INTEROPERABILITY MODEL FOR E-HEALTH SYSTEMS IN PUBLIC HEALTH FACILITIES IN KAKAMEGA COUNTY, KENYA

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DECLARATION

This thesis is my original and has not been presented for a degree in any other University.

Signature: ____________________________ Date:_________________

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DEDICATION

I dedicate this work to my late mother Floice my grandmother for her sacrifice throughout my preliminary education, my beloved wife Lilo for her immense support and encouragement, my children Cheryl and Migel whose presence spurred the motivation to undertake the research, my elder brother Ken and my big sister Florah for her unrelenting push and above all Supreme God Almighty

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ABSTRACT

The Government of Kenya together with its partners have invested in a wide array of health information technologies geared towards enhancing health service delivery to the public. Despite the presence of numerous electronic health (e-Health) systems in most public health institutions in the country, the usefulness of these systems beyond the facility gates is yet to be realized. Getting these systems to seamlessly exchange data irrespective of their geographical location has up to date remained a mere pipe dream. This study aimed to developing an interoperability model for e-Health systems in government health facilities to enable the inter-facility exchange of medical data. This investigation was motivated by the use of interoperable e-Health technologies in many developed countries as a means of enhancing healthcare services. The specific objectives of the study included: To evaluate the status of e-Health systems in public health facilities in Kakamega County; to determine the factors influencing the interoperability of e-Health systems in public health facilities in Kakamega County and to develop an interoperability model for e-Health systems in public health facilities in Kakamega County. The study was anchored on the theoretical model informed by three theories and one model namely organizational information processing theory, the unified theory of acceptance and use of technology, task technology fit theory and the technology acceptance model. The research employed a descriptive research design and targeted a sample of 95 health workers drawn from a population of 1800 using Slovin's formula. The study used stratified sampling and simple random sampling techniques to select the targeted sample. The study found that e-Health innovations in Kakamega County suffer poor infrastructural investment (52.5%), lack of integration, and poor implementation practices such as low (40.0%) stakeholder involvement and non-adherence to standards. This results in low user satisfaction scores (40.0%) which significantly affect interoperability and e-Health pervasion at 0.7 and 0.6 Pearson correlation coefficients respectively. The research concluded that the county's e-Health progress has not kept up the pace with the strategy, funding mechanisms, implementation practices and infrastructural investment capable of providing a standard interoperable e-Health solution. The research recommended that the government through the Ministry of Health and its partners should adopt a holistic approach such as the proposed Wheel Interoperability Model in implementing e-Health interoperability and transform it into a realistic and practical health solution.

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ABBREVIATIONS

AMCA	American Medical Collection Agency
BI	Behavioral Intention
BLIS	Basic Laboratory Information System
CDC	Disease Control and Prevention
CDSS	Clinical Decision Support Systems
CGH	County General Hospital
CHIS	Check Health Information System
DFID	Department for International Development
E-Health	Electronic Health
EHR	Electronic Health Records
EMR	Electronic Medical Records
HIS	Health Information Systems
ICU	Intensive Care Unit
IEEE	Institute of Electrical and Electronics Engineers
IFMIS	Integrated Financial Management Information System
IPPD	Integrated Payroll and Personnel Database
I-TECH	International Training and Education Center for Health
KenyaEMR	Kenya Electronic Medical Records
KHISIF	Kenya E-Health Interoperability Framework
KNBS	Kenya National Bureau of Statistics
MOH	Ministry of Health
NACOSTI	National Commission for Science Technology and Innovation
NASCOP	National AIDS and STIs Control Programme

NDHIS2	Hospital Information System Version 2
NII	Next Generation Information Infrastructure
OIPT	Organizational information processing theory
PEOU	Perceived Ease of Use
PU	Perceived Usefulness
SDGs	Sustainable Development Goals
SDMX.HD	Statistical Data and Metadata eXchange for the Health Domain,
SOAP	Simple Object Access Protocol
SPSS	Statistical Package for Social Sciences
STREP	Small or medium-scale focused research projects
TAM	Technology Acceptance Model
TTFT	Task Technology Fit Theory
UHC	Universal Health care
UKAid	United Kingdom Aid
UNICEF	United Nations International Children's Emergency Fund
USAID	United States Agency for International Development
UTAUT	unified theory of acceptance and use of technology
WSDL	Web Services Description Language

DEFINITION OF TERMS

E-Health policy: A set of law, regulations, directives, statements and judicial interpretations that manage and control the lifecycle of e-Health

E-Health: Healthcare services provided electronically through the internet.

Facility: In this case the word refers to a public health amenity in Kakamega County

Health system: means of delivering health value to the public wherever and whenever they need them.

Health workers: A group of individuals whose core mandate is the provision of healthcare services regardless of their organizations.

Healthcare services: Prevention, control and management of illnesses physical and mental impairments, injury, pain and diseases delivered by healthcare professionals to the public through the healthcare system.

Information system: A systematic way of organizing the handling of information, from information gathering to information retrieval and use.

Interhospital Communication: Exchange of information among several facilities

Interoperability: The ability of several disjoint information systems, components, or organizations to seamlessly exchange information and utilize the exchanged data.

Intrahospital Communication: Involves any information exchange within the same institution

Management Information System: An integrated and holistic reporting network system in an organization that provides planning and controlling information for effective decision making.

Model: A pictorial or graphic representation of key concepts of a given phenomenon.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The Government of Kenya has a solemn responsibility to provide responsive and prompt services to its citizens [1]. Particularly, the Ministry of Health (MOH) has to guarantee that the health division plays its part in the realization of Vision 2030 master plan and the attainment of the Sustainable Development Goals (SDGs) espoused by the United Nations General Assembly through the implementation of universal health coverage (UHC). The 2015 inauguration of the sustainable development goals by the United Nations brought to the limelight the need for timely inter-facility information exchange [1]. The 2019 flare-up of the Coronavirus pandemic further reinforced the need for reliable real- time e-Health systems for the synchronous exchange of health information [2], predominantly among healthcare professionals.

In an attempt to play its role in the vision 2030 master plan, the Ministry of Health developed the Kenya Health Policy (2014–2030) [3]. As part of the policy's key objectives, the Ministry anticipates to plan, design, and implement ICT infrastructure and health information systems (HIS) to manage and deliver essential health care to the public [1]. In partial fulfilment of its Big 4 agenda (2018-2022) [3], the government of Kenya has put the top in its priorities the need for universal healthcare (UHC). The World Health Organization (WHO) [5] notes that the utilization of health information and communication technologies will enhance patient safety, improve the quality of healthcare service delivery, and lead to informed decision-making at apex levels.

The Ministry oversees a wide variety of health facilities run by the government, non-governmental organizations (NGOs), faith-based groups, the foreign community, and private citizens. Government-run healthcare institutions are categorized into levels numbered 1 through six according to the National Health Sector Strategic Plan II, defined in the National Health Sector

Plan II [8]. The classification defines Level 1 as the community, level 2 as a dispensary, level 3 as a health center, level 4 as a district hospital, level 5 as a provincial (secondary) hospital, and level 6 as a tertiary (national) referral hospital. County health services are divided into three levels under the devolved form of government: community, primary care, and referral services. [8]
A fundamental aspect of the realization of these visions through the enhancement of healthcare service delivery is the implementation of frictionless, seamless, and timely exchange of health information between a facility and another. Both governments at national level and devolved level have been on the run to reap the benefits that come with automation of internal processes and information exchange through deployment of various electronic health information systems to aid in achieving the above goal.

In Kakamega County, the most common e-Health software systems in use are KenyaEMR and the National District Hospital Information System version 1 and 2 both from developed by International Training and Education Center for Health (I-TECH) and the National Government of Kenya; Basic Laboratory Information

System (BLIS) by Global Health Systems Solutions, Webadt by Insta Inc., CHIS from Webtech Kenya and Funsoft Hospital management software from Funsoft Inc. [9]. Generally, most of these systems are either open source or vendor software developed by vendors who woe the governments into business or are donated by the government partners in health such as the United States Agency for International Development (USAID), United Kingdom Aid (UKAid), United Nations International Children's Emergency Fund (UNICEF), World Health organization (WHO), Department for International Development (DFID) among others [10]. It is imperative to mention that the initiators of the systems are rarely the service users or consumers but rather external partners who supply systems that are mostly used in developed countries or purely off-the-shelf vendor-supplied systems.

Kakamega County has 341 health facilities of which 192 are public institutions ranging from primary healthcare centers to top level teaching and referral amenities [11]. In a bid to automate health services and enhance efficiency of healthcare services, both the national government and the county government of Kakamega, together with their partners have made tremendous efforts in the acquisition, deployment and use of various e-Health systems in public health facilities. It is therefore expected that exchange of information between two facilities irrespective of their tier be effective and efficient. Despite the existence of these systems and the governments’ colossal investments in modern health ITs, the fruits of interoperability among these systems are yet to be reaped. While most public facilities have proprietary electronic health information management systems, most of these systems only serve one particular section within the facility or at most all the departments within the facility. Nevertheless, none of these systems has the capability to communicate with a counterpart system in a distant location, making inter-facility health records exchange a strenuous experience especially during patient referral cases [12].

The impetus behind increased deployment of e-Health systems for the last one decade has been the connotation that these systems facilitate the provision of high quality care [13]. E-Health system features such as clinical decision support systems (CDSS) play a vital role in minimizing medical errors by enhancing timely access to information needed for decision making. For instance, the system may alert the doctor about the patient's drug allergies or special requirements when the doctor is making an electronic prescription [17].

The concept of digitizing operations in Government health facilities in Kenya is a decade old idea. E-Health systems have been widely used in health projects that support the management of chronic ailments such as HIV/AIDS and tuberculosis (TB). Digitization leads to enhanced record-keeping, patient monitoring, medical supplies stock control and patient follow up [5-8]. Munga et al. [5] observe that although the implementation of e-Health systems are largely successful in Kenya, lack of interoperability among these systems and the non-utilization of these systems by the healthcare givers serve as the major deterrence towards realization for the full benefits of these systems.

In the light of the perceived success of these e-Health systems, the government of Kenya in partnership with the International partners and local organizations developed an e-Health framework standards specifications and guidelines for e-Health systems adoption in public hospitals [15]. Two major health information technology projects were thus rolled out in 2012 namely the Open Medical Record System (OpenMRS) system to support healthcare provision for patients with HIV/AIDS and the District Health Information Software Version 2 primarily used to collect information on healthcare indicators countrywide.

The OpenMRS was later revised to Afya Electronic Health Management System (AfyaEHMS) and later KenyaEMR that has been deployed in over 300 health facilities in the country, out of which 45 are from Kakamega County [24]. Although the system provides a platform to carry out holistic surveillance of HIV/AIDS and other infectious diseases, emphasis were laid data quality and utilization while the aspect of interoperability that facilitates data exchange across facilities shyly features. This was brought to the limelight in the 2010 joint report by the Health Management Information Systems department (HMIS in MOH), the US Centers for Disease Control and Prevention (CDC), and the National AIDS and STIs Control Programme (NASCOP) on Electronic Medical Records Standards and Guidelines Report [18].

In order to ensure quality of software, maintainability, common understanding among the workforce and compatibility the taskforce made several recommendations touching on the software development, interoperability and implementation [8]. Particularly on interoperability, it was recommended that the existing systems continue transmitting and receiving data through the Health Level 7 messaging. It was also recommended that systems transmit aggregate data to District Health Information Software Version 2 via Statistical Data and Metadata eXchange for the Health Domain, (SDMX.HD), messaging. The KenyaEMR has since been in place to date with revisions ongoing to expand the service catalog of the system.

The National District Hospital Information Software version 2 (NDHIS2) is another popular free licensed health information management system used in various organizations including the European Union (EU) and multiple governments worldwide including Kenya [9] . Since the systems' release in 2006, the system has been widely used in various health projects including outbreaks alarm, disease surveillance, and patient health monitoring and enhancing accessibility to health data. For instance, the systems has been translated into eight international languages, and offers several mobile solutions such as plain HTML, Short message services (SMS) and java alternatives [50]. In addition, Clients can use their mobile phones for registering cases, events, and personal information tracking individuals, conducting surveys and collecting aggregate data. DHIS2's mobile solutions make it easier to use effectively, particularly in a number of low- and middle- income regions where DHIS2 is currently being deployed [119]. Kenya was the first Country in Sub-Saharan Africa to deploy a totally online health information system (HIS) powered by DHIS2 [50]. As such, all the District health facilities and several other selected health amenities were connected to the DHIS2 server. With the features and the technology behind

DHIS2, it goes without saying that this is a fully interoperable health information system and with the MOH having deployed the system in all of its district hospitals, information from one facility to another should be a tap away. Particularly, in County served with 11 district hospitals and several model health centers, exchange of information between the facilities should not be a problem. Most puzzling though is the realization that the exchange of data among these facilities is still an illusion in the eyes of many. Other systems that purely originated from the National government and escalated to the devolved facilities include the open source Basic Laboratory Information System (BLIS) used in automation and management of laboratory information, OpenMRS AMPATH, IQ Care, and C-PAD [20].

At the county level, several systems have been deployed in various facilities. For instance The County Government of Kakamega in 2016 released the Check Health information system (CHIS), a system that in not only used for health information management but also revenue collection from these facilities. The CHIS is a purely offline system that is highly effective within the facility and is thus the main system at the County General Hospital. The system is currently in use in all the County's level 4 hospitals and the county General hospital [24].

It is uncontended that there are several health information systems currently in use in many county and National hospitals. Statistics reveal that interoperable Health Information Systems and reliable ICT infrastructure to facilitate judicious exchange of information between these health facilities have been in short supply [26]. Most of the government's institutions, despite having information systems in place have narrow access to the data they need to effectively and competently deliver service to the public [26]. This situation points towards a series of underlying factors that are yet to be studied or have insufficiently been studied yet negatively impact service delivery in the health sector. This research, therefore, aims to examine the factors affecting the interoperability e-Health in public health facilities before designing a model that effectively ensures interoperability among HISs in public health facilities.

1.2 Statement of the Problem

The lack of interoperability between various e-Health systems deployed in various hospitals greatly impedes access to patient's medical data before, during and after treatment [27]. This scenario is evident during transition of healthcare from one facility to another. Healthcare givers at the referral facility are only left to extract the patient data and history from the referral summary sheet or interrogate the patient who in some cases may not be able to talk. Doctors may therefore miss out on vital patient information which could have otherwise been retrieved from referring facility. Intermittent knowledge occasioned by lack of sufficient patient information may result in delayed treatment to the patient, misdiagnosis and in worst cases loss of patient's life [37]. Having e-Health systems that are not interoperable became a point of concern for this study. There was therefore need to device a meaningful methodology for enhancing interoperability of e-Health systems in public health facilities to efficiently deliver healthcare services to the public.

1.3 Objectives

1.3.1 General Objective

To develop an interoperability model for e-Health systems in public health facilities in Kakamega County, Kenya.

1.3.2 Specific Objectives

Specific objectives of this study were:

i. To evaluate the status of e-Health systems in public health facilities in Kakamega County.

ii. To determine the factors influencing the interoperability of e-Health systems in public health facilities in Kakamega county.

iii. To develop an interoperability model for of e-Health systems in public health facilities in Kakamega County.

1.4 Research Questions

i. What is the state of e-Health systems in Kakamega county health facilities?

ii. What are the factors influencing the interoperability of e-Health systems in public health facilities in Kakamega County?

iii. What model can be used to enable interoperability of e-Health systems in public health facilities in Kakamega County?

1.5 Justification

Empirical evidence has underscored the need for interoperable information technology as the key enabler of public service in governmental organizations. Currently, there are still very few studies that explore the adoption of interoperable e-Health in Kenya. This research therefore endeavors to bridge this knowledge gap by contributing to the existing knowledge in this area.

In addition, the findings of this study may serve as a vital reference by the government when designing policy framework for the implementation of interoperable information systems in health facilities. With interoperability being a vital component of information exchange, the findings of this research may also inform decision making in other fields where distributed systems are the key drivers of their operations such as education, finance, security and defense and criminal justice systems.

1.6 Significance of the Study

The interoperability model will ease inter-facility information exchange and utilization of e-Health systems in public hospitals. Medical practitioners will enjoy the efficiency of instantaneous access to patient data from any point of service irrespective of the location. More pertinently, the public will benefit from reduced medical costs, and improved service quality and safety. The model could also be used in other distributed government agencies such as county revenue streams, judiciary information systems, law enforcement agencies and educational institutions. In addition, the study will help the County and National government's policy makers and health partners to design e- Health policies that can promote e-Health systems interoperability in health institutions in Kenya. This study's findings will add to the available knowledge on factors influencing e-Health interoperability and the current state e-Health systems in the county. The study will also create a foundation and literature for future research.

1.7 Assumptions of the Study

The researcher assumed that the selected informants were well versed in the area of health information systems thus competent enough to reliably inform the research. Lastly, the researcher also assumed that he would get the necessary permissions from the necessary bodies to carry out the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This investigation was involved in an initial in-depth study of the existing literature on e-Health systems and the underpinning theoretical frameworks. The knowledge was derived from journal articles, books, reports-health whitepapers and magazines pertinent to the topic of study. The primary objective of this initial inquiry was to provide the researcher with knowledge on the relationship between the key areas of study and the gaps that exist in relation to the application of e-Health interoperability in healthcare facilities.

2.2 Theoretical Literature Review

This research was anchored on several reinforcement theories that collectively informed the research process. Four theories whose constructs formed the pillar of this investigation include the Technology Acceptance Model, Unified Theory of Acceptance and Use of Technology, Task Technology Fit Theory and the Organizational Information Processing Theory. This section looked into these theories and their significance towards the study.

2.2.1 Technology Acceptance Model

The technology acceptance model (TAM) by Davis et al. [38] is one of the most popular information systems theory that explores and examines acceptance in contemporary life [39]. The model scrutinizes acceptance by two variables namely the Perceived Ease of Use (PEOU) and the Perceived Usefulness (PU).

Davis et al. [38], defined perceived usefulness as the extent to which an individual is convinced that a particular innovation would enhance their job performance and defined perceived ease of use as the degree to which an individual believes that a particular system would be friendly to learn and use. The TAM model by Davis et al. [38] is illustrated in [Fig. 2.1]

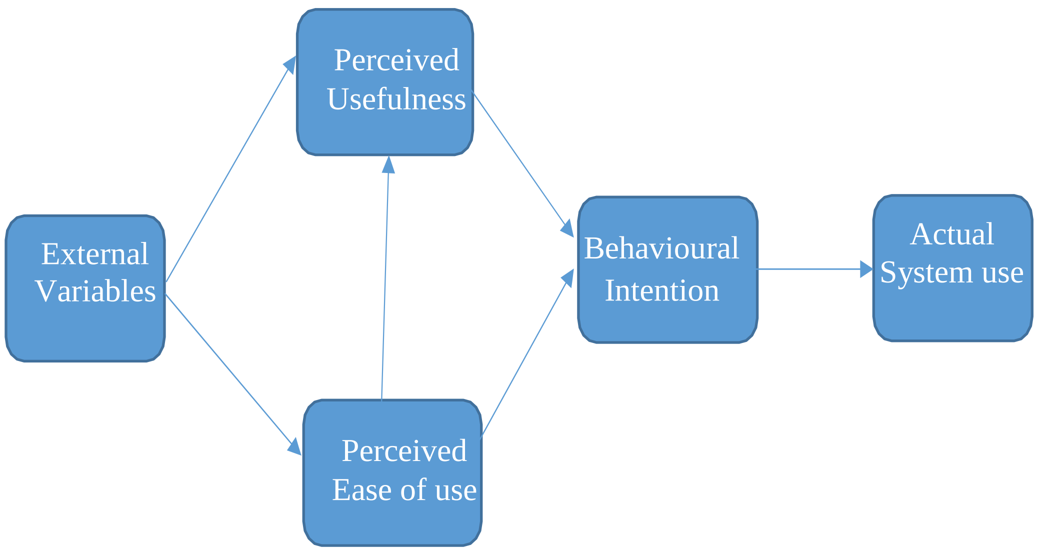


Fig. 2.1. The Technology Acceptance Model
Adapted from [38]

Embedded in this model are two core issues; the usefulness and the user-friendliness of innovations. There is no doubt that e-Health systems are innovations that endeavor to strike a paradigm shift from the conventional modes of operations in health sector such as paper and pen processes. However, two major questions emerge; first, are these innovations useful? And secondly; are these systems easy to learn and use? The present research wonders why there are some interoperable e-Health systems that are not exchanging data at cross-facility level. The TAM model was in itself a motivation behind the present research. In unraveling this mystery, the questions of usefulness and user-friendliness of the existing e-Health systems was paramount in explaining the current status of the present e-Health systems. The theory informed the formulation of the interoperability model by suggesting whether there was need to enhance the usability the current e-Health systems or whether there was need to enhance the usefulness of the existing systems. The attention was thus focused on the current and future systems as to what needs to be done to make them relevant to the user. In this context, the relevancy was the communication beyond the facility borders which is interoperability.

2.2.2 Unified Theory of Acceptance and Use of Technology

Venkatesh and others [40] developed the unified theory of acceptance and use of technology (UTAUT) as a technology acceptance model in "User acceptance of information technology: Toward a unified vision." [32]. The UTAUT theory explains how users intend to use an information system and how they actually utilize it.

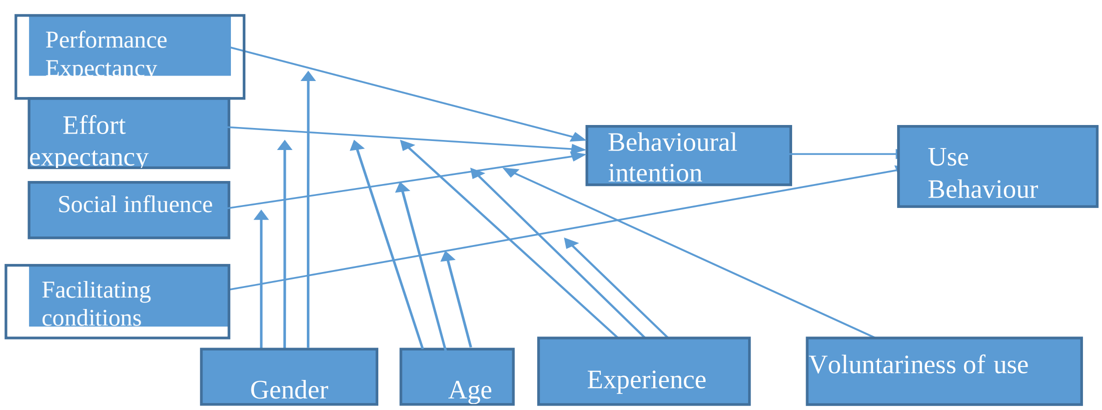


Fig. 2.2. Unified Theory of Acceptance and use of Technology Model
Adapted from [40]

The theory holds that there are four major constructs; performance expectancy, effort expectancy, social influence, and facilitating conditions. While the first three are direct predictors of usage intent and behavior, the fourth is a predictor of user behavior. The impact of the four major constructs on usage intention and behavior is thought to be moderated by gender, age, experience, and voluntariness of use. A review and consolidation of the constructions of the theory led to the development of the theory. Venkatesh et al. [40] observed that UTAUT accounted for 70% of the variance in Behavioural Intention to Use (BI) and nearly 50% of the variance in actual use in a longitudinal study.

In the research, UTAUT was key in explaining why some e-Health users don't use the systems to exchange information remotely despite procuring them for such purposes. Mostly, the research sought to determine whether or not, human factors such as gender and age, play a role in the adoption of emerging health technologies and the lack of interoperability among e-Health systems. The research also based on the effort expectancy pillar to evaluate the user friendliness of the existing systems and the performance expectancy construct to determine whether the systems meet the user expectations. It is from these analyses that the tradeoff between systems performance and user demands can be synchronized to strike an optimal utilization of the existing e-Health systems

2.2.3 Task Technology Fit Theory

The Task Technology Fit (TTF) theory is a theoretical framework proposed by Goodhue and Thompson in 1995 [41] as tool of determining the effectiveness of a given technology in a system [41]. The theory holds that information systems have a higher propensity of positively impacting individual performance and be applied in capabilities of information technology match the tasks to be performed by the technology service user as presented in [Fig. 2.3].

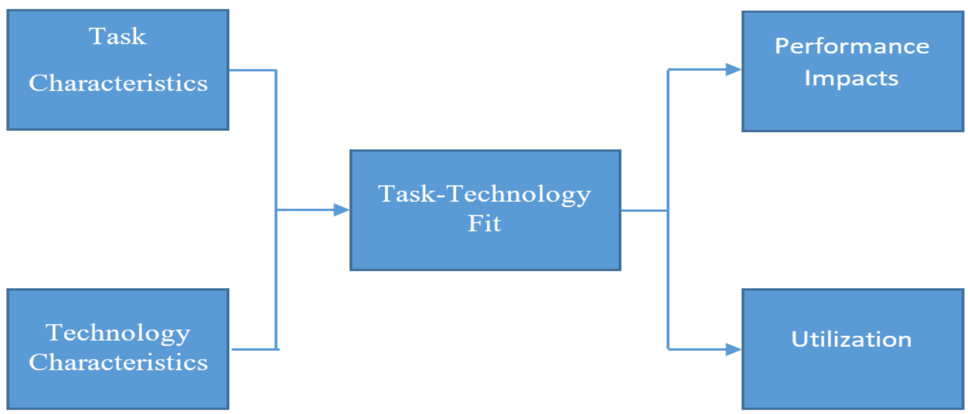


Fig. 2.3. Task-Technology Fit Theory
Adapted from [41]

They content that the magnitude to which the present technology is capable of executing a user's task is proportional to the contingent in which individual capabilities match. In line with this construct, Goodhue and Thompson [41] identified eight factors of consideration namely locatability, compatibility, user friendliness, system reliability, production timeliness, authorization, quality and the relationship with users. Each of the above factors is determined on a scale of seven points ranging from strongly agree to strongly disagree. In other words, the framework assesses the correlation between the technology, say e-Health and the task the technology aims to support say retrieval of patient medical history during emergencies or critical care situations.

The utilization component reflects the act of using the system evaluated by the frequency or diversity of use. The utilisation is determined by a number of attitudinal and belief factors, contributing to the use of technology both in mandatory and voluntary settings. These factors include, but are not limited to, social norms, attitude to behaviour and expected consequences

In determining the relevance or usefulness of the existing e-Health systems, this theory was widely applied in the inquiry. Obviously, the current lack of interoperability among e-Health systems is attributed to a number of factors some of which have been mentioned in the theory. The seven point scale was used to determine the various aspects of the existing systems as well as the system users. The system implementers and the role of the management and the government towards the success of these systems shall also be considered. These shall be considered as the human characteristics.

2.2.4 Organizational Information Processing Theory

Organizational information processing theory (OIPT) is a theoretical framework that focuses on the design structure that an organization must develop so as to effectively manage various types of emergencies that arise from time to another [Fig.2.4].

