INTEROPERABILITY MODEL FOR ELECTRONIC MEDICAL RECORDS END TO END IMPLEMENTATION

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A Thesis Submitted in Partial fulfillment of the Requirements for the Award of Doctor of Philosophy in Information Technology of Masinde Muliro University of Science and Technology

JULY 2025

DECLARATION

This thesis is my original work and has not been presented for an award of a diploma or conferment of degree in any other university or institution.

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance of Masinde Muliro University of Science and Technology, a thesis entitled **"Interoperability Model for Electronic Medical Records End to End Implementation"**

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DEDICATION

This thesis is dedicated to John, Robi, Raziela and Rayshan

ACKNOWLEDGEMENTS

Finishing this PhD thesis has been a challenging and rewarding journey, and so I am deeply grateful to the almighty God for his blessings and providence for me, may his name be praised. Secondly, I would like to express my sincere gratitude to my supervisors, Dr. Jasper M. Ondulo and Dr. Odoyo Collins Otieno for their invaluable guidance, mentorship, and unwavering support throughout my research. Their expertise, patience, and encouragement have been instrumental in shaping my academic journey, and I am truly fortunate to have had the opportunity to work under their supervision. Their constructive feedback and insightful discussions have greatly enriched my research and helped me grow as a researcher. Am also grateful to my lecturer's in School of Computing Dr. Odawa, Dr. Omieno and Dr. Otanga for your guidance, support and patience with me.

I would also like to extend my heartfelt thanks to my friends and colleagues who have been a constant source of support and motivation. A special thanks to Omambia Andrew, Dickson Osore, Adong Grace, Harrison Ochuodho, Dickson Monda, Dr. Esther Kemigisha, Dr. Derrick Deya, and Dr. Amakobe Moody for their advice, encouragement, and for always being there to lend a listening ear. Your support and friendship has been invaluable in keeping me motivated and positive throughout this journey.

I am immensely grateful to my employers at Adventist University of Africa for the motivation and support and former colleagues at University of Eastern Africa, Baraton for creating a collaborative and inspiring environment. I am thankful for the stimulating discussions, shared knowledge, and the many moments of laughter that made the workplace feel like a second home.

Last but not least, I would like to express my deepest appreciation to my family for their unwavering love and support. To my parents, Grace and James Kakwenza and Parents in law Rebecca and Zachariah Marwa, thank you for your constant encouragement, understanding, and belief in me. Your prayers, sacrifices, and support have been the foundation of my success, and I am eternally grateful for your love. To my siblings, Emily, Emmanuel, Edmund, Eunice, and Elly thank you for your financial, moral and spiritual support and for always being there to lift my spirits.

To my dear husband John Chacha and my children Robi, Raziela and Rayshan, you have been my pillars of strength throughout this incredible journey. Without your support and encouragement, this accomplishment would not have been possible may God bless you abundantly.

ABSTRACT

The adoption and utilization of Electronic Health Records can address numerous patient care difficulties and facilitate a paperless environment in hospitals; nevertheless, their full potential remains underexploited due to significant interoperability challenges. Patients typically pursue healthcare services from diverse providers operating inside either affiliated or independent organizations. In the absence of a consistent linkage across various healthcare providers, patient medical information becomes fragmented, incomplete, and obsolete. Numerous health institutions in Kenya have adopted EHRs/EMRs; nonetheless, both the nation and the facilities that have automated their records suffer from inadequate data convergence due to interoperability challenges among the various EHR systems. The interoperability of EHRs, a complicated and challenging undertaking, is predominantly lacking in poor countries. The identified target audience encounters these problems, along with architectural and technological obstacles, in facilitating seamless communication across EHRs. The study's main objective was achieved through four specific objectives as follows; to establish EMR services available, their utilization, level of integration in the health sector; to determine the various EMR systems state of interoperability; to determine the strategies that have been used by successful implementers to address interoperability challenges and to develop an interoperability model for EMR implementation. The researcher scrutinized the following frameworks and theories to identify their weaknesses, and thereby guide the development of the interoperability model for EMR implementation: the European Interoperability Framework (EIF), Social technical systems theory, Luhmann's Social Systems Theory and Lopez and Blobel's Interoperability Framework. To underpin the study, the researcher adopted a pragmatic philosophical standing point to guide the researcher's worldview of the research. Further a deductive and inductive approaches were also adopted for the purpose of triangulation of data. The study population included 229 healthcare workers from which a sample of 184 respondents were obtained using stratified and simple random sampling. Key informant interviews and structured questionnaires were used to gather data. Descriptive and inferential statistics were used to analyze and evaluate the quantitative data, while thematic analysis was used for analyzing the qualitative data. The findings of the study indicate technical interoperability ($p=0.000<0.05$), social interoperability ($p=0.006<0.05$), organizational interoperability ($p=0.000<0.05$) and semantic interoperability ($p=0.000<0.05$) and legal interoperability ($p=0.002<0.05$) were significant predictors. From the results of the study, a model of Electronic Medical Records End to End Implementation was formulated. The study concluded that technical, social, organizational, semantic and legal, factors must be addressed to achieve interoperability of EMR end to end implementation. From the findings it is recommended that challenges such as privacy concerns, implementation costs issues must also be addressed to fully harness the benefits of EMR interoperability. The facilities to invest on security measures, capacity building, compliance to government regulation, technology as strategies to address interoperability challenges. The model developed is a basis upon which future implementation of EMR interoperability end to end implementation can be based.

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ABBREVIATIONS AND ACRONYMNS

APIs -Application Programming Interfaces

CDA-Clinical Document Architecture.

CRS-Civil Registration System

CFA- Confirmatory Factor Analysis

DICOM -Digital Imaging and Communications in Medicine

DSR -Design Science Research

EFA- Exploratory Factor Analysis

EHR -Electronic Health Record

EIF-The European Interoperability Framework

EMR -Electronic Medical Record

FHIR-Fast Healthcare Interoperability Resources

GDPR -General Data Protection Regulation

HHIS -Harmonized Health Information Systems

HIE-Health Information Exchange

HIPAA -Health Insurance Portability and Accountability Act

HIS- Health Information System

HIT-Health Information Technology PHI -Patient Health Information

HMIS- Health Management Information System

ICD-10 -International Classification of Diseases

IDSR -Integrated Disease Surveillance

IFMIS-Integrated Financial Management Information System

KeEMRs- Kenya Electronic Medical Records

KHIS-Kenya Health Information System

LOINC- Logical Observation Identifiers Names Code

MOH-Ministry of Health

NDoH -National Department of Health

NHNSF- National Health Normative Standards Framework

OpenHIE -Open Health Information Exchange

RIS-Response Information System

SCR-Summary Care Record

SNOMED- Systematized Medical Nomenclature for Medicine–Clinical Terminology

TAM-Technology Acceptance Model

OPERATIONAL DEFINITION OF TERMS

EHR (Electronic Health Record) is a computerized record of health information. It contains all the data you would discover in a paper. Furthermore, an EHR may incorporate past therapeutic history, imperative signs medicines, immunization dates, lab information and imaging reports. It can contain other important information such as insurance information statistic information and information imported from individual wellness gadgets. EHRs can be streamlined and shared with other providers and labs, etc. It moreover permits a patient's therapeutic data to move with them.

EMR (Electronic Medical Record) can be defined as an electronic form of a chart with patient data put away in a computer. It entails everything found in a paper chart like the medical history of a patient, medications, dates of immunization, hypersensitivities and diagnoses. An EMR is primarily utilized by providers for diagnosis and treatment.

Interoperability - Interoperability denotes the ability of many applications or information systems to exchange information. In the healthcare sector, interoperability refers to the exchange of health or hospital information among multiple healthcare facilities.

CHAPTER ONE

INTRODUCTION

1.0.1 Overview

The chapter presents foundational issues and discusses them topically. This is presented as sections and sub-sections outlined as follows. 1.1 presents the background of the study, challenges in Health are highlighted, the need for Electronic Health Records and what EHRs entails. Furthermore, benefits of EHRs are covered while also noting the challenges that come with the implementation process. Section 1.2 introduces the statement of problem; section 1.3 contains the research objectives exploring the main and specific objectives and research questions. Section 4 covers research questions, Section 1.5 covers justification of the study, section 1.6 covers the significance of the study, 1.7 covers assumptions, 1.8 covers the scope of the study while 1.9 discusses the limitations.

1.1 Background of the Study

1.1.1 Challenges in Health Care

Reinhardt & Balikuddembe (2019) hold the opinion that some of the challenges to service delivery of healthcare in less developed countries include: shortage of trained medical professionals, poorly constructed and inadequate healthcare facilities, unpreparedness in dealing with disasters, inadequate medical resources and supplies, poor coordination and lack of plans for resource distribution. Technology, medical personnel and health infrastructure alone are not enough, there is a need for proper planning and development of policies to deal with different conditions.

Maphumulo and Bhengu (2019) list seven main challenges to the provisions of quality healthcare in Africa, these include: shortage of healthcare personnel leading to long waiting time, poor measures for controlling infections and poor hygiene, increasing litigation cases as a result of errors that could be avoided, shortage of needed equipment plus related resources and poor keeping of records. Furthermore, poor record keeping leads to delays with missing or lost records sometimes making it difficult to follow the patient's history, a problem attributed to wrong diagnosis and even deaths in many African countries.

According to Olirebe et al, (2019) the leading challenges facing healthcare in Africa include inadequate medical professionals and other supporting staff, limited resources due to constrained budgets and poor management and leadership in the sector and healthcare facilities. The management and leadership challenge were attributed to among other reasons poor oversight of healthcare systems, inefficiencies and poor resource management.

Provision of healthcare in Kenya faces a number of challenges in the health sector. Some of those challenges include but not limited to unaffordable services to the larger population, poor access to healthcare, shortage of health workers and inadequate resources (Kariuki and Okanda, 2017). The study indicates that technology can be a tool to solve such challenges.

In a study by Kipruto and Leting (2017), it was found that healthcare facilities in Kenya were not allocated sufficient funds as per the prepared budgets, the study highlighted that the resources received from county governments were inadequate for their effective operations, with late supplies being noted as a major reason hindering timely diagnosis and treatment of patients. Further the study pointed out the challenge of drug procurement by county governments coming as a result of inflated costs and bureaucratic processes, the study also cited poor terms of employment being the cause of shortage of health care professionals.

Kimathi (2017) identifies another challenge of people's location relative to healthcare facilities which then limits timely access to healthcare services. The author notes that this affects 37% of

Kenyans. Additionally, the author cites the disparity of health service delivery between rural and urban occasioned by the disproportionate distribution of healthcare professionals within these locations. The author equally notes that devolution of healthcare from the national government to the county government has witnessed management problems, poor coordination and a number of inconsistencies. (Kimathi, 2017)

1.1.2 Need for EHRs/EMRs

The need for EHRs and EMRs is proportionate to the overarching need to improve diagnostics as well as patient outcomes. When clinicians and care teams have access to accurate and complete information, patients have been shown to receive optimum medical care. EHRs have been able to enhance the capacity to diagnose accurately and minimize, even avert, medical errors, thereby enhancing patient outcomes. Surveys on EHRs show that a significant number of providers consider the tools critical as they make records readily available at all points of care (Fennelly et al., 2020). Further, they have been noted to offer clinical benefits for practice and ensure the delivery of better care.

EMRs make patient visits swift and efficient, and at this age, their need is almost inevitable. Theoretically, the usage of the tools ought to make patients visits better and shorter through better organization of patient records and requests. This also means that patients can be seen sequentially by different clinicians. The information that each of these clinicians' update is immediately made available (Fennelly et al., 2020). Clinicians are then able to gain immediate access to the patient information, as well as the capacity to make and store orders for tests, prescriptions, as well as other services (Alpert, 2016). This saves a lot of time and space that would have otherwise been used by the paper records.

Electronic Health Records and Electronic Medical Records provide an invaluable resource in improving health evaluation and surveillance. Tracking patients and updating their charts has been easier with the digitization of the patient journey. Research shows that most clinicians employ the information available in examining the general condition of their patients and to inform clinical decisions. The tools are also greatly valuable in sharing communication across care teams and clinicians (Dornan et al., 2019). For these reasons, EMRs and EHRs have found widespread adoption both in developed countries as well as in low- and middle-income countries with low resources.

1.1.3 What EHR/EMR entails

Electronic Health Records, abbreviated as EHRs, and Electronic Medical Records, abbreviated as EMRs, are both digital versions of patients' health information. (Heart, T., Ben-Assuli, O., & Shabtai, I. 2017). EHRs refer to electronic version of the health records of patients that were initially created, stored, and used as paper charts. It is a more in-depth snapshot of the medical history of a patient (USF Health, 2017). EHRs are developed for collaboration among health providers, and authorized health providers may access the records instantly even if the records were initially created in a different healthcare institution. Digital representations of the paper charts typically found in a physician's office are called Electronic Medical Records, or EMRs. (Belletti, D., Zacker, C., & Mullins, C. D. 2010). They include patient medical and treatment histories from a particular practice or healthcare facility. Electronic Health Records differ from Electronic Medical Records based on what they entail (Ehrenstein et al., 2019).

Hardware requirements for running the EHR applications are largely dependent on the particular software vendor (Evans, 2016). Some strategies are to place laptops or desktops in every patient room (Underwood, 2011). This strategy concerns some physicians as they feel it interrupts the physician-patient interaction, and the patient may feel the doctor is more interested in the computer than listening to their concerns (Nagasubramanian et al., 2020). Other popular hardware devices include netbooks, convertible laptops, and mobile devices such as iPads or other tablet computers (Underwood, 2011).

A approach employed by certain healthcare providers for hardware requirements is referred to as COWs, or computers on wheels. These COWs can be relocated from one site to another. A prevalent option for physicians is accessing the EHR via their smartphones (Razzaque, 2020). Popular cellphones that are compatible with EHRs include the iPhone and Blackberry handsets.

Clinical documentation constitutes a substantial segment of an Electronic Health Record (EHR) due to the extensive patient data recorded by physicians, nurses, and other healthcare professionals. Clinical reports, assessments, and Medication Administration Records (MAR) exemplify the data contained within these clinical notes (Electronic Health Records Overview, 2006). Additional elements of clinical documentation encompass vital signs, discharge summaries, transcription records, and utilization management (Electronic Health Records Overview, 2006).

Patient confidentiality is paramount in the healthcare sector. Healthcare providers face stringent federal fines for failing to uphold patient confidentiality and secure medical records, as required by the Health Insurance Portability and Accountability Act (HIPAA). Comprehensive security measures must be incorporated into EHRs to avert unauthorized access to a patient's medical record. EHRs employ passwords, biometrics, and network firewall protection to thwart unauthorized access to patient records. The debate regarding the security of paper vs electronic health records is a commonly addressed topic (Cowie et al., 2017).

Electronic health records enable auditors to determine if an unauthorized employee accessed the chart, as most EHRs timestamp the record upon each access by an employee. Paper records cannot be audited in this manner.

Electronic Medical Records enhance communication and interactions between family physicians and their interdisciplinary team members (El-Kareh et al 2009). Consultation letter templates, medical note summaries, and chart summaries provide consultants and team members with structured, comprehensible information. Prescription errors have diminished due to the systematic and unequivocal formulation of orders (Canada Health Infoway; 2013). Electronic Medical Records enable the delegation of requests and tasks to diverse team members. Booking schedules are readily accessible to clinical staff, doctors, and, in certain instances, patients who may make appointments remotely. Electronic medical records may enhance contact with patients via patient portals and personal health records, thereby more effectively involving patients in the management of their own care. In this study, the phrases "Electronic Medical Records" and "Electronic Health Records" will be utilized interchangeably.

1.1.4 Key challenges in healthcare addressed by EHRs/EMRs

There are various challenges addressed by both EMRs and EHRs. EMRs allow better tracking of patient's records over time, timely reminder regarding checkups, and improved care of the patient. EHRs on the other hand ensure streamlined collaboration of real-time, updated patient information, access to various tools that clinicians can use to make decisions, and a complete medical history of the patient, diagnostics, and results (Menachemi, N., & Collum, T. H. (2011). The two systems offer great benefits to both healthcare providers and patients. Both EHRs and

EMRs provide accurate and fast access to updated patient information that reduces the changes for medical errors during care. Both systems make it possible to have clearer and more complete patient charts. Sharing of information reduces chances of duplicating tests and hence saves the patient and provider's money, trouble, and time. EMRs and EHRs make access to information readily available hence making prescription of medication reliable and safer. Electronic records encourage patients to participate in the entire process and encourage them to make more frequent application of preventative care.

Ayaad, et al (2019) note that although paper charts are simple, easily accepted, and only needs a low cost of implementation, healthcare has been enhanced through the use of Electronic Health and Medical Records. In addition, paper charts hinder the healthcare environment owing to their inaccessibility, inability to be accessed remotely, illegibility, and high cost of storing huge files. Through the adoption of EHRs and EMRs, providers have made patient files more accessible and organized. Electronic records are also supported by implementation tools, such as ordering and prescribing tools, hence leading to safe and more efficient care.

EMRs and EHRs have improved relationships and communication between clinicians and their interdisciplinary teams. Medical notes, chart summaries, and consultation letter templates offer the clinicians, consultants, and different team members with structured and legible information. The prescriptions done by the clinicians are clear and in a structured format, which minimizes medication errors during the process of prescribing. Electronic records also facilitate requests and assignment of tasks to various members of the team; it is easier to book schedules and the schedules are accessible by clinicians, clinical staff, and patients are able to book for appointments remotely (Evans, 2016). Electronic Medical Records are also able to improve communication between clinicians and patients through patient health records and patient portals that engage patients in a more effective manner (Manca, 2015).

1.1.5 Key challenges in implementing EHRs/EMRs

In order to reap the benefits of EMRs and EHRs, physicians need to support the implementation process actively. There are several implementation barriers including time, computers availability, fear of scalability, customizability of the EHRs and EMRs, cost, and reliability among others. Training is also a major issue during the process of implementing EHRs and EMRs (Schopf et al., 2019).

Most of the physicians worry about the time limitations of machine-based health systems. They fear that as time passes by, the systems will become obsolete. Researchers have also documented issues regarding the customizability of the health systems. Most surveys show that one of the reasons health institutions do not implement is because they find that the systems will not meet their special needs. However, others use this as an excuse (Ajami & Bagheri-Tadi, 2013; Schopf et al., 2019).

The dependability and reliability of machine systems that comprise the EHRs and EMRs has been a key subject of discussion in implementations. High reliability is critical for systems that handle patient information, and most physicians are concerned with the transient loss of the access to patient related information in the event of crashes, power fails, and virus attacks. Furthermore, some fear that information systems might lead to the loss of records owing to technical hitches. These fears are magnified by the potential financial loss and the increasing cost of information systems (Schopf et al., 2019).

There are huge costs related to EMR hardware and software. This is because both cannot be used "straight from the box." There is need to configure, integrate with other complementing devices, and convert data into digital formats. In essence, EHRs and EMRs are not compatible with the existing patient systems and most clinicians are reluctant to make changes and get rid of systems that are already functional (Ajami & Bagheri-Tadi, 2013). This issue is more acute in smaller implementations as opposed to bigger implementations.

Electronic Health Records might have solved many issues in patient care including the need to make hospitals paperless, but they still face major interoperability issues. Patients normally seek healthcare services from various service providers practicing in either their affiliated or unaffiliated institutions. When there is no systematic connection between different healthcare providers, medical information pertaining to patients becomes fragmented, incomplete, and outdated (Kruse et al., 2018).

Interoperability, sometimes referred to as Health Information Exchange (HIE), refers to the exchange of data between entities through different mechanisms. It was introduced in 2009 through the health information technology for economic and clinical health act to enhance the coordination of care among different healthcare providers and minimize medical errors. HIE requires the communication of electronic data among healthcare institutions to ensure that patient health information from one facility are seamlessly incorporated into another facility. Information can be transmitted real time or near real time and it leads to the optimization of healthcare systems, particularly in case management, clinical care, and public health (Walker et al., 2005). While it does not necessarily involve the transfer of data about administrative functions such as billing or historical data for research and statistics, HIE can also assist in such purposes and thus creates efficiencies for healthcare organizations leading to patient satisfaction among other benefits.

There are different mechanisms of sharing data used among healthcare providers to facilitate the exchange of information. Existing publications in interoperability and HIE show that the following models are majorly employed by healthcare providers to transmit patient health information electronically: direct, query based, and patient centered. Direct model allows sharing of encrypted medical records where the recipient of the data is known. This form of exchange facilitates the exchange of data from point to point where the sending provider is aware of the recipients' identity and the medical records are able to exchange from one healthcare organization to another directly through email protocols that are universally adopted. This direct exchange methods that are basically based on trust between the two parties, incorporate medical records into the Electronic Health Record (EHR) of the recipient or clinical inbox in a secured network (Reisman, 2017). The direct method enhances communication and coordination between the parties sharing the information through the method that assure secure exchange of information of patients.

The second method, the query or lookup-based system, offers healthcare providers the access to information they need by allowing them to query. This method of exchange requires a central repository that plays a significant role in aggregating the medical records from various healthcare providers. The requesting organization is able to use the lookup process to get the needed information from the repository. This method is basically designed to create a mechanism to provide aggregated, relevant, and cross-provider health records for the quality assessment and measurement of patient progress and patient care. In contrast, the last model involves the transfer of the medical records from the provider to the patients. For example, patients are allowed to view their results for tests, progress notes, medications, and imaging reports that are uploaded to their portals following every visit to a healthcare provider. They are able to share this information with other entities as needed (Esmaeilzadeh & Mirzaei, 2019). This form of architecture was developed to allow patients be engaged in the process of getting patient care. Patients are able to leverage the patient centered models of HIE designed and managed by healthcare institutions to reinforce as well as control the access to their own health records.

Health Information Exchange has brought several benefits in the healthcare system, but providers still meet hurdles in the attempts to share information. The most significant hurdle is the lack of clear and coherent standards for patient identification across the HIEs. Lack of national identifier standards for patients poses as a significant issue; numeric, alphanumeric, and alphabetical methods of registering patients are used in different forms by different entities across regions. This is a core issue and hinders the seamless access of patient related information in the primary repositories. Another significant challenge is lack of involvement of the payers in the sharing of patient data across the entities. Payers have significant amounts of data that would be significant to healthcare providers and would help in working towards enhancing the outcomes of the patients (Barrick, 2019). Unfortunately, the payers are keen to protect their data and this makes it a significant part of their profit model. The movement of payers from public HIEs to private ones increases integration and interoperability costs and hence extra challenges for providers. Lack of communication standards and high cost of integration across EHRs also stand as significant impediments (Pringle & Lippitt, 2009).

1.2 Statement of the Problem

EMRs and other Health IT Systems (HIT) must be able to interact with each other in order to facilitate accurate, efficient, and meaningful exchange of clinical data. The use of Electronic Medical Records (EMRs) in the healthcare industry to streamline operations is growing throughout many different countries. (Ngugi, P. N., Were, M. C., & Babic, A. (2021).

Despite the widespread use and advancement of EMR technology, these systems nevertheless lead to data silos which pose a significant challenge to interoperability. It is also notable that interoperability is crucial to accessing patient data for proactive care delivery and better outcomes, but quite often, it is lacking among EMR systems. The study therefore sought to address interoperability challenges in relation to EMR implementation and uptake in health.

1.3 Research Objectives

1.3.1 Main Objective

To assess EMR services available, their levels of interoperability and develop a Model for an interoperable EMR end-to-end implementation in a developing economy.

