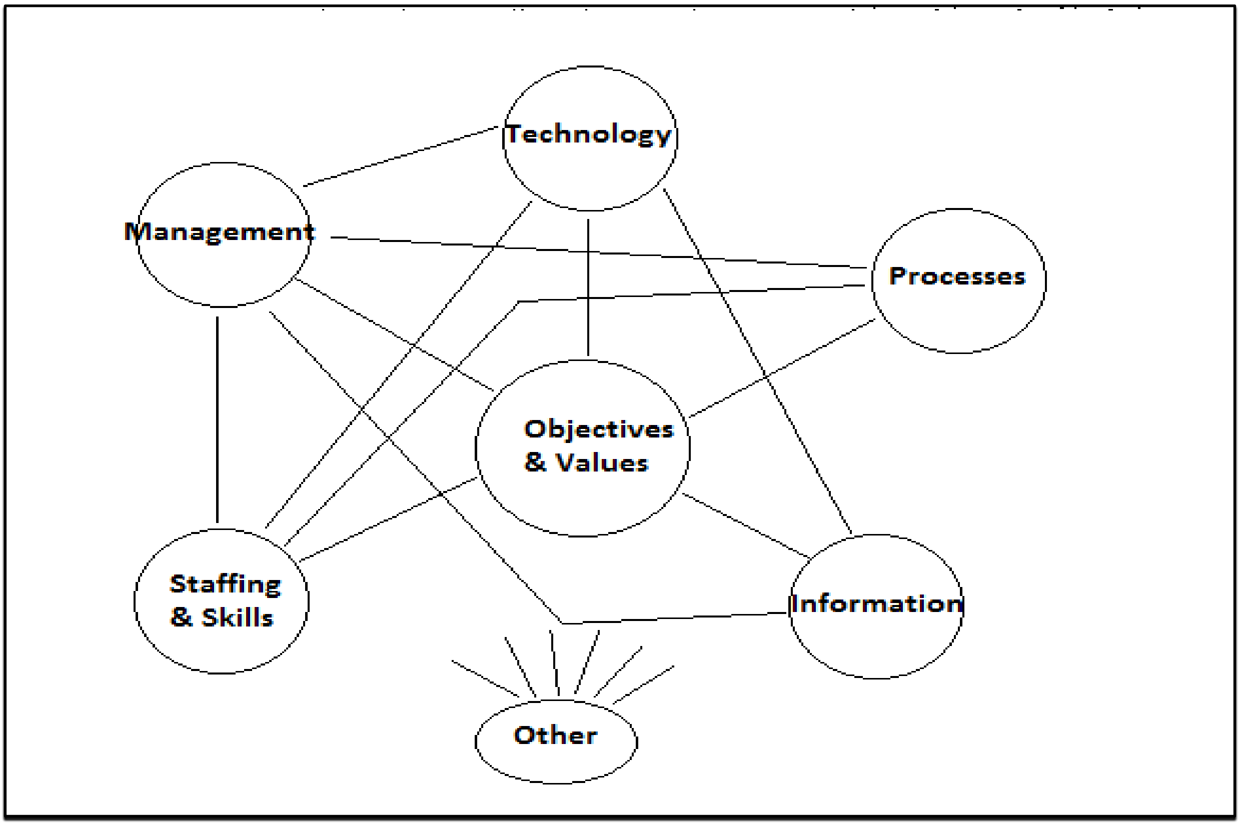

Figure 24: Relationships among the Dimensions of the Model

5.2 Limitations of the Research

The dimensions of the Design – Reality Gap model are broad. The evaluation of the dimensions might need to extend to managers and senior managers to seek out some specifics of the relevant dimensions. Aspects like vendor management, organizational objectives, management structures and organizational culture may need a more comprehensive study beyond what was possible within the scope of this project. This study is limited to systems that are setup internally in the institutions, and managed internally either by staff or by the vendor. Now and in future, systems are being implemented in the cloud. The availability of these is different due to the specialization of the providers, and the investments that go to install them. However, accessing cloud based systems still does require local area networks and local internet network routing, themselves being subject to unavailability due to the enumerated factors.

5.3 Conclusion

It is seen from the results that high availability is achieved by a convergence of by multiple factors. The different factors do not stand alone but feed into each other in varying degrees. Objectives and values strongly influence the quality of management that is put in place and the expectations set for them. The Objectives and the quality of management in turn have a strong bearing on the quality of processes and standards adopted for systems operation. They also determine the level and effectiveness of enforcement of these standards and processes to ensure the required delivery by the staff. At the same time, the effective delivery of results requires the placement of adequately skilled technical and management staff. These are all made complete by the installation, monitoring, maintenance and replenishment of the right complement of technologies and adequate information resources to support the effective delivery of results. Each of the dimensions contributes to high availability of systems. Each can on its own right cause degraded availability. Recognition of these factors provides business managers as well as systems managers, educators, trainers, vendors of technology and implementers, and other participants in the rollout and management of systems in Kenya with a structure by which to address these challenges.