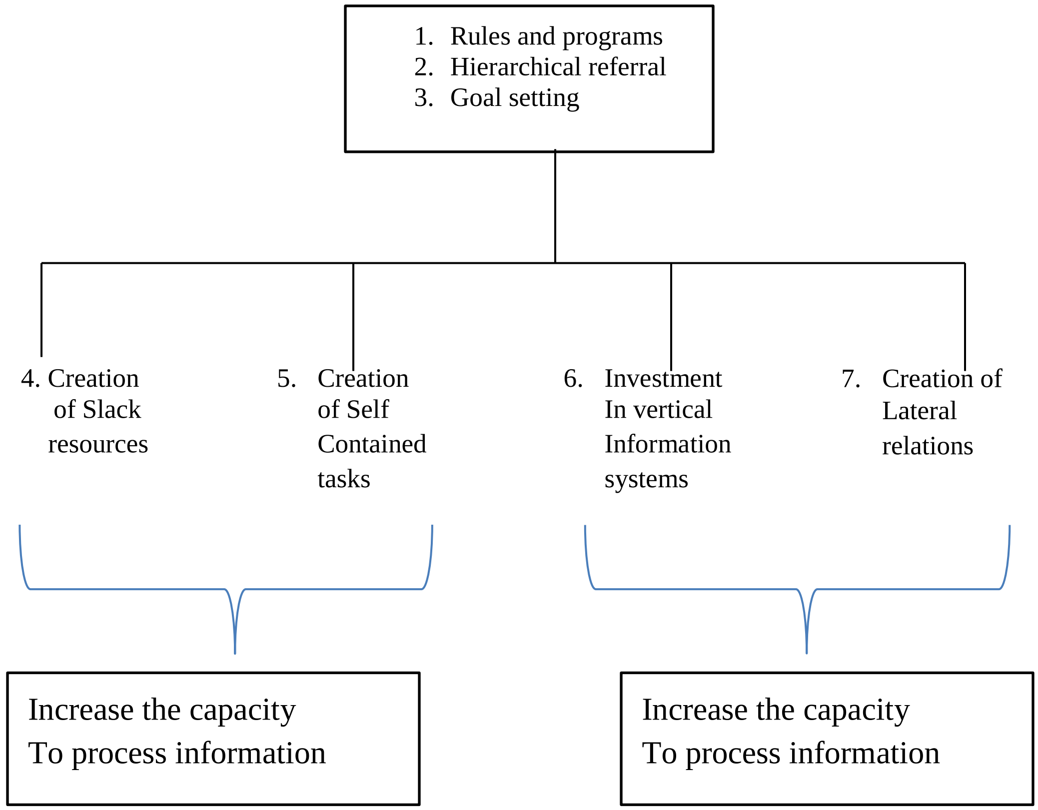


Fig. 2.4. Organizational Information Processing Theory
Adapted from [43]

The theory posits that the organizational structure should bears a reflection of the company's information processing needs so as to effectively handle and deal with different types of unknown factors [37]. The OITP identifies three pertinent concepts namely the information processing needs of an organization, its capability to process information and tradeoff between the two to attain optimal performance. According to Premkumar et al. [37], organizations need high quality information to survive the contemporary business environment characterized by a plethora of uncertainties. Premkumar et al. [37], adds that such quality information enhances organizations decision making while giving it a strategic advantage. Premkumar and colleagues [37] argue that environmental uncertainty emanates from the dynamism and the complexity or frequency of alterations to environmental variables. In healthcare environment, numerous uncertainties abound including but not limited to occupational accidents, emergency patients, infernos, pandemics among many others. Such incidents necessitate the need for reliable and efficient external communication network that can efficiently facilitate external information exchange.

Characteristically, organizations, including healthcare amenities have two strategies to manage emergencies and the increasing desire for quality information [37]. First, they need to develop cushioning mechanisms to mitigate the effects of uncertainty and secondly, put in place structural mechanisms and data exchange capacity to improve the flow of information from the source to the consumer in timely manner to reduce uncertainty [37, 42]. A classic use case of the first strategy is the construction of inventory cushions to minimize the effect of emergency in supply or demand. Another example of the second strategy is the reengineering of business processes in an organization and the deployment of integrated information systems that enhance data transfer while minimizing uncertainty within organizations sections [37]. A similar approach is development of enhanced information channels between organizations and their peers to reduce uncertainties in their operations [37].

This research drew its motivation heavily from this theory. First it is worth noting that health facilities in Kenya are one of the busiest and most dynamic working environments in Kenya. The lives of hundreds and thousands heavily depend on the decisions that are made by healthcare givers in these facilities. In order to make sound decisions, these healthcare providers need accurate and timely data to facilitate the decision-making process. As such as Premkumar et al. [37], observes information systems enhance decision making. It is therefore important keep the information systems in health facilities operational and efficient to sustain lives. The second pillar of this theory is the idea of the complexity of healthcare environment. These are facilities with numerous activities both medical oriented and otherwise, all geared towards sustaining the existence of humanity. With numerous diseases, patients and uncertainties to handle on daily basis, manual data or uninteroperable systems only serve to make the work of healthcare givers more difficult while putting the lives of patients in danger with some falling victims to these systemic failures [37]. It is against this argument that the present research endeavors to identify the factors leading to lack of interoperability among e-Health systems in use and suggest a model to avert them.

Lastly, the theory holds that organizations have two strategies of combating uncertainties which include developing suppression mechanisms to mitigate the effects of uncertainty and secondly, put in place structural mechanisms and data exchange capacity to improve the flow of information from the source to the consumer. Pertinently, the second strategy directly leaves the burden of mitigating emergencies on the shoulders of information systems [35]. Strategy six under increasing the capacity of information processing is investing in vertical information systems. It therefore goes without saying that the more efficient and interoperable the e-Health systems are, the lesser the uncertainties surrounding the healthcare environment. A number of questions however emerge: Do facilities have enough resources to invest in next generation information systems? Are the facility workers ready to embrace change? Are these e-Health systems sustainable? It was the anticipation of this investigation that through an interoperability model, these among other questions will be addressed. E-Health systems will be more efficient in facilitating information exchange within and without of the facility, thus enhancing healthcare service provision in the country.

2.3 Empirical Literature Review

2.3.1 Definition of a Model

The end product of the investigation was the development of a model that will be used by information systems designers and implementers in the health sector to develop and implement interoperable health information systems. Palva et al. [60] defined a model as a pictorial or graphic representation of key concepts of a given phenomenon. A model illustrates the relationship between various types of variables e.g. independent, dependent, moderating, mediating variables etc. Palvia and colleagues [60] content that the use of use of models in modern day scholarly research is of great significance particularly in the field of information technology. They observe that research published in the top information system journals have theoretical underpinnings and has some type of model or framework driving the research. According to Palva et al. [60], there are eleven categories of models which include; list of variables; list of variables and levels; list of variables and implicit relationships, simple influence diagram; multitier influence diagram; Temporal influence diagram, Simple grid, Complex grid, Venn-Diagram, mathematical model, and a hybrid combination of any two or more of the listed models above.

The findings of the ongoing research will inform the choice of the most appropriate model to be used in presenting the concept of e-Health systems interoperability. A model will be used to express the interoperability phenomenon because a model is almost always an oversimplified map consisting of a few, primary variables that will be tracked, measured, and perhaps controlled for experimentation [60]. Palva et al. [60] argues that models are generally straightforwardly accepted as an important methodological tool in both applied and physical sciences. This is because according to Palvia et al. [60], models are the only way to simulate reality and break down an otherwise complex phenomenon into a simplified concept.

2.3.2 Definition of Interoperability

The Institute of Electrical and Electronics Engineers (IEEE) [9] defines interoperability as the ability of several disjoint information systems, components, or organizations to seamlessly exchange information and utilize the exchanged data. E-Health systems interoperability is thus the ability of various healthcare systems to share, interpret, and cohesively use data within and across the institutional boundaries [10].

2.3.3 Levels of Interoperability

Health and informatics scholars are yet to reach a consensus on the levels of interoperability. While some pundits define interoperability in three levels [53] [54], others have gone as far as seven levels [55]. This research adopts the four levels of interoperability defined by Whitman and Panetto [56] and the European Telecommunication Standards Institute [57]. These levels include technical interoperability, syntactic interoperability, semantic interoperability and organizational interoperability. Each of these levels are illustrated in [Fig. 2.5].

Fig. 2.5 Levels of interoperability

Adapted from [61]

2.3.3.1 Technical Interoperability

Whitman and Panetto [56] perceive technical interoperability as the enablement of heterogeneous systems to seamlessly share information but does not guarantee meaningful utilization of the same by the sharing agents. It incorporate the fundamental requirements needed to secure inter- connectivity between one system and another [10]. In this level, there is no need for the recipient system to interpret the data as the information is readily available for use.

2.3.3.2 Syntactic Interoperability

Syntactical interoperability operates at an intermediate level and delineates the syntax, format, and arrangement of the data exchange. This level guarantees the safeguarding of the clinical aim of the data during exchange of data between two or more healthcare systems. Various standards and protocols ensure that the information exchanged passes successfully through the various communication components and platforms without alteration [10].

Semantic Interoperability

Semantic interoperability is the highest level of connection [10]. This type of interoperability guarantees that two systems sharing data similarly understand the meaning of data and interpret and utilize the data in diverse systems or subsystems can cohesively exchange and use data. This is achieved by using common underlying codifications and models of information that incorporate the use of standardized data elements from a publicly-available pool of coding terms and value sets, providing shared understanding and meaning to the users. At this level, the data exchange framework and the format into which data is coded allows the medical practitioners to share patient data across dissimilar systems and components.

2.3.3.3 Organizational Interoperability

Organizational interoperability is the highest level of interoperability according to the European Telecommunication Standards Institute [57]. The level enables the integration of organizational workflow and procedures beyond its boundaries. This level of interoperability requires strong willingness and dedication and some level of trust for the involved organization to implement.

2.3.4 Drivers of Interoperability

Drivers of interoperability are the broad constructs that define the environment under which interoperability of systems exist. There are seven key drivers of interoperability [57] as shown in [Fig.2.6].

Fig. 2.6. Drivers of interoperability

Adapted from [57]

2.3.4.1 Leadership and Governance

Governance establishes the required decision-making rules and procedures for directing and overseeing an organization [57]. Without the existence of governance frameworks, it is difficult to synchronize and coordinate health projects in accordance with national health priorities. It also offers the crucial political leadership and facilitates participation with relevant stakeholders [57].

2.3.4.2 Strategy and Investment

This is the process of creating a national masterplan to guide the coordination of e-Health projects. The country's e-Health plan should be in line with the country’s health priority areas. It should recognize interoperability objectives and a plan of action to accomplish them [57]. Funding for E- Health initiatives should be in tandem with the identified interoperability goals.

2.3.4.3 Legislation, Policy and Investment

One of the factors affecting widespread adoption of interoperable e-Health systems is concern for privacy, security, and confidentiality of healthcare information [57]. These are genuine problems that must be addressed by establishing an adequate legal framework that can facilitate effective healthcare information interchange [57]. Policies addressing e-Health interoperability, in particular, should be in place. Such policies should be reviewed on a regular basis to verify that they are still in line with interoperability goals. There should also be a process in place to guarantee that interoperability policies are followed [57].

2.3.4.4 Workforce

This component is required to ensure that the health informatics knowledge and skills required to implement e-Health initiatives are available [57]. A workforce capable of developing, building, and managing interoperable e-Health systems, as well as the technical expertise to participate in standards creation and localization of international standards to fit local requirements, should be developed in order to create a workforce that's capable of designing, building and operating interoperable e-Health systems, together with the technical expertise to participate in standards development and localization of international standards to satisfy local requirements [57].

2.3.4.5 Standards

International Organization for Standardization (ISO) defines a standard as “a document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context" [66]. Standardization is arguably the foremost critical driver of interoperability [57]. It comes with numerous benefits most of which have been discussed in the earlier sections. The European commission classifies standards into four main categories namely the industry, voluntary, official and open standards. Although the relevance of these classifications largely depends on the national or regional context, the significance of health standards cannot be downplayed in whichever context. The adoption of e- Health standards to support interoperability should be coordinated at national level, preferably through an independent governance structure all the way to the devolved units [57].

2.3.4.6 Infrastructure

This component forms the physical infrastructure that creates the foundation for the exchange of health information across geographical and health-sector boundaries [57]. Money should be set aside for the procurement of physical infrastructures, comprising of the computer hardware and network connectivity that will facilitate secure and expeditious exchange of health information [57].

2.3.4.7 Services and Applications

This component represents the tangible means for enabling necessary applications, tools and services that will facilitate secure exchange of health information [57]. The figure below summarizes the key components of interoperability

2.4 Interoperability Status of e-Health Systems

2.4.1 Global e-Health Interoperability Status

Achieving healthcare systems interoperability remains a global challenge in both developed and third world countries; studies by Benson and Grieve [11] reveal. In America for example, while the US government has invest vast resources in the interoperability of health systems in the country, there is dragging adoption and utilization of the existing systems as evidenced in [Fig. 2.7].

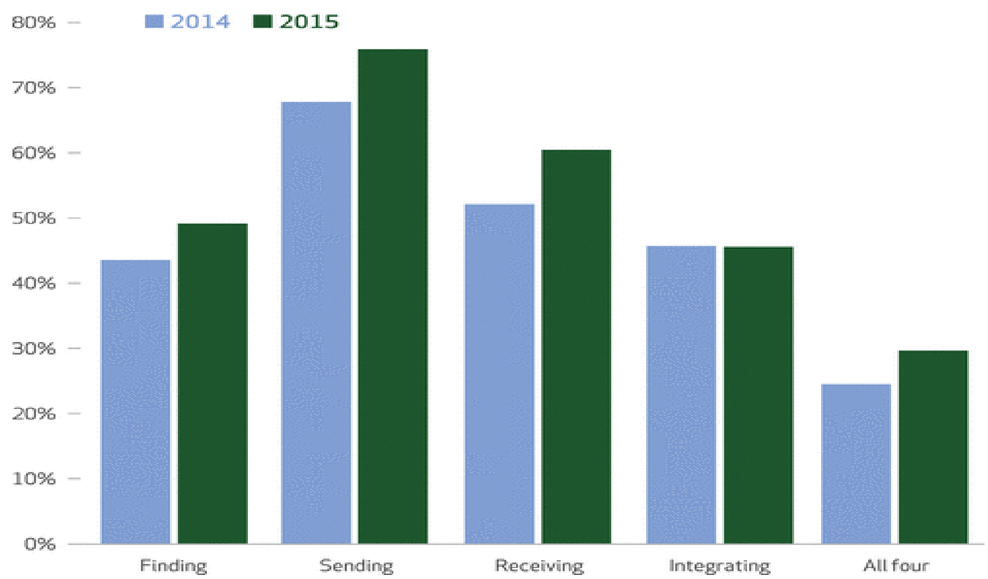


Fig. 2.7. Interoperability trends in US between 2014 and 2015

Adapted from [12]

Thus, despite the presence of interoperable e-Health systems, the extent to which the data has been used for the benefit of the public is still low. Holmgren, Patel, and Adler-Milstein [12] measured the progress of interoperability in the US and concluded that although attaining a unified healthcare system remains America's top priority, hospitals' progress towards interoperability is snail paced and that emphasis are being laid on exchange of information between health facilities rather than usability of information in clinical decision making. Studies have been done on four domains of interoperability namely the retrieval, transmission, receiving and the integration of electronic patient data form outside sources [12]. The findings reveal that only 29.7 percent of the health amenities in US are actively involved in the four domains while the two most progressing domains were sending and receiving with each 8.1 percent and 8.4 percent increase respectively. It's worth noting that there was no change in systems integration.

To combat low interoperability levels in the US, the adoption of e-Health systems is initiated and promoted by the government and local authorities through incentive schemes such as the Technology for Economic and Clinical Health Act of 2009. Under these schemes, healthcare workers are reimbursed for costs incurred in the use of a given heath IT system if they are able to provide evidence that by so doing, the system increased the quality and the efficiency of the service [45]

In Asia, the situation is no different as revealed by the Asia-Pacific Government Roundtable on Interoperability report [62]. The 2021 report was a document prepared by IT authorities and digital health representatives from Nine Asian countries namely Bhutan, Hong Kong, India, Japan, Malaysia, Singapore, Thailand, Pakistan and the Philippines [62]. In the report are five key takeaways which content that interoperability is a vital component towards digitally transforming healthcare services through agile and patient-centred approach. This implies that the world in general acknowledges the potential role of interoperability towards enhancement of health services.

Secondly, the report acknowledges that technical standards implementation guides and education are important requirements for a country's journey towards interoperability. This takeaway presents two key factors essential in the implementation of interoperability namely standardization and employee involvement. According to [62], standardization of health technologies, data formats and standard operation procedures is the first step towards the realization of interoperability in a given healthcare ecosystem. Multiple investigations agree that most information systems end up failing or in a challenged state due to lack of user involvement [26, 32, 46]. User involvement includes but not limited to contributing towards the requirements of the system, users being allowed to liberally give their honest feedback on the system during and after implementation to help fine-tune the system and user education to enhance their competency in interacting with the system [32, 46]. This user involvement in turn increases acceptance and thus a key contributor to the success of a given technology as attested in the technology acceptance model.

Thirdly, the joint report notes that measuring the progress towards digital transformation is a means through which an organizations strengths and opportunities for improvement can be determined. In simpler terms, the implementation of interoperability must be done in a manner that is specific, measurable, achievable, and realistic and time bound. This makes it easier to monitor progress and determine the implementation shortfalls and well as strengths.

The fourth take way is sort of cautionary in the sense that it emphasizes on the need to make patient data privacy a top priority when implementing health systems, however, this should be exercised with moderation to help health workers to extract data from the patient with trust and confidence and to help the patients to freely give their personal data without fear of compromise. Akhlaq et al. [26] avers that patients are likely to give false data in the event that they feel their data may be compromised. This is consistent with the findings of Johnson [25] and Iroju [32] who both caution that in as much as systems need to be interoperable; security of these systems is a key consideration in cultivating patient confidence in them.

Lastly, the report acknowledges that despite there being a clear interoperability implementation roadmap and measurement mechanisms, challenges are still imminent in the road towards interoperability. The report cites moderating factors such as political environment and cultural contexts as some of the factors that may negatively influence interoperability in a given state. This reveals that in the vast world full of diverse cultural beliefs, political systems and heterogeneous populations, impediments of interoperability are almost certain and unavoidable.

The report concludes that Hospital IT departments still grapple with interoperability challenges in facilitating their healthcare personnel to utilize massive data generated and domiciled in various distributed health systems in the

Asian countries [62]. It is therefore evident that Asia, like the rest of the world, still faces data quality and inconsistency issues despite the efforts by the concerned authorities to enforce standardization and compliance. To avert the challenge, the report proposes a close collaboration between healthcare providers and vendors during development and deployment of e-Health systems in hospitals. Taking America and Asia as examples, it can be concluded that globally, there is strong desire to implement interoperable health technologies [32, 62]. Counties acknowledge the need for interoperability in health systems, the need for user involvement, standardization, performance measuring and monitoring, patient data privacy, and the preparedness for the unseen impediments to interoperability. These benchmarks conversely serve as the major challenges the world faces in implementing interoperability in health systems.

2.4.2 Regional Interoperability Status

While developed nations are grappling with the usability of information in clinical decision making, Africa and most third world countries are struggling with how to share the data, leave alone utilizing it. In Egypt for example, despite the government launching a nationwide EHR system for use in the public health facilities, several factors still negatively impacted on the adoption of the system in health facilities [22]. These included the failure by the government to pay attention to the healthcare consumer's standpoint, budgetary constraints that consequently impede the adoption of Next Generation Information Infrastructure (NII) and the ineffective deployment strategy used [22].

Findings by Adbesin et al. [61] consider lack of standardization as the major barrier that impedes the widespread adoption of interoperability in African countries. Other barriers include lack of appropriate experience in the application of standards in healthcare systems, lack of foundational infrastructure such as electricity, computers and computer accessories, and stable LAN and WAN connectivity; cost barriers and limited human resource capacity for development and implementation of interoperable health systems[61].

Adebesin and colleagues [61] suggest a transformation of the standards development procedures in African countries to fast track the interoperability implementation process. In addition, the paper appeals to African governments to prioritize investment in requisite infrastructure and development of human resources capacity through rigorous training and capacity building. Finally the paper calls upon the governments of the day to play a more active role in adoption of interoperability standards through appropriate guidelines and national policies [61].

One African government that seems to keenly follow the recommendations of Adebesin et al. [61] study is the Tanzanian government if the findings by Nsaghurwe et al. [63] is anything to go by. According to this publication, Tanzania has successfully completed the first-phase activity in integrating the country's vertical e-Health information management systems through and interoperability layer that facilitates cross-platform sharing of data. The 2014-2019 project saw the government and its partners implement a five-step procedure that seeks to crack the interoperability nut by addressing the existing gaps [63].

The four major gaps identified in the procedure include standards, program management, information systems architecture and governance. Through cohesive collaboration with multiple stakeholders and partners and by use of both open source tools and proprietary, the implementation taskforce was able to develop an interoperable system that guarantees interoperability of distributed e-Health systems while sealing the potential loopholes in its deployment [63]. The works comprised of developing the architecture for e-Health systems data exchange, deploying a middleware interoperability layer and training users to support and utilize the system and the data it generates [63]. With data exchange currently enabled in 15 different health facilities [63], The Tanzanian approach is perhaps a classical example of the approach to be adopted by middle income countries in developing, deploying and supporting interoperable health information systems.

2.4.3 Local Interoperability Status

The Kenyan Government has for the last one decade strived to enhance its service delivery to the citizens through commissioning of various ICT flagship projects [1]. A key highlight is the government's deployment of eCitizen services that permits the public to access government services through the internet [65]. Launched in Mid-August 2014, the eCitizen service portal, facilitates individuals to apply for passports on the immigration department, register and manage businesses, apply and pay for police clearance certificate, register marriages and societies, apply for death and birth certificates among so many other services. According to KRA, the platform collects an estimates sum of KES 10 million daily and boasts of over half a million subscribers. Other flagship projects pertinent to interoperability include the national fiber backbone (NOFBI) that connects all 47 counties to the countrywide fiber optic grid, Digital government payments, the M-akiba initiative, the laptop project for schools and the Konza Technocity project. Such initiatives demonstrate the government's desire to digitize and automate its operations and service delivery to the citizens [65]. It is however arguable that although other government sectors have done so well in digitization of their operations, health, as a sector still lugs behind in this aspect particularly interoperability [24].

Compared to developed countries like the UK and USA, the interoperability levels in developing nations like Kenya are way too far from those of developed countries. For instance while the developed countries have few and minor interoperability challenges, developed countries are still grappling with acquisition of basic infrastructure such as electricity and physical space to host the communication equipment to facilitate interoperability [25]. This does not however, imply that there are no efforts by developing countries to automate and integrate their health systems. In Kenya for example, efforts are geared towards standardization of e-Health which is part of the primary processes of integration.

The recent launch of the Kenya e-Health Interoperability (KHISI) Framework by the MoH [1] serves as a great milestone towards the journey of interoperability. However, given the pace at which the developments are taking place, the efforts are not yet enough to guarantee speedy implementation of interoperable systems in a resource inhibited environment like Kenya [1]. To achieve expeditious deployment of the KHISI Framework and the subsequent interoperability processes, there is need to employ evidence-based models at all levels of its implementation. Kenya like the rest of the world also faces a myriad of challenges in achieving interoperability of its systems [6]. According to Musabi, Thiga, and Karume [6], the nation faces standardization challenges, lack of skilled manpower, intermittent financial resources and misuse of funds intended for digitization projects. However, borrowing from the success of other information systems like the integrated Financial Information management system (IFMIS) and the Integrated Payroll and Personnel Database (IPPD) used to manage Government financial transactions and the Government payroll respectively, there is hope that the country can rise above the existing challenges to implement an interoperable network of e-Health systems in the country.

From global and local perspectives, it is evident that interoperability remains a challenging target to achieve in healthcare. Nonetheless, both the developed and middle income economies are in a haste to digitally transform their healthcare services through the deployment of interoperable e- Health systems. With application of appropriate implementation models and increased research in the area, seamless exchange of medical information among health facilities could soon be a reality.

2.5 Factors Influencing Interoperability of e-Health Systems

2.5.1 Interoperability Standards

Standards are normative documents that are jointly formulated, approved by recognized authorities, and used throughout the industry to achieve the best objective. Thus, data standards are agreed-on stipulations about data components and their associations used to facilitate semantic interoperability of information from diverse origins and enhance their quality [23]. Globally and locally, there exits numerous standards pertinent to e-Health that have been put in place for adoption. The existing interoperability standards are summarized in [Tab. 2.1].

Table 2.1 Interoperability Standards

ORGANIZATION	STANDARD/INITIATIVES
National Electrical Manufacturers Association (NEMA)	Digital Imaging and Communications in Medicine (DICOM)
Health Level Seven International (HL7)	HL7 family of standards relating to the exchange, storage, and use of electronic health information
World Health Organization (WHO)	Global Observatory for e-Health
Comité Européen de Normalization (CEN)	CEN/TS 15699:2009: Health Informatics
International Telecommunication Union (ITU)	Multimedia Framework for e-Health Applications; and Emergency e-Health
International Organization Standardization/ Institute of Electrical and Electronics Engineers (ISO/IEEE)	Multimedia Framework for e-Health Applications; and Emergency e-Health Services Standardization
Ministry of Medical Services, and Ministry of Public Health and Sanitation, Kenya	Standards and Guidelines Electronic Medical Record (EMR) Systems in Kenya, 2010
Ministry of Health (MoH), Kenya	Kenya Health Enterprise Architecture, 2015
Ministry of Health (MoH), Kenya	Kenya Standards for e-Health Systems Interoperability, 2015

Despite the presence and significant role that standards play in data collection, proliferation, and management, little is known about the quality of standards and how they can be applied in practice [23]. In fact most data standards are outdated and impractical in application [23]. Zhao and Xia [24], as cited by [23] looked into the importance of data standards in achieving interoperability and business performance enhancement. They content that although interoperability has been widely discussed from the conceptual perspective; little study has been done on the conceptualization of the actual implementation of interoperability in business. For instance, there is no clear outline of how interoperability is designed and whether it can improve organizational services delivery efficiency [23]. Adopting inter-organization Systems (IOS) standards as the key pillar behind achieving interoperability among diverse IT infrastructure in heterogeneous business environments [24]. However, although the IOS standards seem appealing, a number of challenges are still inherent.

Studies by Johnson [25] revealed that although international standards and guidelines offer effective frameworks for deployment of HISs, these standards are limited in situations of system failures. In US and the UK for example, during system failure, medical staff are forced to revert to manual operations that consequently lead to delayed service delivery and increased risk on the side of the patient [25].

Non-adherence to standards and policies are part of the factors impeding health information exchange in developing countries [26]. Many low-income countries have failed to embrace technologies that facilitate information sharing and policies and standards that support such technologies in an organization [25, 26]. In this circumstance, therefore, there is also need to pay attention to the individuals involved in the interaction with the information systems. Most software projects in developing countries, and particularly Kenya fail because of a lack of skilled human experts to support the systems, competition, lack of standardization and communication breakdown between the users and the system implementers [6, 26, 32]. Therefore, it is paramount for the organizational leadership to adopt a collaborative approach in developing new technologies in the health sector.

2.5.2 Information Security

Information security refers to the preservation of the confidentiality, integrity, and availability of data through security technologies and operational frameworks. The 21st century has witnessed an alarming increase of cybercrime cases sweeping across the globe like wildfire. According to cyberpeaceinstitute.org [27], e-Health across the world experience an average of 3.8 cybercrime incidents targeting per week with each incident breaching approximately 163,000 medical records.

These attacks are rampant in America, Asia and Europe. The 2018/19 hacking of American Medical Collection Agency (AMCA) that left 25 million patients' data compromised and the Wolverine ransom ware attack of 2019 that affected 600,000 patients is just but a few of the reminders of how targeted healthcare systems are across the world [29]. Africa, too has had its fair share of information security predicaments. The continent is fast turning into a hotbed of cyber- attacks, with some of these malicious activities crossing the continental boundary. Continentally, South Africa is the worst hit with the latest incident being the Disruptive malware attack of 29th July 2021 against a medical Specialist in that paralyzed operations of a non-profit blood bank [27]. Such statistics make individuals and organizations skeptical about embracing e-Health systems whenever and wherever they are introduced. In cognizance of the situation, many African countries have turned to legislation, proactive enforcement, and adaptive security infrastructure to curb the vice. The government of Kenya, for instance, passed into the law the cyber-crime act No. 5 of 2018 [44]. According to this act, malicious cyber activities such as unauthorized access, unauthorized interception, and unauthorized disclosure of security codes attract enhanced penalties of up to KES 5 million, or a jail term not exceeding ten years or both [44]. Owing to the sensitivity of the vast medical records in various information systems in various county health amenities in Kenya, there is a need to adopt a holistic approach that encompasses all the key elements of information security in the implementation of HIS.