1.3.2 Specific Objective

This study focused on the following specific objectives:

i. To establish EMR services available, their utilization, level of integration in the Health sector
ii. To determine the various EMR systems state of interoperability
iii. To determine the strategies that have been used by successful implementers to address interoperability challenges
iv. To develop an interoperability model for EMR end to end implementation

1.4 Research Questions

i. What are the EMR services available, their utilization and level of integration in the Health sector?
ii. What are the various EMR systems and their state of interoperability?

iii. What strategies have been used by successful implementers to address interoperability challenges?

iv. Are there suitable interoperability models for EMR implementation?

1.5 Justification of the study

It is hoped that the findings of this study will be beneficial to the management of health facilities as EMR interoperability has an impact in healthcare quality, efficiency and accessibility. By tackling obstacles and possibilities related EMR interoperability implementation this study can make an impact on patient healthcare, financial savings, legal compliance and technical advancement. Interoperable Electronic Medical Records (EMRs) are becoming increasingly important as healthcare systems continue to change, and researchers, legislators, and healthcare providers should all be concentrating on this important topic. In addition, the study hopes to address the current fragmentation of data in healthcare systems, incompatible EMR systems which hinders exchange of patient information which can lead to medical errors.

The research will also make a significant contribution to the body of knowledge in the area of health Informatics. It can further arouse a debate and further research work in Kenya and other developing countries in the area of health informatics.

1.6 Assumptions

This research worked on the assumption that:

i. Every patient requires quality service delivery in the healthcare facilities.

ii. There is value in sharing data, and in receiving data from data structures which must be clearly understood.

iii. The clinical users often refer their patients to other facilities who often require references or previous clinical encounters.

iv. The respondents have heard at some point an experience with EMRs.

v. Respondents truthfully responded to the questionnaires to the best of their knowledge. The respondent's response was to increase the validity of the study and effectiveness through knowledge received hence improve the study outcome in interoperability of information sharing.

1.7 Scope of the study

Whereas interoperability application spans through EHR and EMR across the globe, this study was restricted within Kenya context. The researcher resides in Kenya and also given the limitation of resources and timeline available for the research work, Kenyan context was deemed sufficient; more so that the study was focused on understanding interoperability in a developing economy of which Kenya is one. Whereas the key challenges of implementing EMRs in the Kenyan health care facilities encompasses various components like infrastructure, skills, funding, security, only the interoperability construct was covered in the study.

1.8 Limitations

A significant limitation faced during the study was the attitude of the participants. Some participants were reluctant to provide information about their facility's use of EMRs, which limited the quantity and quality of data collected from the facilities they represented. To overcome this restriction, the researcher reassured the participants that the data they provided would remain confidential and be used solely for research purposes. This approach helped to alleviate concerns and encourage greater participation in addition availing letters from Nacosti and Ethics committee. Funding also posed a limitation to the study. As the research was solely funded by the researcher, there were insufficient funds to support the entire research operation comprehensively. This financial constraint limited the scope of the study, necessitating the focus to be confined to facilities in Uasin Gishu and Nandi Counties which are in close proximity to each other in order to ensure that expenses of data collection were manageable within the available resources

1.9 Summary

To simplify the topics discussed in this chapter, the chapter highlights key challenges in health globally and locally which necessitates the need for Electronic medical records sometimes referred to as Electronic Health Records. What EMRs entails was mentioned as well as Key challenges in healthcare addressed by EMRs was also discussed. The chapter also looked at challenges in implementing EHRs leading to the study problem. The chapter further, articulates the study objective and the ways of achieving it through distinct specific objectives. Significances of the study is equally articulated, besides study assumptions and scope.

CHAPTER TWO

LITERATURE REVIEW

2.0.1 Overview

This chapter presents a review of studies on the topic of interoperability model for electronic medical records end to end implementation. This section reviews related studies based on literature, theories, frameworks, models.

2.1 Key Concepts Explained

2.1.1 Interoperability

Interoperability refers to the capacity of more than two applications or information systems to communicate. In the health sector, interoperability would entail sharing of health or hospital information between two or more health facilities. With the advancements in technology in the health sector, the need to share information will increase but the capacity to do so has been marred with challenges in the past (Bhartiya, Mehrotra, & Girdhar, 2016). The amount of data in the healthcare sector is growing by the day and projections show that in the next decade or so, the growth will be exponential leaving the players in the health sector with a daunting task on how to manage, share, and utilize the data (Kent, 2018). Interoperability will have to consider availing necessary information without compromising the quality of the content that is shared across platforms.

In the healthcare sector, interoperability can be considered from three broad levels: functional, structural, and semantic. The functional level of interoperability entails exchange of data between systems that do not bear the capacity to interpret the data that they receive (Becker Hospital, 2015).

Elsewhere, the functional level, also known as the foundational level, is thought to include establishing the interconnectivity needs needed to transmit data securely (HIMSS, 2016). Since the receiving information system can analyze the data it receives, the structural level is greater than the foundational level. For the purpose of data interchange, this level specifies the data format and related grammar. Healthcare information systems are capable of exchanging, interpreting, and using data at the third level. (Becker Hospital, 2015). A new level of interoperability has been proposed – the "New" Organizational level – which involves governance, policy, legal, and organizational considerations in exchanging data across facilities (HIMSS, 2016).

2.1.1.1 Interoperability in Health Systems in Africa

There are some developments that have been made as far as interoperability of Electronic Health Records is concerned in Africa. In south Africa, the National Department of Health (NDoH) has made several endeavors in ensuring interoperability of systems in the country's healthcare system. Efforts can be traced back to March 2014 when the National Health Normative Standards Framework was launched to provide standards and guidelines for the country's electronic health records (Ngxabane, M., & Cilliers, L. 2020, March). Phillips, a leading technology firm in the healthcare network, is striving to turn policies and guidelines such as NHNSF into action, but there are challenges in developing an enterprise wide interoperability strategy and pragmatic application of shared data.

Such developments in sub-Saharan Africa are evident that there is some progress with regards to the implementation of Electronic Health Records in Africa. The recent interest and implementation of Electronic Health Records in Africa is due to increasing realization that a stronger Health Information Technology (HIT), which is critical in ensuring enhanced patient care. Timely as well as precise patient information is critical to meet the needs of patients from any population. Doctors and other healthcare providers need high quality information in order to be able to make clinical decisions that are sound; however, their information needs are usually not met. This absence of high-quality information usually leads to lesser quality as well as inefficient patient care; reporting as well as research in clinical areas has also been adversely affected. The dire need for good health information systems in sub-Saharan Africa is currently of great attention. (Ngxabane, M., & Cilliers, L. 2020, March).

Most EHRs are currently web and client server based, using relational databases, entry screens and data access and are navigated using pointer and mouse like scrolling devices. In Sub-Saharan Africa, the EHRs are employed in ambulatory care settings. However, not much has been done in terms of interoperability of the EHRs as the region is resource constrained and suffers greatly. While sharing of information in health care institutions in the United States and other developing countries has become popular, there is little that has been achieved in so far as sharing of medical information from one healthcare facility to another is concerned. As such, healthcare facilities that in Africa work with Health Management Information systems do so little as to share medical information from one facility to another. The following sections includes a review of benefits that are accrued to the application of interoperability in healthcare management information systems.

2.1.1.2 Benefits of Interoperable Healthcare systems

The first benefit of health management information systems becoming interoperable is better public health data. In the ideal medical industry where every hospital's information system is interoperable, developing a network of shared data across the facilities means that long term health trends can be able to be predicted. The interoperable digital health technologies aid in the transfer of health information that is more accurate that can be used for every purpose and interpretation. In recent years, the benefits and needs of sharing medical data to improve clinical outcomes and advance research have been documented, especially in the area of rare diseases where expertise and knowledge are scarce and patient populations are dispersed geographically. (Courbier, Dimond, & Bros-Facer, 2019)

Interoperability increases sharing of health data thereby helping to understand the what patients need and want. With regards to rare diseases and research on diseases, interoperability of health management systems or EMRs ensures that the needs and wants of the patients are embedded in the process of research and design (Courbier, Dimond, & Bros-Facer, 2019). Further, researchers are quickly noting the contribution of interoperability of EHRs in making care effective through exchange of relevant information. The exchange of information enables understanding adverse outcomes among patients and fragmentation of care, especially for patients with intricate care needs and co-morbidities (Clarke, Warren, Arora, Barahona, & Darzi, 2018).

Interoperability bears the potential of increasing productivity among healthcare teams while reducing costs in medical facilities. Researchers note that the productivity of medical staff can be significantly stalled when there is no system interoperability. While the implementation of EHRs is considered an important step in improving quality of care and performance among healthcare teams, only when these systems are interoperable is the real performance realized. Authors note that performance can best be documented when there is cross provider interoperability and full integration of EHRs (Weiner, Fowles, & Chan, 2012). Jones, D. N. (2022) in his study showed that clinicians waste over 45 minutes every day because of using outdated information and related technologies, leading to a lot of losses annually. As well as enhancing the availability of new information, interoperability of EHRs means piles of paper documents can be digitized or replaced by digital information, which is a profoundly easier way to access, log, and store information.

Interoperability of health management information also means that there are reduced errors in the healthcare sector. The integration and sharing of information among digital applications and programs facilitates better flow of information, leading to enhanced efficiency and faster outcomes for patients. Interoperability also minimizes the need for inputting patient data manually, which reduces the time needed for data entry, reduces errors, and alleviates issues surrounding readability of text emanating from poor handwriting. Thus, as long as data is correctly entered when the patient is being registered first and going through the first encounter, health facilities stand higher chances of holding accurate patient health information all through the life cycle.

Interoperability is related to privacy of Patient Health Information (PHI). When healthcare organizations do not know exactly where the data they hold for patients is at any given point in time, there are high changes that there will be breaches of the data. There are no guarantees that printed PHI will not lead to breach of privacy. On the other hand, when data is communicated through secure interoperable networks, there is confidence that the data of the patient is secured.

Ultimately, interoperability of EHRs improves patient experiences. The overall patient experience improves as the amount of attention and care that patients receive from the care team's increases. Physicians will be taking less time to process data, and more time to analyze and understand the needs of their patients. What interoperability of EHRs seek to achieve is improved patient engagement and patient care. While technology firms such as Apple are obsessed with the experience of customers, healthcare should also take advantage of the savviness that comes with interoperability to improve patient experience.

2.1.2 Interoperability Architecture

Basically, in interoperable EHRs, data from one EHR is shared with another for the caregivers to make meaningful decisions. The development of the right framework and environment is key to achieving interoperability. The right framework ensures that inter and intra sharing of data is possible. There is also need to ensure that the right fragmentation is maintained to allow interoperability and that the requirements of the user are met. The "same" language or message format is important for interoperability of EHRs. The ANSIX12 and HL7 have been the most common message formats for sharing data.

The diagram below presents the basic architecture and the flow of data in interoperable systems. The thick line provides the layer between syntactic and semantic interoperability. The semantic operability stands above the line that typifies the tools and models much required for application in designing interoperable health information systems. Syntactic interoperability combines design and interfaces and ensures compatibility along with the required guidelines in the specific domain. The applications can collaborate with the assistance of interoperable functions and permit the sharing of data. Semantic interoperability presents as a mechanism that ensures data is processed automatically and with ease. The relationship between the two is regarded as inclusive: a semantic pattern is considered valid and will always be valid syntactically, but not vice Versa. Secured and smooth transition of data between HER systems that are heterogeneous need accurate and correct syntactic interoperability. Syntactic significant limitations include false positive or negatives (Carmagnola & Cena, 2006). On the other hand, matching the syntactic requirements introduces myriad problems, and there is a need for addressing the various challenges from various viewpoints and angles.

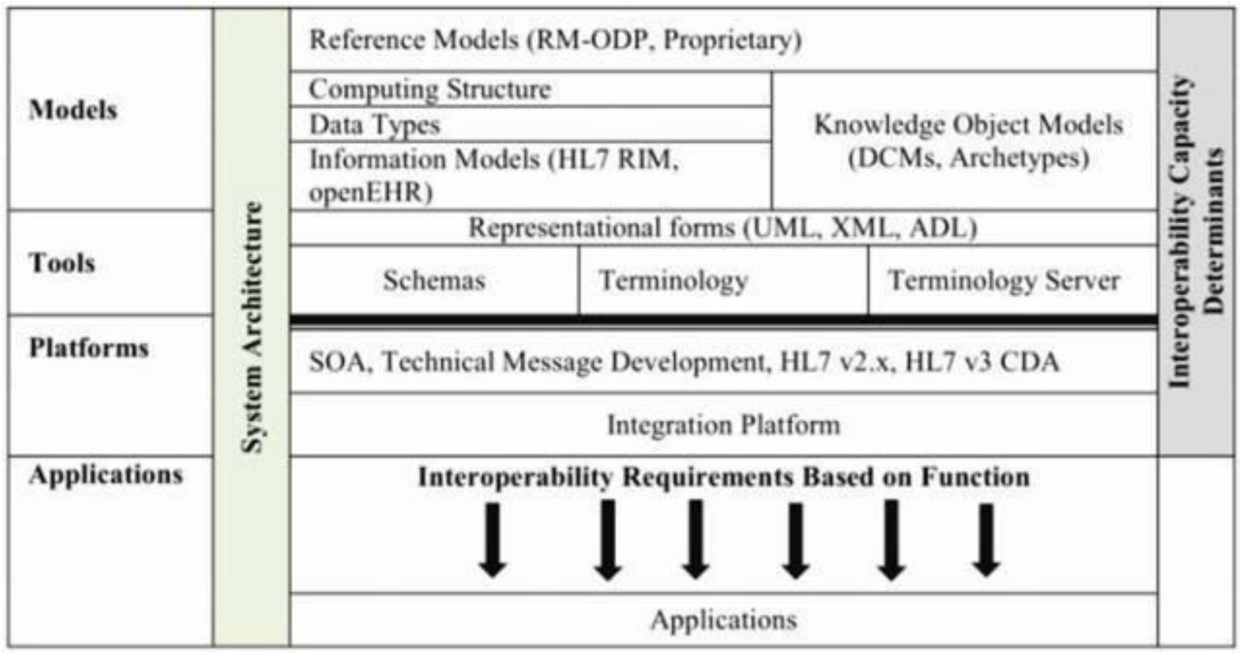


Figure 2.1: Architecture of interoperability in EHRs

Source: (Carmagnola & Cena, 2006).

Many researchers and developers assume that EHRs share some qualities from open source applications, that imply that the source code is made available for review and modification. It is also the expectation, on the other hand, that developers of EHRs should offer their clients with access to escrowed copies of their source code to assist them in developing interoperability layers among other continuity issues.

Some researchers argue that the programming language used and underlying data structure of EHRs are critical to determining the capacity for interoperability. More specifically, that EHRs use structured query languages and relational databases are more interoperable compared to those that are based on hierarchical databases such as Cache. Regardless of the internal selection of EHRs, the exchange of data with other applications needs significant effort to change the data from one format to another while retaining meaning in the data. This transformation has to take into account the syntax, semantics, and pragmatics. The biggest burden usually in on the data model for sharing data and translating the archived data to that model.

The JASON report (2013) to the Agency for Healthcare Research and Quality notes that EHR should avail data through programmatic interfaces for secondary use.

Table 2. 1: The EXtract, TRansmit, Exchange, Move, Embed (EXTREME) use cases provide more information on the interoperability of EHRs.

EXTREME use cases	Requirements
A hospital securely extract patient health information while assuring granularity of structured data.	Secure sign in and access based on roles Structured programmatically importing of data into another database Audits of retrieved records Enough metadata subsumed in the extract to ensure interpretability Openly available data dictionary shows where data is stored and what the data means.
A user with authorizations can transmit all or sections of patient health information to another healthcare provider using a different health information system without losing the structure of the data.	Methods for data selection that permits the user to identify the data to include and the data to exclude. Standard methods for structuring data such as Consolidated-Clinical Document Architecture (C-CDA)) or sections thereof (such as Digital Imaging and Communications in Medicine (DICOM) Standard methods used to deliantate the implications of the data.
A healthcare facility in a decentralized or distributed EHR exchange can allow programmatic requests for copies of a PHI from	EHR infrastructure has the capacity to respond to queries throughout

an external EHR and return records in a standard format.	Record-locator service functionality is available and applied. Standard method used to structure data (e.g., C-CDA) Sending EHR's data dictionary available to receiving EHR "Internet robustness principle" respected
Healthcare providers can move all its PHI to a new EHR.	Standard method in which to structure key clinical data (e.g., laboratory results, medications, problems, admission history) provided (e.g., Health Level Seven (HL7) v2.x or v3) Data dictionary used to define clinical and administrative data Existing metadata (e.g., timestamps, source, and authors) preserved in the new system Transaction history of data items (e.g., renewals and dose changes for a medication) preserved
A healthcare organization can embed encapsulated functionality in their EHR through Application Programming Interface (API) in order to access particular data, manipulate the specific data, and then store the new values.	External information systems have "read" and "write" access to PHI. Programmatic approach to embed external applications with which the user can interact via the EHR's user interface without re-compiling the existing EHR's codebase Appropriate support and maintenance to ensure that encapsulated functionality will continue to work and meet user needs following system configuration changes or upgrades

2.1.3 EHR/EMR issues which are fundamental in the implementation of EHR/EMR

Electronic Medical Records and Electronic Health Records serve as means to create organized and legible recordings to access medical information regarding patients. However, even though they have been in great usage over the past, the adoption rates of both EHRs and EMRs has been low and implementers have had to battle resistance from medical workers. (Woody II, E. W. 2020). The EHRs serve and represent critical tools for enhancing quality and safety of healthcare, though medical officers have to actively employ these systems in order to garner the benefits. Barrett, A. K. (2018). This review details a number of issues that implementers and stakeholders need to consider during implementation of EHRs and EMRs.

Fundamental issues

2.1.3.1 Privacy and security

Past studies on the issues associated with EHRs identify privacy and security apprehensions as major concerns (Ajami & Arab-Chadegani, 2013a; Bates, 2005; Sprague, 2004). Several other authors including Gariépy-Saper & Decarie (2021); Keshta & Odeh (2021); Ozair et al. (2015) document fears of privacy as barriers to the adoption of EHRs across geographical locations.

Communication technologies have led to situations where patient's health information are surrounding with privacy and security threats (Rothstein ⁎, 2007). Currently, there are myriad privacy and security threats of secured patients' health data and these concerns stand as the biggest barriers to the implementation of Electronic Health Records (Sittig & Singh, 2015); and thus, there is need for healthcare organization to seek strategies that can assist them secure such data.

Literature also documents privacy, confidentiality, and security as core issues that require address in EHR implementation. Security, in this sense, and privacy are strongly linked, but are indeed different. Privacy issues refer to issues of right that an individual may have to determine for themselves as to when, how, and the degree to which they can be able to access personal information. Security, on the other hand, refers to the level to which the information of an individual may be restricted or allowed for those who are in authority only (Häyrinen et al., 2008). Sharing or transferring sensitive patient information without authority leads to data breach. Privacy can also be breached in various situations through systemic identification that may be unpreventable and that may take place in the electronic health infrastructure as a whole and by central parties and technologies that look at the decisions and activities of healthcare workers as well as patients (Sittig & Singh, 2015).

Dehling & Sunyaev (2014) also note that the three core information technology fundamentals are integrity, confidentiality, and availability. Confidentiality basically involves the restriction of information to persons who are not authorized to gain access to data in any of its state, be it in storage, transit, or usage. Confidentiality can be attained through technological approaches such as encryption of data or through securing and controlling access to systems. Confidentiality is also attained through working on the moral dispositions such as silence in the professional circles. However, Dehling & Sunyaev (2014) realized that in as much as encryption is used in patient data for exposed networks, it is less commonly applied to data stored in hand held devices and other media for storage. The confidentiality need is a response to privacy issues that are also key in the healthcare sector owing to the sensitivity of data that concerns patients as well as clients.

Healthcare workers are usually highly concerned that unauthorized individuals could access healthcare information stored in electronic health records systems and misuse it leading to medical legal issues appertaining to breach in patient records' confidentiality. According to Wikina (2014), physicians are keen on confidentiality and security issues more than their clients themselves. Most of the physicians who make use of EHRs believe that paper records are more confidential and secure. This is a clear indication that the security and privacy of EMRs needs to be taken seriously. If the patients do not have the assurance of privacy, they could decide to withhold key information in order to avert inappropriate access and use (Hussain et al., 2018).

2.1.3.2 Resistance to change

There is need for proper planning and change management in order to gain acceptance for any information system's implementation. Readiness for EHR should be conducted prior to implementation, and it is a critical process that may determine success (Ford et al., 2006; Jennett et al., 2003). In most studies on implementation of EHRs, focus has mostly been on acceptance with great adoption of the Technology Acceptance Model (TAM). However, only a few have focused on resistance. Moreover, studies involving healthcare workers' resistance, particularly nurses, are rare. Past studies have shown that nurses as well as physicians can exhibit resistance to the use of information systems. As such, the resistance to the use of novel information systems should be regarded as a major indicator of how much successful EHR implementation should be.

Studies show that individuals' limits of behavior attitude or resistance to change are more critical factors when compared to other limitations. Resistance bears many facets including lack of use and usefulness, resistance to changing work processes and habits, lack of the desire to work with an EHR, and lack of the desire to tackle implementation challenges (Cho et al., 2021). Implementation challenges, such as cost, organizational support, system circumvention availability, and perceived threat, all contribute to resistance (Kruse et al., 2016). Jung et al. (2021) notes that resistance can emanate from low computer literacy levels, alert fatigues, intricacy of the system, and resistance arising from legacy systems. In a study on the successful and selection implementation of EHRs in a small ambulatory showed that the implementation of EHRs depends on a myriad of factors including the change management process and the character of every ambulatory practice milieu.

2.1.3.3 Cost

The cost of EHRs is a major barrier as most implementations requires a huge investment. Any upgrade is costly, but EHRs are costlier as software upgrades generally call for hardware upgrades. Older hardware might not perform optimally with new EHR implementations, while old networking equipment and older servers might fail to support the high intensity processing powers required by most modern applications. Menachemi & Collum (2011) notes that costs have to be assessed as acquisition costs, continuous maintenance costs, and the costs that come with the disruption of workflows. There is great loss in productivity as workers try to learn new systems. While the use of EHRs leads to averted costs, ensuring that the implementation is successful and fighting resistance attracts huge costs.

Resneck (2019) details the costs associated with implementing EHRs in a technical report about digitizing healthcare. In the report, the author notes that financial costs involved in implementing EHR systems subsume myriad factors, including licensing, maintenance costs, costs for initial and perpetual labor, and fees. These costs, surveys show, add up to even billions of dollars or at least millions depending on the type of purchase. Other costs are directly associated with the implementation of EHRs. There are also other indirect costs such as costs associated with workforce that occurs when the organization has to hire additional staff because the current staff leave owing to frustrations caused by EHRs. Despite these challenges, however, scholars note that the growth and expansion of EHRs will continue. EHRs continue to be core components of healthcare.

Gray, (2014) notes that some EHR practices and decisions increase the cost of implementation and may stifle the long-term sustainability. For instance, EHR implementations may either done through office-based servers or on cloud-based services. Cloud based implementations may find that there is need to increase internet bandwidth in order to support efficient operations, which adds to the total cost of implementation. Vendors normally advise on the necessary networking and hardware requirements, and proper planning is needed upfront. While implementing EHRs, implementation teams should also plan for additional costs that will emanate from the need to integrate the current EHRs with other systems, such as medical insurance applications. The additional interfaces may attract fees that vary depending on the amount of work that developing the interface will entail and the overall IT environment.