5.4 Recommendations

Systems managers should advise senior management and influence the process of procuring the systems for high availability. Availability features touted by vendors may not be effective if the factors in the destinations negate their effectiveness. They should put a lot of effort to develop and implement effective operational and management processes. The systems professionals should also educate the management and procurement on the far reaching influences of these factors, and the benefits they stand to gain immediately and more in the long term when they setup systems with these factors already factored in. In research terms, this study represents foundational work in the study of high reliability systems in the given scope. The use of the Design Reality Gap Model provided a compelling and well developed theoretical basis for the study. It would be fruitful to do similar and more comprehensive studies in the measurement of financial implications of downtime for these institutions.

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APPENDIX 1: QUESTIONNAIRE

MSC. INFORMATION TECHNOLOGY MANAGEMENT – RESEARCH PROJECT

APPLICATION OF THE DESIGN–REALITY GAP MODEL TO ENHANCE HIGH AVAILABILITY OF SYSTEMS FOR HEALTH CARE PROVIDERS IN NAIROBI, KENYA

NOVEMBER 2014

This questionnaire is for use by the researcher to carry out interviews in the process of research. The respondents are information technology professionals with systems administration and operations knowledge and skills. The objective of the questionnaire is to understand the failure characteristics of specific business information systems. For most of the questions, a more detailed description of the answer may be sought following the first response. Information gathered during this study will be treated as confidential. The identity of the respondent and the identity of the associated institution will also not be disclosed at any time.

HIGH AVAILABILITY SYSTEMS IN KENYA

APPLICATION OF DESIGN-REALITY GAP MODEL TO ENHANCE SUCCESS

Kindly take time to answer the following questions per system in operation. Make assessment of the system as accurate as possible. The information you provide in this exercise is solely for academic research purposes and will not be used for any other purpose. It will be treated in confidentiality.

Respondent's Name (Optional)	Designation

SECTION 1. About the System: Give brief information about the system you oversee.

Name of the System	
Type of System	Number of Users
Main Function of the System	Year Installed
Operating System Platform	Server or Network Device Hardware Model

SECTION 2. Failure Characteristics

Has the System failed in the last 1 year?	
Briefly describe the most recent 3 failures	
What was the measured availability of this system the past year?	
What is the most common cause of failure?	
What other causes of failure are known in the past year?	
What was the longest downtime of the system in the last 2 years?	
How long does it take to restore the system from failure?	
What Do you Propose To Achieve The Highest Possible Availability (Over 99.99%)	

SECTION 3. Roles in Improvement

What should the Board (Owners) do to improve systems availability?	
What should the Managers do to improve systems availability?	
What should the Systems Administrator do to improve systems availability?	

SECTION 4. Fault Tolerance Mechanisms

Identify any fault tolerance mechanisms of this system	
Are these mechanisms fully activated?	
Does the system vendor actively support the system?	

SECTION 5: Measurement of Systems Qualities That Influence High Availability

In this section, please tick **[√]** the current level of system quality aspect being assessed.

(1 Represents Best Level and 5 Represents Worst Level)

Perspective	**1**	**2**	**3**	**4**	**5**
1) System Information Aspects					
Availability of documentation for the system					
Quality of technical support from the vendor of the system					
Effectiveness of training offered by the vendor					
Online Documentation, forums and support					
2) Technology Aspects					
Control of the Software changes					
Complexity of the Software Configuration					
Complexity of Server and Network Hardware					
Frequency of software configuration and program changes					
Frequency of hardware configuration changes					
Frequency of Power systems failure					

In this section, please tick **[√]** the current level of system quality aspect being assessed.

(1 Represents Best Level and 5 Represents Worst Level)

	1	**2**	**3**	**4**	**5**
Technology Aspects					
Frequency of failure of Local Area Network Links					
Frequency of failure of Wide Area Network Links					
Quality of WAN expert support available					
Problems caused by software configurations					
The frequency of failure of software					
3) Management Processes Aspects					
Appropriateness of system operation procedures					
Completeness and documentation of the processes					
Maintenance Schedules in Place for Hardware					
Maintenance Schedules in Place for Software					
Effectiveness of Systems Monitoring Reports					
4) Objectives & Values Aspects					
Commitment of senior management to the systems availability					
Financial Investment for system availability					
Investment in high quality systems staff					
Communication about the importance of the system to Business					

In this section, please tick **[√]** the current level of system quality aspect being assessed.

(1 Represents Best Level and 5 Represents Worst Level)

	1	**2**	**3**	**4**	**5**
5) **Staffing & Skills Aspects**					
Certification levels of the administrators					
Vendor driven training for this system					
Level of expertise of administrators					
Level of technical education for the administrator					
Level of Administrators' Skills					
Frequency of Configuration Errors causing Failure					
Severity of Configuration Errors causing Failures					
6) Management Aspects					
Enforcing regular systems health reporting					
Management Controls of Changes to Operating System, Network or Application Programs					
Active Service Level Agreements with vendors					
Management Enforcement of Standards of Proper Systems Operation					
Management Support for Full Utilization of the System					
Management Control for System Backups					
7) Other Aspects					
Quality of Backup Procedure in place					
Environment setup for the system					
Users expectations of the system					
Availability of Finances for System Maintenance and Vendor Support					

Thank You for Your Participation