2.5.3 Heterogeneity of Data Communication Technologies

Distributed systems are often characterized of different architectures, varied platforms, computational speeds, network traffic loads, data format and machine loads. There are four main types of heterogeneity prominent in distributed namely data heterogeneity, middleware heterogeneity, application heterogeneity and non-functional heterogeneity [29].

This heterogeneity often results into incompatibility which if not well managed, could translate to increased troubleshooting time, increased maintenance costs, increased resource contention and overall low productivity on the part of an organization [29]. To curb incompatibility, inclusion of the Internet of Things technology into health ITs is viewed as the optimal solution. However empowering the utility of advanced IoT technology in Public health Systems is still significantly challenging in the area considering many issues, like shortage of cost-effective and accurate smart medical sensors, unstandardized IoT system architectures, heterogeneity of connected wearable devices, multi- dimensionality of data generated and high demand for interoperability [29]. In India for example, research by Mitel et al. [31] concluded that despite there being numerous models for adoption of IoT into healthcare systems, none of the models could explain how practically incorporate IoT in e-Health.

Challenges associated with heterogeneity of systems are same both in and out of Africa [32]. In Nigeria for example, studies reveal that e-Health used within the healthcare organizations in the country are developed independently with diverse and heterogeneous ICT tools, methods, processes and procedures which result in a large number of heterogeneous and distributed proprietary models for representing and recording patients' information [32]. Similar observations were made by Rono, Omieno and Mutua [33] who identified systems compatibility as one of the key factors affecting the adoption of interoperability. They add that this heterogeneity emanates from various coding languages, different vendors, different middleware platform used in implementation and the use of diverse storage types and data formats.

2.5.4 Resistance to Change

Resistance to change is no new phenomenon in organizations. People resist change because of ten main reasons. These include loss of control, excess uncertainty, surprise decisions imposed on people without due information or consultation, too many changes at once, and loss of face when the individuals associated with the old system feel like the legacy system can still work an want to defend it [22]. From the consumers' findings by [22] revealed that demographics such as gender and place, facilitating conditions, effort expectancy and price value are the key determinants impacting the decision by healthcare consumers to embrace health ICTs in Egypt. These factors are globally and locally cross cutting as evidenced in the studies [22]

2.5.5 Complexity of Healthcare Systems

Benson and Grieve [11] explored why achieving interoperability in healthcare systems remains a global challenge and not just a reserve for developing countries. The duo observe that interoperability is an amalgamations of multiple operational and technical layers namely human, data, technology and institutional factors that together form a complex environment of automation. These layers present forth different types of interoperability such as process, semantic, technical and clinical interoperability [11]. A challenge therefore is coming up with a model that achieves interoperability in all the four categories concurrently without jeopardizing or biasing on one particular one.

The experts suggest that Standards are the first hand solution in taming the combinatorial explosion of the number of links needed to merge systems. There is also the need to motivate the users and vendors of these interoperability systems. They conclude that in order to effectively conquer complexity in implementation of interoperable healthcare systems, change management, which is a vital element of any organizational service lifecycle is needed in this respect, [11] looked at the social dimension of project implementation. However, other factors such as Technical, economical and legal aspects were not investigated in detail. This research aims at developing a combinatorial solution that systematically and holistically address each of the aforementioned types and aspects of interoperability in order to achieve a unified system.

2.5.6 Connectivity

Connectivity is a requisite requirement for any data exchange in a distributed environment [33]. First, there is need for the supportive infrastructure that includes the physical building, physical security such as door locks and grills, electricity and fire suppression systems. Secondly, a Local area network (LAN) ought to be set up in a facility followed by a wide area connection that connects the LAN to the distributed network [33]. However, owing to the exorbitant initial costs involved in connectivity, many information systems projects end up challenged due to cheap implementation that compromises the functionalities of the ideal system [6, 14].

2.6 Distributed Systems Implementation and Policy Management Models

2.6.1 ARTEMIS

Artemis is part of the 6th Framework projects of Small or medium-scale focused research projects (STREP) funded by the European Commission that envisages at developing interoperability frameworks for healthcare domain. The project [13] seeks to achieve this objective in two respects: First, Artemis recommends that healthcare organizations develop their proprietary systems as web- based applications. This is seen as a move from the traditional offline systems with are so common among the African healthcare institutions. Web services rely on international standards like Web Services Description Language (WSDL) that is often used in combination with Simple Object Access Protocol (SOAP) to specify information exchange schemas in the deployment of web- based services across a computer network [6].

Also, in Artemis infrastructure, semantic interoperability is achieved by means of semantic annotation of intersystem communication and functions through the OWL-S and ontology mediation [13]. The framework facilitates discovery of healthcare web services through its peer- to-peer architecture that presents health care facilities as peers. The interfaces between the Artemis peers provide connectivity between the peers and subsequent consumption of web services. Semantics are therefore essential in describing the functions of the service, in the domain [13]. For instance, in the healthcare context, a patient searching for radiography services should be able to retrieve the hits irrespective of language, infrastructure, technologies or their location. To this end, the framework presents recommendable approach in bridging the interoperability gap through implementation of web-based e-Health systems that can be accessed globally [13].

Although Artemis presents a closer-to-reality solution, the methodology may be somewhat at higher level than the interoperability challenges faced by healthcare institutions in third world countries. For instance, while Artemis offers a solution from the software systems perspective, Africa still grapples with basic infrastructural issues that first need to be addressed before invoking the software solution. This observation is echoed by Farzandipur [14] who notes that the use and deployment of ICT projects in developed countries is very different from that of developing nations.

Low and middle income countries are still struggling with concerns of basic ICT systems infrastructure such as availability of electricity, wide and local area connectivity and lack of skilled personnel to administrate ICT systems and infrastructure. Statistics from the World Bank [15] indicate that 25% of Kenyans do not have access to electricity with majority of these population coming from rural settlements. Although these figures look commendable compared to the rest of East African countries, deployment of ICT technologies like IoT and interoperable health systems still remains a challenge for a country that is yet to guarantee 24/7/365 power connection to all its inhabitants[15, 16]. Given this scenario, priority must thus first be given to development of basic Health IT infrastructure before amalgamating the technologies. The precedence of installation of requisite structures such as power connections, computers, and LAN installations in health facilities is thus an issue that Artemis does not address but which this paper endeavors to consider in its solution proposal.

2.6.2 Kenya Health Information Systems Interoperability Framework

While recognizing e-Health as a mode of health service, the Kenya Health Act, 2017 [17] emphasizes the need for the standardization of health information exchange through an interoperability framework, and establishment and maintenance of a comprehensive integrated health information system.

It is against this background that MOH, in 2020, came up with Kenya Health Information Systems Interoperability Framework (KHISIF)

[Fig.2.8].

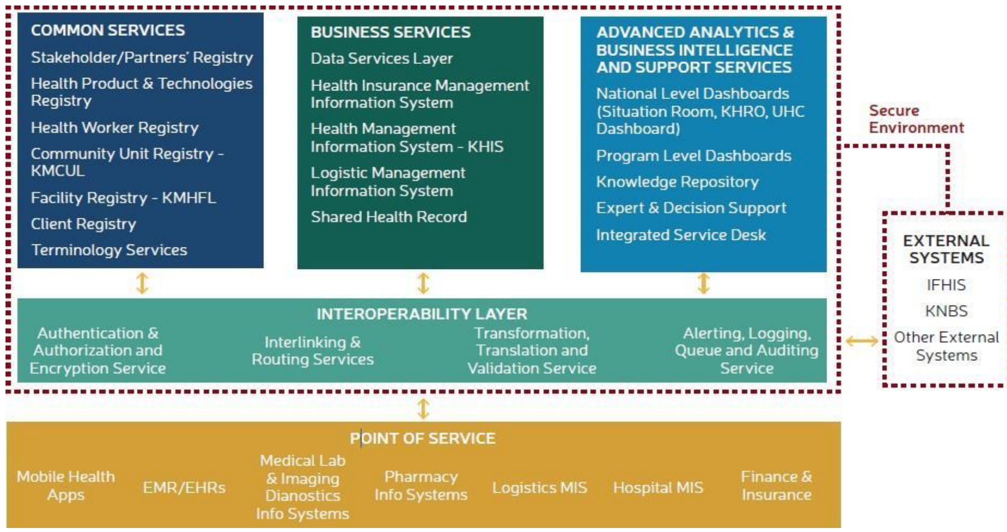


Fig . 2.8. Kenya Health Interoperability Architecture

Adapted from [1]

The framework suggests a conceptual model for integrated architecture to guide the planning, development, and implementation of the KHISIF. The model is segmental and is made up of loosely coupled constituents interlinked through shared infrastructure [11]. The conceptual model promotes the idea of interoperability by design and is anchored in the open health information exchange (OHIE) framework [1, 11, 13].

According to the framework, health systems across the country should be planned in accordance with the proposed model and with specific interoperability and reusability criteria in mind. This approach is undertaken to ensure interoperability among the various heterogeneous health systems currently in use. The model emphasizes reusability as a driver for interoperability, understanding that health systems can reuse information and resources that already exist and may be accessible from a range of sources both inside and outside the organization as proposed by the Kenya Standards and Guidelines for e-Health Systems Interoperability [1].

The KHISIF model comprises of three layers namely the service layer, the interoperability layer and the service point layers. At the top layer is the service layer that comprises of three common services, business services and advanced analytics and business intelligence and support services [11]. The interoperability layer concerns with authentication, connectivity, data transformation and auditing services. The service point deals with the various points of service present in a contemporary health facility search as pharmacy, finance, and laboratory as shown in figure 2 below.

Although the model endeavors to capture pertinent aspect of information aggregation such as authentication, interlinking and entity mapping in its interoperability layer, the architecture falls short of a number of gaps. First, just like the Artemis, the model does not recognize the significance of the requisite infrastructure which is the core driver of digitization and health services automation.

Secondly the model is more of data centered that environment centered [13]. The OHIE blueprint does not capture the human resource aspect that plays a significant role in the implementation of health information systems such as employee training and interaction with the system, system management which should occur at all layers. Lastly there is no specific domain dealing with security apart from the application-based security at the interoperability layer. There is need to incorporate an elaborate security domain based on a standardized security architecture that will safeguard all the data in and out of transmission. Lastly this paper finds the OHIE models as being an implementation of standalone automation systems rather than automated interoperable health technologies. The model does not demonstrate significant cloud-based concepts such as virtualization and web based services that are associated with inter-operable systems.

2.7. Research Gaps

From the literature reviewed herein, it is evident that a number of knowledge gaps pertinent to the interoperability in health information technologies do exist. A tabular summary [Tab. 2.2] of the major gaps identified in various authorities and how the researcher anticipates to bridge them is shown.

Table 2.2 Summary of Research Gaps

Author(s)	**Research Focus**	**Major Findings**	**Knowledge Gaps**	**How the Study Intends to address the Gap**
H. Ronoh, K. Omieno, and S. Mutua [33]	An interoperability framework for E- Government Heterogeneous Information Systems"	The study found that there are inherent factors that affect interoperability of E-Government Heterogeneous Information Systems	The study looked at interoperability in e-government systems i to public health systems	The current study intends to address this gap by looking atthe interoperability influencing factors pertinent to e- Health systems in the health environment.
F. D. Davis, R. P. Bagozzi, and P. R. Warshaw [38]	User acceptance of computer technology: A comparison of two theoretical models	The authors argue that users of computer technology are likely to accept a given innovation if they are convinced of the usefulness of the innovation and its use in addressing their technological needs	A technology may be both useful and easy to use but still end up not being used. Some more factors beyond the two highlighted in this theory need to be researched on.	The current study intends to address this gap by looking at the interoperability influencing factors beyond the user perspective.
Goodhue and Thompson [41]	Task-technology fit and individual performance	The theory holds that IT is more likely to have a positive impact on individual performance and be used if the capabilities of the IT match the tasks that the user must perform.	The theory looked at two important aspects of information processing namely the task and the technology capability. However, it does not consider the technology user /task executor and his/her environment	The current study intends to address this gap by looking at the technology user in this case the health workers and the environment that they work in.

2.8 Conceptual Framework

The core contribution of this research is an interoperability framework for distributed e-Health systems. The independent variable is the interoperability model include leadership, governance and strategy, legislation, policy and standards; infrastructure and investment; and the workforce. The conceptual framework is shown in [Fig. 2.9]

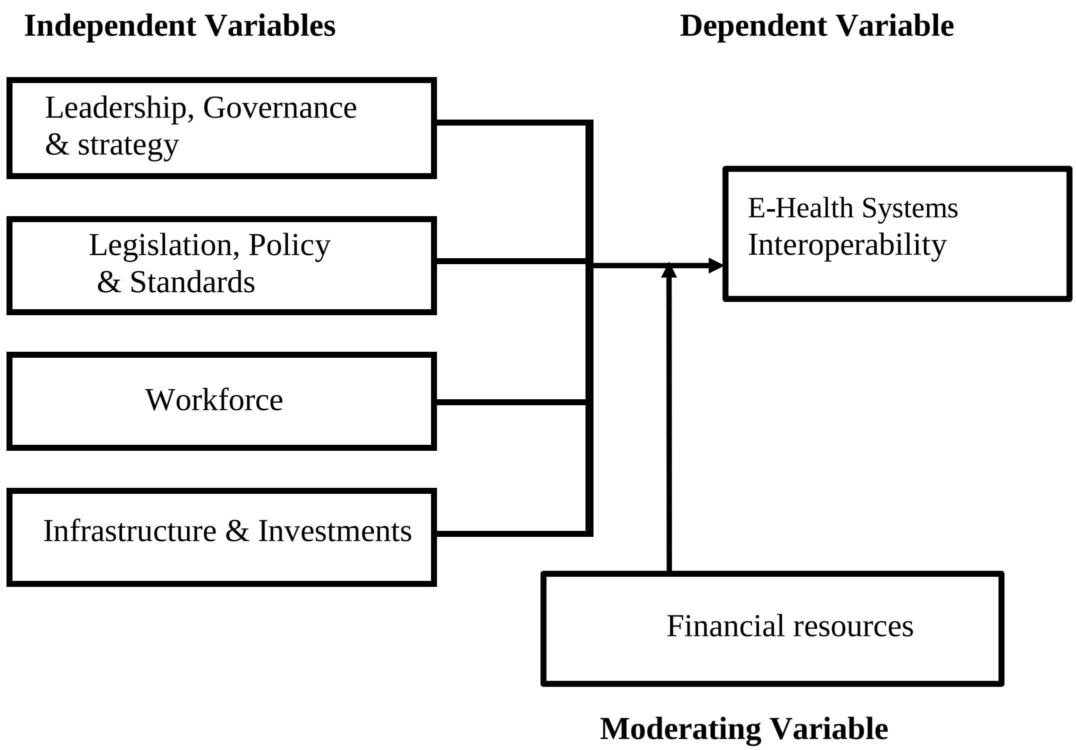


Fig. 2.9. Conceptual Framework

The dependent variable is the interoperable e-Health system whose magnitude of reliability, availability and effectiveness is directly depended on four underpinning variables namely: Leadership, governance and strategy; Legislation, policy & standards; workforce, and Infrastructure and Investments. The intervening variables is the financial resources whose presence or lack of it significantly affects all the determining variables and the subsequent outcome.

While it's true that without a leadership framework in an organization, it is difficult to attain interoperability [57], it is also true that there can be leadership in an organization but still experience difficulties attaining interoperability in an organization. The senior management needs to be involved right from the inception phase to the deployment. If the leadership is not well involved, they are likely not to waver the required support needed for the success of the system. Without the management support, there is likely to be minimal or no policy frameworks to streamline e-Health operations, underfunding and mismanagement of resources needed to champion e-Health interoperability and subsequent low uptake of any e-Health interventions deployed at the facility. Getting the support of the management will ensure financial prioritization of the project as well as policy frameworks to guide the process to the end. The management will also provide the much needed influence to their subjects to embrace e-Health systems.

Proper legislation, policy and standards provide a clear and agreed way of doing things [57]. For instance, in the e-Health implementation process, there is need for all the three named aspects to provide order, cohesion and clear service operation procedures before, during and after the deployment of a given health technology in the facility. Management instruments are strategic tools used by the management to govern the deployment of e-Health systems as well as the people interacting with these systems. Without these management tools, e-Health systems may end up deployed in a manner devoid of best practice, standards and order. Absence of harmony may in turn lead to mistakes such as inadvertent data breaches that could land an organization in endless court battles and subsequent damage on its reputation. The workforce on the other hand will operate in confusion leading to conflicts among themselves, negative attitude towards e-Health systems and the eventual system failure.

Human resources is one of the fundamental determinants of the success of interoperability in an organization. Since these are the individuals who will be consumers of the technology service on daily basis, their inclusion in the system development process from inception to capacity building is equally important. This incorporation increases acceptance probability and product ownership. It is therefore important the system be implemented with the user at the center. As such the user interface/user experience (UI/UX) should be enhanced while ensuring that the system meets the organizational information processing needs as contemplated Premkumar et al. [37]. In a nutshell, the technology should meet the Perceived Ease of Use (PEOU) and the Perceived Usefulness (PU) as illustrated by Davis et al. [38], in the Technology Acceptance Model. In addition, human resources include the leaders who are needed to provide the much needed leadership to the organization including formulation and revision of ICT policies to support e-Health interoperability. It is the same leadership that is required to develop management tools to aid the smooth running of the organizations ICT infrastructure. Lastly, infrastructure is another fundamental aspect that greatly influences the interoperability. Infrastructure can be viewed in two perspectives i.e. the supporting infrastructure such as electricity, server rooms and LANs and the active infrastructure such as the WAN/LAN devices, servers and software systems.

In summary, the first objective of the study was to identify the Status of e-Health systems in public health facilities in Kakamega County. The objective corresponds to the infrastructure and investments variables as an independent variable. The second objective was to determine the factors influencing interoperability of e-Health systems. From the literature review, all these factors emanate from humans, systems and processes also known as strategies. The second objective just like the third objective encompasses all the four aspects of the conceptual model.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the various approaches that were used in conducting the research. Principally, the section looks at the research design; location of the study; population sample and sampling technique; validity and reliability of the research instrument; data collection instruments; sample size, data collection procedure and data analysis plan.

3.2 Research Design

The inquest adopted a descriptive research design in examining the status of e-Health systems in the government-owned facilities and to determine the factors influencing interoperability of e- Health systems in these facilities. As Green and Thorogood [18] argue, descriptive investigations are not just limited to factual discoveries. Still, they can also lead to the development of key concepts of knowledge and the resolution of critical problems. Mugenda and Mugenda, [51] notes that descriptive research design helps the researcher in understanding the genesis of the problem, understand the causes of the problem and helps suggest a solution to the issue. This design fitted into the objectives of the study since the later began by first seeking to understand the status of e- Health systems in government health facilities, finding out the factors leading to lack of interoperability among these systems and lastly attempted to provide a solution by suggesting a model that will enhance interoperability among the said systems. The design permits both statistical and textual data analyses of data, and allowed more flexibility when designing research tools [18].

3.3 Location of the Study

The study was conducted in eight sub counties of Kakamega County. Kakamega County is the fourth most populous county in Kenya with a population of 1,867,579 people served by 192 health facilities evenly distributed across the county's twelve sub counties [8, 21]. Kakamega county boarders Siaya County to the West, Nandi, and Uasin Gishu, to the East, Vihiga County and to the South and to the North is Bungoma and Trans Nzoia counties. The County consists of twelve constituencies and twelve sub-counties, sixty county assembly wards (60), eighty-three locations (83), two hundred and fifty sub-locations (250), one hundred eighty-seven (187) Village Units, and four hundred (400) Community Administrative Areas [21]. The study location is shown in [Fig.3.1].

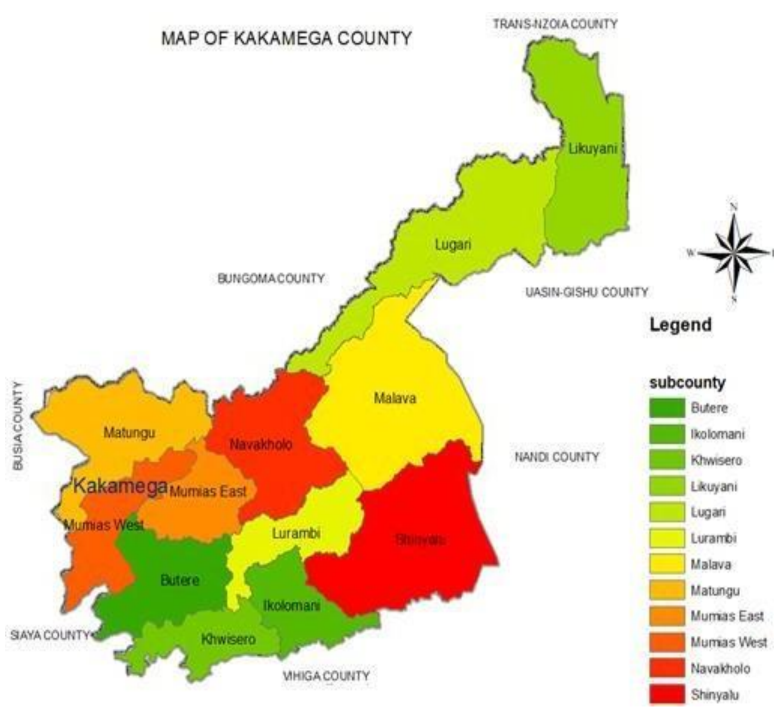


Fig. 3.1. Map of Kakamega County

Adapted from [21]

Kakamega County was chosen as the ideal location for conducting the research based on several factors. First, Kakamega County has a large number of both urban and rural health facilities serving a large number of populations. Therefore, it provides a good room for looking at factors that affect the interoperability of e-Health systems in both urban and rural settings. According to Adam [20] collecting information from diverse settings in a descriptive survey presents an almost real situation on the field which in turn enhances the accuracy of the research findings. Besides, Kakamega County represents a significant 3.92 percent of the country's population. Such a substantial population is a noteworthy representation of the Country's population.

Given that the anticipated model is meant for use not only in the County but the Country at large, it is imperative that the findings are drawn from a significant representation of the Country's population. Lastly, in 2020, the USAID through PATH deployed Kenya EMR system and established Local area networks in the County's 45 health amenities. The county was one of the three pilot counties for this project [20]. The findings of the research are therefore considered a key element in informing the deployment of similar systems other remaining Counties in the Country. A total of eight out of twelve sub counties were identified for study. They were Matungu, Butere, Khwisero, Ikolomani, Lurambi, Shinyalu, Malava and Lugari Sub County. The expansive nature of the county did not permit the study to cover all the twelve sub counties thus necessitating the need to randomly select the eight sub counties. The research could not cover all the 12 level four hospitals due to the accompanying expenditures. The sub counties with their respective level IV facilities were randomly selected and represent 66 percent of the total number of sub counties in the County; thus sufficient enough to draw a conclusion about the entire county [51].

3.4 Population and Sampling Technique

3.4.1 Target Population

The targeted population in this study were health workers serving in public health facilities in Kakamega County. According the Kakamega County Public Service Board [36] there are 1800 healthcare workers employed by the government [Tab. 3.1].

Table 3.1 Distribution of the Target Population

Sub County	Number of Healthcare workers
Butere	122
Shinyalu	120
Matungu	173
Ikilomani	161
Lurambi	223
Malava	147
Mumias West	172
Mumias East	136
Khwisero	153
Navakholo	127
Lugari	131
Likuyani	135
Total	1800

The workforce includes community health workers, doctors, surgeons, psychologists, pharmacists, nurses, midwives and physiotherapists. The County health departments have endeavored to equitably distribute this workforce based on the need and population.

The respondents were randomly drawn from all the service points of the facility. The service points include but not limited to Admissions, Anesthetics, Breast screening, Burn center, cardiology, Central Sterile Services Department (CSSD), critical care, diagnostic imaging, Finance department, General surgery, Gynecology, Hematology, health and safety department, intensive care unit (ICU),Human resources, ICT department, Patient accounts, pharmacy, renal units, radiology, social work, sexual health department, VCT, maternity, Theatre, and mental health section. Both the employees on permanent and contractual or temporary terms were interviewed or issued with questionnaires. The target facilities were eight public health facilities and ranged from model health centers to level 5 facilities. The amenities of interest were Lugari level 4 hospital, Malava level 4 hospital, Kakamega County teaching and referral hospital, Shibwe level 4, Butere level 4 hospital, Matungu Sub district Hospital, Iguhu Sub county hospital and Khwisero Model health center.

3.4.2 Sampling Techniques

The study employed two sampling techniques namely stratified sampling and simple random sampling. Stratified sampling was used to categorize the informants into homogenous subsets where the study population was divided into three broad categories namely the management / administration, medical staff and the ICT officers. This classification was done because the sample population is heterogeneous with varying levels of interaction with the existing systems. According to Kothari [34], stratified sampling is the most appropriate technique used to acquire a representative sample from a heterogeneous population. Under this technique, the study population was divided into strata that were characteristically similar than the total population. After classifying the study population into strata, simple random sampling was applied to each stratum since the method is simple and devoid of bias [35].

In addition the technique is effective in attaining research objectives and accurate findings [35]. This study picked ICT officers stratum as experts with responses to most technical questions, the medical staff strata as IT service users and the management strata were picked on basis of their knowledge and experience on leadership, policy and financial matters in health facilities.

3.4.3 Sampling Size and Frame

Since the target population were staff working in county health facilities, the study categorized the employees into homogeneous sets based on their roles, academic and professional training as well as their level of exposure to the existing HISs. Based on the above factors, three major strata are identified to form the sample frames. The divisions were the management team, the medical staff and the technical staff. The management staff included but not limited to medical superintendents, facility in-charges, facility administrators and the nurse in-charge. The technical team were majorly ICT officers, ICT champions and Health Records Information officers while the medical team included doctors, surgeons, dentists, physiotherapists, radiographers, pharmaceutical technologists, entomologists; counselors, clinical officers, and nursing staff. The Slovin’s formula was used to derive the sample size since the target population was already known.

The formula first put forward in 1967 [20] as shown.

$$n = N/ (1+Ne^2),$$

where;

n is the sample size,

N is the population size and e is the margin of error

From a population of 1800 health workers using a 10% margin error, the sample size was determined as shown below:

$n = N/ (1+Ne^2)$

$n= 1800/ 1+1800(0.01^2)\}$

$n=95$

The distribution of the sample population is presented in [Tab. 3.2].

Table 3.2 Sample Size Distribution

STAFF CATEGORY	**TARGET POPULATION PER FACILITY**								
	Matungu	**Butere**	**Iguhu**	**CGH**	**Malava**	**Lugari**	**Khwisero**	**Shibwe**	**Total**
Management	2	2	2	4	2	2	2	2	**19**
Medical staff	5	5	5	10	5	5	5	5	**49**
Technical Staff	4	4	4	4	4	4	4	4	**32**
Total	**11**	**11**	**11**	**18**	**11**	**11**	**11**	**11**	**95**

Except for the County General Hospital (CGH), two management staff, five medical staff and four technical workers were picked per facility. At the County General Hospital, Four members from the management team, ten medical staff and four technical team members were selected as informants. The county general hospital had the highest representation of informants because it is the top referral facility in then county with a high concentration of informants as compared to other facilities under study. The respondents drawn from the facility are thus proportionate to the number of health workers in the amenity. The distribution above was meant to reach the most number of respondents based on the distribution of health workers per facility. In most organizations, management is the minority in terms of numbers whereas the medical staff is the majority. The technical staff is average and as Kothari [34] opines, the main goal of combining stratified random sampling and simple random sampling is to focus on particular characteristics of a population that are of interest while maintaining the much needed impartiality in the research outcomes.