2.1.3.4 Other barriers

A study conducted by Gans et al (2018) reported that the top hindrances that medical teams list in the implementation of EHRs are the cost of implementation, concerns regarding supporting the

EHRs, and the ability of the clinicians to make use of the new system. According to Baron et al. (2017), moving hospital processes to EHRs without considering the support that will be required is one of the greatest mistakes that an organization may do. This is because migrating to EHRs requires a variety of support, including financial support. As such, the authors note enhanced reimbursement models are needed to ensure wider adoption of EHRs.

2.1.4 Challenges faced by the healthcare service providers in sharing of patients' data/ Information

Healthcare providers face myriad challenges in sharing patient data and information. The absence of universal interoperability is usually cited as one of the major shortcomings of sharing data across EMRs, leading to duplication in costs, workload fatigue among clinicians, and probable risk to patients' safety (Li et al., 2021). This is particularly problematic for patients who have chronic conditions, multiple comorbidities, and polypharmacy who are dependent on the effectiveness of sharing of the patient data from one EMR to another.

Poor EMR interoperability is detrimental to the safety of patients and costly for healthcare organizations. Its consequences vary from increased prescribing errors, to iatrogenic harm, to fragmentation of patient data emanating from redundant testing and extra expenditure (Zaheer et al., 2017). In the fragmented EMR landscape, assessing the impact of poor interoperability is highly challenging. However, there is a growing body of literature assessing the areas such as barriers and facilitators to EMR greater adoption, usability, and technical capabilities. A number of studies have highlighted some of the major issues affecting interoperability as detailed in the sections below (Thompson & Graetz, 2019).

2.1.4.1 Cross provider sharing

Cross-provider sharing of patient health information is an intricate undertaking with the capacity to significantly increase clinical effectiveness and research. Firstly, healthcare institutions are usually highly reluctant when it comes to sharing of patient data owing to privacy and confidentiality concerns, and may shun sending information with the fear that it will give the recipient provider competitive advantage. Secondly, there is no universal consensus regarding the technical infrastructure required to support sharing of data. Thirdly, sharing of data across institutions is a daunting process in itself and there is need for a mutual comprehension of both data structures as well as meaning (Esmaeilzadeh & Mirzaei, 2019). Just the mere assumption that data can be shared in a secure and efficient manner is not enough and leaving the trust issues in interoperability unchecked means limited utilization of such functions and data (Rudin et al., 2011). Despite advancements in health information exchange, the trust, infrastructure, and interoperability issues remain substantial barriers.

In the United States, the journey of the health systems reveals meaningful pointers to factors that support interoperability. The US enjoys a wide adoption and coverage of HER with more than 96% of the facilities in the country enjoying the adoption. This is a nine-fold increase compared to the situation in 2008. Further, more than 80% of the physicians in the United States have access to an EHR that is certified(Reisman, 2017). However, not much has been achieved in terms of interoperability and a review of the situation and the factors are then important to determine the hurdles.

2.1.4.2 Standards

Having properly laid out enforceable standards is critical for interoperability to be successful. There are myriad certified EHRs that are in use across continents and locally, each with unique clinical terminologies, functionalities, and technical specifications(Kennedy, n.d.). These make it hard to have one format for interoperability to enable sharing of data. Actually, not even the EHR systems that are using the same platform are necessarily able to synchronize data across themselves in a seamless manner because they are usually customized to meet the unique preferences and workflow of an organization (Evans, 2016).

In itself, interoperability is intricate. The term refers to more than simply the capacity to exchange health information. For two systems to be completely interoperable, they should be able to exchange and then utilize the data (Lehne et al., 2019a). For this to take place, the transmission of messages should be in standardized formats that the receiving end could be able to interpret the data. However, since there is a general lack of standards, transmission and use of data is hard and there are limitations to share and utilize data across facilities.

2.1.4.3 Cost

The cost for implementing interoperable EHR remains high and a barrier for further implementation. The cost of implementing an EHR ranges from Ksh. 1,500,000 to Ksh. 7,000,000 per provider depending on whether the system will be web based or server based. Additionally, maintenance costs and costs for customizations make it an expensive venture. In surveys, physicians have expressed concerns over the financial burden of upgrading EHR systems, particularly given the trending practice issues such as shortage of physicians(Ryan et al., 2014).

In Kenya, trust stands as a significant issue particularly in every situation when there is a distance between the vendors and the consumers. HIE networks are weak and almost absent and sharing of individual health information through electronic platforms to enhance coordination of care is daunting. National initiatives for HIE have not borne much fruit. Further to that, sharing of data is hurdled by the absence of sufficient technical infrastructure and architecture to support HIE(Payne et al., 2019). Most attempts to share data either need a central source of data or the moving of bulk data to third party organizations. Both scenarios create unique challenges. Ultimately, interoperability of patient data needs a clear understanding of semantics and structures, each a prerequisite to the successful exchange of healthcare information. To this, there are no clearly laid out standards (Peterson et al., 2010).

2.1.4.4 Human infrastructure

Human infrastructure is a critical factor that determines interoperability of health systems across the globe. Human infrastructure refers to the human users including network administrators, designers, developers, and generic end users. Generic users with access to IT service and appliances comprise a significant part of the human infrastructure factor. This is specifically so with the advent of user centric IT service development. The development of these technologies and the needs of the information from the generic users should go hand in hand. In a Malawian study, it was shown that good information is key to establishing a comprehensive system capable of providing information to the users at health facilities in different levels starting from the community to the national level. As such, lack of computer literacy can be a factor for information systems interoperability in the health sector.

2.1.4.5 Interoperability culture

Perhaps the biggest factor in ensuring success in interoperability is not technological at all but cultural. As in other sectors, interoperability in health systems needs the close collaboration and coordination of myriad stakeholders, including providers, patients, vendors, health information technology professionals, and legislators. Yet, in the health systems of many countries, there continues to be defined by fragmented processes, silos, and disparate stakeholders, and where data have become more of a competitive advantage tool and commodity rather than a basis for offering coordinated care(OECD, 2020).

There have been reports from surveys that have shown that there is a big gap when it comes to culture change as far as interoperability is concerned. For instance, it has been reported that in some scenarios, there have been cases of information blocking in the health sector. Legislators have gone ahead to create legislation to penalize those who block access to the information across the organizations. It is not necessarily healthy to enforce a change of this culture through legislation, but there may be need to have a clearly defined line of action to ensure that there is no inhibition of appropriate exchange of information across entities (Adler-Milstein & Pfeifer, 2017).

2.1.4.6 Addressing physical burden

While incentives increase meaningful use, interoperability increases clerical work and consequently increases the risk for professional burnout. In a recent research, it has been shown that the use of EHRs and interoperability need has made physicians to spend around 33% of their work hours performing their actual clinical work while 49% of the time is spent on completing clerical tasks that include interfacing with HER (Collier, 2017). This means that for every hour of clinical work, physicians have to spend two hours of clerical work or work that is related to EHR tasks. There is then a need to take care of the physical burnout in order to maintain support of the clinical team.

2.1.4.7 IT Infrastructure

IT infrastructure, which comprises the composite hardware, network resources, software, and services needed for the interoperability to work are a significant determinant of its success. Kyalo et al. (2018) notes that the technical aspects that comprise ICT infrastructure determine the adoptability of EHRs and their interoperability in developing nations such as Kenya. The infrastructure allows the organization to collaborate and deliver IT solutions to its employees and partners. The interoperability landscape should comprise robust hardware resources including computers, servers, data centers, hubs, switches, routers, and others. Software that can be integrated with other software is also a critical determinant of the success of interoperability.

2.1.8 EHR/EMR Interoperability related studies– Strengths, Omissions, and Limitations

A number of researchers have looked at EHR/EMR interoperability. Sharing patient data between independent institutions, each having implemented electronic health record or health information systems, involves major concerns. The sharing of data requires an interoperable and integrated environment that is commonly understood by users in the domain. The sheer number of standards, systems, developers, and procedures are a serious hindrance to interoperability. Several authors document strengths, weaknesses, and limitations as far as standards are concerned in EMR interoperability efforts.

2.1.8.1 Strengths

Systems that have leveraged on similar standards have been documented as being successful in interoperability. Ngugi et al. (2021) document KeEMRs successes, an EMR that employs a communication layer referred to as interoperability layer (IL) to allow the exchange of health data with other health information systems like ADT pharmacy system. The Ministry of Health (MOH) Kenya, in a document on the Kenya Health Information Systems Interoperability provides details of the interoperability layer as comprising authentication and authorization of services, interlinking and routing of services, transformation and translation, and alerting and auditing of services (MOH, 2020). This enables the system to communicate with IFHIS, KNBS, and other external systems.

Scholars agree that there are significant developments that have been done in the field of interoperability as far as standards are concerned. Bates & Samal (2018) notes that there is now a single standard for most of the clinical data, as well as standards such as the summary of care document that allow summaries to be shared. Samarth (2016) provide a report on interoperable data and note that the summary of care document stands out as a success in sending out data from one facility. The Norwegian health system is also leveraging on the Summary Care Record (SCR) in order to share patient information across facilities. Dyb & Warth (2018) notes that Norwegians have personalized the SCR.

The Fast Healthcare Interoperability Resources (FHIR), which combines its various versions HL7 v2, HL7 v3, and CDA, has also revolutionized the interoperability landscape. FHIR has served for several years and there are numerous advantages that are attributed to the standard. It enables the sharing of patient data in a manner that is both easily implementable and expressive than previous standards such as HL7 v2, and 3, and Clinical Document Architecture. Owing to the advantages, there are several major EHRs that are adopting the standard such as Cerner, Allscripts, and Epic.

Other than ease of implementation and expressability, Capminds (2020) notes that FHIR is developer friendly, free for use, supports RESTful architecture, and a cost saving approach that supports interoperability. Ayaz et al. (2021) notes that FHIR is able to utilize more than 150 resources divided into five categories: financial, clinical, infrastructure, workflow, and administrative. Pfaff et al. (2019) notes that FHIR could allow rare opportunities for sharing data such as between medical centers and research centers. Thun (2019) note that FHIR promises to aid the use of EMRs, facilitate mobile technologies, and render health data accessible for analytics.

2.1.8.2 Weaknesses

Most of the standards for interoperability are fairly new and there are flaws and issues being identified even as their use increases. Security is one of the core issues of concern when it comes to interoperability. Bhartiya et al. (2016) notes that ascertaining security stands out as an issue that adds to the difficulty in attaining complete interoperability. There are already issues with even some of the most robust interoperability standards such as FHIR as much as security is concerned. For instance, Davis (2021) shares concerns about the vulnerability to abuse that FHIR and its related APIs could face, even when they are designed according to FHIR standards and guidelines.

Interoperability frameworks are also grappling to share accurate and intelligible data across sites. Chawla et al. (2020) notes that precision issues include rounding off numerical data when transferring data across platforms that are built with different architectures such as JAVA and .NET. Other scholars have also documented issues regarding the precision of the data that is shared from one platform to another (Ndlovu et al., 2021). These authors note RESTFUL APIs are designed to resolve this issue. El-Sappagh et al. (2019) recommends JSON RESTFUL messages to resolve accuracy issues given their capacity to handle relatively small amounts of data.

Even with the application of ISO 18308, there are privacy issues with the expansion of interoperability. Seiedfarajollah et al. (2019) notes that security and confidentiality subjects should be regarded before rolling EHR and interoperability implementations. EHRs struggles have also been recorded as far as confidentiality or adhering to laws such as HITECH and ACA that deal with privacy and confidentiality of patient health information (PHI) are concerned (Kruse et al., 2016). Rothstein & Tovino (2019) note that interoperability poses great privacy risks that even EMR or interoperability related policies fail to address.

2.1.8.3 Limitations

As much as a lot of progress has been made in terms of standards in sharing patient data, there is still a lot to be done in order to facilitate interoperability. There is also need to ensure that shared data is intelligible to clinicians, and whether the clinicians can get information that they require (Bates & Samal, 2018). A considerable hurdle in attaining this is the fact that there are hundreds of EHR products, vendors, and developers around the globe, each with varying clinical terminologies, functional capabilities, and technical specifications (Dash et al., 2019). These various make it hard to develop and work with one specific interoperability standard for sharing patientcare data. Some scholars note that not even those EHRs that are built on the same technology are necessarily automatically interoperable because one organization may have unique customizations that are different from another organization's preferences and workflows (de Mello et al., 2022; Reisman, 2017).

Researchers in literature note that interoperability is intricate (de Mello et al., 2022). Since it is more than just the capacity to exchange data, for two systems to be truly interoperable there must be evidence of ability to exchange and utilize shared data (Reisman, 2017). For this to happen, the data has to be transmitted through standardized coded data to enable the receiving team to interpret data. However, interoperability has been marred by a serious lack of standardized data – an issue that has plagued the healthcare system in many countries and for decades now, seriously limiting the ability to share data electronically and enhance patient care from one organization to another (Jha et al., 2009; Reisman, 2017).

There is a need for developers to adhere to interoperability standards while designing and developing EHR systems (Meehan et al., 2016). Developing the interfaces in a standardized manner will enable the seamless transfer and communication of required patient data across EHRs.

As EHRs develop and the need for interoperability increases, developers and vendors will need to make careful considerations when incorporating customized security controls as they normally result in challenges in sharing of data securely (Cresswell et al., 2013).

Beyond interoperability standards, scholars also note that interoperability, even when properly implemented, does not accomplish the expectations and requirements of end users. Sue Bowman has noted issues with improper implementation and specifications of EHRs (Bowman, 2013).

Most of the implementations have design flaws partly due to the rising intricacy of systems, so not fully attaining the promise of enhancing patient safety, care quality, and process efficiency (Keshta & Odeh, 2021). In this case, they miss the required adaptability and flexibility, but rely on the organization and context they have been developed for. This stands as a huge challenge that interoperability has to overcome to become successful.

Interoperability has also been greatly affected by inconsistencies between free text and structured data, as well as lack of transparency of ICT actions and processes. In this context, automated processes such as automated capturing of data, when improperly deployed, can cause issues in documentation (Ehrenstein et al., 2019). This way, inaccurate or out of date information could be captured, particularly when employing templates.

Another great challenge in interoperability is the proper development and implementation of EHRs decision support systems, which normally leads to bias in automation. Partly, these issues could be surpassed by certifying the development of EHRs in a meaningful use context (Reisman, 2017). However, a comprehensive study assessing the experiences of meaningful use have demonstrated weaknesses for meeting the overarching need of patient safety, care quality, and process efficiency.

Ultimately, these issues affect the data shared across systems in interoperability frameworks.

Table 2. 2: Summary of related studies

	Article/ Author	**Common Position**	**Limitation**
1	A multivariate statistical evaluation of actual use of electronic health record systems	A study on use of EMR in developing countries that details the successes and limitations of both EMR use and interoperability. The assessment of use	-Methods do not include facilities that are using other systems.

	implementations in Kenya (Ngugi et al., 2003)	and interoperability of KenyaEMR shows that: a) Only a few of the facilities that were included in the study used health data exchange (interoperability) despite the system's capability. b) Indications are that the use of EHRs and data exchange needs improvement.	-The key factors leading to lack of usage of integration capabilities are not detailed.
2	Final Report: Measurement of Interoperable Electronic Health Care Records Utilization. (Samarth, 2016)	The goal of the report was to advance the assessment of the exchange of information in the health sector. The assessment of interoperability is still in its nascent stages. The project also aimed at measuring the level of interoperability. A number of things emerged including: a) There is a need for patient centered approaches that leverage on sources of data such as data on claims and aggregated datasets. b) Entire care teams need to be considered. c) There is need for both short term and long-term studies in order to measure interoperability properly.	-This study focusses on measurement only. Since it is a new thing, development of measurement goals was quite challenging and there is need for more measurement studies in order to understand degree of utilization of interoperability to a greater extent.

		d) Survey instruments can provide both insight into the utility of interoperability information and the impact that such information has on making decisions.	
3	Evaluation framework for interactive health communication applications (Ayaz et al, 2021)	The study highlights more about Fast Healthcare Interoperability Framework (FHIR). The resource also categorizes FHIR resources into: a) Financial b) Clinical c) Infrastructure d) Workflow	FHIR is presented in detailed and its weaknesses, especially as pertaining to security are portrayed. Data security is still a core concern amid struggles on perfect interoperability standard. Solutions to this issue of security are not clearly presented.
4	A framework for evaluating e-Health: systematic review of studies assessing the quality of health information and services for patients on the Internet (Bhartiya et al. 2016)	The author further discussion on security in interoperability. The key concern on the security of FHIR is on APIs.	The security of APIs needs to be addressed. However, there is no sufficient comparison of various vulnerabilities.

5	"CHEATS: a generic information communication technology (ICT) evaluation framework . (Seiedfarajollah et al., 2019)	The paper discusses a framework for evaluating information communication technologies. It emerges that a multidisciplinary approach is critical when assessing new technologies such as interoperability.	Both quantitative and qualitative approaches are used thereby providing robust assessment on emerging technologies.
7	Security and privacy of electronic health records: Concerns and challenges. (Keshta & Odeh, 2021)	The paper details on the security and data security. The main issue as highlighted is safeguarding of the amount of health data shared during interoperability. Some of the measures include: a) Installation of antivirus b) Cryptography c) Safeguarding d) Physical access control e) Authentication mechanisms	The pros and cons of the various security options have not been assessed so as to as show the advantages and disadvantages. Any one measure is not sufficient on its own.
8	Obtaining Data From Electronic Health Records (Ehrenstein et al., 2019).	As far as interoperability is concerned, the research details how EHRs are or can be linked to research registries and other registries. The authors detail the factors that will lead to better interoperability including: a) Increasing lightweight standards b) New ways to measure interoperability c) Introducing EHRs embedded tools d) Incentivizing workers	There is no sufficient information on guidelines for the integration of registries, which is an important factor for the interoperability to work.

		e) Offering additional clarification regarding application of HIPPA	
9	The Challenge of Making Electronic Data Usable and Interoperable. (Reisman, 2017)	The authors detail three important stages in meaningful use of EHRs: a) Data capturing and sharing b) Advance clinical processes c) Improved outcomes The research also answers questions on why interoperability is so hard and details the following that need consideration: a) Understanding EHRs meaningful use b) Costs are still high c) There is need for a lot of collaboration d) The path for interoperability is not clear	The methodology of the study is not clearly laid out. Further, the factors affecting interoperability are not comprehensive.

2.2 REVIEW OF THE OBJECTIVES BASED ON LITERATURE

2.2.1 Utilization of EMR

The implementation and utilization of hospital wide Electronic Medical Records (EMR) still remains an unachieved quest for many information system managers in the hospital setting. Healthcare stands as one of the most fast moving and intricate industries yet. Novel technologies, including innovative EMRs, are constantly under development (De Benedictis et al., 2020). Yet, the industry still lags behind when it comes to the adoption of technologies in the workplace.

Electronic Medical Records have been considered for long as a major factor in influencing the quality and safety of care, minimizing adverse events during and after care, reducing costs, enhancing research, optimizing processes, and getting the best in clinical performance. However, utilization of EMRs, as well as other technologies, in the healthcare space, continues to lag, and hospitals are still exhibiting resistance from healthcare professionals when it comes to embracing digital technology (Safi et al., 2018).

The rollout of the EMRs has been nationwide albeit many facilities still maintain manual processes or a combination of manual and electronic processes. At the facility levels, routine data is mostly collected through paper-based tools and manual registers (Hagel et al., 2020; Okello et al., 2019). At the county and national levels where there are sufficient data storage facilities, the data is maintained in electronic formats. Other data collection methods have been implemented within the health system including Electronic health records and m-Health (mobile technologies). Other than the HIS, there are also other parallel systems and databases such as the Integrated Financial management Information and logistics supply chain management system, the iHRS, the DHIS2, the Integrated Disease Surveillance and Response Information System (IDSR), the Civil registration system, the community health information systems, the KNBS, TIBU, and EMRs (Kihuba et al., 2014).

There are several challenges as far as the implementation and integration of electronic medical records use in the health system in Kenya. Firstly, the number of the EMRs in the county is still below par and the implementations are not very well coordinated. Regardless of the attention that has been dedicated towards hiring staff to work on the health system automation, there are still huge gaps (Kihuba et al., 2014). Generally, the current implementation of the HIS provides very limited information that can be used for monitoring of health goals as well as providing relevant information towards management of both individual and communal care in a timely and understandable manner. There are still myriad issues of access and culture of information has not diffused to all areas around the country (Lippeveld et al., 2010). The many parallel systems that exist in private institutions have not been integrated either with the HIS or with each other thereby making transmission or sharing of data an arduous task (Bernadette et al., 2016). Further, there is no clear legal framework to coordinate the use and transmission of information across facilities and with the ministry of health.

Several scholars agree to the challenges experienced in the health system in Kenya as far as electronic health records are concerned. Regardless of their significance, there are several performance concerns raised. According to Sittig et al. (2018), there are around nine main challenges that health institutions face when trying to implement HMIS. These challenges include developing models and methods for the implementation of the systems and assessing risk, developing standards for the design of the systems, ensuring that the systems have the right safety and security features in an interfaced and networked environment, implementing a robust method for the identification of patients uniquely, developing and implementing successfully a decision support that enhances safety, identifying proper practices and processes to follow when managing the transition from one system to another, developing methods to conduct surveillance and monitoring of the system in real time, establishing a culture of allowing the sharing of information, and developing models for consumers/clients to enhance the HMIS. Jalghoum et al. (2019) comments further on the challenges in the implementation and usage of information systems in the health sector include privacy concerns, lack of financial muscle, lack of proper support as well as regulations, and the nature of the healthcare sector itself. These challenges, almost all, point to human and cultural aspects, although there are aspects that are purely relating to the adoption of technology and the capabilities of the adopted technologies.

In 2008, the health metrics network conducted a high-level study in the health system in Kenya and showed that there was a rate of reporting and a considerable lack of guidance from policy. Macharia and Maroa (2014) note that it is probably a hard task conducting a successful implementation of a health management information system in a hospital. The raft of challenges that are involved in the implementation of HMIS in health facilities have led to such a conclusion. It is also noteworthy that even facilities that made considerable investments into these systems still experience various challenges with regards to the functionality of these systems (Macharia & Maroa, 2014). These concerns have been voiced at a time when there is need for better performance information, usually connected to particular indicators for vertical programs such as HIV and malaria related mortality rates, immunization rates, and maternal mortality (Bernadette et al., 2016). In reaction, Kenya has greatly invested in policy development and implemented at national scale the second version of DHIS that is currently in use across Africa.

Within the wider HIS, hospital management information systems are one of the main components, and actions required of the management of hospitals to support the collection of data and the generation of information in Kenya are clearly laid out in particular policy documents. Responsibilities vary from the registration of births and deaths within a facility as part of the integrated population based countrywide reporting systems (Kihuba et al., 2014). Additionally, through hospital specific systems, facilities ought to report workloads, causes of illnesses and deaths as per departments, illness specific indicators such as antenatal HIV testing, and the overall outcomes stratified by sex and age among other indicators. These hospital related data are taken and reported in Kenya through the use of paper-based system, which collects the primary data followed by secondary data that is summarized and entered in the DHIS2 for the central aggregation of data (Bernadette et al., 2016). Given the prior experience insinuating that it was at times hard to obtain important hospital data, this study seeks to explore ways to model the health systems in order to facilitate automation and seamless transfer of data through interoperability.