3.5 Data Collection Instruments

The research employed two methods of data collection namely the research survey and interview methods and the corresponding appropriate tools shall be used. Surveys have proven to be dependable means of gathering data more so when the goal of the research is to obtain quantitative data [18]. The strengths of surveys include their accuracy, generalize-ability, and convenience, and therefore the results can be generalized to a larger population within known error limits [34]. Costs and time notwithstanding, interview is considered as one of the most reliable methods of data collection in modern science. Interviews provide unmatched flexibility to the researcher while optimizing on the accuracy of the findings since the researcher is able to seek for clarification on certain responses [19]. In addition, the method permits the investigator to judge the non-verbal characteristics of the respondent and remain in control of the questions to ask and how to frame them.

The method is thus suitable for the collection of both quantitative and qualitative data with a bias on the later [34]. Given that the researcher collected two types of data, then interview as a method of data collection became inevitable. Consequently, two tools were used for data gathering which are questionnaires and interview schedules. The details of the data collection tools are elaborated in the subsequent sections.

3.5.1 Interview Schedules

The interview schedules were primarily used to collect qualitative data. Interviews are the most appropriate technique of collecting data meant for thematic analysis based on literary devices, concepts and analysis of words [18]. Interviews are renowned for yielding detailed information and new insights. They permit direct contact with the sources thus setting an amble environment for information gathering. In addition, interviews provide opportunity to probe for clarifications for responses not clearly elucidated by the respondent. Complex systems, experiences and processes are better addressed via exhaustive interviews because of the gravity of focus and prospect to seek detailed comprehension and clarification [18].

3.5.2 Questionnaires

Questionnaires are inexpensive ways to gather quantitative data more so if the questionnaires are self-administered in nature. They are therefore efficient means of gathering high volumes of data over a short span of time [19]. The scalability of the tool allows a researcher to gather data from a large audience at a relatively low cost and short time [18]. The data collected through questionnaires is easy to analyze and visualize thus can be used to create benchmarks for situation modelling such as the one anticipated in this research. Finally, questionnaires permit respondent anonymity thus creating environment for accurate responses from the audience [18, 19].

3.6 Validity and Reliability

It is imperative that the outcomes of a given research are credible and unbiased [44]. As such, the validity as well as the reliability of the questionnaire and the interview schedule used to gather the data will be determined to ensure that they meet the threshold of instruments needed to produce quality output. To test the validity and reliability of the research instrument, the researcher conducted a pilot study in Kanduyi Level IV Hospital in Bungoma County. The facility is located at the central region of Kanduyi Sub County and serves a diverse population from both urban and rural settings. The pilot study targeted a group of 10 respondents from the facility drawn from different sections relevant to the study. A pilot sample should be 10% of the selected study sample [34], and given that the study sample is 95, then 10 respondents was an appropriate figure for this case.

3.6.1 Reliability

Reliability refers to the extent to which outcomes are consistent over time and a precise depiction of the total population under investigation [19]. It therefore follows that if the results of an investigation can be reproduced under similar methodology, then the instrument of research is considered to be reliable. Conspicuous in this citation is the idea of repeatability and replicability of observations or results. Golafshani [44] identified three types of which relate to: the degree to which a measurement, given repeatedly, remains the same; the stability of a measurement over time; and the similarity of measurements within a given time period. Golafshani [44] subscribes to the thought that consistency with which questionnaire (test) items are answered or individual's scores remain relatively the same can be determined through the test-retest method at two different times. This attribute of the instrument is actually referred to as stability.

The researcher tested for reliability of the instruments by using test-retest correlation to demonstrate stability over time. The researcher confirmed the instrument's reliability and stability through the test-retest procedure using the same set of instruments to the same people under invariable conditions over some time using Cronbach's Alpha test. Cronbach's Alpha is considered a measure of internal consistency, and to accomplish this, the score of the underlying construct accounts for the reliability index .The instruments scored a Cronbach's Alpha test (α) value of $\alpha = 0.9$ indicating high reliability. According to [33] instrument are considered reliable if they gains a score of Cronbach's Alpha (α) value $\alpha \geq 0.70$.

3.6.2 Validity

The present study measured the validity of the instruments using content and factorial validity. Content validity is concerned with the degree to which an instrument measures or assesses what is supposed to be measured. The researcher evaluated content validity through instrument exposure to a rational analysis by ratter (experts) familiar with all relevant subjects to be measured and the construct of interest. The research engaged three experts who reviewed the questionnaires for comprehensiveness, readability, and clarity and guide as appropriate. Once their suggestions were incorporated in the tools, the raters consented that the tools met the required validity criteria and were satisfactory for use in collection of data.

Factorial validity extends empirical content validity by employing the statistical factor analysis model to validate the contents of the construct [34]. The degree of covariance between the judged responses and the actual responses were fairly identical at a 0.8 factorial validity, demonstrating adequate consistency of the tool. Since the instruments passed the validity test, the study findings could be generalized to represent the entire County and even other counties across the country.

3.7 Data Collection Procedure

Upon approval by the university board of senate to conduct the research, the researcher proceeded to seek permission from the relevant authorities to conduct the research. First was the National Commission for Science Technology and Innovation (NACOSTI) followed by the Kakamega County Department of Health. Once granted the permissions, the researcher, through research assistants, conducted validity and reliability test of the tools in a neighboring Bungoma county. Next the researcher through the same research assistants coordinated the process of filling the questionnaires and interview schedules in the field. Upon completion of data gathering, the research tools were checked for completeness in preparation for data analysis.

3.8 Data Analysis and Presentation

Both qualitative and quantitative data was analyzed using techniques deemed appropriate for each of the two types of data. Detailed description of analyses per type of data are described in the subsequent subsections.

3.8.1 Quantitative Data

The researcher used descriptive and inferential statistical techniques to analyze quantitative data from the field. Braun and Clarke [67], argue that descriptive statistics are important in helping the investigator to understand the details of the sample while inferential statistics are relevant in making generalizations about the population from which the sample was drawn from. Under descriptive approach, the research employed five statistical tests namely the mean, median, mode, standard deviation, and skewness. With the research being conducted in a heterogeneous environment, it was paramount to highlight difference between different groups, say health facilities or age groups [67]. Furthermore, it was important to bring out the relationships between different variables in the investigation [67].

To achieve the above two goals, the research used three inferential statistics namely the analysis of variance, popularly known as ANOVA, correlation analysis and regression analysis that will further help in understanding the causes and effects between various variables in the research. The Statistical Package for Social Sciences (SPSS) software tool was used in the above analysis as well as presentation of the findings. The data presentations and comparisons was done in form of frequency tables, graphs and charts.

3.8.2 Qualitative Data

The interview transcripts were used to collect qualitative data. This research adopted a six-phase thematic analysis procedure by Braun and Clarke [67] in analyzing the gathered qualitative data. First, the research team undertook the familiarization stage which involves reading the interview scripts and making notes of any analytic observations. Secondly, the coding stage immediately began which involved systematically identifying and labelling relevant characteristics of the data considered important to the research objectives.

The coding phase was followed by the theme searching stage which involved the clustering together of codes to form a reasonable mapping of strategic patterns in the data [67]. The fourth stage was the review of themes in which the research team assessed the themes to determine whether or not the themes were consistent with both the research topic and the objectives. At this stage some themes were discarded and others retained. The second last phase was the definition and naming of themes. This involved composing a brief summary of each theme and giving it a name to ensure conceptual clarity of each subject in readiness for the eventual write-up [67]. Finally, the researcher assembled an analytic report that providing a per-theme analysis and analytic generalization drawn across the themes. Similarly, the data visualization process was used to graphically represent thematic relationships for further evaluation, presentation and generalization. The Atlas ti-9 tool was used to aid the thematic analysis and visually present the outcomes.

3.9 Formulation of the e-Health Interoperability Model

The core objective of the present research was to develop an e-Health interoperability model for public health facilities in Kakamega County. The process entailed problem identification, problem conception, data collection and situational analysis, creation of the model and the model testing to assess its performance. The first step which was problem identification was done through a background analysis that revealed lack of interoperability among e-Health systems in Kakamega County. To conceptualize the problem, a review of existing literature was conducted to gain an in- depth understanding of the problem from the global down to the local perspective. Previous interventions by other researchers were looked at and gaps in their solutions identified.

The third phase involved data collection and situational analysis where field research was conducted to bring in firsthand information on the problem and critically analyzed to further inform the research and shade light on possible intervention cues to the problem. Armed with data from the field and theoretical and empiric al literature; the model was formulated. First the contributions of each of the studied theories were factored and how they aligned to the conceptual framework. Various aspects of the empirical literature particularly the drivers of interoperability and the existing e-Health stands were also factored in the formulation of the model. Secondly, the results from the field particularly the data on the status of e-Health systems and the factors influencing interoperability were analyzed and important areas of concern highlighted.

Critical areas such as the need to integrate silo systems and the need to incorporate all stakeholders in the implementation process were noted as key areas that necessitated an intervention through the model. The suggestions offered by the respondents from the field were also categorized thematically and considered in the model. From the vast information gathered from both primary and secondary sources, a model was developed in fulfilment of the third and main objective of the present research. The model details together with the testing procedures are discussed in later sections of this document.

3.10 Ethical Considerations

The research was guided by strict adherence to behavioral, environmental and social concerns that affect the target population. Particularly, the research respected the participants' right and freedoms, their privacy and confidentiality and integrity. As such, the respondent's anonymity was keenly considered. All the findings gathered were securely safeguarded and were only used for purposes of this study. The research sought consent from the participants while respecting their right on whether or not to participate.

CHAPTER 4

DATA PRESENTATION, ANALYSIS AND DISCUSIONS

4.1 Introduction

This chapter presents the findings of the data which was collected from the respondents, analysis and interpretation. The chapter also presents the proposed interoperability model for e-Health systems in public health facilities which was the main objective of this research.

4.2 Demographic Traits of the Respondents

4.2.1 Response Rate

The study targeted 95 respondents, however, out of the anticipated total, the research was successful in obtaining information from ninety (90) respondents which represents a response rate of 96% as shown in [Tab. 4.1].

Table 4.1 Response Rate

Response	Frequency	Percent
Returned	90	96%
Unreturned	5	4%
Total	**95**	**100%**

The findings are nonetheless valid due to the high response rate. In fact, according to Mugenda and Mugenda [51], a response rate above 70% is indeed excellent. Eleven (11) respondents answered the interview questions posed by the researcher while 79 filled the questionnaires. The five (5 %) non response was due to busy schedules of the physicians or failure by the informants to completely fill the questionnaires

4.2.2 Gender of the Respondents

The research covered both genders i.e. female and male informants. Out of the 90 respondents, 42 (47%) were female and 43 (48%) male while 5 (5%) opted not to disclose their gender. With a four percent difference between the genders, the study is considered well sensible in terms of gender balance. This is an indication that the results obtained are unbiased from the gender perspective.

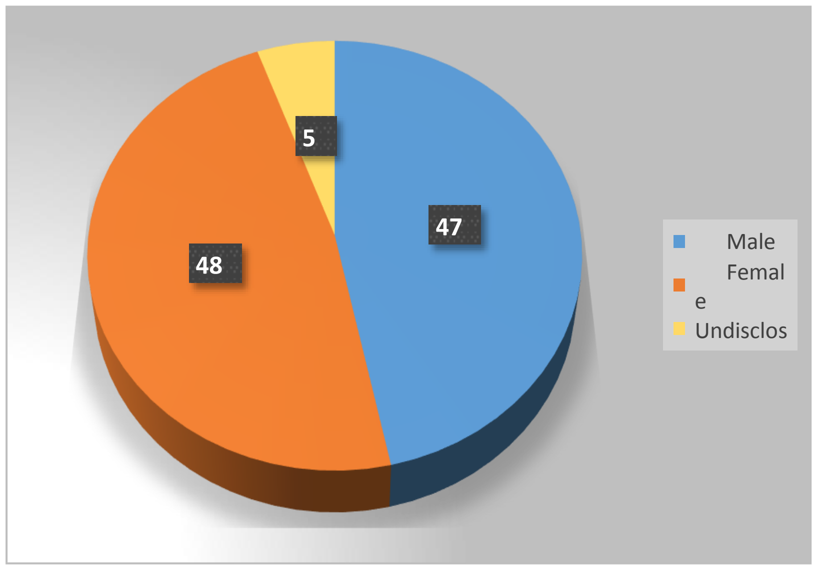


Fig. 4.1. Representation by gender

As represented in [Fig. 11], there was a gender balance in terms of gender representation. Both Cresswell [69] and Mugenda and Mugenda [51] postulate that a gender balance in the research sample population does not only help in mitigating against gender bias but also increase the credibility of the results. This research therefore affirms that the findings herein were based on balanced views, reactions and feelings from both genders in Kakamega county and can now be used to draw generalizations across similar areas.

4.2.3 Age of Respondents

With respect to age, the informants were divided into four categories with age ranges from 20-29 to 50 and above. Due to the need to keep the interviews as brief and concise as possible, the age question was omitted in the interview schedules thus only the respondents who filled the questionnaire answered. Fig.4.2. presents the gender distribution across the responding population.

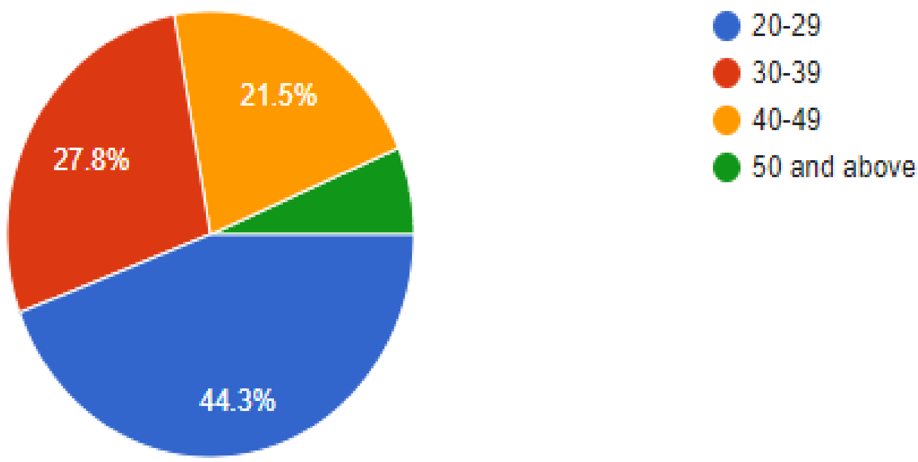


Fig. 4.2. Respondents' age.

Consequently, a total of 79 informants responded to this question. The findingsshow that the 20- 29 category had the highest number of respondents, (35) representing 44.3% of the total respondents, followed by the 30-39 and 40-49 categories, each with 27.8% (22) and 21.5% (17) respectively. The 50 and above category had the least representation with only 5 respondents representing 6.3% of the total respondents as shown in the figure 12 below.

As depicted in [Fig. 12], there was a variation in terms of age of respondents. The age variations confirm that the study was also well-proportioned with respect to age. From these patterns, it is evident that the youthful age group (20-39) is the majority healthcare providers accounting for over 70% of the workforce in public hospitals. In addition, with the respondents of 30 years and above being over 50%, there is sufficient indication that majority had stayed long on their jobs and able to provide appropriate answers. The low representation by the healthcare workers above 50 years can be ascribed to exit of service.

4.2.4 Professional Cadre of the Respondents

The study also sought to find out the professional cadre of the respondents and their role in interacting with various e-Health systems in the facility. A summary of the respondents' distribution based on professional cadre is presented in [Tab. VI].

Table 4.2 professional Cadres of Respondents

Professional cadre	Frequency	Percent	Cumulative Percent
Management	16	18	18
Medical	37	41	59
Technical	32	36	95
Others	5	5	100
Total	90	100	100

The professional cadres were categorized into three groups namely the management, medical and technical staff. All the eleven (11) respondents who responded to the interview questions were drawn from the management, however in situation where a management officer was not available at the time of research, a questionnaire was left behind for them to answer instead. Therefore, five respondents at management level filled the questionnaires. As such, a total of 16 management officers informed the survey. The medical staff were the majority at 37, followed by technical staff at 32 while other categories were only 5. Among the officers who fell in the others category were revenue officers and health promotion officers. The balance in terms of professional cadres is also reflected in the statistics above. The above equilibrium was significant in collection unbiased opinions.

4.3 Status of e-Health Systems in Public Health Facilities in Kakamega County

The first objective of the study was to find out the status of e-Health systems in public health facilities in Kakamega County. This section presents the findings from the field with regard to the above object. The e-Health systems status was measured by three constructs; the availability of the requisite infrastructure to support the existing e-Health systems, the current modes of communication in the facilities and the functional status of the e-Health systems in these facilities.

4.3.1 Status of the Requisite Infrastructure

Requisite infrastructure are the physical fundamental investment that facilitates a conducive and proficient computing environment in which the information exchange across facilities takes place [80]. The infrastructure plays both an active and passive role in enabling transfer of information between two or more distant locations. The findings and discussion on this aspect are presented in three sections namely availability of electricity, LAN and WAN connectivity and the computing hardware.

4.3.1.1 Electricity

The study sought to find out the connectivity levels of hospitals to stable power supply in the county. In addition the study interrogated the availability of an auxiliary power source such as a power generator or solar system. Out of the 79 informants who responded to this question, all the respondents (100%) agreed that their facility had access to electricity. However, when asked about the stability of this power, 31 out of 90 (34%) of the respondents noted that the power supply at their facility was unstable with frequent blackouts and brownouts. Majority (56%) were however satisfied with the reliability of their power connection. The 88.6% presence of complimentary source of power as evident in [Fig4.3] validates the view of the majority.

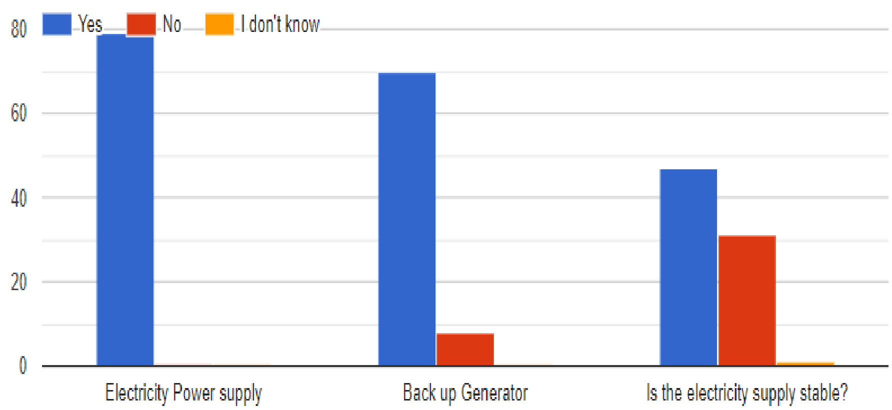


Fig. 4.3. Availability and stability of electricity in public hospitals

The 100% access to electricity in public health facilities is attributed to the joint initiative by the Government of Kenya and the World Bank that involved connecting households and government institutions located 600 meters from an existing transformer to the national power grid [68]. According to Global Infrastructure hub [68], 78 percent of the Kenyan population had connection to electricity by April 2018. By 2020, the Government of Kenya had provided 5 million new connections to its citizens as part of its fulfilment of the Sustainable Development Goal (SDG) number 7 [70]. The findings thus strongly agree with the joint report by International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), United Nations Statistics Division (UNSD), the World Bank, and the World Health Organization (WHO) and the United Nations (UN) as cited by [68] that there was extensive connection of electricity to households and institutions in Kenya.

The results however conflict with the findings by Musabi et al. [6] and Farzandipur [14] who both reported low level of electricity power connectivity as one of the key impediments towards implementation of e-Health systems in Africa. To some extent, the research findings somehow agree with the assertions by Musabi et al. [6] and Farzandipur [14] in the sense that although the current study reveals high levels of power connectivity in hospitals, the stability of this electricity stands at 56% is not sufficient to sustain e-Health interoperability.

4.3.1.2 Internet Connectivity

Access to stable internet connectivity is one of the most essential facilitators of communication between a facility and another. This research further attempted to establish the prevalence of internet connectivity to public health facilities and the quality of the connection. Forty two (42) out of 79 respondents who answered this question agreed that there was internet connectivity at their places of work. However, when asked about the reliability of the connection, majority (28) 54% reported that the internet connectivity at their facilities was unreliable.

The results are shown in [Tab. 4.3].

Table 4.3 Internet Connectivity and Reliability

Statement	Responses	Frequency	Percentage
My office has internet connectivity	Yes	42	53.2
	No	37	46.8
The internet is my office is reliable	Yes	14	17.8
	No	28	35.4

This coincides with the findings of Njoroge and colleagues [84] who observed that although there are efforts to connect government's institutions to the internet, the availability and reliability of these services is still a bedlam. Findings as illustrated in [Tab. VII] indicate that only 54.2% of the respondents had access to internet against a significant 46.8% who did not. Out of the 42 respondents who agreed having internet connectivity in their offices, only 14, representing 17.8% of all the respondents confirmed that the internet was stable. This unpredictability or absence of internet connectivity is a huge setback towards the attainment of interoperability.

The findings coincide with the works of Gichoya [70] who asserts that unsound resources is one of the factors affecting the successful implementation of ICT projects in government. Internet connectivity is a crucial resource in implementation of interoperability, thus its instability or lack of it greatly impedes information exchange between a facility and another. Ledwaba [72] attempted to measure the quality of internet connectivity services rendered to South African public libraries and his findings agreed with the observations of Gichoya [70] and this research. Tanzania, despite its reported success in implementation of interoperability still highlighted unstable internet connectivity as one of the key hindrances in achieving this course [63]. The volatility in internet connectivity is caused by high initial investment costs and recurrent expenses. While some hospitals remain locked out of the web by exorbitant internet costs, other organizations opt for cheap but low quality shared internet connections with fluctuating bandwidths as opposed to high quality dedicated internet services.

4.3.1.3 Availability of Computers and Allied Accessories

How can an organization attain interoperability without computers? In respect to answering this question, the study sought to find out whether or not there were sufficient computers and allied accessories in the facilities under study. Respondents were therefore asked to state if they had computers and computer appliances at their work place.

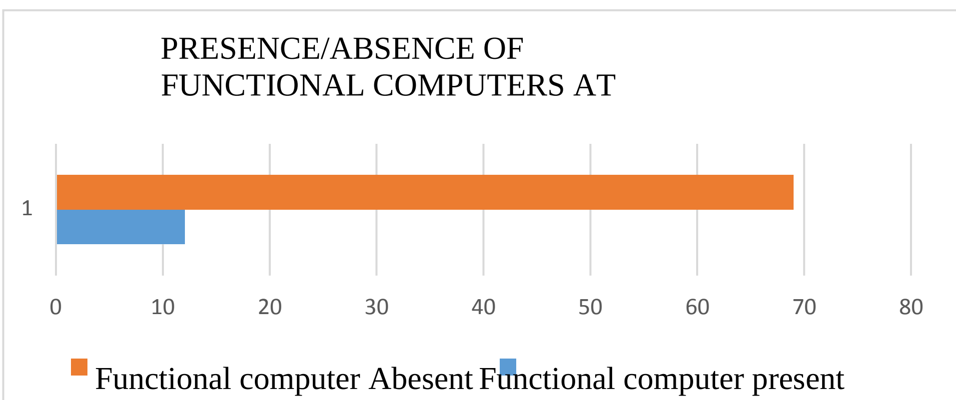


Fig. 4.4. Availability of computers at service points Source.

From the findings, a majority of the respondents 67(84.8 %) stated that they did not have a functional computer in their office while a paltry 12 (15.2%) agreed to having a functional computer at their point of service delivery. When asked about the presence of other ICT equipment such as printers, scanners, cameras, and projectors at the workplace, 60 (75.9%) out of 79 respondents agreed that their facilities had at least one of these devices against 19 (24.1%) who indicated that their facilities did not have these equipment. These findings are illustrated in [Tab.4.4].

Table 4.4 Availability of Computer Peripherals

Category	Frequency	Percentage (%)
Workplaces with printers and other ICT equipment	60	75.9
Workplaces without printers and other ICT equipment	19	24.1

From the data above, very few individuals have working computers at their service points but can still access shared ICT resources such as printers from other offices within the hospital. With only 15.2% of the respondents having access to a functional computer and 75.9 % access to other computing resources, the availability state can only be described as appalling but not surprising since previous studies in and outside the state point to the same problem. For example, similar studies carried out by Zayyad et al. [73] in Nigeria showed that the level of adoption and implementation of e-Health systems was low and mostly unsuccessful due to insufficient infrastructural investment. But why should infrastructural challenges remain to be a perennial challenge in implementation of e-Health systems? Financial and budgetary constraints have been identified as the main challenge in acquisition of basic computing infrastructure. This contention is supported by a wide majority of the previous investigations across the globe [14, 32, 47, 63, 71,73].

This problem is more pronounced in developing countries than developed countries. Further details into the financial pandemonium in health facilities have been discussed in later sections of this analysis.

4.3.2 Communication Means and Systems

The study also sought to find out the various means of communication available in various hospitals and how the employees in these facilities communicate externally particularly during transition of care. First, the respondents were asked about there being a corporate email system, mobile application, website of office telephone in their facility. From the information gathered, the number of respondent who agreed to having a corporate email at their facility and those who denied tied at 32 (41.6%) each, while the remaining 13 (17.6%) were not aware of the existence of such a system in their facility. This summary is presented in [Fig.4.5]

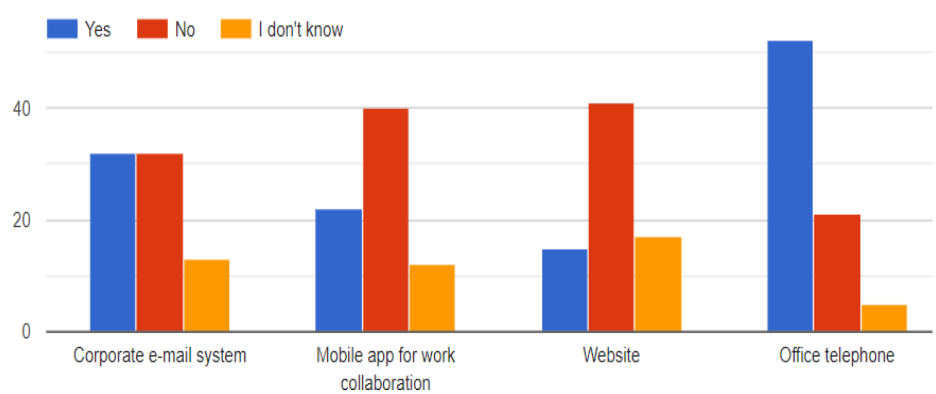


Fig. 4.5. Knowledge of the existence of a communication system.

Secondly, the respondents were asked to select the means they use in communicating with other facilities from a given list. The summary of findings on this aspect is shown in [Tab. 4.5].

Table 4.5 Modes of Communication

Mode of communication	Frequency	Percentage
e-Health system	3	1.6
Mobile app	19	9.9
Personal phone	38	19.8
Paper and pen	46	24.0
Office telephone	55	28.6
Personal mail	23	12.0
Corporate mail	7	3.6
Others	1	0.5

From the findings as presented, office telephone is the most prominent mode of communication with a popularity index of 28.6%, followed closely by paper and pen at 24.0%. Others include personal mobile phone, personal email and mobile application each with 19.8%, 12.0% and 9.9% respectively. The remaining modes of communication of which e-Health system is part of scored below 5%. In fact e-Health system communication was the second least popular means of inter-hospital communication.

One wonders why an employee would prefer to use their personal mobile phone or applications such as WhatsApp at the expense of their own mobile credit. In attempt to unravel this puzzle, the research revisited the technology acceptance model (TAM) by Davis et al. [38]. The model defines Perceived Ease of Use (PEOU) as the degree to which individuals believe that a particular system would be friendly to learn and use. Once an individual threshold of system user-friendliness has been attained, they will easily embrace and use the system frequently [38].