There is paucity of literature on EMR implementations in Kenya. However, there are few studies, such as Akanbi et al. (2012; Haskew et al. (2015); Oluoch et al. (2014) that detail about the implementation of EMRs in Kenya. Haskew et al. (2015) writes about EMR usage in providing HIV care in rural Kenya. The authors note that EMR-based data helps in clinical decisions and verification and has helped in reducing gaps in HIV care. Cloud based model has been lauded over local clinic setup as it reduces the cost of implementation. The authors also note a number of issues including patient confidentiality, data management, and data quality that have to be considered in the EMR model. Akanbi et al (2012), on the other hand, did a survey to establish the role of EMRs in the appropriate placement of HIV on ART in Western Kenya. They show that EMRs can improve the quality of care given to HIV patients through the appropriate placement of patients eligible for ART in resource limited settings.

2.2.2 Various EMR systems state of interoperability, HL7 v.3 and OpenEHR

Interoperability between the two frameworks HL7 and OpenEHR is more focused at the technical and structural interoperability of the information model of rubrics. The basic structural mapping between the two information models is shown in the figure below and is critical for recording and transmitting clinical findings that are related to the results. There are already many efforts for interoperability between the two frameworks that are ongoing including the harmonization of the development of the specifications in each of the frameworks(Dafny & Lee, 2016).

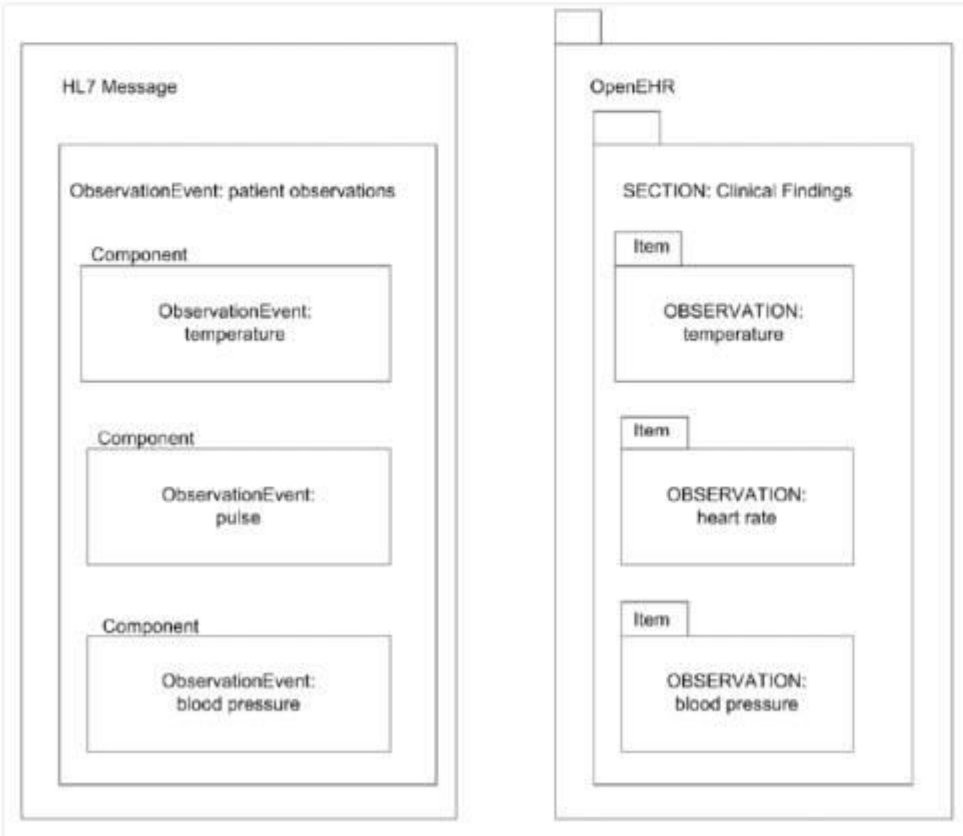


Figure 2.2: Mapping HL7 and OpenEHR Structures (Dafny& Lee, 2016)

In a distributed healthcare system, the following structure portrays the interoperability and exchange of data. Hospital A is able to share data with hospital B and hospital C through a shared XML database and a centralized access portal through requesting the information by use of a unique patient identifier (Winter et al., 2018).

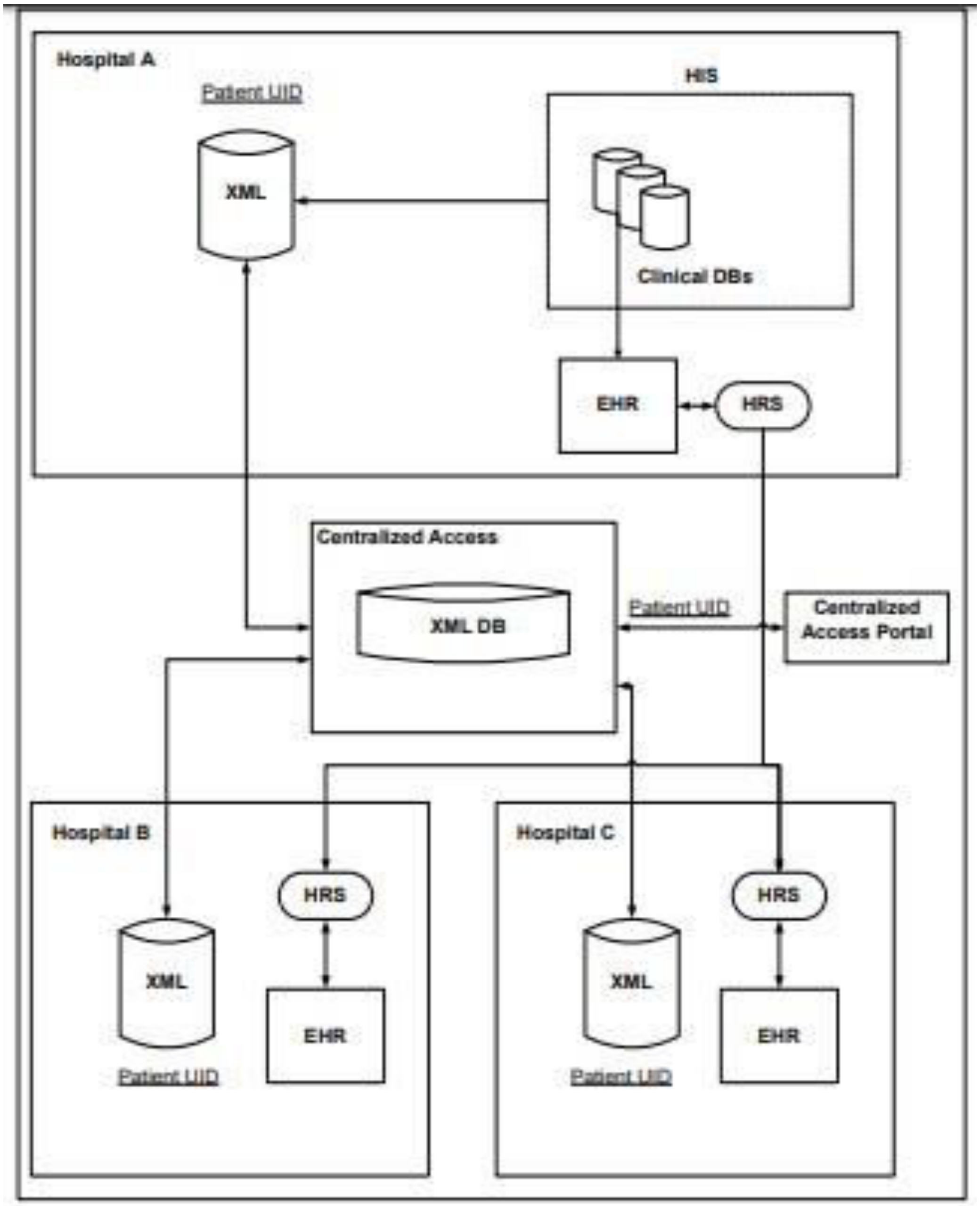


Figure 2.3: distributed healthcare system (Dafney et al 2016)

2.3 Strategies that have been used by successful implementers to address interoperability challenges

There are a number of answers to the challenges in interoperability including artificial intelligence and machine learning.

2.3.1 Machine learning

Machine learning is one of the answers to interoperability issues. Machine learning has been gaining a lot of traction owing to the ability to sift through huge volume of low-quality data. Through the use of machine learning, it is easier to map together complex and intricate interoperability data and their associated terminologies. Lehne et al. (2019) note that machine learning and artificial intelligence are a treasure trove when it comes to handling of huge data in healthcare interoperability settings. Being able to find correlations and patterns in high dimensional interoperability datasets can help clinicians and researchers alike when looking at high volume patient data (Lehne et al., 2019).

There are myriad sources of data related to health such as demographics, medical lists, wearables, which are unusable because they are not fully supported in interoperability. Machine learning promises gains. It has been shown that interoperability can be successfully implemented using machine learning applications. Ratwani et al. (2018) notes that new efforts in healthcare interoperability are putting their focus on a handful of well-defined web APIs, including Reusable Technologies (SMART) on FHIR, which are leveraging on machine learning. According to Dunskiy (2021), AI and ML systems can help in the processing of the ever increasing flow of clinical notes, patient forms, and clinical notes. This helps in addressing most of the healthcare interoperability related challenges. Additionally, AI can help in providing real time insights regardless of the source of data.

2.3.2 Blockchain

Blockchain has been publicized as a viable answer to myriad issues in the healthcare sector including interoperability issues. However, its application is still a little bit unclear. This is the underlying technology used in bitcoin and it entails a distributed ledger to assist in tracking transactions in a manner that is highly secured. In the healthcare sector, blockchain would be beneficial in enabling someone looking at a patient's health record know and trust the bits of data that make up that record. Blockchain databases are made to be read only and cannot allow deletion, hence preventing unwanted altering of transactional data in permanent health records (Gordon & Catalini, 2018). However, preventing cases of fraud in healthcare interoperability where records are of low quality would not nothing to make the situation better. Instead, the health systems first have to ensure that data is of high quality before working out data governance and quality.

Before healthcare sector players spend precious resources implementing blockchain for interoperability, they need to fix the sources of data. Rather than having multiple interoperability standards, the EMR developers can focus on creating one single set of data format, terminology, and exchange standards for a bigger and more comprehensive patient health data set. This data set should comprise perinatal, maternal, cardiac, and social health data determinants. Rather than searching through the various text notes, healthcare providers would only be required to access the codified data through standard based terminologies that are formatted in a manner that can be analyzed by ML/AI technologies. This will make it easier to identify critical information and not just critical data.

Choosing an independent organization to handle interoperability matters has been touted as a solution to a variety of interoperability related issues. The independent platform is able to provide expertise and time to verify data requests to ensure they are secure and appropriate. Through the independent platform, organizations do not have to choose time when it is appropriate to make data available. Instead, data can be made available at all times for all entities. There is also need to have an independent party look at data inconsistencies from various sources, export data into single uniform format, and provide a unified interface and network (Khan et al., 2021).

Clear interpretation of all shared information is necessary for effective communication in all interoperability areas. When parts from several vendors are included into a system, it might cause issues. (Ambrosio, R., & Widergren, S. (2007, June).

2.4.0 EMR Interoperability Models

2.4.1Theories, Models and frameworks

Implementing an interoperability model for Electronic Medical Records (EMRs) involves several steps, ranging from setting standards and protocols to ensuring secure data exchange and integration across various healthcare systems (Ndlovu, Mars & Scott, 2021). Globally, standards such as HL7 (Health Level 7), FHIR (Fast Healthcare Interoperability Resources), DICOM (Digital Imaging and Communications in Medicine), and ICD-10 (International Classification of Diseases) provide the framework for the exchange, integration, sharing, and retrieval of electronic health information (Ndlovu et al., 2021). Data security and privacy are safeguarded through regulations like HIPAA (Health Insurance Portability and Accountability Act) in the U.S. and GDPR (General Data Protection Regulation) in the EU (Jabbar, Fetais, Krichen & Barkaoui, 2020). The infrastructure supporting EMR interoperability includes cloud computing for scalable and accessible storage, APIs (Application Programming Interfaces) for communication between different healthcare applications, and emerging technologies like blockchain for secure and transparent data exchange. Implementation strategies can vary, including centralized systems, decentralized systems, and hybrid approaches that combine elements of both (Jabbar et al., 2020).

In the African context, regional standards and initiatives such as OpenHIE (Open Health Information Exchange) and Harmonized Health Information Systems (HHIS) aim to improve health information exchange across the continent. However, challenges such as limited internet connectivity, unreliable power supply, insufficient financial resources, and a lack of trained personnel often hinder implementation. Despite these challenges, there are success stories, such as Rwanda’s national health information exchange platform and South Africa’s National Health Normative Standards Framework (HNSF) for interoperability (Tsegaye & Flowerday, 2021).

In Kenya, national initiatives like the Kenya Health Information System (KHIS) and the Kenya National eHealth Strategy provide a framework for implementing digital health solutions, including EMR interoperability (Ndungu, 2020). Key projects such as AfyaInfo, a national health information system to improve health data collection and utilization, and KenyaEMR, an opensource EMR system used in public health facilities, highlight the country's commitment to enhancing healthcare through technology. However, implementation challenges remain, including ensuring data privacy in compliance with Kenya's Data Protection Act, integrating various EMR systems used by different healthcare providers, and building capacity among healthcare workers and IT professionals (Ndungu, 2020).

Opportunities for improving EMR interoperability in Kenya include leveraging the high mobile phone penetration for mobile health (mHealth) initiatives, fostering public-private partnerships to fund and implement EMR systems, and strengthening community health information systems for better data collection and reporting at the grassroots level (Ndungu, 2020).

The end-to-end implementation process involves several critical steps. It starts with assessment and planning, where a needs assessment is conducted to understand the current state of health information systems, followed by the development of a strategic plan outlining goals, timelines, and required resources (Ngugi, 2021). The next step is selecting and customizing appropriate international and regional standards, such as HL7 and FHIR, to fit the local context. The system design and development phase involve designing the architecture of the EMR system for scalability and flexibility, and developing or customizing software to meet healthcare providers' needs. Setting up the necessary infrastructure, including reliable internet connectivity and power supply, and establishing data centers or cloud-based infrastructure is crucial (Ngugi, 2021).

Data migration from existing paper-based records or legacy systems to the new EMR system follows, ensuring all relevant data is transferred accurately. Integration and interoperability are achieved using APIs and other tools to enable different healthcare systems to communicate and share data while ensuring compatibility with other national and regional health information systems (Mkayula, Mbise & Mahundi, 2022). Training and capacity building for healthcare workers, IT staff, and administrators on using and managing the EMR system is vital for successful implementation. Pilot testing in selected facilities helps identify and resolve issues before a gradual rollout to other facilities. Continuous monitoring and evaluation of the system's performance, collecting user feedback, and making necessary adjustments are essential for long-term success (Mkayula et al., 2022). Lastly, developing plans for sustainability and scaling the system to cover more regions and healthcare providers ensures the EMR system's long-term maintenance and support. By following these steps and leveraging international best practices while considering local contexts, Kenya and other African countries can successfully implement interoperable EMR systems that enhance healthcare delivery and outcomes (Mkayula et al., 2022).

2.5.2 The European Interoperability Framework (EIF)

Different models and frameworks give a structured approach towards getting a seamless exchange of information and communication between different systems and organizations in the health sector system (Katehakis et al., 2018).

The European Interoperability Framework (EIF) is such a framework that facilitates the exchange of information in the health sector. It broadly looks at four key layers of interoperability namely; technical, legal, organizational and semantic operability (Kouroubali et al., 2019). Under legal interoperability, the different legal frameworks of different organizations are aligned to ensure they operate in the same legal framework. Different organizations operating in different legal frameworks are made to collaborate with one another. This is of huge significance regarding data privacy laws as well as protection laws, which are important, many and vary across different jurisdictions (Kouroubali et al., 2019). Organizational interoperability on the other hand deals with the harmonization of the workflows and the business processes. This enables the providers of the healthcare to carefully coordinate the patient care. The layer is important in integrating the multifaceted and complex systems in the healthcare. It allows the health care systems to not only to share but also to work towards the same goal, which is the patient-centered care. Semantic interoperability is a critical layer ensuring standardization (Katehakis et al., 2018). Different types of data in different forms is shared between users of the health care systems. Semantics ensures there is a uniform way of sharing these types of data. One way of achieving semantics is through having specific data formats to ensure information remains the same through different systems and contexts (Katehakis et al., 2018). A health care system is a critical system that requires consistency and accuracy in different areas including diagnosis, treatment and research. Semantics interoperability allows the above to be achieved. Every system requires and deals with the technical aspect of the system (Katehakis et al., 2018). Technicality varies from creation, implementation, use and even the maintenance aspects of the system. The technical interoperability layer deals with the aspects of connection and implementation of the IT system. The aspects vary from the security of the communication protocols of communication to the specifications of the data exchange (Katehakis et al., 2018). The EIF supports the development of interoperable eHealth systems. The four layers looks to address seamless integration and sharing of patient information ensuring efficiency and quality of healthcare delivery (Katehakis et al., 2018). This framework facilitates quality and quantity of healthcare systems by not only empowering the people but also proving practical solutions to the sharing of health records. It also promotes and works within the very important principals of user-centricity, openness and transparency. It facilitates the availability of information to the people working within the system hence promoting sound and timely decision making regarding the patients improved health outcomes. EIF in its completeness provides some guideline on the building of a secure, integrated, and user-friendly eHealth system (Katehakis et al., 2018).

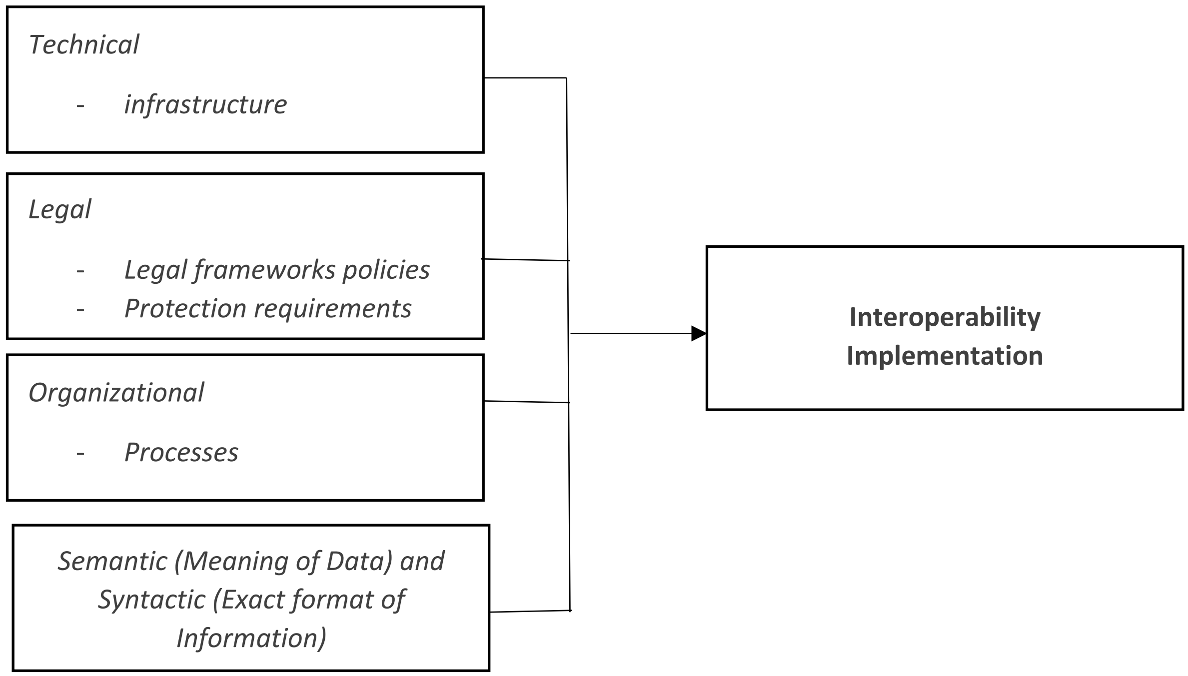


Figure 2.4: The European Interoperability Framework (EIF) (Katehakis, D. et al 2018), (Kouroubali, A., et al 2019).

2.9.2 Social technical systems theory

According to van Lier et al., (2011) interoperability involves the creation of connections between two or many systems in order to facilitate the exchange of information, in order to operate, act or generate more information on the earlier gathered piece of information. The socio- technical systems theory can be used to elaborate on the interoperability challenge. The theory, (Social technical system theory), was first established in London at the Tavistock Institute of Human Relations (Hackman, RJ and Oldham1980). It is widely pinned to the employee involvement and work design. Its popularity can be attributed to the fact that it's applicable universally, hence can be applied and used in any organization subject to reviews and further improvements. Its primary root runs from the idea that organization or work unit composed of both technological and social components. Work systems yield to psychological and social output in addition to physicals yields since the technological and social components need to work together to complete any given task. The most important thing is planning a task so that all components involved provide good results; a process known as joint optimization. The three major levels of interoperability, semantic, technical and organizational layers are important for any system to reach its optimum operations and mold the type of interoperability required. The foundation for sharing information between entities and systems is established once the requirement have been met for each entity and system.

Interoperability is an exercise that requires socio-technical systems theory- based approach. According to the theory, the systems performance is relied to its technological and social components that the system is made up. The system should be designed to optimize the two components simultaneously. Sociotechnical Systems Theory provides a basis for addressing and understanding the complexities of interoperability in the healthcare. It looks at the interplay between technology, social and processes, which are important for the successful implementation of the interoperability. However, STS dose not focus on any given set of layers. Its focus is on the interplay between the technical and social factors complementing the traditional factors. In essence, STS provides a bigger perspective on interoperability by putting emphasis on the organizational and human factors that are often looked at as purely technical factors.

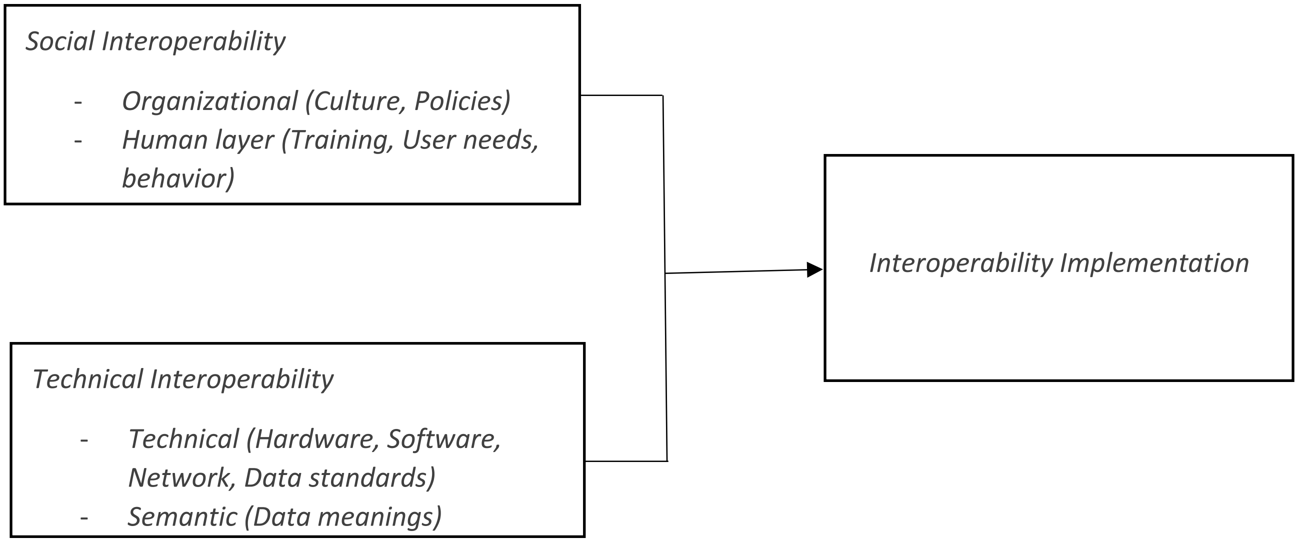


Figure 2.5: Social technical systems theory. Source (author)

2.9.3 Luhmann's Social Systems Theory

Luhmann bases his argument on the principle of a system being self-referential and autonomous in nature. The theory argue that any system is made up of functional elements that function as a functional unit creating relationships amongst themselves as unit relationships to create a system itself. A system should be self-referential enabling it to re-produce itself through new elements that originate from the system. The reproduction originates from the relation of the system with its surrounding environment, which acts as a key factor in the system. The system contains several critical factors that lead to the interaction and operation with other systems around forming "another system" all together. The three major factors considered by Luhmann's theory include function systems, organizations and interactions (Ben van Lier, C. M. C., & Hardjono, Luhmann)

According to Luhmann, every (society is divided into various autopoietic and separated (sub) systems, such as the legal system, the political system, the educational, the scientific or the economic system. These systems have to be merged at the end of the day in one way or another.

The small systems have to not only be linked together but work seamlessly to succeed. However, there may be other subset of the systems that enables the interoperability (Van Lier & Hardjono, 2011).

2.9.4 Lopez and Blobel's Interoperability Framework

Blobel et al came up with an interoperability framework that took a comprehensively approach towards achieving interoperability in the health care system by looking at various layers and dimensions. Their framework looks at ensuring effective data exchange and communication between different health care systems. The framework comprises of five levels including; organizational interoperability, technical interoperability, semantic interoperability, syntactic interoperability and organizational interoperability. Technical interoperability elaborates interoperability at protocol and signal level. It explains how data is exchanged and recorded. For example, ‘010001011’. Structural interoperability explains simplicity in the informational exchange in its correct form. For instance, interpretation of data as string or integer. Syntactic interoperability allows for data exchange that is meaningful using the acceptable informational vocabularies. For example, the height and name of the patient. In semantic interoperability, both communication of applications behavior and agreed upon vocabularies are required. In such an instant, an entry such as “Sarah” used as gender will be labelled as an incorrect (Lopez & Blobel, 2009).

Technical Interoperability – The aspect deals with the software systems and the hardware that enables communication to take place between different IT systems. They range from data formats, network protocols and communication standards.

Syntactic Interoperability all forms of data structure and formats are dealt with in this layer. They have to be consistent in every system to enable seamless communication and interpretation between the systems. There are rules and syntax, standards that are adhered to in all systems such as XML or HL7.

Semantic interoperability it ensures that data meanings are consistent and understood across the systems. The use of common terminologies is implemented to ensure the same. For instance, terms such as SNOMED CT or ICD which are common are implemented across the systems.

Organizational interoperability the alignment of procedures, policies and workflows is ensured to facilitate persistent and consistent exchange of information within different organizations. It encompasses different aspects such as collaboration agreements, business processes and governance (Lopez & Blobel, 2009).

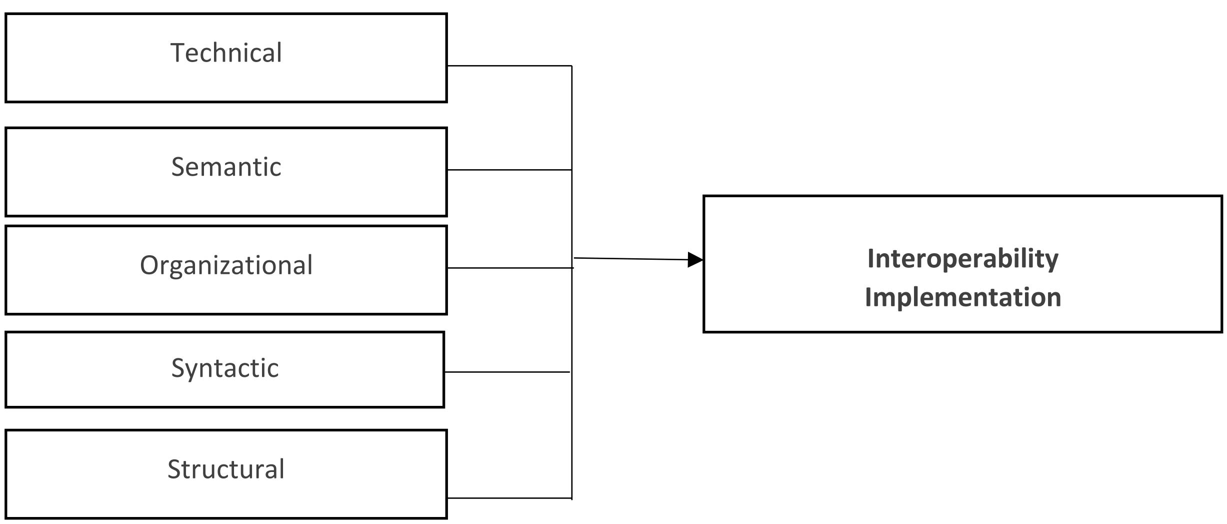


Figure 2.6: Lopez and Blobel's Interoperability Framework.Source(Author)

Table 2.3: Aspects of interoperability influencing adoption of EMR end-to-end implementation

Layers/ constructs	**Variables/concepts**	**Theory/Model/Framework**
Social	Human layer e.g. Training, user needs, behavior,	Social Technical systems Theory Luhmann's Social Systems Theory
Legal	Legal framework policies, protection requirements	European Interoperability framework
Organizational	Processes, policies, culture, environmental interaction	European Interoperability framework Lopez and Blobel's Interoperability Framework Social Technical systems Theory
Technical	Infrastructure such as hardware, software, network	European Interoperability framework Lopez and Blobel's Interoperability Framework Social Technical systems Theory Luhmann's Social Systems Theory
Semantic, Syntactic and structural		Lopez and Blobel's Interoperability Framework European Interoperability framework Luhmann's Social Systems Theory

Table 2. 4 Summary of the theories/Models/ frameworks and their limitations

Theories/ Models/Frameworks	Author	Constructs	Limitations
European Interoperability Framework	Kouroubali & Katehakis, (2019).	Technical Legal Syntactic Semantic Organizational	Does not address social aspects of interoperability
Lopez and Blobel's Interoperability Framework	Diego M. Lopez ∗ , Bernd G.M.E. Blobel	Organizational Technological Syntactic Semantic Structural	Does not address social aspects of interoperability plus legal interoperability
Social technical systems theory		Social Technological	Does not address legal interoperability. Does not address the fundamental aspects of organizational interoperability and categorizes them as social aspects living out important aspects like business processes of the organization
Luhmann's Social Systems Theory	Niklas Luhmann	Social Organizational Technological	Does not address the legal aspects of interoperability

Based on the 4 (theories and frameworks) the researcher developed a model for the study as shown in figure and tabulated in table. The theory can be viewed as an extension of the European Interoperability Framework with an inclusion of social aspects of interoperability, which were lacking, or an extension of Luhmann's social systems theory by including the legal aspect, that is important aspect of sharing private data. The researcher saw an inclusion of social factor as necessary to address its contribution to EMR interoperability end-to-end implementation. The process of ensuring that information systems operate well in the real world is known as social interoperability, and it addresses issues such as an information system's effectiveness efficiency, and other practical considerations. Social interoperability is defined by the Intelligent Information Systems Review (2008) as a human activity engaged in information exchange and comprehending the motive behind the data interchange. Garlapati and Biswas, (2011) revealed that, despite not being prioritized in definitions or information system implementation, social interoperability is crucial. Ignoring social interoperability is akin to ignoring human involvement in communication, which can lead to challenging circumstances. Therefore, while the necessity of social interoperability may vary depending on the place and circumstance, it is essential for the protection of patient care and health data.

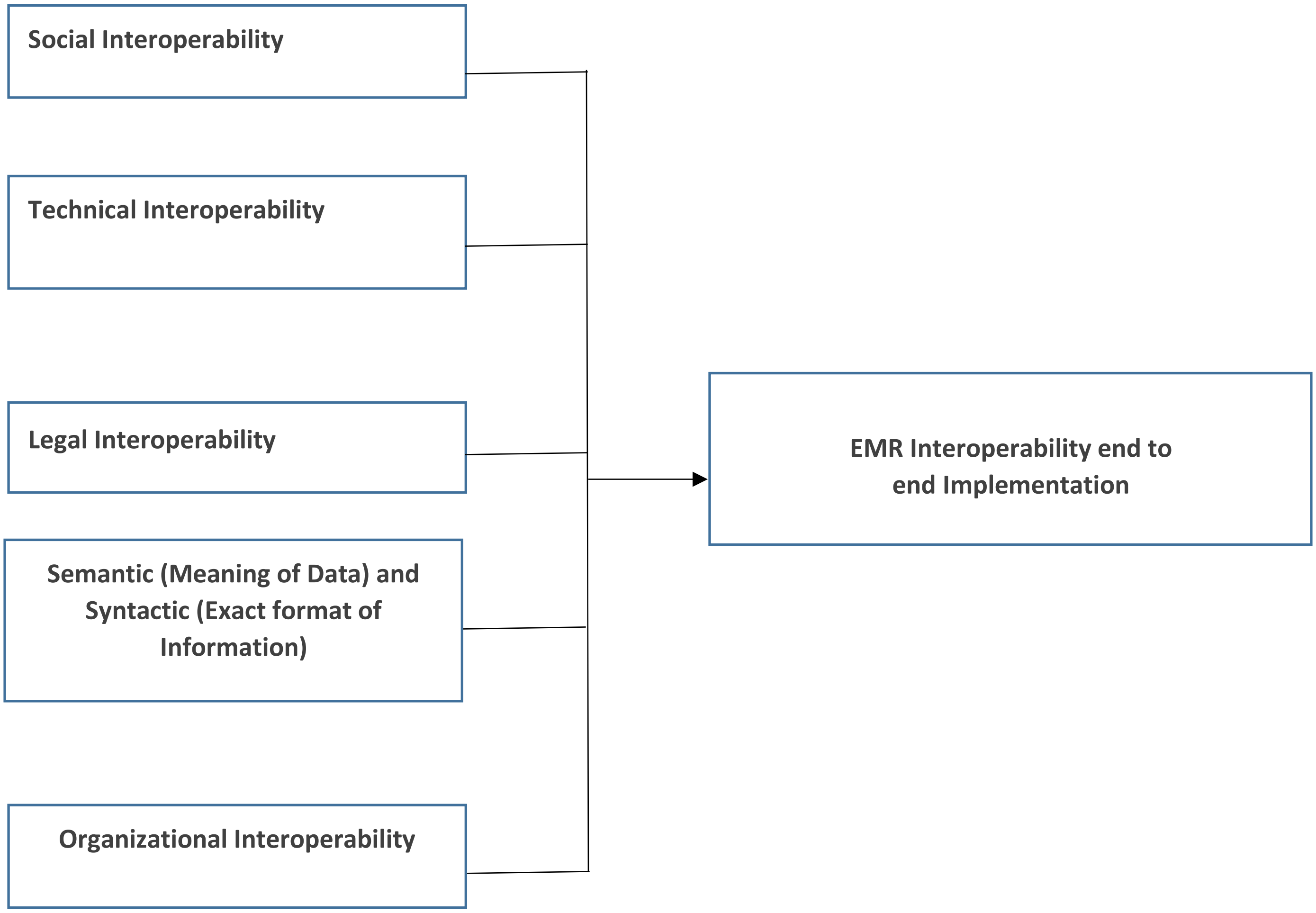
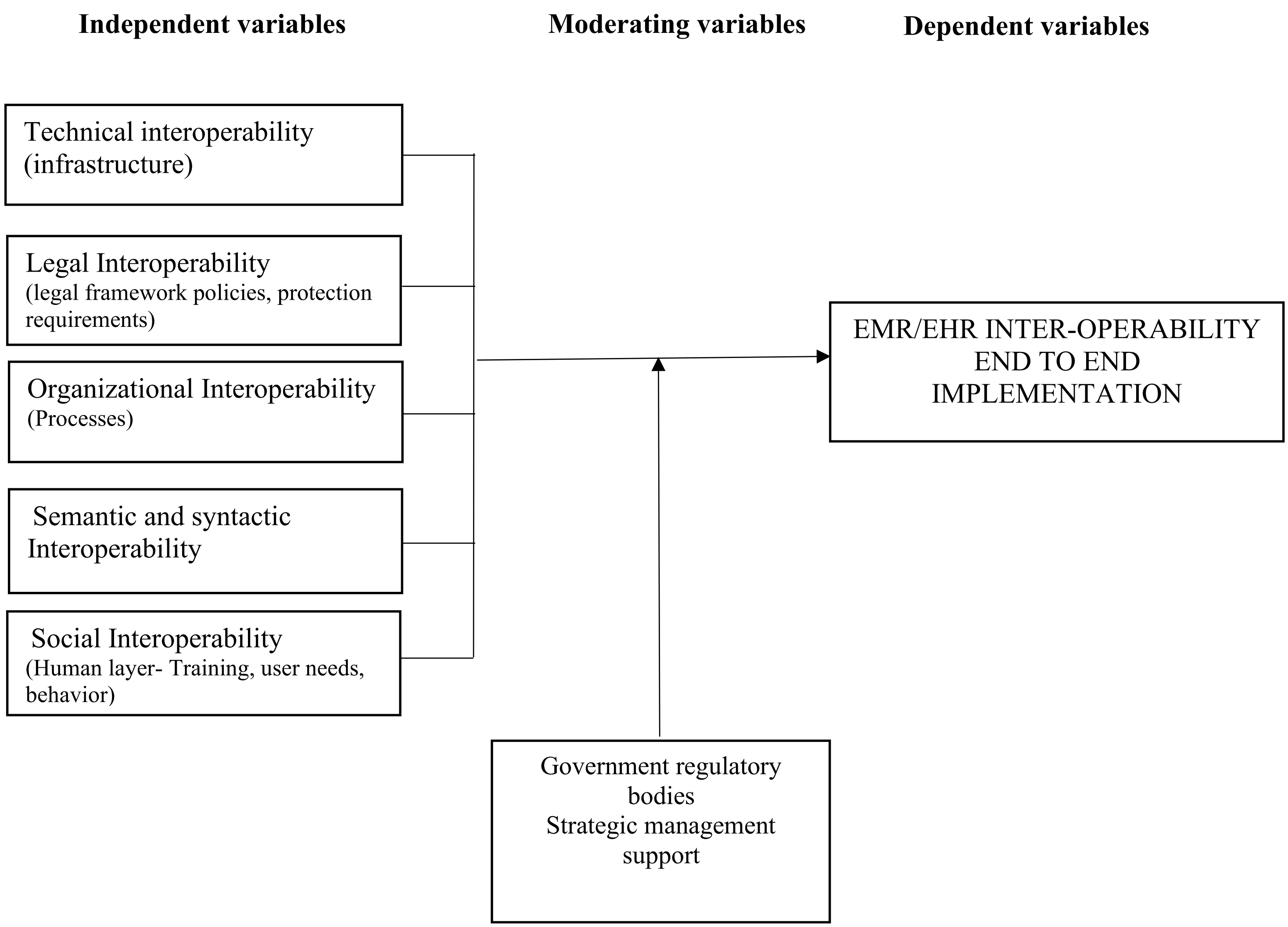


Figure 2.7: Modified Model for interoperability of EMR end to end implementation



2.10 Conceptual Framework

Figure 2.8: Conceptual Framework

According to Miles et al., (1994), A conceptual framework is an analytical tool used to organize and structure ideas, concepts, and theories within a field of study. Conceptual frameworks can be represented visually or in written form and are often developed based on a literature review of existing studies (Miles, Huberman & Saldaña, 1994). The conceptual framework depicted in Figure 2.9.5 served as the study's compass and the foundation for the model that was created at its conclusion. The researcher looked for a means to help explain the intricate interactions between the various factors crucial to the interoperability of EMRs end to end implementation.

The independent variables which are the factors that affect the EMR/EHR interoperability implementation include technical interoperability. This refers to the infrastructure aspects needed for different systems to communicate effectively. Hardware, software, network protocols are considered in this context. Legal interoperability is another factor necessarily for EMR interoperability implementation, it includes legal frameworks, policies, protection requirements that health facilities that support EMR interoperability by ensuring data protection, security and compliance with laws. Organizational interoperability is another factor considered. It involves alignment of organizational processes and structures to support interoperability. This includes workflow integration, process standardization, and change management practices that facilitate the seamless exchange of information between different healthcare facilities. Semantic and Syntactic Interoperability is another independent variable. This factor focuses on the meaningful exchange of information, where "semantic" relates to the meaning of data and "syntactic" pertains to the data's structure. Examples include using standardized medical terminologies like SNOMED CT or LOINC to ensure that data is understood consistently across different systems and facilities. Social Interoperability Emphasizes the human factors and user interactions with interoperable systems. Social interoperability is the ability that provides a support to human work flow in understanding the technical data exchange and semantic consistency. Examples include Training healthcare professionals to use EMR/EHR systems, understanding user behavior, and aligning systems with user needs to improve usability and adoption Moderating Variables Moderating variables are factors that might influence the relationship between independent and dependent variables. They act as catalysts or inhibitors in the process. In this study, Government Regulatory

Bodies and Strategic Management Support are the moderating variables. Government Regulatory Bodies are government agencies that set regulations and standards that can affect EMR interoperability. They can either facilitate or hinder implementation through policy-making and enforcement. Examples are the Data protection commission that enforces data protection act in Kenya. Strategic Management Support refers to backing from top management in an organization, crucial for driving initiatives and securing resources for interoperability projects. Examples include Leadership commitment to digital transformation, investment in technology, and fostering a culture of collaboration. Dependent Variables are the outcomes or effects that are measured to assess the success of EMR/EHR interoperability implementation. EMR/EHR Interoperability end to end Implementation is the dependent variable. The objective is to achieving seamless data exchange and integration across different healthcare systems and providers, resulting in improved patient care, operational efficiency, and healthcare outcomes. Examples include Successful implementation would mean that healthcare providers can access complete patient records across different systems, reducing errors, improving diagnostics, and enhancing patient safety.

By understanding the interplay between these independent, moderating, and dependent variables, stakeholders can better strategize and implement effective solutions to achieve seamless healthcare interoperability.

2.11 Hypothesis

i. H_{01}: There is no significant relationship between technical interoperability and EMR interoperability implementation

ii. H_{a1}: There is a significant relationship between technical interoperability and EMR interoperability implementation.

iii. H_{02}: There is no significant relationship between Legal interoperability and EMR end to end interoperability implementation.

iv. H_{a2}: There is a significant relationship between Legal interoperability and EMR end to end interoperability implementation.

v. H_{03}: There is no significant relationship between Organizational interoperability and EMR end to end interoperability implementation.

vi. H_{a3}: There is a significant relationship between Organizational interoperability and EMR end to end interoperability implementation.

vii. H_{04}: There is no significant relationship between semantic & syntactic interoperability and EMR end to end interoperability implementation.

viii. H_{a4}: There is a significant relationship between semantic & syntactic interoperability and EMR end to end interoperability implementation.

ix. H_{05}: There is no significant relationship between social interoperability and EMR end to end interoperability implementation.

x. H_{a5}: There is a significant relationship between social interoperability and EMR end to end interoperability implementation

CHAPTER THREE

RESEARCH METHODOLOGY

3.0.1 Overview

This chapter discusses the research design in section 3.2; research paradigm in section 3.3 and looks at an in depth exploration view of the philosophical and methodological underpinnings of research in section 3.4, The study further describes the options, choices and influences, the range of approaches and strategies of inquiry and also time horizon, the scientific community's and researcher's worldview, and the methods appropriate to enable and facilitate the research design in answering the research questions based on six layers of Saunders' et al., (2019) research onion as applied through the study. The study further discusses the study population, sample size determination besides data collection instruments, data collection procedures and data analysis strategies.

3.1 Research Design

According to (Churchhill & Gilbert, 1979) research design helps guide how data is collected and analyzed in a study. A research design provides a structured framework that guides researchers in collecting, analyzing and interpretation of information ensuring integration of theoretical concepts with practical methods, minimizing bias and allowing for valid conclusions about relationships between variables (Nachmias & Nachmias, 2008). A research study can be exploratory, descriptive or explanatory. Sometimes these types can mix together depending on what the research aims to find out or the research's stage (Cooper & Schindler, 2006). This study applied Saunders et al research onion in conjunction with Creswell 2012 design which encompasses all exploratory, descriptive and explanatory. The objective of this was to assess the EMR services available, their levels of interoperability and formulate a Model for an interoperable EMR end to end implementation. Th study also addressed both inductive and deductive approaches. This research design involves using existing data from EMR systems to test and evaluate the interoperability model. It allows for more realistic testing conditions but may be subject to confounding variables. This design allows generalization of findings to other EMR systems, as the data used in the study is collected from real-world EMR systems. Data was collected from selected health facilities concerning the current state of EMRs usage especially the medical personnel and IT practitioners.

3.2 Research Philosophy

This is the first layer of the research onion and is considered the most crucial one. According to Levin (1988), research philosophy is considered a belief or an idea about the collection, interpretation, and analysis of data collected. Research philosophy also refers to the development of knowledge in a specific field. Thus, the study adopted this layer to reflect important assumptions, opinion and views as the researcher understood the world; in line with Simpson (2018) assertion which seeks to account for lived experience. This layer therefore influenced the researcher's strategy in relation to the research plan/method adopted for the study.

According to Saunders and Thornhill (2012), a number of philosophies are reflected in this layer of the research onion as they relate to epistemology, ontology, and axiology. Different authors have had diverse opinion on this; some broadly classifying the philosophies as positivism and postpositivism. Another school of thought however classify this philosophy layer into different philosophies; the most significant being positivism, realism, interpretivism, and pragmatism that influence the way in which the researcher thinks about the research process.

Critical realism is a research philosophy that emphasizes the importance of understanding the underlying structures and mechanisms that shape the social world. It recognizes that reality is not simply a matter of objective facts or subjective experience, but rather that social phenomena are complex and multifaceted and can only be understood by exploring the underlying causes and processes that give rise to them.

Interpretivism is the idea that knowledge is socially constructed. This means that the meanings and understandings that individuals have about the world are shaped by their social and cultural contexts. Interpretive researchers seek to understand these social and cultural contexts in order to gain insight into the meanings and values that underlie human behavior. Pragmatism is primarily interested in specific connections between objects and phenomena, particularly those between causes and effects.

This study adopted a pragmatic philosophy which offered an appropriate framework for comprehending the study's quantitative and qualitative components and which also emphases on empirical evidence and scientific methods, this research philosophy was useful for developing an interoperability model for EMR.

3.3 Research Approaches

The study adopted a mixed method approach which include both deductive and inductive

approaches, this is because interoperability in the health sector can better be studied using a variety of research approaches to deeply understand this phenomenon better. The study's main objectives were to evaluate the interoperability of the EMR services that were offered and to provide a model for the end-to-end implementation of an interoperable EMR in a developing nation. An empirical research, or the collection of data led by the theory, was employed after a thorough literature review (secondary data-study) that resulted in the construction of a model (an inductive process of: observation, pattern, tentative hypotheses, and theory). Following testing and validation, these were established (a deductive path of theory, hypotheses). In order to lead the research and create a model that addressed the research questions, a conceptual framework had to be developed.