However, with the reported intermittence of internet connectivity, meagre computing resources and power stability issues as shown in [Tab. 4.1 and 4.3] and [Fig. 13], it is evident that users are more likely to encounter difficulties communicating via the existing e-Health systems thus opt for more convenient means such as office telephone and personal handsets. Although office telephone and paper and pen are the most popular and convenient means of communication, with them comes numerous shortcomings such as security concerns, data inconsistencies, delays in transition, increased chances of practice errors and subsequent increased care bills.

A comparative analysis with other parts of the world on this aspect reveals a mixed bag of outcomes. For instance, studies by Alagoz et al. [74] found out that Modern communication technologies such as telemedicine were the most prevalent means of communication in Europe, followed by office phone as auxiliary method. Similar studies in Algeria revealed that paper and pen was the most prominent mode of communication among physicians during inter-facility transfer of care [90]. To this extent, it is evident that Kenya just like the rest of Africa [90] still lugs behind in adoption of e-Health systems as a means of sharing patient data.

4.3.3 The Functional Status of e-Health Systems in Kakamega County

Delving deep, into the status of interoperability in public health facilities in Kakamega County, the present investigation sought to know whether or not there were e-Health systems installed in these facilities, the type of systems installed and their functionality.

4.3.3.1 Presence and Pervasiveness of e-Health Systems in the Facilities

First, the research sought to establish whether there were any e-Health systems in public health facilities. Out of the 79 informants who returned the questionnaire and 11 respondents who respondent to the interview questions, 88 informants responded to the question of whether or not there were e-Health systems in their facilities. Sixty nine (69) respondents agreed that there were e-Health systems in their facility while 10 dissented. Nine (9) respondents were not sure while 2 did not respond. The statistics are presented in [Tab. 4.6].

Table 4.6 Availability of E-Health Systems in Facilities

Question	Responses	Frequency	Percentage	Cumulative Percentage
Does your facility have an e-Health system?	Yes	69	76.7	76.7
	No	10	11.1	87.8
	Not sure	9	10.0	97.8
	No response	2	2.2	100

Kenya EMR, was mentioned as the dominant e-Health systems in the facilities with 54 out of the 78 who answered this question confirming its presence in the facilities. This represented 69.2% and was followed by DHIS2 and CHIS at 46.2% and 39.7% respectively. Other systems include Point of Care, Unimed, KHMIS, WebAdt, Imarisha Afya and Linda Mama Systems all of which were below 11%. The findings are sen in [Fig. 4.6].

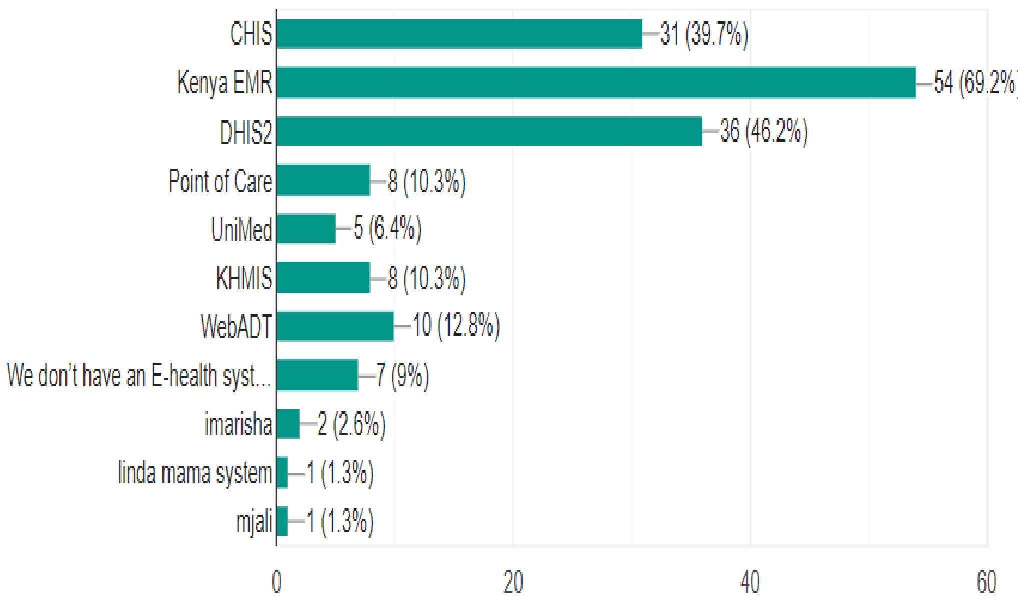


Fig. 4.6. Popularity of e-Health systems in health facilities.

The reputation of KenyaEMR as the most prominent e-Health system in the county is not without a cause. KenyaEMR is a decade old e-Health system developed by Intel iSOFT on behalf of I-TECH (University of Washington), and the Ministry of Health in Kenya in 2012 [64]. The system is specifically designed to enhance surveillance of HIV & TB patients on care, tracking of drug inventory, improved National reports- the system was able to generate and feed reports, and surveillance of maternal healthcare for HIV patients [64]. It is imperative to note that the system does not involve any other service points beyond the HIV and TB clinics in a hospital [45, 64].

Respondents were further asked to state whether their facilities had more than one e-Health systems. The findings on this question are presented in [Tab. 4.7].

Table 4.7 Existence of Multiple E-Health Systems in One Facility

STATEMENT	RESPONSE					MEAN	STD. DEV.	Skewness
	SD	D	NS	A	SA			
There are several e-Health systems at my facility	8 (10.1%)	15 (19.0%)	14 (17.7%)	28 (35.4%)	14 (17.7%)	3.2	0.5	0.9

The research reveals that majority of the respondents approved at 53.1% that their facilities had several e-Health systems as opposed to 23 respondents who dissented at 29.1%. Two respondents failed to respond while 12 others were not sure. Although there exists several e-Health systems in the facilities studied, none of the systems has all the functional modules needed to incorporate all the facility service points. Since each system is a dedicated software aimed at managing only one particular aspect of service delivery say HIV/AIDS care, management in these hospitals find it irresistible when offered another system that addresses the needs of another service point say Pharmacy. As such it is no surprise that one would encounter up to three systems in a facility with each system dealing with only one particular service. Typical examples are the HIV/AIDS management for the case of KenyaEMR and CHIS for revenue collection.

The researcher wondered whether this was a unique case in Kakamega or if the same problem was also witnessed elsewhere in the world. In their works; *Implementation science approaches for integrating e-Health research into practice and policy*, Glasgow and colleagues [76] concluded that technology powered healthcare service delivery suffers from one dimensional approach in which single purpose systems are designed to address a single need in multidisciplinary facility. They argue that Africa and other developing countries in the world usually receive health donations which are not tailored to address the specific needs of the target population.

These conclusions are father reinforced by Nicoya [70] adding that ICT projects fail to meet user needs due to lack of customization. For instance most donor funded projects are geared towards one aspect such as HIV/AIDS and so are the deployed systems. Although these systems may to a greater extend effectively serve the particular point of service, their overall contribution towards the organizations goal may be insignificant since they do not support other areas. This research therefore agrees with the previous studies [70, 76] while emphasising on the need to not only make systems interoperable but also integrate them. Further details on integration are discussed under recommendations.

4.3.3.2 Usability of e-Health Systems

An e-Health system is considered practical if it meets the needs of the user, has all the components required to attain a given task and is easier to learn and use [7,12]. It is against these principles that the research sought to know the usability levels of the existing systems in the facilities of study. First, users were asked whether their current systems met their expectations. This question was posed to both the interviewees and the questionnaire respondents. The statistics on user satisfaction are shown in [Tab. 4.8].

Table 4.8. Customer Satisfaction Scores

STATEMENT	RESPONSE					MEAN	STD. DEV.	Skew ness
	SD	D	NS	A	SA			
e-Health systems at my places of work meets my expectations	9 (10.0%)	30 (33.3%)	15 (16.7%)	28 (31.1%)	8 (8.9%)	3.3	0.5	0.9

The findings presented in [tab. 4.8] show that majority of the respondents disagreed at 33.3% that the systems they interacted with met their expectations. While a significant 31.1% had a contrary opinion. Fourteen (14) informants representing 15.6% were not sure while one opted not to answer. In summary, 43.3% of the respondents were unsatisfied with the performance of their existing systems while the remaining 40.0% agreed. The dissatisfied lot cited failure of the systems to incorporate all service point modules in them, failure by systems to share information across other facilities and snail-pace loading and execution time of the systems.

The study further sought to establish whether or not the existing systems had all the functional components that cover all the relevant service points of the facility. The responses are seen vide [Tab. 4.9].

Table 4.9. Functional Modules in Existing Systems

STATEMENT	RESPONSE					MEAN	STD. DEV.	Skew ness
	SD	D	NS	A	SA			
e-Health systems at my places of work has all the functional components that cover all the relevant service points of the facility	9 (11.4%)	28 (35.4%)	15 (19.0%)	20 (25.3%)	7 (8.9%)	2.8	0.3	0.0

The findings indicate that majority of the respondents disagreed at 35.4% that the systems had all the functional modules for all the service points in the facility. While 25.3% observed that the existing systems had all the components, another 17.7% remained uncertain.

Still under the usability status of the existing e-Health systems, the investigation interest was then drawn to the ease of use of the existing systems commonly referred to as user friendliness.

Table 4.10 User-Friendliness of the Existing Systems

STATEMENT	RESPONSE					MEAN	STD. DEV.	Skew ness
	SD	D	NS	A	SA			
The e-Health system at my place of work is easy to learn and use	5 (6.3%)	22 (27.8%)	12 (15.1%)	27 (34.2%)	13 (16.5%)	3.2	0.9	0.3

The study findings presented in [Tab. 4.10] shows that more than half of the respondents agreed at 50.7% that the existing systems were user friendly while 34.1% disagreed. Eleven (12) users could not tell whether their systems were user friendly or not while only 2 remained silent on this question. Considering the results on the three issues; user satisfaction, functional modules and the user-friendliness of the systems as presented in [Tab.4.3, 4.4 & 4.5] several points of concern emerge: What level of customer satisfaction is good enough? What makes a user satisfied with the system? Does user friendliness always imply satisfaction? Customer satisfaction score of 80% and above are the gold standard for good or very good [77] although this may vary. In the US for example majority of the companies dropped by 1.2% to 74.4% between the second and third quarter of the financial year 2020/2021 [77].

Thus a 40.0% CSAT score is not only way far below the average but too low to match similar scores in developed countries. Obviously there are reasons as to why there was such poor CSAT ratings. The answer lies in the findings in [Tab. 4.8 & 4.9]. With a whopping 46.8% of the respondents reporting failure of the systems to incorporate all facility service points in their modules, one cannot expect CSAT scores for the same systems to be anything beyond the inverse of this score. On the issue of what quantifies a user satisfaction with the system, The TAM models read together with the UTAUT model helps explain the current scenario.

Engraved in the Technology Acceptance model (TAM) [68] are two core issues; the usefulness and the user-friendliness of innovations. Two major questions emerge; first, are these innovations useful? And secondly; are these systems easy to learn and use? Based on the findings presented above, there is no doubt that the existing systems suffer low acceptance levels due to their functional features and poor user experience. The low CSAT ratings and dismal uptake of these systems are further elaborated by the unified theory of acceptance and use of technology (UTAUT) [40] in which Vankatesh and colleagues aver that users are likely to use the system if it meets their performance expectancy, effort expectancy, social influence, and facilitating conditions. It is therefore the contention of this research that the user-friendliness and usefulness of the current e-Health technologies do not meet the sufficient threshold needed to declare them satisfactory to the user needs in the facilities. From the revelations of this research, user- friendliness of a system does not always denote user satisfaction. A system may be easier to use and interact with yet limited in its capabilities. This is evidenced in the case of several standalone system in the facilities whose user-friendliness score are well above average but scoring low on user satisfaction matrix.

The research therefore concludes that although there are some significant levels of two builds of the UTAUT theory namely; the performance expectancy and the effort expectancy; these matrices are not prominent enough in the current systems to declare them sufficiently usable.

4.3.3.3 Systems' Security Features and Constraints

To further establish the status of interoperability in health facilities in Kakamega County, the study sought to understand the security measures and features engraved in the present systems. Consequently, the respondents were asked to indicate if the e-Health systems in their places of work had security features such as passwords and biometric credentials. A total of 59 respondents representing 75 percent either agreed or strongly agreed to the position that the existing e-Health systems had security features while another set of 8 respondents (10%) had a dissenting opinion. The remaining 10 (12%) were uncertain about there being such features in their systems. The answers summary can be seen in [Tab. 4.11].

Table 4.11 Security Features of Current Systems

STATEMENT	RESPONSE					MEAN	STD. DEV.	Skewness
	SD	D	NS	A	SA			
e-Health systems at my places of work had security features such as passwords and biometric credentials	2 (2.5%)	6 (7.6%)	12 (15.0%)	34 (43.0%)	25 (31.6%)	3.8	0.8	0.5

It is worth noting that patient privacy is a critical concern in the medical profession and as such any e-Health system put in place to domicile and exchange patient data must ensure the confidentiality, integrity and availability of patient information at all costs [7,82,84]. While three quarters of the respondents confirmed that the existing e-Health systems had security structures, the remaining 25% who are either unsure or reporting otherwise is a concern that should not be taken lightly by any implementer intending to develop an interoperable e-Health system. Security constraints are the key pillars that protect the privacy of a patient in an electronic health information management system. Any security vulnerability, however trifling it may be, could be extremely detrimental to the organization in the event of a data privacy breach [25, 32]. With the ballooning wave of cybercrime hitting approximately 4 incidents per week and a breach average of 163,000 per incident [27], any organization anticipating digitizing its information system should consider investing heavily in the security of its information. Incidents like the 2018/19 hacking of American Medical Collection Agency (AMCA) [27] and the Wolverine ransom ware attack of 2019 [29] serves as reminders of how information security ought to be taken seriously so as to avoid privacy breaches and subsequent legal suites.

4.3.3.4 Interoperability of the Existing Systems

The main objective of this study was to develop an interoperability model for e-Health systems in public health facilities. The research was thus interested to establish the interoperability status of the existing systems in various public health facilities. The respondents were asked if they were able to access patient data from another facility through the e-Health system at their facility.

Table 4.12 Interoperability Rating of the Existing Systems

STATEMENT	RESPONSE					MEAN	STD. DEV.	Skewness
	SD	D	NS	A	SA			
I can access patient data from another facility through the e-Health system at my facility.	16 (20.0%)	30 (38.0%)	16 (20.0%)	9 (11.4%)	8 (10.4%)	2.5	0.2	-0.41

Summarily, forty six (46) respondents accounting for 58.2% of the respondents noted that they were not able to access patient data from a remote facility while 17 respondents (21.5%) agreed that they were able to. The remaining 16 (20%) respondents were not sure whether their system could exchange data, one individual chose not to respond.

The results present very low levels of interoperability among the e-Health systems in the county. A 21.5% interoperability rating is a figure too small that it cannot go without begging for a solution. This outcome solidifies the justification for the development of an e-Health interoperability model. In US, studies by Holmgren, Patel, and Adler-Milstein [12] in 2020, revealed that only 30% of the facilities in the country met the required metrics necessary for true interoperability. This was a slight improvement from 2017 where only 24.5% of the facilities studied were compliant [12]. The findings of this study thus agree with the widespread agreement of similar studies in three out of 15 Southern African Development Community (SADC) countries namely South Africa, Namibia and Botswana. The 2013 SADC report on conformity and interoperability assessment concluded that there are very low levels of conformity and compliance to interoperability which is one of the key impediments to the interoperability progress in the region [78].

Implementation of e-Health systems in a resource constrained environment like Africa is often met with a myriad of challenges including financial constraints [26, 84]. These constraints deter acquisition and deployment of modern technologies sufficient enough to effectively meet the facility information needs. The Task Technology Fit (TTF) theory by Goodhue and Thompson in [41] places the low interoperability levels on task versus technology misfit. Whereas the existing technology globally can efficiently and effectively facilitate interoperability, finances to afford that kind of technology that can facilitate the execution of the intended task are sparse [6, 15, 42]. Thus the technology and task mismatch leads to low uptake and adoption of interoperable systems thus low interoperability levels not only in Africa but across the globe.

4.4 Factors Influencing the Interoperability of e-Health Systems

The second objective of the present investigation was to determine the factors influencing the interoperability of e-Health systems in public health facilities in Kakamega County. This section looks at human, intervening and systematic factors influencing interoperability in public hospitals.

4.4.1 E-Health Legal and Administrative Frameworks

As earlier discussed, legal and administrative frameworks refer to specifications for ownership, legitimacy, authority and accountability for health information systems management and data exchange [57]. . Respondents were asked to indicate if they had an ICT policy, standards document of ICT guidelines at their place of work. The results were tabulated as shown in [Tab. 4.13].

Table 4.13 Availability of ICT Legislative and Administrative Tools

Question		Responses			
		Yes	**No**	**Not sure**	**Total**
Does your facility have any of the following?	ICT Policy	32 (40.5%)	31 (39.2%)	16 (20.3%)	79 (100%)
	ICT standards	28 (35.4%)	30 (38.0%)	20 (25.3%)	79 (100%)
	ICT Guideline	33 (41.8%)	27 (34.2%)	19 (24.0%)	79 (100%)

As part of the broader quest, this research was curious to determine whether or not there were these administrative tools in the facilities under study and if the existing management took time to formulate them for their organizations. From the findings, majority of the respondents agreed at 40.5% that there were ICT policies at their place of work as opposed to 39.2% who indicated otherwise. Some sixteen respondents representing 20.3% were not sure if their organizations had ICT policies. On standards, 38.0% of the informants reported that their facilities did not have ICT standards while 35.4% said they did. The minority (25.3%) were uncertain on this aspect. As to whether or not there were ICT guidelines, 33 respondents representing 41.8% indicated that they had ICT guidelines against 27 (34.2%) who reported absence of ICT Guidelines. 24% of the respondents were not sure of the response to this question.

The findings are illustrated in [Fig. 18]

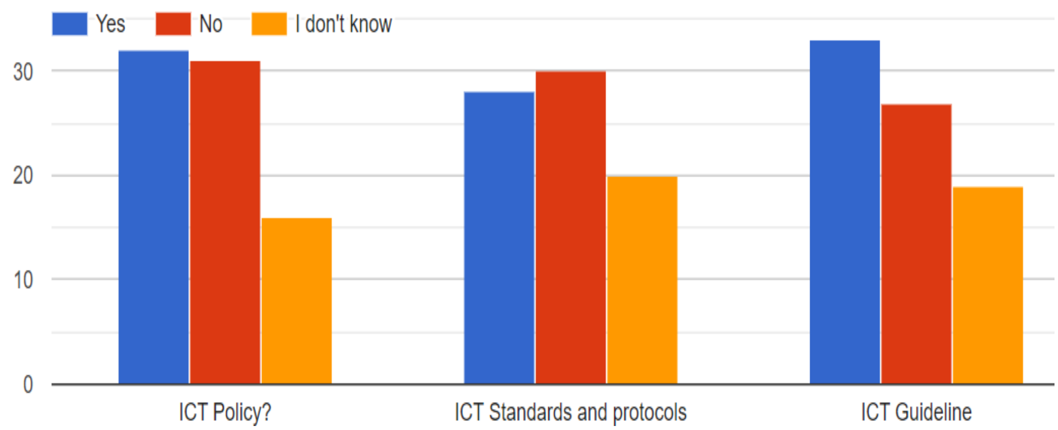


Fig. 4.7. Availability of Administrative Tools

The respondents were then asked whether the management at their place of work formulates the above tools. The summary of the findings on this questionnaire item is seen in [Tab.4.14]

Table 4.14 Management Reactiveness in Formulating Administrative Tools

STATEMENT	RESPONSE						STD.	Skew
	SD	D	NS	A	SA	MEAN	DEV.	ness
The management formulates policies and guidelines for ICT usage at my workplace.	12 (15.0%)	12 (15.0%)	19 (23.0%)	20 (25.0%)	16 (20.0%)	3.2	0.4	-0.2

In broader perspective, an average of 39.2% of the facilities in Kakamega have ICT administrative tools as opposed to 37.0% that do not have. These statistics concur with the findings of Adam [79] as cited by ITU [78] who argue that there is insufficient comprehension of fundamental ICT standards and how they should be applied in majority of the 15 South African Development Community States such as Angola, Botswana, Democratic Republic of Congo (DRC), Lesotho, Malawi, Mauritius, Mozambique, and Namibia just to mention a few. This observation is corroborated by the research findings at 38.0% absence of standards in facilities and the 25.3% uncertain group who both are indeed the majority. Despite the glaring absence of ICT policies in these facilities, there is little effort (36%) by the respective managements to formulate, implement, adopt or revise the necessary management tools to fit their organizational information needs.

This research however, absolves the National government from the blame of lack of these administrative instruments due to the wide availability of legislative and regulatory instruments. These tools include the Constitution of Kenya 2010, Open Data Protection Bill, 2013, Kenya e- Health Strategy (2011-2017), Kenya Health Policy (2014-2030), Health Information Policy (2014-2030), and the ICT Policy 2006 [80]. The indication is that these frameworks have not been devolved down to the individual facilities as required.

No wonder a significant representation (23.2%) of the staff are uncertain of the existence of such instruments at their place of work. The research also disagrees with Gichoya's conclusion that there is lack of ICT policies and master plans to guide investments in Kenya [70]. This research hold that indeed there are policies and masterplans, however, these tools are not well devolved, adopted or revised downwards to the facilities.

With a surfeit of administrative instruments to foster proper acquisition and utilization of health information technologies, one wonders why there is little utilization of these instruments in the facilities. The leadership approach and employee enthusiasm are key factors of consideration. The availability of competent personnel to initiate such policy formulation undertakings at organizational level shall also be discussed in subsequent sections.

4.4.2 Information Security and Privacy Concerns

Patient's information and security and privacy is a key concern in the medical profession. As already presented in [4.10], a total of 59 respondents representing 75 percent either agreed or strongly agreed to the position that the existing e-Health systems had security features while another group of 8 (10%) had a dissenting opinion. The remaining 10 (12%) were uncertain about there being such features in their systems. By eliminating the "Not sure", "disagree" and "strongly agree" respondents, there is a significantly flagrant gap in the information security of the existing systems as shown in the [Fig. 4.8].

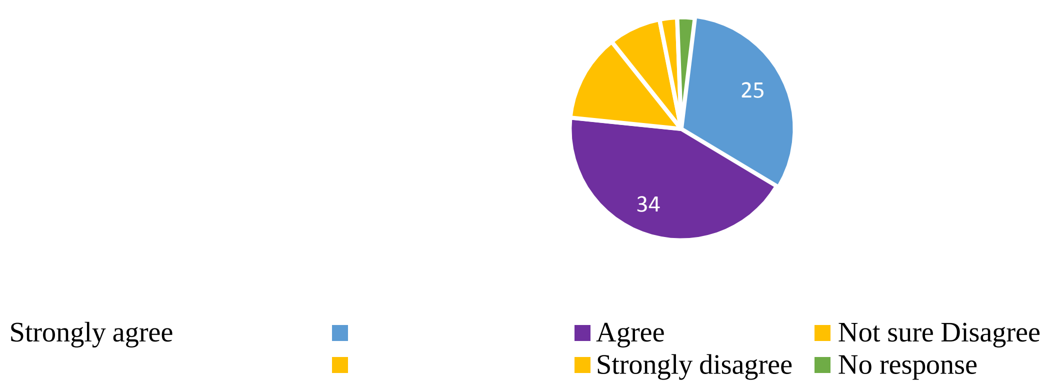


Fig. 4.8. Security status analysis

The study revealed that lack of interoperability among some of the e-Health systems in Kakamega County is a deliberate design occasioned by misinterpretation of the existing policies that are construed as forbidding information sharing across facilities. In turn, e-Health systems are so designed to remain standalone edifices so as safeguard patient information privacy. This is an indicator that there has not been proper sensitization of the staff on these management frameworks. As part of the suggestions proposed to enhance interoperability, users called on the management to revise the existing regulations to allow for sharing of patient information between a facility and another, albeit within the professional, legal and ethical tenets. For instance one respondent suggested only authorized personnel to be granted rights in the system to share information from an organization.

A scrutiny into existing standard documents revealed that the standards do not in any way deter patient information sharing but rather provide general provisions that should be tailored at facility level. For instance, the Kenya National e-Health policy [80] provides; "To monitor compliance to legal and ethical requirements, the government shall provide legislation for consent for care in e-Health, to ensure that consent is sought before transferring or sharing patient information electronically through platforms such as social media, short messaging service (SMS) or videoconferencing applications"

This research therefore disagrees with the assertions of Zhao and Xia [24], and Zhu, Lee, and Rosental [23] that exiting policies are outdated and impractical. Apart from periodic reviews, the existing policies and standards are accommodative to use of emerging health technologies in professional healthcare and do not contravene the provisions of patient information privacy. Conversely, both the national and county governments need to do more sensitization and sufficient de-escalation of these documents to lower cadre officers to avoid misinterpretation.

4.4.3 Heterogeneity and Complexity of e-Health Systems

Previous studies cited heterogeneity and complexity of e-Health systems as part of the factors incapacitating health systems interoperability among hospitals [7, 12, 74]. This research sought to know the levels of heterogeneity and the user-friendliness of existing system in its quest to confirm this prerogative. On the issue of heterogeneity, users were asked to indicate the source of their e- Health systems. The data on this aspect is seen in [Tab. 4.15]

Table 4.15 Sources of E-Health Systems

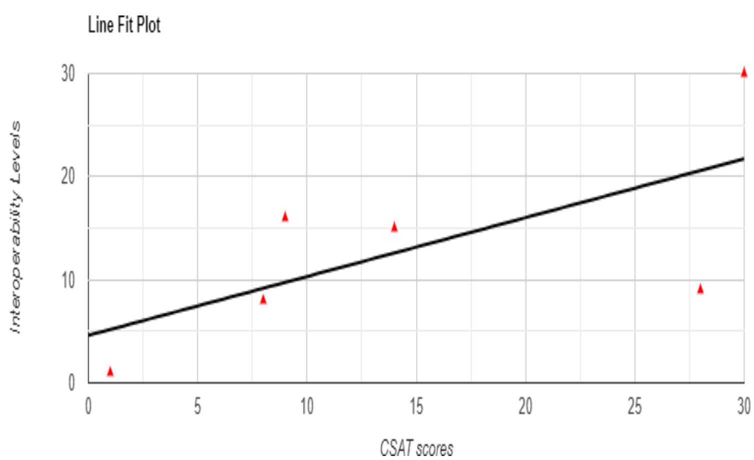
Source of the system	Frequency	Percentage
NGOs/Health partners	9	60.0
County Government	4	26.6
National Government	1	6.7
Don’t know	1	6.7
Total	15	100

Eleven (11) respondents answered this interview question giving a total of 15 responses. Some responses indicated having several systems delivered by different vendors or donors hence 15 answers. From the field gatherings as evidenced in table 18 above, 60.0% of the e-Health systems are ready made systems supplied by Nongovernmental organizations (NGOs) commonly referred to as health partners, followed by those form the County government at 26.6% while only 6.7% draw their genesis from the national government. None of the systems is a facility initiative. The findings coincide with the suppositions of Gichoya [70] who posits that majority of ICT infrastructure are donations from well-wishers and Government partners. However, most of these donations are made without prior consultation [70]. As such, the deployed systems may not accurately fit the user’s information needs. Furthermore, already made systems are donated to facilities without backend code to customize them. This lack of customization leads to "forced" adoption of inconsiderably and badly defined system and the subsequent inability to handle the system complexity [85]. The complexity streams right from the developers to the users culminating into loathsome user experience and poor adoption rates.