3.4 Research Strategy and time Horizon

The study employed cross-sectional research strategy involves collecting data at a single point in time and was used to study the current state of interoperability in the health sector in Kenya. This approach was useful for answering questions about the prevalence and distribution of

interoperability, as well as for identifying the barriers and facilitators to its implementation. Cross sectional study was conducted to assess the level of interoperability in different healthcare systems in Kenya such as to identify the factors that contribute to differences in interoperability. The study also surveyed healthcare providers, to gather information on the current state of interoperability, the challenges faced, and the ways in which it can be improved, information that will guide the formulation of Interoperability Model for EMRs in Kenya. The data collected through a cross-sectional study was analyzed using descriptive statistics and correlation analysis to identify patterns and relationships in the data. The results of the study were used to inform the development of best practices and strategies for improving interoperability in the health sector.

3.5 Research Method

Saunders and Thornhill (2018) categorize research methods into mono method quantitative, mono method qualitative, multi method qualitative, multi method quantitative, mixed method simple and mixed method complex. The study adopted mixed methods complex research design which address a complex problem that involves technical, social, and organizational factors. Mixed complex methods research is a research approach that combines both quantitative and qualitative research methods to provide a more comprehensive understanding of complex phenomena. In the context of EMR interoperability, a mixed methods approach can be used to gain a more holistic understanding of the challenges and opportunities involved in achieving seamless data exchange between different EMR systems. A mixed methods approach to studying EMR interoperability could involve several stages. First, a qualitative research method such as interviews, focus groups, or ethnography could be used to explore the experiences and perspectives of different stakeholders, such as healthcare providers, IT specialists, regarding the challenges and benefits of EMR interoperability. This qualitative data can help to identify barriers to data exchange, such as technical incompatibilities, information governance, and cultural factors that may impact the adoption of new technology. Next, a quantitative research method such as surveys, experiments, or secondary data analysis could be used to collect and analyze data on the technical aspects of EMR interoperability, such as the types of standards and protocols used, the level of data quality, and the efficiency and effectiveness of data exchange. This quantitative data can help to provide an objective and reliable measure of the effectiveness of different technical solutions and can identify gaps and opportunities for improvement. Finally, the results of the qualitative and quantitative data can be integrated using a process called data triangulation, which involves comparing, contrasting, and synthesizing the two types of data to gain a more complete and nuanced understanding of the research question. This integration can help to validate and explain the results of the individual data sources, and can provide a more robust and generalizable conclusion.

3.6 Identification of study sites

The inclusion criteria was determined as follows: must be a public or private health care institution having implemented EMRs. The study applied purposive method to determine the study sites. 3 healthcare facilities were conveniently selected. The study area and facilities were selected because the healthcare facilities have adopted and use EMR systems in their major operations thus providing a ready source of data for testing and evaluating the interoperability model. The healthcare facilities within this region can be generalized or mapped to the broader healthcare facilities in Kenya. The researcher was compelled to take 2 regions because of the cross- sectional design of the time horizon. Primarily a number of healthcare facilities both public and private have implemented EMR funded by donor partners or for private facilities having self-initiatives.

3.7 Target Population

According to Parahoo (2006), a population includes all the groups or items that are part of a study. Hair et al., (2007) defines the target population as all individuals relevant to the study who share similar traits. While it's ideal to gather from everyone in the population, this is often impractical because the population is usually too large. Instead, a smaller representative is chosen. For this study the population was drawn purposively from ~~various backgrounds notably~~ medical personnel, ICT practitioners and medical health record practitioners and health facilities administrators.

3.8 Sampling Procedures and Sample size

Selecting a sample size is very important in a study. Kothari (2004) notes that the sample should be unbiased and large enough to satisfy the needs of the research. It is impossible to survey the entire population of a particular study because of limited resources and time. Therefore, it is necessary to survey a representative sample of the population as an alternative in order to formulate predictions about the entire population.

3.8.1 Sample size

This study used Yamane's formula to determine the sample size for the study. The desired level of accuracy was set to a confidence level of 95% and an absolute precision (relative margin of error) of 5%. The population proportion was set conservatively to 0.05 (Yamane, 1967). The sampling frames to be used for the research were three healthcare facilities from the Nandi and Uasin Gishu Counties. Respondents (Medical personnel, ICT practitioners, medical health practitioners and administrators) were broadly stratified into the three facilities. Hence sample frames mentioned above helped to make the data collected more reliable and accurate.

$$n = \frac{N}{1 + Ne^2}$$

Where: n = sample size to be studied

N = Total population

e = Margin of error (0.05)

Facility A

$$n = \frac{131}{1 + 131(0.05)^2}$$

=98.6

Facility B

$$n = \frac{71}{1 + 71(0.05)^2}$$

=60.3

Facility C

$$n = \frac{27}{1 + 27(0.05)^2}$$

=25.29

3.8.2 Sampling Procedure

The study used three stage sampling methods. Stage one involved determination of selection criteria. This was followed by purposive sampling of three healthcare facilities meeting the set criteria. Stratified simple random sampling was then used to determine the respondents as summarized below.

Table 3. 1: Sample size of participants in the study (Source: Author)

Facility	Population	Sample
Facility A	131	99
Facility B	71	60
Facility C	27	25
Total	**228**	**184**

3.9 Questionnaire Development Process for Data Collection

The quantitative questionnaire comprised of three sections; Section “A”, captured demographic data while Section “B” consisted of several Likert-scale-type questions aimed at collecting information about EMR systems availability and their capability to communicate vertically and horizontally with other EMRs across the county facilities (interoperability). Section “C” captured the questions which sought to unveil the contents of the theoretical framework as they impact on EMR Interoperability model innovation. For the purpose of questionnaire development, the researcher adopted Churchill and Iacobucci, 1979 approach that comprises nine steps to develop the research questionnaire.

3.10 Pilot study

Research instruments were piloted at a facility which was not part of the ones included in the survey and also met the inclusion criteria. 15 respondents were selected for pilot testing. This helped to check whether there were any ambiguities in the research instruments.

3.11 Validity and reliability of the Instruments

Content validity of the research instruments was done to ascertain that such instruments gathers the information the study purports to collect. Content validity is the extent to which an instrument covers a sufficient sample of the topics it is meant to cover, free from errors, imbalances, or omissions. (Streiner, Norman & Cairney, 2015). According to Gay (2005), content validity is determined by expert judgment. It is not necessary for an instrument to encompass every aspect of a notion, though, as this would make it too huge. Therefore, a representative sample of domains and potential problems pertaining to the idea of interest must be included in the instrument (Alarcon & Muñoz, 2008)

Therefore, the researcher relied on the expert advice from supervisors and other members of the Faculty of Information Technology at Masinde Muliro University of Science and Technology, ICT experts, medical personnel and health record experts. Below is the table showing results from expert assessment of the questionnaire ranked on a scale of 1-5 where 1 is poor and 5 is excellent. With an average of 4.2 the instrument was deemed fit.

Table 3. 2: Results from Expert Assessment

Expert	Clarity	Content Validity	Relevance	Comprehensiveness	AVERAGE
ICT EXPERT 1	4	3	5	5	4.25
ICT EXPERT 2	3	4	5	5	4.25
MEDICAL EXPERT	5	5	4	5	4.75
MEDICAL EXPERT	5	5	4	4	4.5
HEALTH RECORDS EXPERT1	4	5	5	4	4.5
HEALTH RECORDS EXPERT 2	3	4	4	3	3.5
SUPERVISOR 1	4	4	3	4	3.75
SUPERVISOR 2	4	4	4	5	4.25
AVERAGE	**4**	**4.25**	**4.25**	**4.375**	**4.21875**

Reliability of measurements concerns the degree to which a particular measuring procedure gives similar results over a number of repeated trials. Reliability is an important aspect of any measuring instrument, as it ensures that the results obtained from the instrument can be trusted and used to make important decisions. In fields such as medical fields the reliability of instruments can have a significant impact on patient care, product development, and scientific discoveries. There are different ways of measuring reliability, such as test-retest, alternate form, and inter-rater reliability. They are used to determine the consistency of the measuring instrument over time, across different forms of the same instrument, or when different raters are using the same instrument. The researcher used piloting and Cronbach's alpha a statistical test to test for reliability.

3.12 Data collection Procedures

The researcher got approval letter from the school of post graduate studies which was used to seek permit from NACOSTI that gave the researcher the authorization to go to the field meet the selected respondents in various facilities. Two Research assistants who were trained so as to understand the research context assisted in data collection and for ease and convenience and to the researcher, Zoom was used for interviews.

3.13 Data Analysis Methods and Presentation

After collection, data was cleaned and verified using SPSS version 27 including inspecting data to identify any mistakes or any other wrongly answered or un responses to items. Data was coded, cleaned and verified. Data analysis entailed descriptive and inferential statistics besides manual thematic analysis of the qualitative data. This involved relating the various variable being tested based on the adopted Model used to advance this study. This was done with the aid of Statistical Package for Social Sciences (SPSS) version 27.

3.14 Ethical Consideration

Adhering to ethical norms is of essence in any research work. Research is a multidisciplinary involving different people, as such, great care should be taken to prevent any one being negatively affected by the research work (Saunders, Lewis & Thornhill, 2007). It is an ethical responsibility of the researcher to protect the confidentiality of the information and identity of all participants in the research activities (Saunders et al., 2007). In this study therefore, consent was sought first from an Ethics committee and from all participants before they were involved, they were fully informed of the purpose of the study, the confidentiality of the information provided and their anonymity were assured. The questionnaire had a cover letter attached guaranteeing the participants anonymity and confidentiality. The participants were allowed to voluntarily participate acknowledging their rights to withdraw from the process also participants were assured that data collected was used for the intended study and not for anything else.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0.1Overview

This chapter outlines the results and discussion from the statistical analysis and interpretation of both quantitative and qualitative data. The findings, along with their analysis and interpretation, are aligned with the study's objectives. Data analysis was conducted using both descriptive and inferential methods, with results presented in tables. The analysis utilized SPSS software version 27. The discussion of the results includes graphical and tabular formats to enhance readability and comprehension.

4.1 Reliability and validity tests

Table 4.1: Cronbach's Alpha Coefficients

Variable	Cronbach's Alpha Reliability
EMR services available, their utilization and level of integration	0.710
EMR systems state of interoperability	0.706
Strategies used by successful implementers to address interoperability challenges	0.734
Average	**0.717**

Table 4.1 presents the Cronbach's Alpha coefficient for the dataset. The findings indicated that every variable analyzed had a Cronbach's Alpha value exceeding 0.7, meeting the necessary threshold for internal consistency. The construct validity and reliability of the alphas used in the study were considered to be adequately acceptable (Schrepp, 2020). The questionnaire demonstrated the capability to produce consistent results across identical or similar tests administered to the same individuals in equivalent conditions. This reliability was assessed using Cronbach's Alpha coefficient, which measures internal consistency by evaluating how closely

related a set of items are as a group. Essentially, it is a coefficient of reliability (or consistency), and a high alpha value indicates that the items effectively measure the main constructs (Sürücü & Maslakci, 2020). Cronbach's alpha is influenced by the number of test items and the average inter-item correlation. The alpha coefficient should range between 0.50 and 0.90, with higher scores indicating greater reliability of the scale (Sürücü & Maslakci, 2020).

4.2 Response Rate

Table 4.2: Response Rate

Response Rate					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Completed	180	97.8	97.8	97.8
	No response	4	2.2	2.2	100.0
	Total	**184**	**100.0**	**100.0**	

Table 4.2 presents a summary of the questionnaire response rate. A total of 184 individuals participated in the study. Out of the 184 questionnaires distributed to the selected respondents, 180 were completed and returned. A total of 180 questionnaires were properly completed and included in the analysis for this study, yielding a 97.8% response rate. This rate falls within the range considered to represent a large sample size (Meyer, Benjamens, El Moumni, Lange & Pol, 2022).

4.3 Demographic information

The study sought to gather general details about the respondents, including their gender, age, professional specialty, years of experience, years of using the EMR system, name of the health facility, category of the health facility, level of the facility, and the duration of EMR services. While not all of this background information was essential for the study, it provided context for the findings and facilitated appropriate approval in line with the study's objectives. The primary purpose of this section was to understand the background information.

Table 4.1: Background Information

Background Information	Frequency	Percentage
Gender of Respondents		
Male	87	48.3%
Female	93	51.7%
Age of Respondents		
Below 25 years	54	30.2%
26-35 years	57	31.8%
36-45 years	46	25.7%
46-55 years	13	7.3%
Above 55 years	9	5.0%
Personnel Specialty		
Medical personnel	152	84.4%
ICT practitioner	10	5.6%
Medical health record practitioner	6	3.3%
Administrator	12	6.7%
Years of experience		
Less than 1 year	36	20.0%
1-4 years	58	32.2%
5-8 years	55	30.6%
9-12 year	16	8.9%
Above 12 years	15	8.3%
Years of using EMR system		
Less than 1 year	49	27.5%
1-2 years	34	19.1%
3-4 years	43	24.2%
5-6 years	33	18.5%
Above 8 years	19	10.7%
Name of Facility		
Facility A	98	54.4%
Facility B	57	31.7%
Facility C	25	13.9%
Category of the health facility		
Public	155	86.1%
Private	25	13.9%
Level of the Facility		
Level 1	0	0.0%
Level 2	0	0.0%
Level 3	0	0.0%
Level 4	57	31.7%
Level 5	123	68.3%

How long has EMR service been operation at this facility		
≤4 years	180	100%
5 years	0	0.0%
6 years	0	0.0%
7 years	0	0.0%
Above 7 years	0	0.0%

4.3.1 Gender

According to figure 4.1 below, there were 93 (51.7%) female and 87 (48.3%) male. The findings indicate that there were more female respondents than the male respondents. It was important to note that both male and female participated in this study. This is because including both genders in this study was essential for producing accurate, reliable, and applicable results that benefit the entire population. It enhances the quality of this study and ensured that the findings are inclusive and equitable.

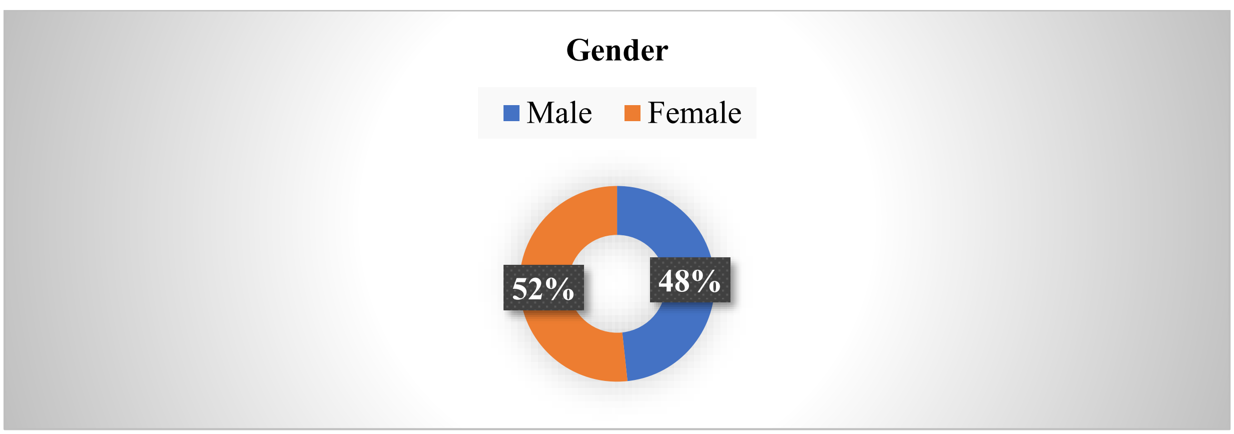


Figure 4.1: Gender of Respondents

4.3.2 Age of respondents

As a background information, age was used by the researcher to categorize the respondents into five groups. Respondents who were aged below 25 years, 26-35 years, 36-45 years, 46-55 years and above 55 years. In this study, majority of the respondents 57 (31.8%) were aged between 26-35 years, those who were below 25 years were 54 (30.2%), 46 (25.7%) of the respondents were aged between 36-45 years, 13 (7.3%) of the respondents were aged between 46-55 years with only 9 (5.0%) of the respondents who were above 55 years of age. The majority of the respondents who participated in this study are young people. This implies that this young population are tech survey which will help the healthcare facilities to design better services and foster technological advancements that are well-aligned with the needs and behaviors of younger generations.

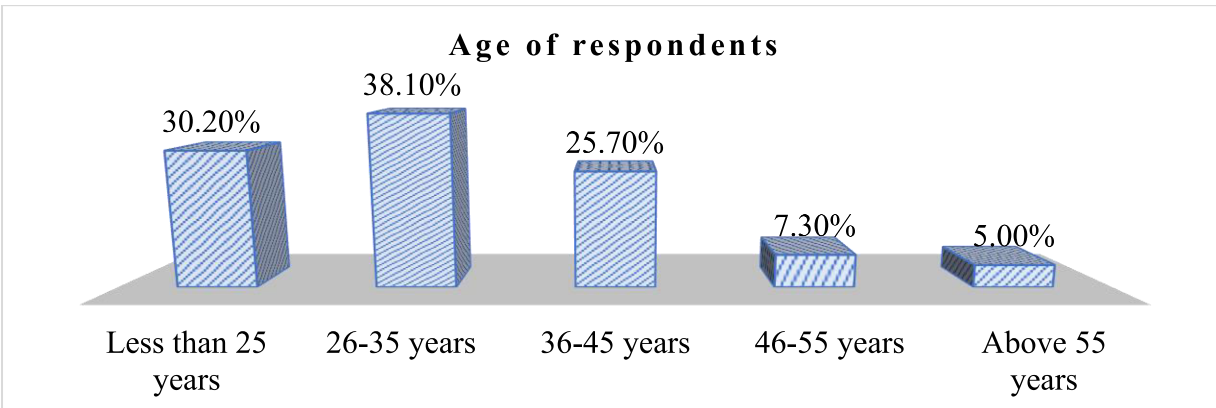


Figure 4.2: Age of Respondents

4.3.3 Personnel Specialization

From figure 4.3 below, majority of the respondents 152 (84.4%) were medical personnel (nurses, doctors, pharmacist's lab technicians), 12(6.7%) were administrators, 10(5.6%) were ICT practitioners and 6(3.3%) were medical health record practitioners. This shows a more cohesive, efficient, and high-quality healthcare delivery system where each group brings its expertise to ensure the system functions optimally, benefiting patients and healthcare providers alike.

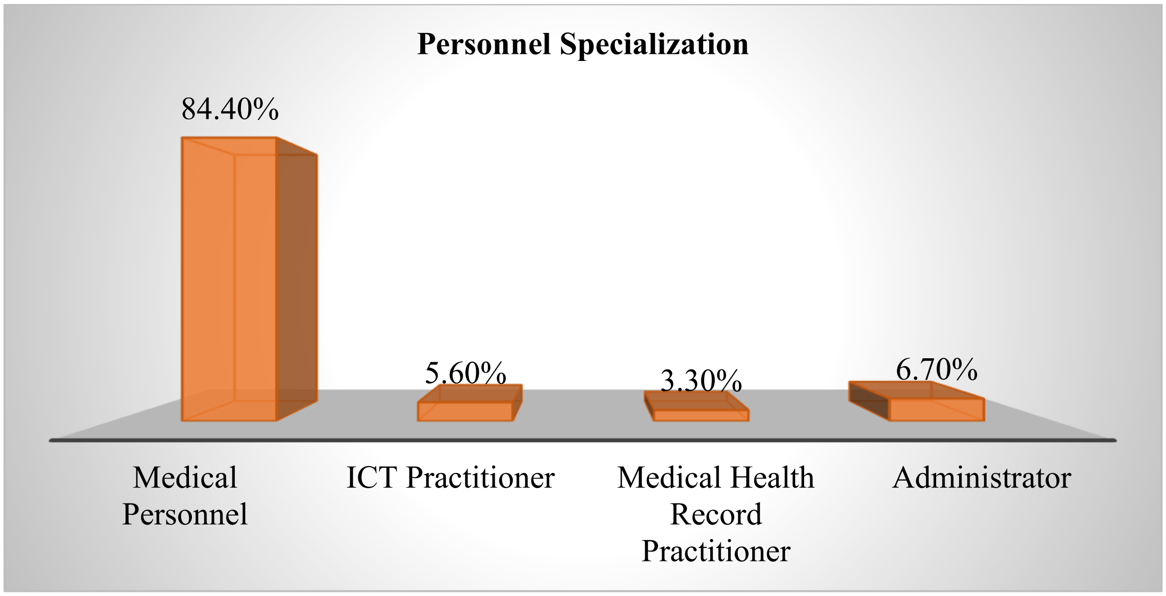


Figure 4.3: Personnel Specialization

4.3.4 Years of Experience

The study sought to know the years of experience of the respondents. As indicated in figure 4.4 below, majority of the respondents 58 (32.2%) had 1-4 years of experience, 55 (30.6%) had 5-8 years of experience, 36 (20.0%) of the respondents had less than 1 year of experience, 16 (8.9%) had 9-12 years of experience and 15 (8.3%) had more than 12 years of experience. This is an indication that majority of the respondents had more than 1 years of experience. Hence, understanding the years of experience of respondents of this study enriched the analysis, making the findings more robust, nuanced, and actionable.

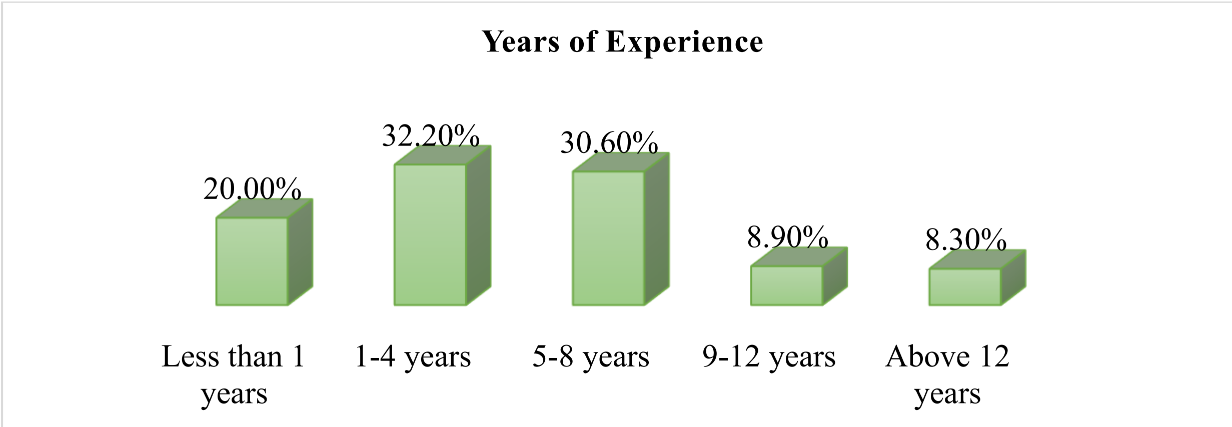


Figure 4.4: Years of Experience

4.3.5 Years of Using EMR System

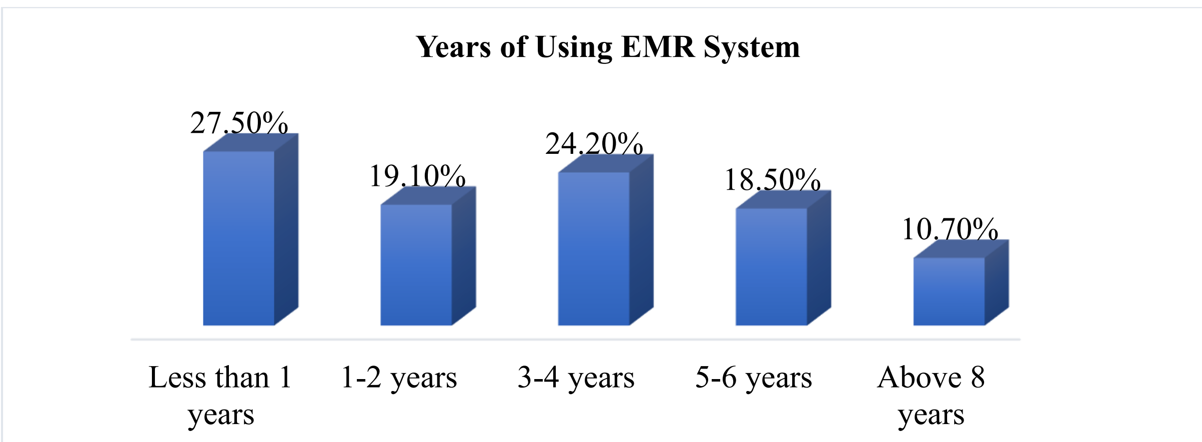


Figure 4.5: Years of Using EMR System

Based on the findings in figure 4.5, majority of the respondents 49 (27.5%) indicated that they have been using EMR system in less than 1 year, 43 (24.2%) indicated that they have been using EMR system for 3-4 years, 34 (19.1%) of the respondents indicated that they have been using EMR system for 1-2 years, 33 (18.5%) indicated that they have been using EMR system for 5-6 years and only 19 (10.7%) of the respondents indicated that they have been using EMR system for more than 8 years. The above findings indicate that majority of the respondents had less than 1-year experience on using EMR. However, the findings still show that respondents in this study had experience using EMR system. This ensured that the study gathered information from knowledgeable sources, which points to more precise and actionable conclusions regarding EMR systems.

4.3.6 Name of the Facility

The study sought to identify the healthcare facility to help in understanding the background of the respondents. For confidentiality the facilities were labelled A, B and C. As indicated in figure 4.6 below, majority of the respondents 98(54.4%) were of Facility A, 57(31.7%) of the respondents were from Facility B and 25(13.9%) of the respondents were from Facility C.

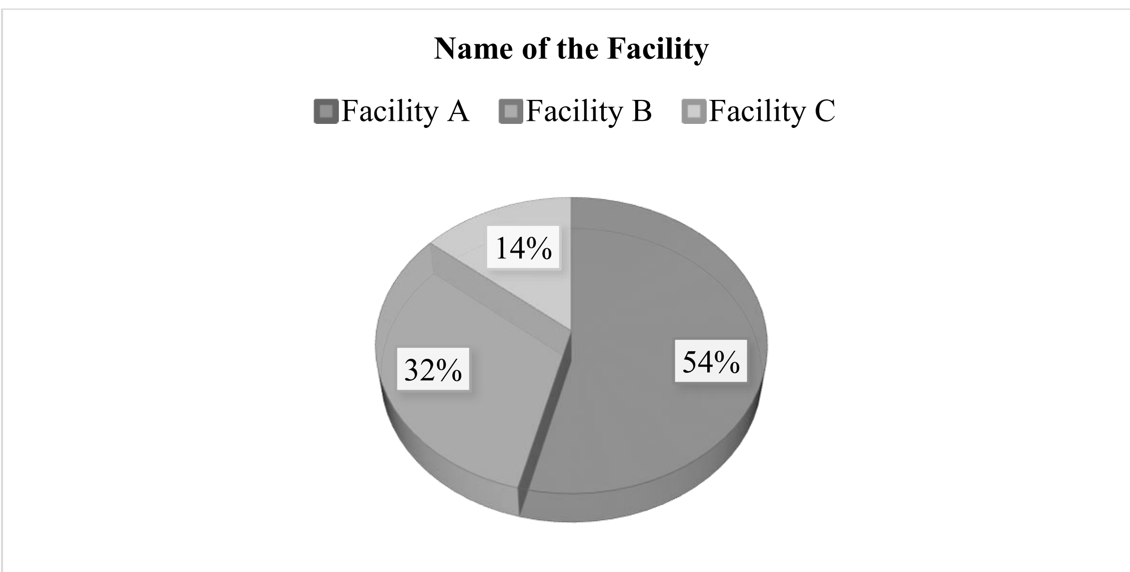


Figure 4.6: Name of Health Facility

4.3.7 Category of the Health Facility

According to figure 4.7, 155(86.1%) of the respondents were from the public health facility with only 25(13.9%) of the respondents from private health facility. Obtaining data from respondents from both public and private health facilities implies that the findings on EMR system were holistic. This approach supports evidence-based decision-making and contributes to improving healthcare quality and accessibility for all patients.

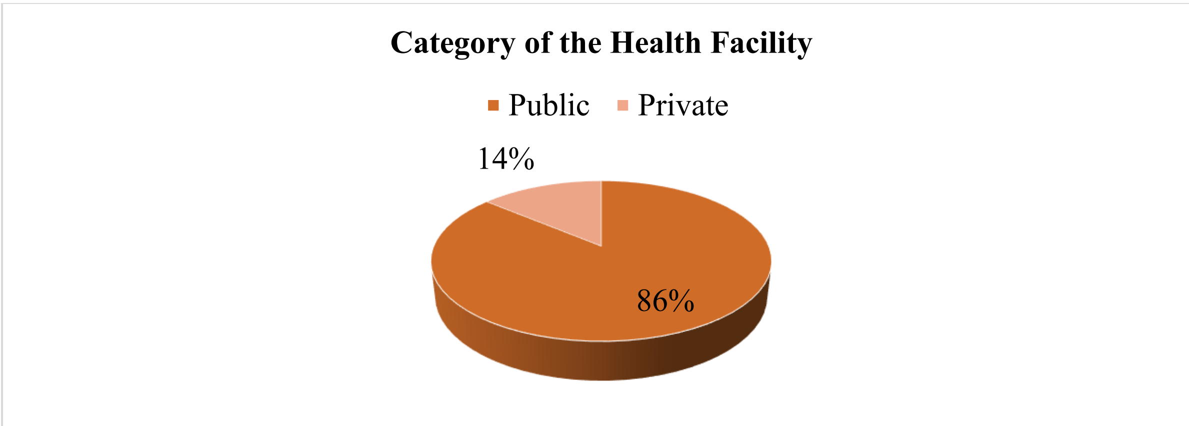


Figure 4.7: Category of Health Facility

4.3.8 Level of Health Facility

Based on the system of health care in Kenya, respondents of this study were categorized in 5 levels. As indicated in figure 4.8, 123(68.3%) of the respondents were level 5 healthcare facility, 57 (31.7%) were from level 4. This also gave the study a holistic view of the healthcare system. This comprehensive approach leads to more informed decisions and improvements in healthcare delivery and outcomes.

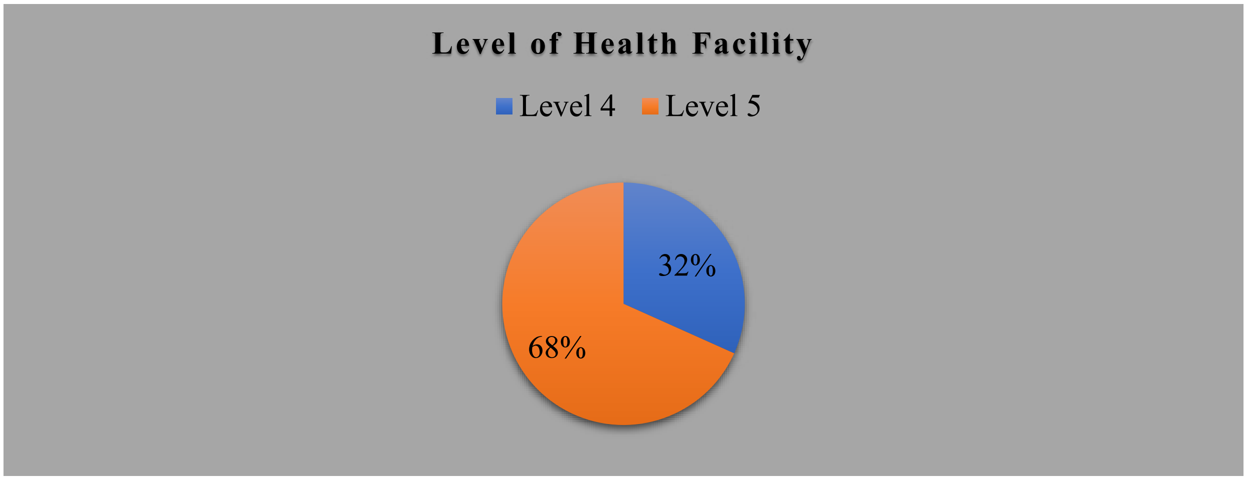


Figure 4.8: Level of Health Facility

4.3.9 Duration of EMR Service Operation at the Facility

To wrap up the background information in this study, the researcher focused to identify the duration of EMR service operations in the respective healthcare facilities. From figure 4.9 below, all the respondents 100(100%) of the respondents indicated that EMR services have been operating for ≤ 4 years. These findings signify that there is a deliberate commitment to leveraging technology to enhance healthcare delivery, improve operational efficiency, and ultimately provide better care for their patients.

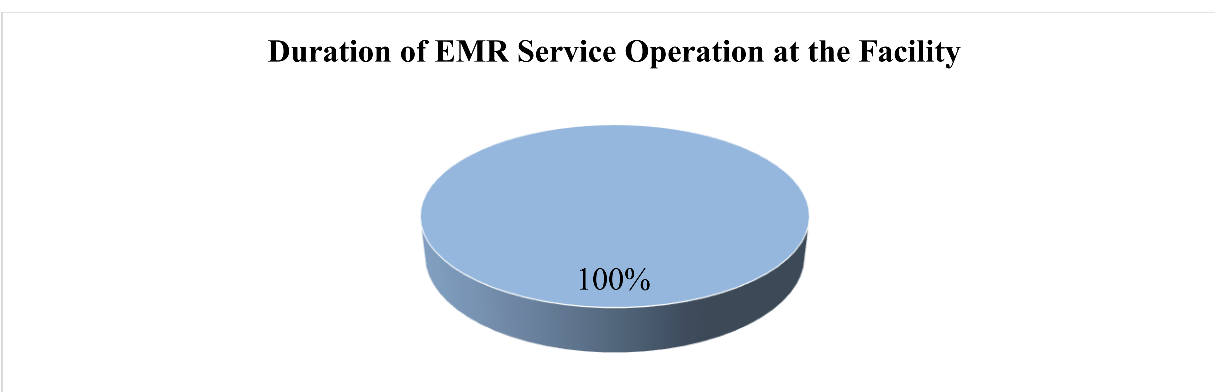


Figure 4.9: Duration of EMR Service Operations at this Facility

4.4 Descriptive statistics on the EMR services available, their utilization and level of integration in the Health sector

The study sought to establish EMR services available, their utilization and level of integration in the Health sector. Respondents were asked to indicate their level of agreement on a scale of 1 to 5 with 1 representing strongly disagree, 2 representing disagree, 3 representing not sure, 4 representing agree and 5 representing strongly agree. The mean scale (level of integration) was interpreted in a range of 1-5 where 1.00-1.49 represented strongly disagree (no integration), 1.502.49 represented disagree (low integration), 2.50-3.49 represented not sure (medium integration), 3.50-4.49 represented agree (high integration) and 4.50-5.00 represented strongly agree (very high integration).

As shown in table 4, respondents agreed that EMR services are fully utilized in the facility, utilization of EMR service contribute significantly to improving healthcare delivery and patient outcome and the system offers an end to end coverage of all the service delivery points with means of 4.36, 4.24, 4.05 and a standard deviation of 0.740, 0.776 and 0.752 respectively. Respondents were not sure that EMR system is able to provide real time imaging, statistical outputs or visualizations, the features/functionalities of EMR services offered to healthcare providers are sufficient, patients interact with EMR service to schedule for appointment and EMR system sufficiently covers all administrative tasks within the facility including staff schedules, leaves and rosters with means of 3.97, 3.94, 3.77, 3.64 and standard deviations of 0.825, 0.842, 1.046 and 1.142 respectively.

The study established that the EMR services available were fully utilized to improve healthcare delivery through end to end coverage of all the service delivery. The finding of this study in one way does not agree with the statement by Safi et al., (2018) that utilization of EMRs in the healthcare space, continues to lag. On the other hand, the findings of this study agree with the statement of Safi et al., (2018) that utilization of EMRs in the healthcare space continues to lag since respondents were not sure of service provision of EMR system, sufficiency of features and services of the EMR system.

On average, the study yielded a mean of 4.00 and a standard deviation of 0.875 which is a low standard deviation indicating that the response tends to be very close to the mean. This means that there is high integration of the EMR services at the healthcare facilities (4.50-5.00 high integration). Therefore, this implies that there is an enhancement in the quality of care, operational efficiency, communication, data management, compliance, and financial performance, ultimately leading to better health outcomes and patient satisfaction. The findings of this study are consistence with the findings of Akanbi et al. (2012; Haskew et al. (2015); Oluoch et al. (2014) who all established the implementation of EMR services in Western Kenya. This points to a comprehensive and seamless connection of various medical and administrative systems within the hospital.

Table 4. 4: EMR service available, their utilization and level of integration

Descriptive Statistics			
Questions on EMR services available, their utilization and level of integration in the Health sector	**N**	**Mean**	**Std. Deviation**
EMR services are fully utilized in the facility	178	4.36	.740
Utilization of EMR service contribute significantly to improving healthcare delivery and patient outcome	178	4.24	.776
The system offers an end to end coverage of all the service delivery points	177	4.05	.752
EMR system is able to provide real time imaging, statistical outputs or visualizations	180	3.97	.825
The features/functionalities of EMR services offered to healthcare providers are sufficient	175	3.94	.842
Patients interact with EMR service to schedule for appointment	178	3.77	1.046
EMR system sufficiently covers all administrative tasks within the facility including staff schedules, leaves and rosters	180	3.64	1.142
Average	**178**	**4.00**	**0.875**

4.5 Descriptive statistics on the various EMR systems state of interoperability

The study sought to determine the various EMR systems state of interoperability. Respondents were asked to indicate their level of agreement on a scale of 1 to 5 with 1 representing strongly disagree, 2 representing disagree, 3 representing not sure, 4 representing agree and 5 representing strongly agree. The mean scale (interoperability) was interpreted in a range of 1-5 where 1.00-1.49 represented strongly disagree (low interoperability), 1.50-2.49 represented disagree (minor interoperability), 2.50-3.49 represented not sure (moderate interoperability), 3.50-4.49 represented agree (major interoperability) and 4.50-5.00 represented strongly agree (extreme interoperability). From table 5 below, respondents agreed that their facilities have different EMR systems and they are able to communicate with each other, or the EMR systems available are able to communicate end to end throughout all service delivery points, the facilities have in the past encountered challenges and barriers in achieving interoperability between EMR system and other healthcare systems, they have encountered instances where the lack of interoperability between EMR systems has resulted in adverse events or delays in patient care and they have observed notable improvements in the facility's healthcare delivery/patient outcomes as a result of achieving interoperability in the facility's EMR systems with means of 4.11, 4.08, 4.02 and standard deviations of 0.945, 0.766, 0.927 and 0.811 respectively. Respondents were not sure that the effect of interoperability between EMR systems on workflow efficiency and productivity within the facility is over all good and the facility's EMR systems are capable of exchanging data with other EMR systems within and without an indication of interoperability with means of 3.99, 3.85 and standard deviations of 0.896 and 0.939.

This study has therefore established that while the existing EMR systems are able to communicate, the facility encounter challenges and barriers in achieving interoperability between EMR systems and other healthcare systems. In addition, the healthcare facilities experience notable improvements in the healthcare delivery. The findings of this study demonstrate that the EMR is crucial for improving patient care, reducing costs, and enhancing operational efficiency.

On average, the study produced a mean of 4.02 and a standard deviation of 0.88 which was a low standard deviation indicating that the individual scores were closer to the mean. This means that there is a major interoperability of EMR systems in the health care facilities (3.50-4.49 major interoperability). This implies that the existing interoperability of EMR systems in the health care facilities ensures that patient information can be shared across different systems and institutions in a secure, efficient, and effective manner. This leads to better patient care, reduced costs, enhanced data security, and improved overall healthcare outcomes.

Table 4. 5: EMR systems state of interoperability

Descriptive Statistics			
Questions on EMR systems state of interoperability	**N**	**Mean**	**Std. Deviation**
My facility has different EMR systems and they are able to communicate with each other, or the EMR system available is able to communicate end to end throughout all service delivery points.	179	4.11	.945
The facility has in the past encountered challenges and barriers in achieving interoperability between EMR system and other healthcare systems	178	4.08	.766
I have encountered instances where the lack of interoperability between EMR systems has resulted in adverse events or delays in patient care	180	4.08	.927
I have observed notable improvements in the facility's healthcare delivery/patient outcomes as a result of achieving interoperability in the facility's EMR systems	179	4.02	.811
The effect of interoperability between EMR systems on workflow efficiency and productivity within the facility is over all good	178	3.99	.896
The facility's EMR system is capable of exchanging data with other EMR systems within and without an indication of interoperability	176	3.85	.939
Average	**178**	**4.02**	**0.880**

4.6 Descriptive statistics on strategies that have been used by successful implementers to address interoperability challenges

The study sought to determine the strategies that have been used by successful implementer to address interoperability challenges. Respondents were asked to indicate their level of agreement on a scale of 1 to 5 with 1 representing strongly disagree, 2 representing disagree, 3 representing not sure, 4 representing agree and 5 representing strongly agree.

Respondents agreed that their organizations are aware of common data standards that make it easier for different EHR systems to communicate with each other and the facility's personnel are informed about the latest development and advancements in EMR interoperability standards and practices with means 4.24, 4.12 and standard of deviations of 0.877 and 0.830. Respondents were not sure that the hospital put in place security measures for sharing patient's data/information, their organizations are capacity building the already existing workforce to handle the sharing of data/information through different levels of training, government has created regulation that mandate interoperability thus providing a framework for organizations to follow when sharing data, there is trust and cooperation between healthcare organizations, which has made it easy to agree on standards and protocols for sharing data and their organization has invested in the right technology like middleware application programming interface (APIs), and cloud computing to enable interoperability with means of 3.98, 3.97, 3.95, 3.93, 3.88 and standard deviations of 0.877, 0.830, 0.941, 0.883, 0.760, 0.756 and 0.958 respectively.

The study therefore, established that there is awareness of common data standards and latest development and advancements in EMR system as a strategy used by successful implementer to address interoperability challenges. However, the respondents were not sure of security measures, capacity building, government regulation, trust, cooperation and investment in technology as strategies used by successful implementer to address interoperability challenges. Since this study acknowledge challenges on interoperability of EMS system in health care facilities, awareness of data standards and latest developments alone cannot address the challenges. To address these challenges, the healthcare facilities need to develop and implement strategies such as adopting standardized protocols, investing in middleware solutions, fostering collaboration between different stakeholders, and continually monitoring and updating their interoperability frameworks.

In addition, the study sought to find out challenges to the utilization and integration of EMR services in the healthcare facilities. The respondents were asked to state if they have challenges with integration of EMR services or not. Figure 4 represents their responses.

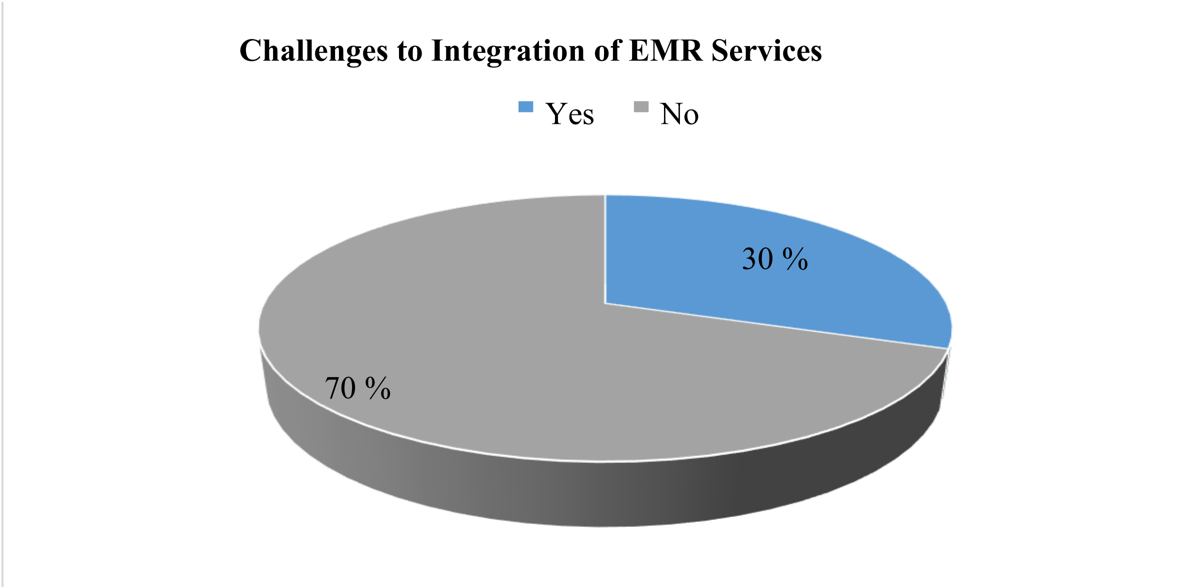


Figure 4.10: Challenges to Integration of EMR Services

As indicated in figure 4.10 above, opinion of majority of the respondents (70%) was that there are no other challenges to the utilization and integration of EMR services in their healthcare facilities.

However, 30% of the respondents did indicate that there are other challenges to the utilization and integration of EMR services in their healthcare facilities.

For the respondents who indicated there are other challenges to the utilization and integration of EMR services, they were asked to give explanation. From table 8 below, respondents indicated that other challenges to the utilization and integration of EMR services in healthcare facilities are; Communication between the systems, functioning service delivery points, data capturing, efficiency, updating computer systems, machine failure, personnel training, internet connection, system breakdown, modernization of equipment, knowledge and awareness, delayed patient care, network coverage, resource allocation, skilled personnel, identity, confidentiality, data request and maintenance of computers.

Therefore, overcoming these challenges requires careful planning, robust solutions, effective training, and ongoing support to ensure successful EMR integration and to fully realize its benefits.

Table 4.6: Reasons for the Challenges to utilization and Integration of EMR Services

If yes give reasons					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Systems are not able to communicate with each other	2	1.1	4.2	4.2
	Service delivery points are not fully functional	2	1.1	4.2	8.3
	Inadequate capturing of data	1	.6	2.1	10.4
	Poor efficiency	4	2.2	8.3	18.8
	Outdated computer systems	1	.6	2.1	20.8
	Failure of machines	1	.6	2.1	22.9
	Needs provisional training to the personnel	3	1.7	6.3	29.2
	Internet connection and system breakdown	1	.6	2.1	31.3
	Inadequate modern equipment	3	1.7	6.3	37.5
	Lack of knowledge and awareness	3	1.7	6.3	43.8
	Delayed patient care	1	.6	2.1	45.8
	Inadequate network coverage	16	8.9	33.3	79.2
	Lack of resource allocation	1	.6	2.1	81.3
	Lack of skilled personnel	6	3.3	12.5	93.8
	Checks on identity and confidentiality	1	.6	2.1	95.8
	Difference in data request from partners	1	.6	2.1	97.9
	Poor maintenance of computers	1	.6	2.1	100.0
	Total	48	26.7	100.0	
Missing	System	132	73.3		
Total		180	100.0		

4.7 Exploratory Factorial Analysis

To assess the dataset's suitability for Exploratory Factor Analysis (EFA), the study examined the Kaiser-Meyer-Olkin Measure (KMO) for Sampling Adequacy (Table 4.7), with a threshold of above 0.50. The KMO measure from this table is 0.789, exceeding the 0.5 cutoff, and was therefore deemed acceptable. Table 4.7 represent the results of the EFA that was run.