County Government on the other hand contracts developers who develop a system that is only meant to address a particular concern of interest. For instance CHIS system was developed particularly for revenue collection and without hospital management involvement. The result is a one dimensional system that only serves one purpose and cannot be customized. Most vendors supply their systems without back end code and even if they did, integrating will be an uphill task since the development architectures, platforms and languages differ from a developer to another. The research was interested to establish the extent to which the complexity and heterogeneity of existing systems has affected the interoperability among them. Using the Pearson Correlation Coefficient formula, an analysis was conducted to quantify the strength of the relationship between customer satisfaction and interoperability in hospitals. The data sets for each of the variables were extracted from [Tab. 4.7] and [Tab. 4.11] respectively.

CSAT scores	Interoperability Levels
9	16
30	30
14	15
28	9
8	8
1	1

[a]



[b]

Fig. 4.9. [a] SCAT and Interoperability indices [b]Correlation Analysis between CSAT scores and Interoperability levels.

Result Details and Calculation:

$$\bar{x} = \frac{9+30+14+28+8+1}{6} = 15$$

$$\bar{y} = \frac{16+30+15+9+8+1}{6} = 13.1667$$

$\Sigma(x - \bar{x})^2 = (9-15)^2+(30-15)^2+(14-15)^2+(28-15)^2+(8-15)^2+(1-15)^2 = 676$

$\Sigma(y - \bar{y})^2 = (16-13.17)^2+(30-13.17)^2+(15-13.17)^2+(9-13.17)^2+(8-13.17)^2+(1-13.17)^2 = 486.8333$

$\Sigma(x - \bar{x})(y - \bar{y}) = (9-15)*(16-13.17)+(30-15)*(30-13.17)+(14-15)*(15-13.17)+(28-15)*(9-13.17)+(8-15)*(8-13.17)+(1-15)*(1-13.17) = 386$

$$SXY = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{n - 1}$$

$$SXY = \frac{386}{6 - 1} = 77.2$$

$$r = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\Sigma(x_i - \bar{x})^2 \Sigma(y_i - \bar{y})^2}}$$

$$r = \frac{386}{\sqrt{676*486.8333}} = 0.6729$$

R=0.7

The analysis established a Pearson Correlation Coefficient of R=0.7 suggesting a strong correlation between a user satisfaction rates and the subsequent interoperability outcome. Similar analysis was done to compare the correlation between user satisfaction with the current e-Health systems and the pervasiveness of e-Health systems. The analysis reached at a Pearson Correlation Coefficient of R= 0.6. The analysis reveal that the uptake and pervasiveness of interoperable e-Health solutions in hospitals largely depended on the user friendliness of the systems and the extent to which the systems satisfied the users' needs. These findings are thus consistent with the Technology Acceptance Model [38] that pin technology adoption on the Perceived Ease of Use (PEOU) and the Perceived Usefulness (PU). It therefore follows that complex and heterogeneous systems are likely to face challenges in adoption and prevalence by users.

4.4.4 Human Factors

Human factor is arguably the most important component of interoperability. This component has an array of several other subcomponents that directly influence interoperability, hence significant to be discussed. These subcomponents include leadership, governance and strategy; user involvement and capacity building; and personnel attitude.

4.4.4.1 Leadership, Governance and Strategy

To find out the composition and the role of the management in steering interoperability in public health facilities Kakamega county, respondents were asked to state if there was an ICT manager or officer at their work place, if the management was passionate about use of ICT in providing healthcare services and if the management formulates policies geared towards enhancing ICT and health information technologies. In [Tab.4.16] the summary in shown.

Table 4.16 Leadership, Governance and Strategy

STATEMENT	RESPONSE				
	SD	D	NS	A	SA
There is an ICT Manager/officer at my work place	18 22.8%	10 12.7%	14 17.7%	15 18.9%	22 27.8%
The management at my facility is enthusiastic about the use of ICT and e-Health	9 11.4%	9 11.4%	15 18.9%	28 35.4%	18 22.8%
The management formulates policies and guidelines for ICT usage at my workplace.	12 15.2%	12 15.2%	19 22.8%	20 25.3%	16 20.3%

From the findings, 27.8% of the respondents strongly agreed that indeed there were ICT managers or personnel at their workplace against 22.8% who were for the dissimilar opinion. In general majority of the informants (46.7%) confirmed that there was ICT management as opposed to 35.5% who observed otherwise. On the issue of management enthusiasm, 35.4% of the respondent greed that the management were passionate about IT, followed by those who strongly agreed at 22.8% while17.7 % were not sure. Those who disagreed and strongly disagreed tied at 11.4% each with only 1.3% of the respondents not answering. Lastly, on whether or not the management formulated ICT guidelines and policies at the workplace, majority either agreed or strongly agreed at 45.6% while 22.8% weren't sure. The remaining 30.4% thought that the management did not make ICT policies to govern the ICT operations. In general, most (46.7%) respondents observed that there were IT managers at their work place, with 35.4% of the management being passionate. They also agreed that most (45.6%) of the management put in place governance frameworks to manage usage of IT equipment and projects.

Whereas there has been a general increase in the number of healthcare personnel over the years to peak at an average of 20.7 doctors and 159.29 nurses for every 100,000 persons by 2013 [4] both the county government and the national government are not doing enough to ensure that the same facilities are resourced with enough ICT personnel to effectively support delivery of health services through IT. This is evident in the results with only 28.7% of respondents attesting to there being ICT manager at their place of work.

IT governance encompasses five key areas namely; aligning IT strategy with the business strategy, implementation of IT new technologies, work on increased customer satisfaction ratings; prudent use of resources, and management of IT related risks [88]. Based on the above five objectives of IT governance, the results attest to little efforts by the management to effectively govern ICTs under their jurisdiction. For instance the results in table XX above point at blatant inconsideration of ICT personnel in health facilities. While they play an enabling role in the facility, their contribution towards the overall attainment of the facility targets cannot be overlooked to the extent of not hiring them at all. The results agree with the findings of Azubuike and Ehiri [47] who note that lack of sufficient manpower in developing countries results in equal measures of failures in IT projects. This is evident even with the enthusiasm levels and policy formulation rates which are way far below the average. Failure by the management to adopt or customize existing policies to fit their organizational needs leads to lack of ICT policies and strategies to guide Health IT investment to the extent that several donors end up investing in the same system due to lack of coordination [70].

4.4.4.2 User Involvement and Capacity Building

Involvement and empowerment of the staff in any given project is a powerful component towards the success of that project. This investigation south to establish whether the respondents were involved in the implementation process of the systems at their work place. Additionally, the research sought to know whether the staff were trained on how to use the systems and subsequently provided with the user manuals to help them interact with the systems. The outcomes are summarized in [Tab. 4.17].

Table 4.17 User Participation and Capacity Building

STATEMENT	RESPONSE %					
	SD	D	NS	A	SA	NR
I was involved in the implementation of the e-Health system at my facility	16 (17.8%)	24 (26.7%)	14 (15.6%)	22 (24.4%)	14 (15.6%)	0 (0.0%)
I was trained on how to use the e-Health system at my facility	9 (11.4%)	18 (22.8%)	7 (8.9%)	22 (27.8%)	21 (26.6%)	2 (2.5%)
There are user manuals on how to use the e-Health systems at my facility	14 (17.8%)	16 (20.3%)	16 (20.3%)	19 (24.1%)	14 (17.8%)	0 (0.0%)

The research reveals that majority of the respondents (44.5%) reported being excluded in the implementation of the systems while another 40% differed with the formers' opinion. Fourteen (14) out of the 90 respondents were not sure. The question of user training and availability of training manuals was posed to 79 respondents who answered the questionnaire. Majority of the respondents (54.4%) agreed that they had been trained on how to use the e-Health systems at their place of work while the minority (34.2%) reported otherwise. Seven users representing 8.9% were not sure while other two skipped the question. Users were also asked about the availability of user manuals on the e-Health systems. Majority of the users agreed at 41.9% that there were system user manuals to help them navigate through the systems while another 38.1% denied the existence of such documents at their facilities. Sixteen (16) respondents were not sure whether or not there were training manuals and represented the minority at 20.3%. The findings on user capacitation are seen in [Fig. 21].

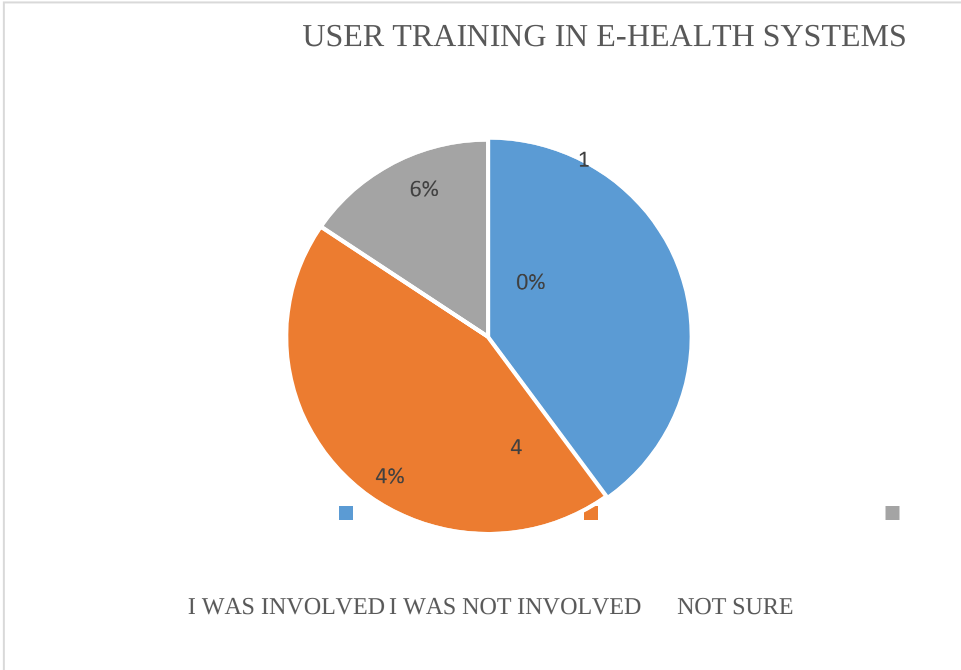


Fig. 10. User Training in e-Health.

The findings herein illustrate why there are numerous e-Health systems and yet most of them are not interoperable despite being designed so. Gichoya [70] avers that most ICT projects in Africa are challenged due to lack of institutional coordination and ownership of projects leading to inadequate monitoring of project activities. This is corroborated by Charette [85] and Adebesin [61] who argue that software projects fail due to poor communication among customers, developers, and users. According to Project Management Body of Knowledge (PMBOK) [89], 28% of the projects worldwide fail due to poor communication. With only 40% of the users having been involved in the implementation process, e-Health projects are likely not to attain the anticipated impact. This research further revealed that these users are mostly involved at training level and not at system development level. As such they are only trained to use what has been designed without their input. Although these users may learn the systems and become proficient users, the system may not be addressing their needs adequately. For the users who are neither involved nor trained on the system, their attitude towards the systems is nothing short of negative as it shall be illustrated in the next section.

4.4.4.3 Attitudes of Health Professionals to e-Health

Personnel morale and attitude towards a given e-Health system majorly depends on several factors top among them the level of involvement, training and after-sale support. This present research sought to establish the levels of user's involvement in functional suitability of the existing systems and their levels of enthusiasm towards the systems. First, the study sought to determine the interest levels among the user staff. Respondents were asked whether they thought the employees at their workplace were enthusiastic about the use of e-Health systems in healthcare. The study used the parameters where: 5 = Strongly Agree (SA), 4 = Agree (A), 3 = Not Sure (NS), 2 = Disagree (D) and 1 = Strongly Disagree (SD) 0 = No response. The summary of the findings are as, shown in [Tab. 4.18].

Table 4.18 Attitudes of Health Professionals to E-Health

STATEMENT	RESPONSE					MEAN	STD. DEV.	Skew ness
	SD	D	NS	A	SA			
Employees at their workplace were enthusiastic about the use of e-Health systems in healthcare	12 (15.2%)	32 (40.5%)	11 (13.9%)	19 (24.1%)	5 (6.3%)	3.3	0.6	1.3

The findings show that majority (55.7%) of the health professionals had a positive attitude towards e-Health systems as opposed to 30.4% who observed negative attitudes of employees towards e- Health. Eleven (11) out of 79 employees representing 13.9% were neutral on the question. This implies that there is low user enthusiasm towards the existing e-Health systems in Kakamega County.

The study made an attempt to find out the cause of low level of enthusiasm towards the system. This was achieved by regressing the levels of involvement against the attitude levels of the healthcare professionals. To begin with, the outputs of the two variables were summarized in the [Tab. 4.19].

Table 4.19 Summary of User Participation Versus Attitude

Response	User involvement Frequency	User Attitude frequency
Strongly disagree	16	5
Disagree	24	19
Not sure	14	11
Agree	22	32
Strongly agree	14	12

A regression analysis of the independent variable (consultation/involvement levels) and the dependent variable (attitude) was done as seen in [Fig. 4.11].

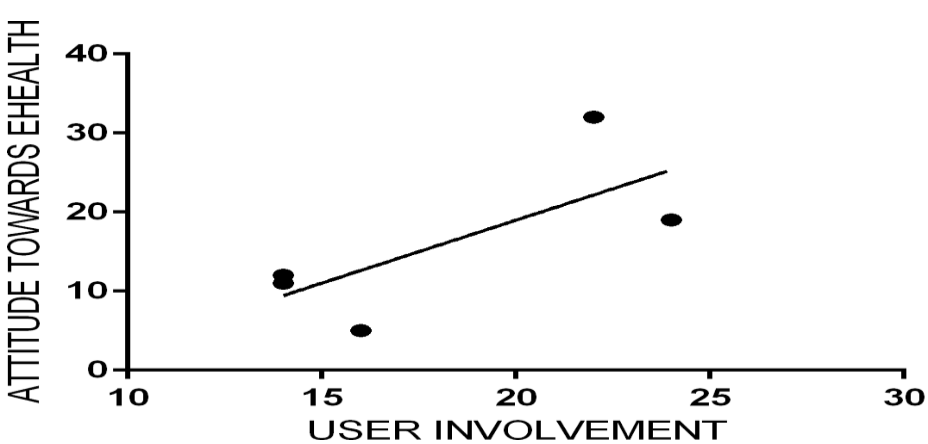


Fig. 4.11. Regression analysis of user attitude against involvement

The regression analysis results are summarized as seen in [Tab. 4.20].

Table 4.20 User Participation Versus User Attitude Towards E-Health Systems

Best-fit values	
Slope	1.591 ± 0.8792
Y-intercept	-12.84 ± 16.25
X-intercept	8.069
1/Slope	0.6286
95% Confidence Intervals	
Slope	-1.207 to 4.389
Y-intercept	-64.54 to 38.87
X-intercept	-infinity to 16.14
Goodness of Fit	
R square	0.5219
Sy.x	8.248
Is slope significantly non-zero?	
F	3.274
DFn,DFd	1,3
P Value	0.1681
Deviation from horizontal?	Not Significant
Data	
Number of XY Pairs	5
Equation	y = 1.591*x - 12.84

The findings on user attitude was subjected to correlation analysis using the Pearson Correlation Coefficient formula and the results yielded a Pearson Correlation Coefficient of R=0.74. This value indicated a strong correlation between the degrees of stakeholders' involvement in an e-Health project and their respective attitude towards the same innovation. Related studies by Kyakulumbye and colleagues [83] adduced a 56.8% positive attitude with standardized error of estimate of 0.436. This low user morale was cited as one of the contributing factors leading to low utilization of ICT in Uganda local governments.

Similarly, the findings of the present research point towards low uptake of e-Health systems. The low positive attitude is caused by low user involvement in the implementation of the system particularly at functional suitability and requirements specifications level, poor communication among customers, developers, and users [85]; Inability to handle the project's complexity and stringent budgets that inhibit thorough consultation among all stakeholders[70] . Similar studies in Australia's construction industry indicated that diffusion of ICTs in the country's construction industry had a significant correlation between the users' impetus to use ICT ant their attitudes such as perceived ease of use, professional credibility, and the relevance of the technology to their daily duties [82]. This research therefore agrees with the findings of Pensan and Walker [82] that when the two variables i.e. advantage of use and ease of use are missing in a system, there is negative attitude towards the system as evidenced in the findings.

4.4.5 Funding and Resource Accountability

Resource acquisition, mobilization and prudent utilization is determinant factor towards the success on any e-Health project. The research sought to establish the extent to which the respondents believed that their respective administrations allocated sufficient resources towards ICT/e-Health projects and if they thought the resources were well utilized to enable these projects to succeed. The responses are summed up in [Tab. 4.21].

Table 4.21 Allocation and Utilization of ICT Funds

STATEMENT	RESPONSE					MEAN	STD. DEV.
	SD	D	NS	A	SA		
The management allocates enough funds for ICT/ e-Health improvement	15 (19.0%)	8 (10.1%)	20 (25.3%)	20 (25.3%)	16 (20.3%)	3.1	4.4
The management ensures proper utilization of resources allocated to ICT	35 (44.3%)	24 (30.4%)	12 (15.3%)	4 (5.1%)	4 (5.1%)	2.0	12.1

The findings reveal that majority (50.6%) either agreed or weren’t sure if the management allocated enough resources for the implementation of e-Health systems in their places of work. However, 19.0% of the respondents strongly felt that the management did not allocate enough resources to the ICT division. In general 45.6% of the respondents agreed that the management portioned sufficient resources to the ICT against 29.1% who had a contrasting opinion. While 25.3% remained uncertain on this issue. Allocation of sufficient resources towards ICT projects is one thing, while prudent utilization of the same if another. Respondents were then asked they thought the funds were well utilized. From the results on table 24 above, majority of the informants strongly agreed at 44.3% that the resources weren’t properly utilized. They were followed by 30.4% who disagreed with the statement that funds were well utilized. In fact, a paltry 10.2 % of the respondents believed or strongly believed that the management was prudent in resource utilization against the 74.7% who opined otherwise. The remaining 15.3% were uncertain about this issue.

While most studies place ICT on the offensive wing against corruption, converse studies in Uganda revealed a 61.6% disagreement with the existence of top management support and financial prudence [83]. This implies that there is low top management support in allocating and ensuring proper utilisation of ICT resources not only in Kenya but East Africa. Globally [87] each year, an estimated $455billion intended for health projects are lost to corruption. Additionally, 45% of the world population perceive health sector to be corrupt [87]. This financial maladministration is responsible for 1.6% of annual fatalities in children under the age of five [87] part of which could have been avoided through the use of elaborate e-Health systems. A 45.6% agreement level that the management portioned sufficient resources to the ICT implies non prioritization of ICT by the management and subsequent underfunding. This research agrees with general cautions [86] that chronic underfunding and opaqueness in utilization of healthcare resources can reduce the quality of healthcare.

4.4.6 Acquisition and Implementation Practices

While the management may be enthusiastic, allocate enough resources and even utilize the efficiently in implementing an e-Health project, the implementation procedure similarly plays a significant role towards the overall success of an e-Health project. The implementation is a holistic undertaking that brings on board various stakeholders that must work in tandem. This research sought to know how the existing systems were acquired, deployed and supported to ease adoption. First, the management were asked how the systems in their facilities were acquired. The results are shown in [Tab. 4.22].

Table 4.22 Sources of e-Health Systems

Source of the System	Frequency	Percentage
NGOs/Health Partners	9	60.0
County Government	4	26.6
National Government	1	6.7
Don’t know	1	6.7
Total	15	100

From the field gatherings as evidenced in table 25 above, 60.0% of the e-Health systems are ready made systems supplied by Nongovernmental organization commonly referred to as health partners, followed by those form the County government at 26.6% while only 6.7% have their root from the national government. Some of the Nongovernmental organizations mentioned by the respondents are USAID, PATH and AMPATH. From the interviews, the researcher learnt that the systems are delivered as complete solutions with little or not room for customization. As one respondent stated: ‘The systems are normally delivered as they are and we are supposed to learn to use them as they are. None of the system has all the functional components we need to carter for all the needs of the facility service points”. For instance CHIS from the county only deals with revenue collection and nothing else. KenyaEMR is confined to HIV patients’ information with no accommodation for any other type of information. They are what we call push systems. [Respondent MGTBTR02]

The research was curious to gain an in-depth understanding of whether there was adequate consultation among all the stakeholders during, before and after the implementation of the systems and the nature of support that was afforded to the users to help them better utilize the system. The figures in [Tab. 4.23] present summary of the systems implementation practice.

Table 4.23 Systems Acquisition and Implementation Summary

STATEMENT	RESPONSE						
	SD	**D**	**NS**	**A**	**SA**	**NR**	**Total**
The e-Health systems at my facility were implemented using the industry best practices	7 (8.9%)	29 (36.7%)	19 (24.1%)	17 (21.5)	6 (7.6%)	1 (1.3%)	79 (100%)
I was involved in the implementation of the e-Health system at my facility	16 (17.8%)	24 (26.7%)	14 (15.6%)	22 (24.4%)	14 (15.6%)	0 (0.0%)	90 (100%)
I was trained on how to use the e-Health system at my facility	9 (11.4%)	18 (22.8%)	7 (8.9%)	22 (27.8%)	21 (26.6%)	2 (2.5%)	79 (100%)
There are user manuals on how to use the e-Health systems at my facility	14 (17.8%)	16 (20.3%)	16 (20.3%)	19 (24.1%)	14 (17.8%)	0 (0.0%)	79 (100%)
There are ICT officers/champions who help us to interact with the e-Health system	11 (13.9%)	12 (15.2%)	11 (13.9%)	28 (40.0%)	17 (21.5)	0 (0.0%)	79 (100%)

From the findings in [Tab. 4.23], majority of the respondents agree at 45.6% that the existing systems were not implemented using the best procedure, however, a total of 23 respondents representing 29.1 % have a contrary opinion. Nonetheless, as earlier discussed, 44.5% of the users reported not being involved against the minority (40.0%) who indicated having been involved. On the aspect of training and capacity building, 34.2% of the informants indicated that they had not been trained on the systems use against the majority (54.4%) who noted otherwise. Further, 41.9% of the respondents reported being in possession of training manuals while 38.1% denied. Lastly, the research revealed that 61.5% of the facilities had ICT officers or ICT champions who were assisting other users in interacting with the systems, however, a significant 29.1% did not have such persons at all.

The findings reveal that best industry practices were disregarded during the development, implementation and maintenance of e-Health systems in public hospitals. This is substantiated by low involvements rates of users, fewer number of staff trained on the system, few copies of system user manuals and shortage of ICT personnel to champion the system ahead. The findings reveal a contravention of section 3.1.4 of the Kenya National e-Health policy states; "Integration into Existing Systems Implementation of e-Health will bring together clinicians and health informatics experts to develop a unified model for integrating e- Health into the healthcare systems [80]."

The results confirm observations by Gichoya [71], Nsaghurwe et al. [63] and Charette [85] who all assert that improper project management is one of the key causes of ICT project failures. High cost of ICT investment pushes developing country's to rely on donor funded projects with little or no room for bargain on system requirements. The health partners together with all the relevant stakeholders should however operate in tandem and in proper coordination to ensure that the benefits of a given e-Health system are realized.

4.4.7 Requisite Infrastructure

Requisite infrastructure are the fundamental physical equipment and constructions required to enable information exchange [80]. These include availability of stable power supply, computers and computing accessories and well as availability of stable internet connectivity [80]. This research was keen to establish the level of investment in requisite infrastructure in the selected facilities. The responses were summarized in [Tab. 4.24].

Table 4.24 Summary of Requisite Infrastructure Availability

Question/Statement	Responses			
	Yes	No	Don't Know	No Response
Does your facility have stable power supply?	47 (59.5%)	31 (39.2%)	0 (0.0%)	1 (1.3%)
My office has a functional computer	63 (79.7%)	16 (20.3%)	0 (0.0%)	0 (0.0%)
My facility has a Local Area Network/Wi-Fi	42 (53.2%)	37 (46.8%)	0 (0.0%)	0 (0.0%)
My office has stable internet connectivity	14 (17.7%)	28 (35.4%)	0 (0.0%)	0 (0.0%)

The findings show that majority of the respondents representing 59.5% agreed to have stable power while the 31 respondents representing 39.2% disagreed. Another 79.7% of the respondents reported having a functional computer at their point of service delivery while the remaining 20.3% did not have. On the issue of internet connectivity and its stability, 42 informants representing the majority at 53.2% agreed to having LAN or WLAN connectivity against 37(46.8%) who did not have. The 42 respondent who agreed that they were accessing internet connectivity were then asked about the reliability of the internet. From table 27 above, only 14 informants representing a paltry 17.7% of the entire sample reported having stable internet. The remaining 28 Indicated that although they had internet connectivity, the connection was unreliable.

This research concludes that deficit infrastructure is closely associated to low interoperability levels as seen in the study facilities. Ledwaba [72] similarly concluded that the prevalence levels of stable internet connectivity in Africa re nail paced. Resource constraints can be attributed to lack of proper e-Health infrastructural investments by facilities. Scherer et al. [90] in a closely related investigation looked at the challenges affecting healthcare workers in three countries namely Algeria, France and Brazil. Their findings came to similar conclusion citing financial constraints as one of the key determinates of interhospital and intrahospital communication [90].

4.5 Impediments to e-Health Interoperability

Literature has pointed towards several causes of lack of e-Health systems interoperability. Although the reasons outlined are general and cut across all the facilities irrespective of the location, this research wanted to ascertain these cause and as well as unearth any other underlying factors that may have been grey to the previous researches. The interviewees were asked to state the reason why their e-Health systems could not exchange information with other counterpart system. Being an open ended question, the question was posed only to the interviewees. The responses were grouped to thematic areas relevant to the study as presented in [Tab. 4.25].

Table 4.25 Inhibitions of e-Health Interoperability

Response	Frequency	Percentage
Policy Constraints	1	9.1
Lack of basic infrastructure internet	2	18.2
System-based challenges	3	27.3
Lack of skilled ICT personnel	2	18.2
Insufficient resources	2	18.2
No Response	1	9.1

Policy constraints included lack of sensitization on e-Health policies while basic infrastructural issues include dilapidated ICT hardware and networking equipment, frequent power outages with eventual damage on computers and other electronic appliances. The informants also mentioned system based challenges as one of the main impediments to interoperability. Particularly the failure by existing systems to incorporate all services in their modules, systems taking too long to load especially after power outage. Informants also lamented about the scarcity of skilled manpower to support users on the systems whenever their services are needed. This went hand in hand with lack of financial support from the county government. "As you know, health was devolved and this is a facility under the jurisdiction of the county government department of health. We generate revenue on daily basis but what comes back to use to support our operations is so meagre that it cannot allow us procure health systems leave alone employing" [Respondent]. This is a cue of the current conditions that to a larger extend disrupts the way e-Health investments are done in hospitals.

4.6 Enhancing Interoperability

The core aim of this research was to develop an interoperability model for e-Health systems in Kakamega County. It was therefore imperative to have both the interviewees and the questionnaire respondents suggest way in which they thought the future e-Health systems and as well as the existing systems can be enhanced to attain interoperability. This information was imperative in the sense that it is the basis upon which the above said model would be based on. The suggestion gathered were subjected to six-phase thematic analysis as anticipated in the data analysis plan [67]. Owing to then pertinence of this subject, this question was posed both in the questionnaire and the interview schedules. Similarly, the results were thematically grouped according to the objects of the research and presented as shown in [Tab. 4.26].

Table 4.26 Thematic Summary of Suggested Improvements

Thematic Area	Suggested Interventions	Frequency	Percentage
System based improvements	Systems to incorporate all service points in their modules	13	18.6
Thematic Area	**Suggested Interventions**	**Frequency**	**Percentage**
	Systems to be made interoperable	9	12.9
	Mushroom systems to be integrated into one whole system	3	4.3
	Purchase and installation of modern systems	2	2.9
	Systems maintenance	3	4.3
Human based improvements	ICT Staffing	9	12.9
	User involvement in implementation	1	1.4
	Staff training	11	15.7
Legislative, administrative and management frameworks	Revise policies to allow inter-facility data sharing	1	1.4
	Policies to protect patient privacy	2	2.9
Basic infrastructure-based improvements	Purchase of more computers and accessories	4	5.7
	Install stable Internet Connectivity	3	4.3
	Ensure stable power	2	2.9
Resource –based improvements	Allocate more funds for e-Health projects	7	10.0

From the table above, most of the suggested improvements touched on systems improvements with majority of the respondents requesting that the existing systems be enhanced to carter needs for all the service points in the entire facility. As it turned out, most of the systems serve only one function in the entire facility. This lack of integration leads to low uptake and pervasiveness of e- Health systems in facilities. Studies in India concluded that failure of systems to integrate with each other contributes to the lack of advancement of the infrastructure [81].

Thirty percent (30%) of the improvement suggestions pointed at human related improvements such as adequate staffing, training and adequate inclusion of all the stakeholders in e-Health projects. On legal and administrative frameworks, respondents called on the Government to revise the existing policies to allow safe interhospital exchange of information. On requisite infrastructure, suggested improvements include purchase of adequate computers and allied appliances as well as installation of local area networks (LAN) and Wide area network (WAN) connectivity to foster remote communication. Lastly on resources, call were made to the government and its partners to channels more resources towards e-Health projects and ensure proper utilization of the same.

4.7 The Wheel Interoperability Model

The main objective of the study was to design an interoperability model for e-Health systems in public heath amenities in Kakamega County. This section introduces the proposed model christened the Wheel Interoperability Model (WIM) for implementation of e-Health systems in developing countries. The suggested model is shown in [Fig. 4.12].

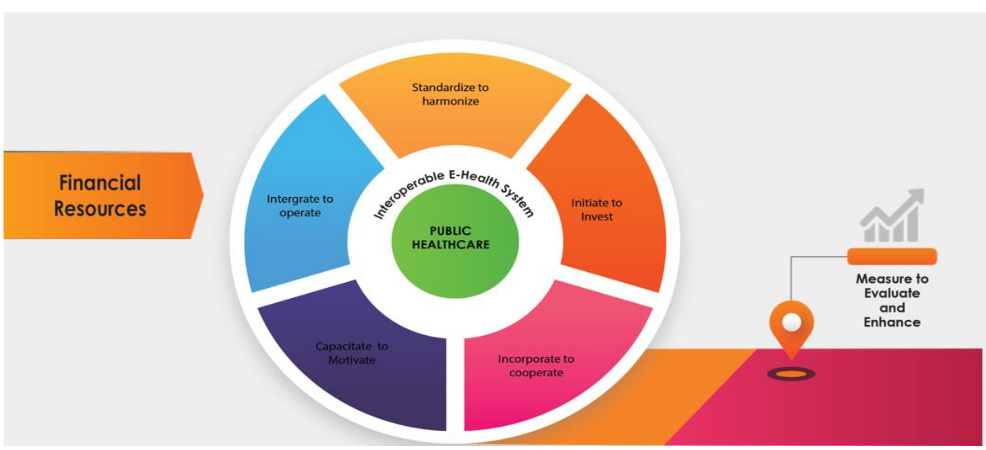


Fig. 4.12. The Wheel Interoperability Model.

The WIM model is anchored on six underpinning components built from the theories and models discussed from the existing literature combined with the research findings which together propose what is considered a holistic approach in implementing interoperable e-Health solutions. The components are; integrate to operate, incorporate to collaborate, capacitate to motivate, initiate to invest, standardize to harmonize all subjected to a continuous monitoring and enhancement. The WIM model presents the system requirements for present and future e-Health systems through continuous system improvement, the user information needs, the system implementers and the infrastructural investments. The model is adaptable and views e-Health interoperability from both the caregiver and the recipients' perspectives.

4.7.1 Components the Wheel Interoperability Model

4.7.1.1 Integrate to Operate

The disparate nature of e-Health systems was cited as one of the key factors deterring interoperability among facilities. The 'integrate to operate' component draws its origin from the infrastructure and investment aspect of the Theoretical framework and consists of three submodules. The component is backed up by the Technology Acceptance Model [38] which advocates for development systems that are easier to use based on its Perceived ease of use principle (PEOU). From the suggestions gathered from the field, a significant 31.5% of the suggestions pointed towards integrating the various standalone systems into one homogenous single entity and making the systems interoperable. This subcomponent is referred to as the collapse to communicate and it entails a systematic approach of gradually phasing out silo systems while reengineering them into one common system. In addition, all the service points not included in the universal model be incorporated in the system to make the system useful to all the relevant users in various service in the facility as well as easier to learn and use.

Backward compatibility is another subcomponent that is greatly considered in this undertaking to ensure that all legacy subsystems can seamlessly exchange data with the new systems so as to ensure seamless interhospital and intrahospital exchange of information. The last subcomponent is the safeguard to secure component. This component requires that mechanisms that protect the patients' privacy throughout the medication process be enforced and reinforced. The systems should be rigorously audited to ensure compliance with the existing e-Health security standards. The issue of security and compliance has also been dealt with by Ateniese et al. [92] who also proposed a protocol that offers pseudonymous privacy to patients while allowing only authenticated authorities to share patient information. In the conceptual model, the 'integrate to operate' was linked to infrastructure construct which involves both computer hardware, software, WAN and LAN infrastructure. All these disparate systems whether logical or physical must be amalgamates into one homogeneous entity to facilitate seamless exchange of information.

4.7.1.2 Incorporate to Cooperate

The incorporate to cooperate module consist of the 'communicate to change' submodule that maintains on effective vertical and horizontal communication to all stake holders before, during and after e-Health system development and deployment. The module originates from workforce and the leadership, governance and strategy facets of the conceptual framework with one submodule that is supported by four KPI principles. As already seen, stakeholders inclusivity will increase the passion of all the system actors leading to higher user acceptance levels and increased system approval ratings. Communication should also include anonymous positive and negative feedback without possibility of victimization. The model therefore advocates for four KPI strategic principles namely; Keep people informed, Keep people involved, Keep people interested and keep people inspired. The KPI approach is expected to greatly spur the pervasiveness and uptake of interoperable e-Health systems in Kenya since the players will be inspired to own the systems.

The 'incorporate to cooperate' also seeks to address negative perception of the users towards existing systems and create positivity for such similar future undertakings among users. According to the Organizational Information Processing Theory (OIPT) [37] creation of lateral and vertical relations is vital tool in increasing the organizational capacity to process information. This lateral relations are well built by the WIM's component of 'Communicate to change' where all stake holders are kept under the four KPI principles of this component throughout the e-Health system development lifecycle.

4.7.1.3 Capacitate to Motivate

One important consideration in implementing successful e-Health systems is the aspect of motivating the system users and thus ensure a positive attitude of the users towards the system. The Capacitate to Motivate component originates from workforce and the leadership, governance and strategy traits of the conceptual framework. Employees are likelier to resist a system if they do not have the proficient skills to effectively utilize the system in their places of work [22]. The time and effort needed to learn and utilize a new system is a significant barrier. This still falls under the PEOU and the PU of the TAM model. The research findings indicated low (54.4) levels of user training on e-Health which necessitated the modelling of the 'capacitate to motivate' component. Poorly trained staff are less productive and subsequently poorly motivated.

To enhance motivation scores, the model suggests user training, availability of system manuals, and availability of user support hotlines especially during system roll out and the presence of enough ICT personnel to offer support to the users. The facility shall conduct a user ICT proficiency baseline survey to determine the competency levels of its staff in usage of IT systems. Consequently, training needs assessment (TNA) shall be carried out do identify knowledge gaps and training requirements. This will form the basis for developing an appropriate capacity building plan relevant for the implementation of interoperable e-Health systems. Survey by PWC in 2013 [93] revealed that best industry practices such as proper sensitization led to a 3.9 percent increase in uptake of new ICT inventions in organizations. It is therefore based on PWC survey together with the present research findings that the 'capacitate to motivate' is choreographed to enhance the success of enterprise interoperability.

4.7.1.4 Initiate to Invest

The research found out that none of the systems in the hospitals is an initiative of the facility. In fact 60% of the systems are foreign solutions initiated by health partners and slightly by the government. Push systems have low propensity of uptake since they fail to address the immediate and long-term information needs of the client. In a bid to counter this expectation mismatch, the model includes an ‘initiate to invest’ approach in which the facility administration is required to take the front lead in the three subcomponents of this component. This include the Plan to budget in which the facilities should draw their plans to invest in ICT resources based on unbiased and objective needs assessment. This can be done through feasibility studies, risk assessment, cost benefit analysis. While the model acknowledges the input by external health partners in enhancing e-Health status, it is the prerogative of the facility managements to be at the center of coordination to ensure that the donated systems fit into the needs of the facility.

Upon availability of funds say from within the facility, government or donors, the relevant departments should purchase install and commission the infrastructure in compliance to the industry best practices, procurement laws and organizational policies. The quality of the equipment must be inspected to ensure compliance to performance and security standards as the two are crucial. This subcomponent is referred to as the ‘acquire to commission’. Lastly under the initiate to invest component, is the ‘Account for the coin’ module in which all the parties involved in the procurement process are required to provide accountability of all the expenses incurred during the procurement of health IT equipment.

The government through its auditing mechanisms should ensure accountability and prudent use of financial resources allocated to e-Health. The initiate to invest component is supported by the fourth strategic action of the (OIPT) which advocates for the creation of slack resources to enhance organization's information processing capabilities. This is further reinforced by the Task Technology Fit Theory [41] which keeps the technology characteristics a brace with the increasing information demands of the organization.

4.7.1.5 Standardize to Harmonize

Standards and legislative frameworks provide guideline of a harmoniously doing things. This models insists on adherence to administrative guidelines in designing, implementing and management of e-Health resources. These guidelines includes industry best practice, e-Health policies and standards; security policies and standards, and technology standards. Heterogeneity in data formats should also be strictly considered to ensure that data is stored in uniform formats across all the facilities for easier exchange. Standards should be also be continuously revised to keep up with the changing demands of the health and technology landscape as envisaged in the Task Technology Fit theory [41] and the facilitating conditions of the UTAUT theory which requited to provide an ample environment for the user and thus positively impact the system user's behavior. The Standardize to Harmonize component aligns with the infrastructure and investments variable of the theoretical framework that visualizes methodical and systematic investment in e- Health infrastructure.

4.7.1.6 Measure to Evaluate and Enhance

There is need to increasingly and continuously test and evaluate the progress made towards interoperability. For instance, when a new e-Health innovation or improvement becomes available, supporting hardware must be replaced to meet the basic requirements of the software. Similar observations are reiterated by the WHO [91] while emphasizing the requirement to test interoperability progress especially in low and middle income countries. This pillar is also backed up by the performance expectancy column of the UTAUT theory that proposes enhancement of ICT resources and investments to match up to the expectations of the user. ICT infrastructure monitoring and improvements is a continuous process and that is the reason it denoted by the 'calibrated road' in the model. This model proposes two submodules under the monitoring and evaluation namely; Record to Report and Improve to Sustain. Whether a small or large government or private hospital, the demand to accurately capture and visualize quantifiable results has never been greater. First a continuous information needs assessment for human resources, supporting infrastructure, policies formulation and compliance to standards and legal frameworks be measured and quantified.

The results should then be used to suggest improvements to keep all the systems in operational state in a 'improve to sustain' phase. Note that the 'monitor to improve' component is not part of the wheel but rather on the 'road' on which the wheel keeps rolling on insinuating that monitoring and evaluation are continuous processes that are conducted on each of the other five components on the wheel to sustain and enhance health service through e-Health innovations. In [Tab. 4.27] a detailed summary of the components of the wheel interoperability model is presented.

Table 4.27 Summary of The Components of The Wheel Interoperability Model

COMPONENT	SUB COMPONENTS/PRINCIPLES
Integrate to Operate	Collapse to Communicate Backward Compatibility Safeguard to Secure
Incorporate to Cooperate	Communicate to Change -Keep People Informed -Keep People Involved -Keep People Interested -Keep People Inspired
Standardize to Harmonize	-Industry best practice, -e-Health policies and standards; -Security policies and standards, -Technology standards
Capacitate to Motivate	-User training -Support documentation -ICT to Support
Initiate to Invest	Plan to Budget Acquire to Commission Account for the Coin
Measure to Evaluate and Enhance	Record to Report Improve to sustain

4.7.2 Intervening Variables

The model is designed to facilitate efficient and effective deployment and maintenance of interoperable e-Health systems. However, the model's results may be impeded by factors beyond the control of the involved stakeholders such as prevailing financial, political and environmental conditions under which a given facility exists. These factors are the intervening variables that either affect all the other variables positively or negatively. For instance, presence of adequate financial resources will rapidly spur the growth and pervasiveness of e-Health interoperability if all other factors are held in accordance to the proposed model. However, lack of it will slow down e-Health systems investments and hence low interoperability levels. For this reason, the intervening variables have been placed as a pushing force of the wheel on the model. It is also worth noting that the intervening factors affect each of the other pillars of the model either independently of as a group.

4.8 Model Performance Evaluation

It was imperative to assess the model performance in real life situation in order to determine whether or not it addressed the problem it was designed to. The testing procedure adopted the Zacharewicz et al. [94] approach of testing modern information systems and models. The evaluation process starts by first identifying the needs and then by being acquainted to the conceptual objectives of the model [94]. The objectives should be transposed enriched and stated into quantifiable indicators. Bourey et al as cited by [94] proposed an evaluation from strategic to operation levels with the transposed evaluation questions formulated from conceptual description to model implementation.

Based on the above outline, a questionnaire containing a list of the factors influencing interoperability and their current status at hospitals was generated and presented to 24 evaluators. Twenty healthcare workers previously drawn from the management, medical and technical levels were purposively selected from the 8 health facilities where the research was done and combined with 4 experts on information systems participated in the evaluation as recommended by [94]. The evaluators were required assess the models' components, subcomponents and pillars in relation to the existing e-Health interoperability status and the factors influencing interoperability and give their independent opinion on the ability of the model to influence interoperability given the prevailing status and factors.

In converting the objectives into quantifiable indicators, the study used the parameters where: 5 = Strongly Agree (SA), 4 = Agree (A), 3 = Not Sure (NS), 2 = Disagree (D) and 1 = Strongly Disagree (SD) against each of the factors in the list. Finally, the assessors were required to declare their verdict score by answering the question of as to whether or not they thought the proposed model would enhance e-Health interoperability amidst prevailing conditions and environment. The evaluation results are presented in [Tab. 4.28]

Table 4.28 Model Testing Results

The proposed WIM model can positively enhance Health interoperability	**Strongly agree (SA)**	**Agree (A)**	**Not Sure (NS)**	**Disagree (D)**	**Strongly Disagree (SD)**
Frequency	17	5	1	0	0
Percentage	71	17	4	0	0

According to [94], a satisfaction score is derived by taking the cumulative frequency of evaluators who rated the model by 4 or 5 and dividing it by the total number of evaluator and expressing the ratio as a percentage.

By using the evaluation formula:

Total number of evaluators who scored the systems (5) or (4): 22

Total number of evaluators: 24

Approval percentage =22/24*100%

<u>R=92%</u>

At an approval rating of 92%, is a strong indicator that the proposed WIM model is an effective approach to adopt in the implementation of e-Health systems that guarantee interoperability in public health facilities. According to [95] an approval score above 80% is indeed excellent.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter delineates the summary of findings, discussion, and conclusions deduced from the findings. It also presents the recommendations that might be used to help improve interoperability in e-Health systems.

5.2 Summary of Findings

This study sought to develop an interoperability model for e-Health systems in public hospitals in Kakamega County, Kenya. The objectives of the study were, to evaluate the status of E-Health systems in public health facilities in Kakamega County; to determine the factors influencing the interoperability of e-Health systems in public health facilities in Kakamega County and to develop an interoperability model for of E-Health systems in public health facilities in Kakamega County.

5.2.1 Status of e-Health Systems in Public Health Facilities in Kakamega County

The present findings shed light on the deplorable state of e-Health systems and the supporting infrastructure. The requisite infrastructure is insufficient and unreliable. Owing to the extreme financial constraints in most facilities, the facility administration choses to channel the meagre resources to the immediate direct essentials that address the patients' needs. The supply of primary infrastructure is therefore left in the hands of donors whose donations rarely satisfy the users' information demands. Although e-Health systems ought to be the epicenter of patient information exchange between facilities, physicians chose other alternatives including primordial means such as paper and pen. This is caused by the unreliability of the present systems, lack of knowledge on how to use them and the negative attitude these physicians have towards the systems. Although there are several e-Health interventions currently in use in most hospitals in the county, most of these initiatives are standalone silo systems that have failed to transit into practical solutions.

5.2.2 Factors Influencing the Interoperability of e-Health Systems

Legal and administrative frameworks provide operational rules and guidelines that offer the maximum degree of order in a given setting. This study unraveled a superficial lack of e-Health administration instruments occasioned by sheer lack of the top facility administration to disseminate, advocate for and implement the existing policies. In addition, there is little formulation or revision of legacy standards and into new holistic documents that can steer the growing e-Health innovations into practical solutions. While the National Government has put forth an elaborate chain of acts, policies and standard documents, a limited number of staff have access to these documents. The situation has led to e-Health solutions service providers opting for their own standards or those from developed countries that may be impractical in the Kenyan health environment. The composition of the facility top management team is devoid of the much needed knowledge and experience due to limited representation of IT personnel to spearhead the IT agenda. It is therefore, no wonder that there is little understanding of significance of standards in implementing e-Health system. The situation has bred an environment that allows unethical practices in e-Health systems implementation.

The findings revealed that although there is substantial evidence of security constraints in the existing e-Health systems, there are still some systems that have relaxed security measures. Such security laxities are the backdoors through which malicious intruders could use to gain access to highly sensitive data in the systems. Health systems are particularly susceptible to intrusion due to enormous volumes of data they carry in their databases, large number of actors, information asymmetry, system fragmentation and complexity; and the financial modules that control andmanage a vast number of financial resources. Due to the complexity of e-Health processes and its obvious needs for massive data, records and monitoring, a secure and powerful infrastructure is vital.

The study revealed alarming rates of user dissatisfaction particularly on the aspect of user interaction/user experience (UI/UX) while interacting with the system. In addition, the existing systems are disintegrated solutions that due to variety of different suppliers, different development platforms and the shortage of skilled personnel to integrate them, the systems continue to be of little help to the majority of the users. Furthermore, the flagrant lack of interoperability in legacy systems prevents the development of easily accessible, cost-effective and reliable electronic services

The research reported low levels of enthusiasm among the leadership, underrepresentation of ICT personnel in the senior management team and limited participation of the management in ICT projects both at policy level and implementation phases. Like many authors, this research argues that leadership is a key determinant of how ICT projects are implemented in a facility and the subsequent impact on the quality of service delivery. A positive attitude of facility management towards e-Health solutions will influence the rest of the organization to be actively involved in its implementation. To a large extend, facility leadership has been relying on the government and health partners to equip facilities with ICT infrastructure. In cases where the administration has set aside some financial resources for investment in e-Health projects, there is blurred accountability for the same.

An innovation is considered successful when it satisfies its objectives and even exceed the expectations of the stakeholders. Stakeholders are individuals with vested interests in the projects. In e-Health for instance, the public, the governments, donors and partners as well as system users are the stakeholders. The present scenario in the implementation of e-Health systems in Kakamega County does not paint an all-inclusive picture in systems implementation. For instance a section of the management and a part of the critical users were not included in the implementation of existing systems leave alone training. These low levels of inclusion lead to eventual low uptake, and negative attitude towards the systems as already evidenced in the results.

The results showed that access to computers, user involvement at requirements specification level and user training are significantly associated with the attitude of health professional towards emerging e-Health solutions. Other factors include user friendliness of the system, the tendency of the system to meet the users' information needs and the strength of the supporting infrastructure. Unfortunately all these factors had dismal scores as depicted in the results leading to the eventual negative attitudes of the employees towards the existing systems. In turn, even if the system was designed to be user friendly and is able to meet the user needs, the negative perception of the users towards it will sabotage the success of what would have been a perfect solution.

The research findings reveal scanty funding of e-Health systems by the national government towards e-Health intervention. Furthermore there is very little effort by the county government towards the same course, and even if they did, the purpose of the investment was to enhance revenue collection and not to enhance the quality of healthcare service through e-Health interventions. Notably, the only system that bears its origin from the county government is CHIS whose only function is revenue collection. Facilities are therefore left to carry the burden of e-Health initiatives on their own. Faced with a myriad of financial challenges, the facility management are then left with no choice but to wait for donors-supplied solutions are devoid of practical applicability. Some management seem to allocate resources to e-Health systems but very few can account for the eventuality of the allocated funds. This observation is evidenced by the decrepit state of e-Health infrastructure in facilities despite funds being set aside by the management to enhance the same. Apparently, there is financial mismanagement that if not addressed from higher levels, could continue to be the facility administrations' cash cows at the detriment of the patient.

The research found out that the manner in which e-Health projects are implemented in most health facilities is deficient of best practices. First, although there is some budgeting for e-Health's by the top management, the eventual outcome is not commensurate to the input. Secondly, both the County government and the partners in health do not engage all the stakeholders during the crucial stages of system development such as functional requirements specifications. Instead they come up with solutions tailored to meet their needs with little regard to the client or system users. A few of the system users are then brought on board slightly towards the end of the system at training level. In some situations, there are no manuals nor ICT officers to offer support to the users. Users interact with these systems oblivious of any other security features installed apart from mere passwords. There is no audit to interrogate the underlying security architecture behind these systems given that they contain sensitive patient information. The supporting infrastructure like computing and networking devices are not checked for standards and quality compliance since they are donations.

In basic terms, the term requisite infrastructure refers to organizational and physical needed for contemporary operations of an organization. Although all the public health facilities in the county are connected to the national electricity grid, the unreliability of this power has led to some facilities purchasing secondary power backups that barely meet the exigent power needs of these hospitals. Very few staff can access functional computers with only a handful of them having access to stable internet connectivity. Lack of adequate infrastructure to support quality, high-speed internet connections leads to poor uptake of e-Health solutions. While there seems to be tremendous milestones being covered by both governments to enhance the basic infrastructure, it is unfortunate that the state of the existing infrastructure cannot efficiently sustain a real-time inter- hospital exchange of information needed to offer efficient quality health services especially during transfer of services.

5.3 Conclusion

Based on the findings presented and discussed herein, this study concludes that the current state of e-Health systems has not kept up the pace with the strategy, funding mechanisms, implementation practices and the infrastructural investment capable of supporting reliable and interoperable e-Health solution. It is abundantly clear that there is still a long way to go in attaining full-fledged e-Health interoperability. All the e-Health interoperability influencing factors discussed and analyzed in this research scored below the required standards thus urging the need for an enhanced computing environment that effectively supports seamless exchange of health information among distributed health facilities.

Efforts to improve e-Health systems interoperability should therefore focus on relooking at all the factors discussed in this research and and taking into consideration knowledge-based interventions such as adoption of the proposed wheel interoperability model (WIM) to make e-Health interoperability a practical reality. This research disclaims that the factors investigated in this study may not be final determinants of e- Health interoperability and that more research can be done by future inquires to enable and sustain interoperability in governmental agencies and departments.

5.4 Recommendations

This study calls for the urgent need to develop and implement long term legislative frameworks, standards, policy guidelines and strategies that govern the adoption, implementation and utilization of e-Health systems in Kenya.

Both the national and county departments of health should through the relevant legislatures initiate legislations that enforce compliance to e-Health driven healthcare. The legislation should also provide for mandatory registration and audit of new e-Health systems to ensure that they conform to the standards.

One of the major focus points so far has been of the integration of the existing disparate silo e- Health systems into a unified entity that holistically addresses the information needs of a hospital.in view of this research, this is a long overdue undertaking that should be given a priority in the journey towards interoperability.

There is dire need to involve all stakeholders and shareholders in the future e-Health projects right from inception to retirement phase. The players include but not limited to both national and devolved governments, the public, department of health, ICT sectors, system developers, system users, and government partners in health as well as the system users.

Continuous acquisition and improvement of both active and passive e-Health infrastructure. This includes stabilizing the requisite infrastructure, supply and installation of stable internet to facilities, supply and delivery of computer hardware, procurement and installation of modern e- Health systems that support interoperability, and continuous updates of e-Health systems to ensure security of data.

There is need to develop policy guidelines on budgeting, funding of e-Health projects both at the county and national government levels. While the guidelines remain open public-private partnerships and donations from well-wishers, the clients should be given the required participation at all levels to ensure that the end product is not a white elephant.

The hospital leadership should consider e-Health a priority in hospitals and allocate budgets that would promote its implementation. The government must through its auditing mechanisms ensure proper accountability of the same.

Both governments should consider recruiting, training and retaining competent ICT personnel at all levels in the facility to reinforce the support of e-Health systems. The lack of a strategic plan for implementing e-Health applications and difficulty in recruiting experienced IT personnel to manage the e-Health technology is an evident barrier. Further, both governments, facility administration and the financing partners should develop strategies to ensure that the public is equipped with basic literacy on e-Health. Also, both the technical and system users should be adequately trained to efficiently discharge their duties using e-Health systems.

E-Health systems development process generates massive yet invaluable data. There is need for elaborate knowledge management systems to preserve, protect and utilize this data.

5.5 Recommendations for Further Study

Interoperability is a fundamental ingredient in enhancing the way modern day communication systems domicile, process and exchange data. This study only focused on interoperability in e- Health systems. Future studies should consider looking at interoperability in other relevant government and private agencies such as law enforcement agencies, judicial departments, transport industry and educational institutions.

Getting more insights and information pertinent to interoperability in specific relevant areas might help unravel more useful knowledge on interoperability that may not have been brought into the limelight by this study.

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APPENDICES

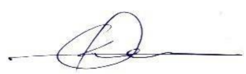
Appendix I: Questionnaire

Dear respondent,

I am a student conducting a study to on "*An Interoperability Model For e-Health Systems In Public Health Facilities In Kakamega County, Kenya***.**"

I therefore, kindly request your assistance in the same by responding to the questions in the questionnaire attached herein.

Thank you.



Eric Okeno Anyonje.

INSTRUCTIONS

1. For responses requiring filling in a checkbox, use the tick ☑ sign
2. There are no correct or wrong answers. Your honest opinion is the right answer
3. Your responses will be treated with the utmost confidence and will be used solely for this study.

Part A: DEMOGRAPHIC INFORMATION

Health Facility Name:___________________________________

MFL Code: ____

Sub County: ______________________________________

1. Gender Male [ ] Female [ ]

2. What is your age?

   i. 20-29 [ ]
   ii. 30-39 [ ]
   iii. 40-49 [ ]
   iv. 50 and above [ ]

3. What is your employment Cadre? Please tick where appropriate.

   i. Administration/Management e.g. In charge, Medsup [ ]
   ii. Medical Staff e.g. CO, Doctor, Nurse [ ]
   iii. Technical staff e.g. ICT, HRIO [ ]

Others (Specify)

PART B: E-HEALTH SYSTEMS' STATUS

E-Health is the use of ICT in delivery of health services and can include the use of health information management systems, email, text messaging, websites, and mobile-based applications

B 1.1 Legislation, Policy and Standards

Does your facility have any of the following?

i.	ICT Policy?	Yes [ ]	No [ ]	Don't know [ ]
ii.	ICT Standards and protocols	Yes [ ]	No [ ]	Don't know [ ]
iii.	ICT Guideline	Yes [ ]	No [ ]	Don't know [ ]

B 1.2 Infrastructure and Investments B 1.2.1 Power and Power backup

i. Power connectivity Yes [ ] No [ ]Power Generator Yes [ ] No [ ]

ii. Is power stable? Yes [ ] No [ ]

B 1.2.2 Communication Systems

Does your facility have any of the following?

i. Corporate e-mail system Yes [ ] No [ ] Don’t know [ ]

ii. Mobile app for work collaboration Yes [ ] No [ ] Don’t know [ ]

iii. Website Yes [ ]No [ ] Don’t know [ ]

iv. Office telephone Yes [ ]No [ ] Don’t know [ ]

B 1.2.3 Connectivity

i. Does your office have a functional computer? Yes [ ] No [ ]

ii. Does your organization have a Local Area Network/Wifi? Yes [ ] No [ ]

iii. Do you have a printers and other ICT appliances? Yes [ ] No [ ]

iv. Does your office have internet connection? Yes [ ] No [ ]

v. If Yes in (iv) above, is it the internet stable? Yes [ ] No [ ]

vi. Does the hospital use any Management Information System e.g. Kenya EMR?

Yes [ ] No [ ] Don’t know [ ]

If Yes proceed to

B 1.3, if No, skip to

B 1.4

B 1.3 e-Health

System

An e-Health system is considered successful if meets the needs and expectation of users. Using the following scale, rate the extent to which you agree to the statement above.

Key: **SA**- Strongly Agree, **A** – Agree, **NS** – Not Sure, **D**- Disagree, **SD**- Strongly Disagree.

STATEMENT		**RESPONSE**				
		SA	**A**	**NS**	**D**	**SD**
i.	The e-Health system at my facility meets my needs and expectations					
ii.	The e-Health system at my facility has all components of service points in the facility					
iii.	I frequently use the e-Health system because it is easier to use					
iv.	I can access patient data from another facility through the e-Health system at my facility.					

B.1.4 Leadership, Governance and Strategy

Key: **SA**- Strongly Agree, **A** – Agree, **NS** – Not Sure, **D**- Disagree, **SD**- Strongly Disagree.

STATEMENT		**RESPONSE**				
		SA	**A**	**NS**	**D**	**SD**
i.	There is ICT officer/Manager at my workplace					
ii.	The management at my facility is enthusiastic about the use of e-Health systems in place					
iii.	The management formulates policies and guidelines for ICT usage at my workplace.					
iv.	The management allocates enough funds for ICT/ e-Health improvement					

PART C: INTEROPERABILITY FACTORS

Key: **SA**- Strongly Agree, **A** – Agree, **NS** – Not Sure, **D**- Disagree, **SD**- Strongly Disagree.

STATEMENT		**RESPONSE**				
		SA	**A**	**NS**	**D**	**SD**
i.	There are several e-Health systems at my facility					
ii.	The e-Health systems at my facility were implemented using the industry best practices and standards					
iii.	The E-Health system at my facility has security credentials such as passwords					
iv.	The e-Health system at my workplace can be accessed outside the facility					
v.	Employees at my facility are enthusiastic about the use of e-Health systems in place					
vi.	I was involved in the implementation of the e-Health system at my facility					
vii.	I was trained on how to use the e- Health system at my facility					
viii.	There are user manuals on how to use the e-Health systems at my facility					
ix.	The system has security features such as passwords					

You have come to the end of this questionnaire.

Once again thank you so much your time.

Appendix II: Interview Schedule for Facility Management

e-Health interoperability factors

i. Does the facility have any e-Health system? Yes [ ] No[ ] Not sure [ ]
If No why?

ii. How did you acquire it?

iii. Were you as the management involved
in the acquisition process? Yes [ ]
No [ ] Not sure [ ]

iv. Does the system address your needs? Yes [ ]No [ ]Not sure [ ]

v. Does the system exchange information with other facilities? Yes [ ]
No [ ] Not sure [ ]

vi. If No Why?

vii. How can the system be enhanced to communicate with other systems?

Appendix III: List of Public Health Facilities in Kakamega County

Code	Name	Keph level	Facility type	Sub county	Ward
26087	Munzakula Dispensary	Level 2	Dispensary	Lurambi	Mahiakalo
25984	Silungai Dispensary	Level 2	Dispensary	Malava	Manda-shivanga
25833	Eshinamwenyuli Health Centre	Level 3	Basic Health Centre	Butere	Marama Central
25831	Bululwe Dispensary	Level 2	Dispensary	Butere	Marama West
25809	Nyortis Dispensary	Level 2	Dispensary	Likuyani	Nzoia
25720	Itete Dispensary	Level 2	Dispensary	Matungu	Koyonzo
25730	Mukavakava Dispensary	Level 2	Dispensary	Malava	Butali/Chegulo
25699	Lutasio Health Centre	Level 3	Basic Health Centre	Matungu	Khalaba
25698	Namasanda Health Centre	Level 2	Basic Health Centre	Matungu	Kholera
25697	Emaira Dispensary	Level 2	Dispensary	Butere	Marama West
25694	Shichinji Dispensary	Level 2	Dispensary	Ikolomani	Idakho North
25692	Munasio Dispensary	Level 2	Dispensary	Shinyalu	Isukha West
25508	Nyapeta Dispensary	Level 2	Dispensary	Mumias West	Etenje
25507	Musanda Dispensary	Level 2	Dispensary	Mumias West	Musanda
25498	Ichinga Dispensary	Level 2	Dispensary	Mumias West	Mumias North
25506	Emung'abo Dispensary	Level 2	Dispensary	Khwisero	Kisa Central
25166	Mumias Level IV Hospital	Level 4	Primary care hospitals	Mumias West	Mumias Central
24686	Eshibembe HealthCentre	Level 3	Basic Health Centre	Butere	Marama South
23136	Mayuge Dispensary	Level 2	Dispensary	Malava	West Kabras
22979	Shiyunzu Dispensary	Level 2	Dispensary	Lurambi	Butsotso Central
22973	Shirakalu Dispensary	Level 2	Dispensary	Lurambi	Butsotso East
22759	Shirumba Dispensary	Level 2	Dispensary	Ikolomani	Idakho Central
22670	Elwakana Dispensary	Level 2	Dispensary	Mumias East	Lusheya/Lubinu

22668	elwakana dispensary	Level 2	Dispensary	Mumias East	Lusheya/Lubinu
22551	Milimani Dispensary	Level 2	Dispensary	Ikolomani	Idakho South
22544	Buyemi Dispensary(Ikolomani)	Level 2	Dispensary	Ikolomani	Idakho Central
22441	Chirobani Dispensary	Level 2	Dispensary	Shinyalu	Isukha East
22191	Vuyika Dispensary	Level 2	Dispensary	Lugari	Chevaywa
21935	Sheywe Dispensary	Level 2	Dispensary	Malava	Shirungu-mugai
21891	Ingolomosio Dispensary	Level 2	Dispensary	Shinyalu	Isukha North
21788	Eshibinga Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa East
21777	Koromaiti Community Dispensary	Level 2	Dispensary	Lugari	Chekalini
21695	Imakuyi Dispensary	Level 2	Dispensary	Shinyalu	Murhanda
21100	Musango Dispensary	Level 2	Dispensary	Mumias East	Malaha/Isongo/Makunga
21089	Ivochio Dispensary	Level 2	Dispensary	Shinyalu	Murhanda
21088	Chepkombe Dispensary	Level 2	Dispensary	Shinyalu	Isukha Central
21043	Shivakala Dispensary	Level 2	Dispensary	Malava	South Kabras
21020	Kakamega County Beyond Zero Mobile Clinic	Level 2	Dispensary	Lurambi	Shirere
20921	Ikhanyi Dispensary	Level 2	Dispensary	Malava	South Kabras
20870	Mukhuyu Dispensary	Level 2	Dispensary	Malava	East Kabras
20843	Malichi Dispensary	Level 2	Dispensary	Malava	Chemuche
20837	Tombo Dispensary	Level 2	Dispensary	Malava	Manda-shivanga
20752	Buyangu Dispensary	Level 2	Dispensary	Shinyalu	Isukha North
20679	Eshikalame Dispensary	Level 2	Dispensary	Mumias West	Musanda
20678	Wang'nyang' Dispensary	Level 2	Dispensary	Mumias West	Etenje
20674	Kamuchisu Dispensary	Level 2	Dispensary	Malava	West Kabras
20673	Ekambuli Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa Central
20672	Mungungune Dispensary	Level 2	Dispensary	Butere	Marama West
20671	Lubanga Dispensary	Level 2	Dispensary	Matungu	Namamali

20516	Mundobelwa Health centre	Level 3	Basic Health Centre	Khwisero	Kisa North
20515	Ebuhala Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa West
20194	Shianda Dispensary	Level 2	Dispensary	Mumias East	East Wanga
20174	Vikunga Dispensary	Level 2	Dispensary	Shinyalu	Isukha West
20044	Kisembe Dispensary	Level 2	Dispensary	Navakholo	Bunyala West
20043	Butingo Dispensary	Level 2	Dispensary	Navakholo	Bunyala West
20041	Sisokhe Dispensary	Level 2	Dispensary	Navakholo	Bunyala West
20039	Emukaba Dispensary	Level 2	Dispensary	Lurambi	Butsotso East
19991	Isumba Dispensary	Level 2	Dispensary	Lurambi	Butsotso South
19900	Ikomero Dispensary	Level 2	Dispensary	Khwisero	Kisa West
19899	Eshiabwali Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa East
18941	Imanga Health Centre	Level 3	Basic Health Centre	Butere	Marama Central
18940	Eshibimbi Health Centre	Level 3	Basic Health Centre	Butere	Marama North
18939	Butere Iranda Health Centre	Level 3	Basic Health Centre	Butere	Marama West
18802	Kamashia	Level 2	Dispensary	Mumias East	Lusheya/Lubinu
18779	Mugai Dispensary	Level 2	Dispensary	Malava	Shirungu-mugai
18625	Mlimani Dispensary	Level 2	Dispensary	Likuyani	Sinoko
18624	Lumino Dispensary	Level 2	Dispensary	Likuyani	Likuyani
18361	Eluche	Level 2	Dispensary	Mumias East	East Wanga
18101	Kakamega Police Line VCT	Level 2	VCT	Lurambi	Shirere
17931	Mirere Health Centre	Level 3	Basic Health Centre	Matungu	Namamali
17929	Indangalasia Dispensary	Level 2	Dispensary	Matungu	Koyonzo
17681	Manda Dispensary	Level 2	Dispensary	Malava	Manda-shivanga
17597	Mugomari Dispensary	Level 2	Dispensary	Shinyalu	Isukha West
17596	Shinyalu Model Health Centre	Level 3	Basic Health Centre	Shinyalu	Isukha Central
17410	Mwikalikha Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa North

17409	Emalindi Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa East
17298	Lukohe Health Centre	Level 3	Basic Health Centre	Butere	Marama North
17297	Mabole Health Centre	Level 3	Basic Health Centre	Butere	Marenyo-shianda
17217	Eshikulu Dispensary	Level 2	Dispensary	Mumias West	Etenje
17178	Namirama Dispensary	Level 2	Dispensary	Navakholo	Bunyala East
17150	Malaha Dispensary	Level 2	Dispensary	Mumias East	Malaha/Isongo/Makunga
17133	Eshirembe Dispensary	Level 2	Dispensary	Lurambi	Butsotso South
17082	Nyaporo Dispensary	Level 2	Dispensary	Mumias East	Malaha/Isongo/Makunga
16865	Musembe Dispensary	Level 2	Dispensary	Shinyalu	Isukha Central
16867	Ematiha Dispensary	Level 2	Dispensary	Navakholo	Ingoste-matiha
16154	Turbo Forest Dispensary	Level 2	Dispensary	Likuyani	Likuyani
15883	Eshiongo Dispensary	Level 2	Dispensary	Navakholo	Shinoyi-shikomari-esumeiya
16033	Mulwanda Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa Central
16077	National Youth Service Dispensary (Turbo)	Level 2	Dispensary	Lugari	Lumakanda
16054	Muting'ong'o Dispensary	Level 2	Dispensary	Malava	Chemuche
16086	Nzoia Matete Dispensary	Level 2	Dispensary	Lugari	Lwandeti
16111	Shikunga Health Centre	Level 3	Basic Health Centre	Butere	Marenyo-shianda
15914	Kakamega Forest Dispensary	Level 2	Dispensary	Shinyalu	Isukha Central
16084	Nzoia (ACK) Dispensary	Level 2	Dispensary	Likuyani	Sinoko
16027	Muhaka Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa West
15801	Ap Line Dispensary	Level 2	Dispensary	Lurambi	Shirere
15803	Apostles Clinic	Level 2	Dispensary	Butere	Marama Central
15804	Approved Dispensary	Level 2	Dispensary	Lurambi	Mahiakalo
15810	Buchangu Dispensary	Level 2	Dispensary	Navakholo	Bunyala Central
15812	Budonga Dispensary	Level 2	Dispensary	Navakholo	Bunyala West

15817	Bukaya Health Centre	Level 3	Basic Health Centre	Mumias West	Etenje
15820	Bukura Health Centre	Level 3	Basic Health Centre	Lurambi	Butsotso South
15827	Bungasi Health Centre	Level 3	Basic Health Centre	Mumias West	Musanda
15833	Bushiri Health Centre	Level 3	Basic Health Centre	Navakholo	Ingoste-matiha
16108	Shihalia Dispensary	Level 2	Dispensary	Ikolomani	Idakho Central
15850	Chegulo Dispensary	Level 2	Dispensary	Malava	Butali/Chegulo
15836	Butere Sub County Hospital	Level 4	Primary care hospitals	Butere	Marama Central
15857	Chevoso Dispensary	Level 2	Dispensary	Malava	South Kabras
15872	Elukhambi Dispensary	Level 2	Dispensary	Lurambi	Butsotso South
15873	Elwasambi Dispensary	Level 2	Dispensary	Mumias East	Lusheya/Lubinu
15874	Elwesero Model Health Centre	Level 3	Basic Health Centre	Lurambi	Shirere
15882	Eshikhuyu Dispensary	Level 2	Dispensary	Lurambi	Butsotso Central
15892	GK Prisons Dispensary (Kakamega Central)	Level 2	Dispensary	Lurambi	Shirere
15900	Ileho Health Centre	Level 3	Basic Health Centre	Shinyalu	Isukha East
15901	Imbiakalo Dispensary	Level 2	Dispensary	Malava	West Kabras
15902	Ingotse Dispensary	Level 2	Dispensary	Navakholo	Ingoste-matiha
15899	Iguhu Sub County Hospital	Level 4	Primary care hospitals	Ikolomani	Idakho East
15916	Kambiri Health Centre	Level 3	Basic Health Centre	Shinyalu	Isukha North
15931	Khalaba Health Centre	Level 3	Basic Health Centre	Matungu	Khalaba
15934	Kharanda Health Centre	Level 3	Basic Health Centre	Navakholo	Bunyala West
15936	Khaunga Dispensary	Level 2	Dispensary	Mumias East	East Wanga
15945	Kilingili Health Centre	Level 3	Basic Health Centre	Ikolomani	Idakho South
15949	Kimangeti Dispensary	Level 2	Dispensary	Malava	Chemuche
15955	Kongoni Health Centre	Level 3	Basic Health Centre	Likuyani	Kongoni
15959	Kuvasali Health Centre	Level 3	Basic Health Centre	Malava	East Kabras

15940	Khwisero Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa North
15964	Lugari Forest Dispensary	Level 2	Dispensary	Lugari	Lugari
15961	Likuyani Sub-County Hospital	Level 4	Primary care hospitals	Likuyani	Likuyani
15970	Lumani Dispensary	Level 2	Dispensary	Lugari	Chevaywa
15972	Lung'anyiro Health Centre	Level 3	Basic Health Centre	Matungu	Namamali
15974	Lunyito Dispensary	Level 2	Dispensary	Lugari	Lugari
15977	Lusheya Health Centre	Level 3	Basic Health Centre	Mumias East	Lusheya/Lubinu
15981	Lwandeti Dispensary	Level 2	Dispensary	Lugari	Lwandeti
15983	Mabusi Health Centre	Level 3	Basic Health Centre	Likuyani	Nzoia
15987	Mahanga Dispensary (Lugari)	Level 2	Dispensary	Lugari	Lwandeti
15988	Majengo Dispensary	Level 2	Dispensary	Lugari	Lumakanda
15991	Makunga Rhdc	Level 3	Basic Health Centre	Mumias East	Malaha/Isongo/Makunga
15997	Malekha Dispensary	Level 2	Dispensary	Malava	Shirungu-mugai
16000	Mapengo Dispensary	Level 2	Dispensary	Lugari	Chekalini
16005	Matete Health Centre	Level 3	Basic Health Centre	Lugari	Chevaywa
16009	Maturu Dispensary	Level 2	Dispensary	Lugari	Lwandeti
16011	Mbagara Dispensary	Level 2	Dispensary	Lugari	Mautuma
16008	Matunda Sub-District Hospital	Level 4	Primary care hospitals	Likuyani	Nzoia
16010	Mautuma Sub County Hospital	Level 4	Primary care hospitals	Lugari	Mautuma
16031	Mukuyu Dispensary	Level 2	Dispensary	Lugari	Mautuma
16035	Mumias Model Health Centre	Level 3	Basic Health Centre	Mumias West	Mumias Central
16042	Mung'ung'u Dispensary	Level 2	Dispensary	Matungu	Koyonzo
16046	Munyuki Dispensary	Level 2	Dispensary	Lugari	Lumakanda
16041	Mung'ang'a Dispensary	Level 2	Dispensary	Mumias East	East Wanga
16051	Musembe Dispensary (Lugari)	Level 2	Dispensary	Lugari	Chekalini

16055	Emutsesa Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa Central
16037	Matungu Sub-County Hospital	Level 4	Primary care hospitals	Matungu	Mayoni
16059	Nabongo Dispensary	Level 2	Dispensary	Lurambi	Sheywe
16064	Namagara Dispensary	Level 2	Dispensary	Malava	Manda-shivanga
16065	Namasoli Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa Central
16070	Namulungu Dispensary	Level 2	Dispensary	Matungu	Kholera
16107	Shibwe Sub-County Hospital	Level 4	Primary care hospitals	Ikolomani	Idakho Central
16078	Navakholo Sub-District Hospital	Level 4	Primary care hospitals	Navakholo	Bunyala Central
16100	Sango Dispensary	Level 2	Dispensary	Likuyani	Sango
16102	Seregeya Dispensary	Level 2	Dispensary	Likuyani	Likuyani
16104	Shamakhubu Health Centre	Level 3	Basic Health Centre	Shinyalu	Murhanda
16105	Shamberere Health Centre	Level 3	Comprehensive health Centre	Malava	South Kabras
16101	Savane Dispensary	Level 2	Dispensary	Ikolomani	Idakho East
16109	Shihome Dispensary	Level 2	Dispensary	Malava	South Kabras
16110	Shikokho Dispensary	Level 2	Dispensary	Ikolomani	Idakho East
16112	Shikusa Health Centre	Level 3	Basic Health Centre	Shinyalu	Isukha North
16113	Shikusi Dispensary	Level 2	Dispensary	Shinyalu	Isukha South
16115	Eshinutsa Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa East
16116	Shiraha Health Centre	Level 3	Basic Health Centre	Butere	Marama North
16118	Shisaba Dispensary	Level 2	Dispensary	Butere	Marama West
16119	Shiseso Health Centre	Level 3	Basic Health Centre	Ikolomani	Idakho North
16121	Shitsitswi Health Centre	Level 3	Basic Health Centre	Butere	Marama Central
16122	Shivanga Health Centre	Level 3	Basic Health Centre	Malava	Manda-shivanga
16123	Shibanze Dispensary	Level 2	Dispensary	Matungu	Kholera
16127	Sinoko Dispensary (Likuyani)	Level 2	Dispensary	Likuyani	Sinoko
16134	Soy Sambu Dispensary	Level 2	Dispensary	Likuyani	Sango

16144	Chief Milimu Dispensary	Level 2	Dispensary	Shinyalu	Isukha South
16147	Sivilie Health Centre	Level 3	Comprehensive health Centre	Navakholo	Bunyala East
16481	Imulama Dispensary	Level 2	Dispensary	Ikolomani	Idakho North
16483	Shikumu Dispensary	Level 2	Dispensary	Ikolomani	Idakho Central
16484	Imalaba Dispensary	Level 2	Dispensary	Ikolomani	Idakho South
16714	Elwangale Health Centre	Level 3	Basic Health Centre	Khwisero	Kisa East
16717	Ikuywa Dispensary	Level 2	Dispensary	Shinyalu	Isukha East
15915	Kakamega County General Hospital	Level 5	Secondary care hospitals	Lurambi	Shirere
	Lumakanda Sub County Hospital	Level 4	Primary care hospitals	Lugari	Lumakanda
16762	Emusanda Health Centre	Level 3	HEALTH CENTRE	Lurambi	Butsotso Central
15851	Chekalini Health Centre	Level 3	HEALTH CENTRE	Lugari	Chekalini
16006	Matioli Dispensary	Level 2	Dispensary	Lurambi	Butsotso South
15859	Chombeli Health Centre	Level 3	Basic Health Centre	Malava	Shirungu-mugai
15996	Malava Sub County Hospital	Level 4	Primary care hospitals	Malava	Shirungu-mugai
16114	Eshimukoko Health Centre	Level 3	Basic Health Centre	Butere	Marama North
15999	Manyala Sub-County Hospital	Level 4	Primary care hospitals	Butere	Marama South

Appendix IV: Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 547404

Date of Issue: 04/July/2022

RESEARCH LICENSE

This is to Certify that Mr.. Eric Okeno Anyonje of Kaimosi Friends University College, has been licensed to conduct research in Kakamega on the topic: AN INTEROPERABILITY MODEL FOR E-HEALTH SYSTEMS IN PUBLIC HEALTH FACILITIES IN KAKAMEGA COUNTY, KENYA for the period ending : 04/July/2023.

License No: NACOSTI/P/22/18653

547404

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

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Appendix V: Sample Filled Questionnaire

Questionnaire

Dear respondent,

I am a student conducting a study on *AN INTEROPERABILITY MODEL FOR E-HEALTH SYSTEMS IN PUBLIC HEALTH FACILITIES IN KAKAMEGA COUNTY, KENYA*. I therefore, kindly request your assistance in the same by responding to the questions in this questionnaire.

Thank you.

Eric Okeno Anyonje.

LUMAKANDA COUNTY HOSPITAL
08 AUG 2022
REVENUE
P.O BOX 240 KIPKARREN RIVER

INSTRUCTIONS

1. For responses requiring filling in a checkbox, use the tick ☑ sign
2. There are no correct or wrong answers. Your honest opinion is the right answer
3. Your responses will be treated with the utmost confidence and will be used solely for this study.

Part A: DEMOGRAPHIC INFORMATION

Health Facility Name: LUMAKANDA COUNTY HOSPITAL.

1. Gender Male [✓] Female [ ]

2. What is your age?

- i. 20-29 [ ]
- ii. 30-39 [ ]
- iii. 40-49 [✓]
- iv. 50 and above [ ]

3. What is your employment Cadre? Please select where appropriate.

- i. Administration/Management e.g. In charge, MedSup [ ]
- ii. Medical Staff e.g. CO, Doctor, Nurse, PHD [✓]
- iii. Technical staff e.g. ICT, HRIO [ ]

Others ………………………………………………………… (Specify)

PART B: E-HEALTH SYSTEMS' STATUS

E-health is the use of ICT in delivery of health services.

B 1.1 Policy and Standards

Does your facility have any of the following?

i. ICT Policy? Yes [ ] No [✓] Don't know [ ]
ii. ICT Standards? Yes [ ] No [✓] Don't know [ ]
iii. ICT Guideline? Yes [ ] No [✓] Don't know [ ]

B 1.2 Infrastructure and Investments

B 1.2.1 Power and Power Backup

Does your facility have:

i. Electricity power supply Yes [✓] No [ ] Don't know [ ]
ii. Backup power generator Yes [✓] No [ ] Don't know [ ]
If "Yes" in any of the above:
iii. Is Electricity supply stable? Yes [ ] No [✓] Don't know [ ]

B 1.2.2 Communication and Communication Systems

a) Does your facility have any of the following?

i. Corporate e-mail system Yes [ ] No [ ] Don't know [ ]
ii. Mobile App for work collaboration Yes [✓] No [ ] Don't know [ ]
iii. Website Yes [ ] No [✓] Don't know [ ]
iv. Office telephone Yes [ ] No [✓] Don't know [ ]

b) How do you communicate with other facilities e.g. during referral or emergency? Tick as appropriate

i. Through our health information system [ ]
ii. Mobile app e.g. WhatsApp [✓]
iii. Personal phone [✓]
iv. Office Telephone [ ]
v. Personal Mail [✓]
vi. Corporate mail [ ]
vii. Filling forms (Paper and Pen) [✓]
viii. We don't communicate at all [ ]
ix. Other.. (Specify)

B 1.2.3 Data Connectivity

i. My office has a functional computer Yes [✓] No [ ]
ii. My facility has a Local Area Network/Wi-Fi Yes [ ] No [✓]
iii. We have printers and other ICT equipment at work place Yes [✓] No [ ]
iv. My office has internet connectivity Yes [ ] No [✓]
v. If Yes in (iv) above, is it the internet stable? Yes [ ] No [ ]

B 1.3 E-Health Systems

a) Does your hospital use any E-health System e.g. KenyaEMR?

Yes [✓] No [ ] Don't know [ ] (Partially)

b) ii) Please tick ☑ on the system(s) currently in use in your facility

CHIS	[✓]
Kenya EMR	[ ]
DHIS2	[✓]
Point of Care	[ ]
UniMed	[ ]
KHMIS	[ ]
WebADT	[ ]
Don't know	[ ]
We don't have an E-health system	[✓]

Others other phone application

B 1.4 E-Health Systems

An E-health system is considered successful if it meets the needs and expectation of users. Using the following scale, rate the extent to which you agree to the statements below.

Key: **SA**- Strongly Agree, **A** – Agree, **NS** – Not Sure, **D**- Disagree, **SD**- Strongly Disagree.

	STATEMENT	RESPONSE				
		SA	A	NS	D	SD
i.	The E-health system at my facility meets my needs and expectations				✓	
ii.	The E-health system at my facility has all components of service points in the facility				✓	
iii.	I frequently use the E-health system because it is easier to use				✓	
iv.	I can access patient data from another facility through the E-health system at my facility.				✓	
v.	We don't have an E-health system				✓	

B.1.5 INTEROPERABILITY FACTORS

Interoperability is the ability of eHealth systems in a health facility to exchange information with counterpart systems in another facility. Using the following scale, rate the extent to which you agree to the statements below:

Key: **SA**- Strongly Agree, **A** – Agree, **NS** – Not Sure, **D**- Disagree, **SD**- Strongly Disagree.

	STATEMENT	RESPONSE				
		SA	A	NS	D	SD
i.	There are several E-health systems at my facility				✓	

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ii.	The E-health systems at my facility were implemented using the industry best practices and standards				✓	
iii.	The E-health system at my facility has security credentials such as passwords				✓	
iv.	The E-health system at my workplace can be accessed outside the facility				✓	
v.	Employees at my facility are enthusiastic about the use of E-health systems in place				✓	
vi.	I was involved in the implementation of the E-health system at my facility				✓	
vii.	I was trained on how to use the E-health system at my facility				✓	
viii.	There are user manuals on how to use the E-health systems at my facility				✓	
ix.	There are ICT support officers/champions who help us to interact with the E-health system		✓			
x.	The E-health system has security features such as passwords		✓			
xi.	We don't have an E-health system				✓	

PART C: Leadership, Governance and Strategy

i) Using the following scale, rate the extent to which you agree to the statements below:

Key: **SA**- Strongly Agree, **A** – Agree, **NS** – Not Sure, **D**- Disagree, **SD**- Strongly Disagree.

STATEMENT		RESPONSE				
		SA	A	NS	D	SD
i.	There is ICT officer/Manager at my workplace				✓	
ii.	The management at my facility is enthusiastic about the use of ICT and E-health		✓			
iii.	The management formulates policies and guidelines for ICT usage at my workplace.				✓	
iv.	The management allocates enough funds for ICT/ e-health improvement			✓		
v.	The management ensures proper utilization of resources allocated to ICT			✓		

ii) Suggest how e-health systems can be improved so as to exchange information with other systems in different hospitals

Linkage to other health facilities for easy tracking patient information.

You have come to the end of this questionnaire. Again thank you so much your time and support.