Table 4. 7: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.789
Bartlett's Test of Sphericity	Approx. Chi-Square	326.036
	df	15
	Sig.	.000

The researcher also examined Bartlett's Test of Sphericity (Table 9; significance level of p=0.000 which was < .05) to verify that the variables had patterned relationships, assessing the strength of their interrelationships. This test evaluates the null hypothesis that the correlation matrix is an identity matrix, which is rejected if the significance value is less than 0.05. According to the same table, Bartlett's Test of Sphericity is significant (0.000), indicating a significance level below 0.05, sufficient to reject the null hypothesis. This implies that the correlation matrix is not an identity matrix. In this study, the tests indicated patterned relationships among the variables (p < .000).

4.7.2 Communalities

The Communalities table 10 presents the initial communalities before rotation. This table indicates the amount of variance each variable share with all other variables, with a communality value greater than 0.4 being the threshold for inclusion in further analysis. Variables with communalities below this threshold were excluded from subsequent steps in the factor analysis. As shown in table 4.45, all initial communalities are above 0.40, which is favorable.

Table 4. 8: Communalities

Communalities		
	Initial	**Extraction**
Technical Interoperability	1.000	.713
Social Interoperability	1.000	.614
Organizational Interoperability	1.000	.697
Semantic Interoperability	1.000	.363
Legal Interoperability	1.000	.467
Extraction Method: Principal Component Analysis.		

4.7.3 Total variance explained, Factor Extraction and Rotation

The Total Variance Explained table (Table 4.9) helps identify the significant factors. It's crucial to note that only the extracted and rotated values are meaningful for interpretation. After determining the number of factors, the next step is to rotate, which allows for the elimination of poor factors and variables that load on more than one factor.

The eigenvalue represents the number of factors extracted, with their total equaling the number of items analyzed in the factor analysis. The eigenvalue table is divided into three parts: Initial Eigenvalues, Extracted Sums of Squared Loadings, and Rotation Sums of Squared Loadings. Table 4.9, "Total Variance Explained," illustrates the distribution of variance among the potential factors.

Based on Table 4.9, one factor has an eigenvalue (a measure of explained variance) greater than 1.0, which is a common threshold for determining the usefulness of a factor. An eigenvalue less than 1.0 indicates that the factor explains less variance than a single item would, making it insufficient to retain. Typically, if not specified otherwise, the computer would attempt to find the best factor solution by "rotating" the factors. For this analysis, only the Extracted Sums of Squared Loadings were considered. It is important to note that the cumulative factor accounts for 53.036%

of the variance. All other factors are not significant, indicating that only one factor has been extracted and it accounts for a substantial portion of the variability.

Table 4. 9: Total Variance Explained

Total Variance Explained						
	In tial Eigenvalues			on Sums of Sc Loadings		
Component	Total	% of Variance %	Cumulative %	Total	% of Variance	Cumulative %
1	3.182	53.036	53.036	3.182	53.036	53.036
2	.936	15.593	68.630			
3	.681	11.345	79.975			
4	.541	9.022	88.997			
5	.389	6.487	95.485			
6	.271	4.515	100.000			

Extraction Method: Principal Component Analysis.

4.7.4 Rotation Sums of Squared Loadings

In Exploratory Factor Analysis (EFA), the goal was to identify underlying factors that explain the patterns of correlations. The extraction of factors was to be followed by a rotation to make the solution more interpretable. When only one factor is extracted, it means that the correlations among the variables can be adequately explained by a single underlying factor. This often happens when the data is highly unidimensional, meaning that there is one dominant factor that explains most of the variance in the observed variables. Only one factor was extracted and therefore, the solution could not be rotated.

Inferential statistics

4.8 Relationship between technical, legal, organizational, social, semantic and syntactic interoperability and EMR end to end interoperability

When examining the significant relationship between technical interoperability, social interoperability, legal interoperability, organizational interoperability, semantic and syntactic interoperability and EMR end to end interoperability implementation, Pearson's correlation was used to determine the degree of the relationship. The range of the correlation was determined from -1 to +1. Where a negative value was an indication of a negative correlation but a positive value was an indication of a positive correlation. The coefficient being < 0.3 indicates weak correlation, > 0.3 <0.5 shows moderate correlation and > 0.5 indicates strong correlation.

Table 4. 10: Correlation

Correlations

		Technical Interoperability	Social Interoperability	Organizational Interoperability	Semantic Interoperability	Legal Interoperability	EMR end to end interoperability implementation
Technical Interoperability	Pearson Correlation	1	.524**	.634**	.415**	.489**	.524**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	168	163	166	165	167	166
Social Interoperability	Pearson Correlation	.524**	1	.639**	.357**	.464**	.360**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	163	171	168	168	170	169
Organizational Interoperability	Pearson Correlation	.634**	.639**	1	.495**	.440**	.734**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	166	168	174	170	173	172
Semantic Interoperability	Pearson Correlation	.415**	.357**	.495**	1	.300**	.680
	Sig. (2-tailed)	.000	.000	.000		.000	.258
	N	165	168	170	176	172	174

Legal Interoperability	Pearson Correlation	.489**	.464**	.440**	.300**	1	.243**
	Sig. (2-tailed)	.000	.000	.000	.000		.001
	N	167	170	173	172	176	174
EMR end to end interoperability implementation	Pearson Correlation	.524**	.360**	.334**	.086	.243**	1
	Sig. (2-tailed)	.000	.000	.000	.258	.001	
	N	166	169	172	174	174	178

**. Correlation is significant at the 0.01 level (2-tailed).

As indicated in table 4.10 above, there was a significant, positive and strong correlation between EMR end to end interoperability implementation with technical interoperability, organizational interoperability and semantic interoperability with a p values of 0.000 and correlation coefficient of 0.622, 0.723 and 0.680 respectively. There was a significant, positive and moderate correlation between social interoperability and EMR end to end interoperability implementation with p value of 0.000 and a correlation coefficient of 0.475. There was a significant, positive and weak correlation between legal interoperability and EMR end to end interoperability implementation with p value of 0.001 and a correlation coefficient of 0.243.

The statistical findings indicate a significant relationship between EMR end to end interoperability implementation and various dimensions of interoperability: technical, social, organizational, and semantic. Technical interoperability, which involves the compatibility of systems and technologies, is enhanced as organizations adopt common standards and protocols, facilitating seamless communication and data exchange. Social interoperability is vital for creating a more collaborative, innovative, and inclusive organization. Organizational interoperability is strengthened as entities harmonize their processes, structures, and goals, leading to better coordination and resource sharing. Semantic interoperability, which ensures consistent interpretation of exchanged information, is achieved through the adoption of standardized data models and vocabularies. The legal interoperability ensures that legal frameworks are aligned, reducing barriers, enhancing collaboration, and supporting innovation, which collectively contribute to the overall effectiveness and sustainability of interoperability initiatives. Overall, the implementation of interoperability measures across these dimensions results in more efficient, effective, and cohesive collaboration among systems and organizations.

4.8.1 Regression Analysis Assumption Tests

Before performing regression analysis, several statistical assumptions need to be satisfied. In this study, the following tests were carried out and are presented as follows: Linearity, Homoscedasticity Test, Shapiro-Wilk Test of Normality, and Multi-Collinearity Test.

4.8.1.1 Homogeneity Test

When homogeneity appears in residual plots, it is crucial to identify whether it is pure or impure, as different solutions are required for each (Tyagi, Rane & Manry, 2022) Ignoring homogeneity can invalidate statistical tests of significance, such as regression analysis, and increase the risk of incorrect conclusions. In this study, the Levene statistic was used to test the null hypothesis that the variance of the dependent variable is equal across all levels of the independent variables. The findings are shown in Table 4.11.

Table 4. 11: Homogeneity Test

Test of Homogeneity of Variances				
	Levene Statistic	df1	df2	Sig.
Technical Interoperability	1.940	2	162	.147
Social Interoperability	.420	2	165	.657
Organizational Interoperability	.266	2	168	.767
Semantic Interoperability	1.072	2	170	.345
Legal Interoperability	1.843	2	170	.161

The Levene statistic in Table 4.11 indicates significance if p<0.05, leading to the rejection of the null hypothesis. According to Table 10, since all p values are above 0.05, we accept the null hypothesis and conclude that the variances of the dependent variable are consistent across different levels of the explanatory variables. This means the assumption of homogeneity of variance was met.

4.8.1.2 Normality Test

The Shapiro-Wilk test was used in this study to assess normality at a 95% confidence level. If the p-value is less than 0.05, the null hypothesis is rejected, indicating that the data does not follow a normal distribution. Conversely, if the p-value is greater than 0.05, the null hypothesis is accepted, suggesting that the data is normally distributed. The study results showed a p-value of 0.000, indicating that the data is not from anormally distributed population. These findings are presented in Table 4.12 below.

Table 4. 12: Test of Normality

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	df	Sig.
EMR end to end interoperability implementation.	.277	179	.000	.787	179	.000
a. Lilliefors Significance Correction						

4.8.1.3 Multicollinearity Test

A multicollinearity test was conducted in the study to assess whether the variables were highly correlated, indicating that one variable could be predicted linearly from another with high accuracy. The results are presented in Table 4.13. A Variance Inflation Factor (VIF) value between 1 and 10 suggests no multicollinearity, whereas a VIF value below 1 or above 10 indicates the presence of multicollinearity.

Table 4. 13: Multicollinearity

Coefficients[a]							
		Correlations			Collinearity Statistics	
Model		Zero-order	Partial	Part	Tolerance	VIF
1	Technical Interoperability	.535	.440	.401	.515	1.941
	Social Interoperability	.371	.172	.143	.551	1.815
	Organizational Interoperability	.344	-.005	-.004	.439	2.279
	Semantic Interoperability	.101	-.178	-.148	.733	1.364
	Legal Interoperability	.232	-.089	-.073	.672	1.489

a. Dependent Variable: EMR end to end interoperability implementation

As indicated in Table 4.13, the VIF values of 1.941, 1.815, 2.279, 1.364 and 1.489 suggests that there were no issues with multicollinearity in the study.

4.8.2 Regression Analysis

When examining the significant relationship between Legal Interoperability, Semantic Interoperability, Social Interoperability, Technical Interoperability, Organizational Interoperability and EMR end to end interoperability implementation, linear regression was used to predict the value of interoperability implementation. The results are shown in table 4.14.

Table 4. 14: Model Summary

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.841[a]	.708	.698	1.29670

a. Predictors: (Constant), Legal Interoperability, Semantic Interoperability, Social Interoperability, Technical Interoperability, Organizational Interoperability
b. Dependent Variable: EMR end to end interoperability implementation

The above table 4.14 gives the R and R^2 values. The R value is a representation of the simple correlation and is 0.841 from the "R" column indicating a high degree of correlation. The value of R^2 obtained from the "R Square column" is an indication of how much of the total variation in the dependent variable, EMR end to end interoperability implementation, can be explained by the independent variables, technical interoperability, social interoperability, organizational interoperability and semantic interoperability. For the case of this study, 70.8% can be explained, which is high.

Table 4. 15: ANOVA Table

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	615.064	5	123.013	73.159	.000[b]
	Residual	253.897	151	1.681		
	Total	868.961	156			

a. Dependent Variable: EMR end to end interoperability implementation
b. Predictors: (Constant), Legal Interoperability, Semantic Interoperability, Social Interoperability, Technical Interoperability, Organizational Interoperability

Table 4.15 above is the ANOVA table, which reports the sensitivity/significance of the overall model and how well the regression equation fits the data . This table indicates that the regression model is significant and predicts the dependent variable significantly well ($p< 0.000$) which is less than 0.05, and indicates that, overall, the regression model statistically significantly predicts interoperability implementation.

Table 4. 16: Coefficients

Coefficients[a]					
	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	T	Sig.
1 (Constant)	4.105	.880		4.666	.000
Technical Interoperability	.181	.065	.169	2.776	.006
Social Interoperability	.088	.072	.074	1.234	.009
Organizational Interoperability	.461	.071	.439	6.527	.000
Semantic Interoperability	.957	.126	.391	7.572	.000
Legal Interoperability	.231	.128	.097	1.811	.002

a. Dependent Variable: EMR end to end interoperability implementation

Table 4.16 gives the prediction of interoperability implementation from technical interoperability, social interoperability, organizational interoperability, semantic interoperability, legal interoperability as well as determine whether they contribute statistically significantly to the model by looking at the "Sig." column. The values in the "B" column under the "Unstandardized Coefficients" column, are used to form the model of the study as shown below:

4.8.2.1 Model/Regression equation:

From table 4.16 the significant predictors contributing to the model are Technical Interoperability Social Interoperability, Organizational Interoperability, Semantic Interoperability, Legal Interoperability, with p values of 0.006, 0.009, 0.000, 0.000 and 0.002 which are below 0.05. therefore, the regression model is given as shown below:

$Y=\beta 0+\beta 1+ \beta 2+ \beta 3+ \beta 4+ \beta 5+\epsilon$

EMR end to end interoperability implementation=4.105(Constant)+0.181(Technical Interoperability) +0.088(Social Interoperability) +0.461(Organizational Interoperability) +0.957(Semantic Interoperability) +0.231(Legal Interoperability) + ϵ

This means that a unit change in technical interoperability will increase EMR end to end interoperability implementation by 0.181. A unit change in social interoperability will increase EMR end to end interoperability implementation by 0.088. A unit change in organizational interoperability will increase EMR end to end interoperability implementation by 0.461. A unit change in semantic interoperability will increase EMR end to end interoperability implementation by 0.957. A unit change in legal interoperability will increase EMR end to end interoperability implementation by 0.231.

4.8.3 Model for Electronic Medical Records End to End Implementation

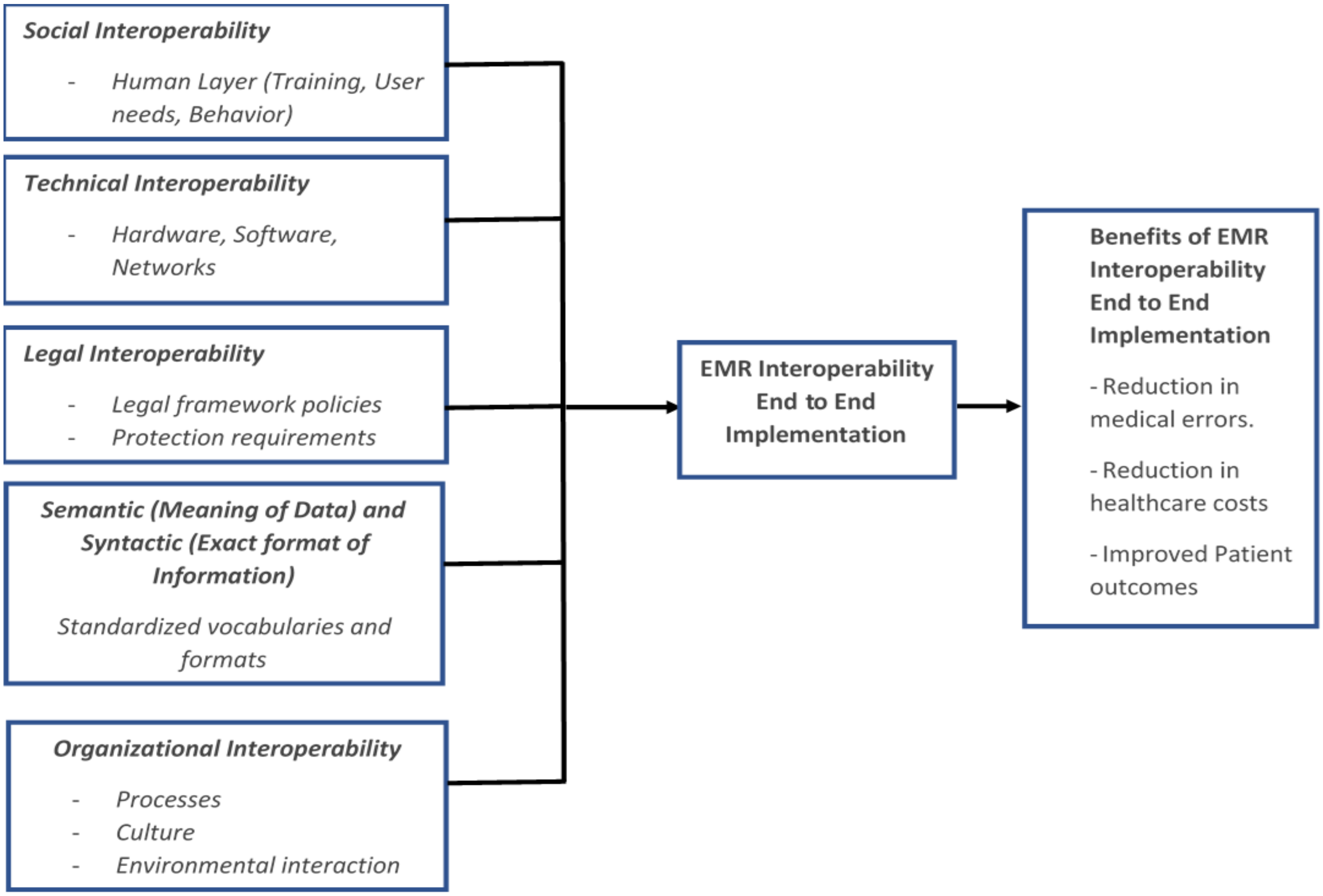


Figure 4.11 Model for Electronic Medical Records End to End Implementation

The Model shown below has been developed as a modification of the European Interoperability Framework (EIF). The study assessed other frameworks and theories that have been used before developing the modified all-inclusive model for Electronic medical records end to end implementation. The foundation for this Model was created by empirical data that was statistically collected based on the research objectives and backed by a literature assessment. This data indicated the gaps in the existing frameworks and theories.

The quantitative data that was gathered, examined, and backed by secondary data was current for the Model development process. The qualitative data was gathered to confirm the quantitative data.

Model variables

There are five variables that lead to the Electronic Medical Records End to End Implementation. Social interoperability, Technical interoperability, organizational interoperability, legal interoperability, and semantic and syntactic interoperability. They are explained below.

Social interoperability is the interoperability that covers the human aspects. It involves the users' activities of Using EMRs in exchange of information and clear understanding of the requirements and motivations in the data interchange. Social interoperability focuses mainly on the communication between the users and EMR systems. Understanding user needs and behavior as they interact with EMRs, user training can enhance social interoperability. Social interoperability is regarded as a mechanism to understand the relationship between the other variables.

Technical Interoperability is about the technologies (Hardware, software) and networks used to communicate among those applications. Technical interoperability ensures that various Electronic Medical Record (EMR) systems, medical devices, and other health IT solutions can share and interpret data without errors or loss of information. It forms the foundation for higher levels of interoperability, such as semantic and organizational interoperability. Technical interoperability ensures interaction between the devices and the user.

Legal interoperability refers to the ability of different EMR systems, healthcare facilities to share and use data across various platforms while complying with legal frameworks, policies and data protection requirements. This concept is critical in ensuring that patient information can be exchanged securely, accurately, and efficiently, all while adhering to the laws governing healthcare data.

Semantic interoperability refers to both the semantic and syntactic aspects of data. Semantic interoperability focuses on the meaning of data, how two or more tools share information and make use of that information and involves the development and use of standardized vocabularies and formats so that the meaning of exchanged data and information is well understood by the different parties. Syntactic interoperability requires describing the exact format of the information to be exchanged. This level of interoperability ensures that when data is transferred between systems, the receiving system can understand and use the information in the same way as the sending system, regardless of the underlying technology or data format.

Organizational interoperability refers to the ability of different health facilities to share and utilize information. It involves aligning processes, governance structures and consideration of cultures and environmental interactions to ensure different facilities can collaborate seamlessly. Business processes need to be thoroughly documented and the relevant reengineering needs to take place in order to achieve integration and alignment to enable relevant information exchange.

EMR interoperability end to end implementation refers to the whole process of setting up EMR systems to ensure that different EMR systems can seamlessly exchange interprete and use patient data to improve patient outcome.

The benefits of EMR interoperability end to end implementation include reduction in medical errors, reduction in healthcare costs, improved patient outcomes, increased efficiency among others.

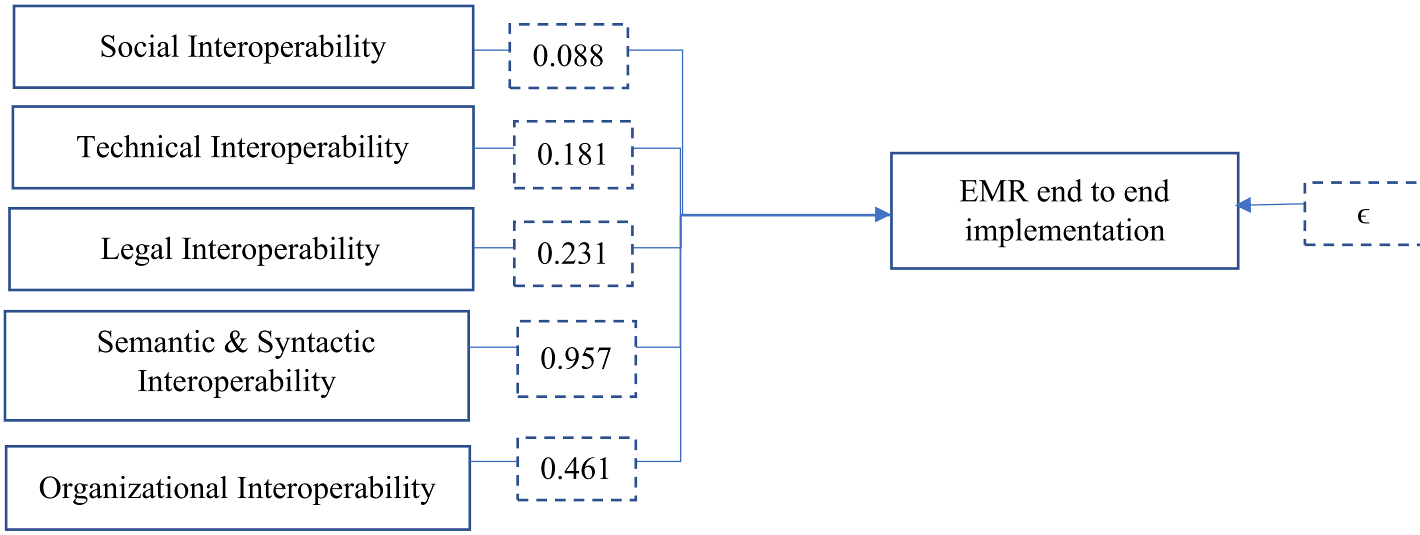


Figure 4.12: Model incorporating the variables

4.8.4 Confirmatory Factor Analysis

Confirmatory factor analysis was done to evaluate the factors influencing implementation of EMR Interoperability. The researcher hypothesized five latent factors: Technical Interoperability, Social Interoperability, Organizational Interoperability, Legal Interoperability and Semantic Interoperability.

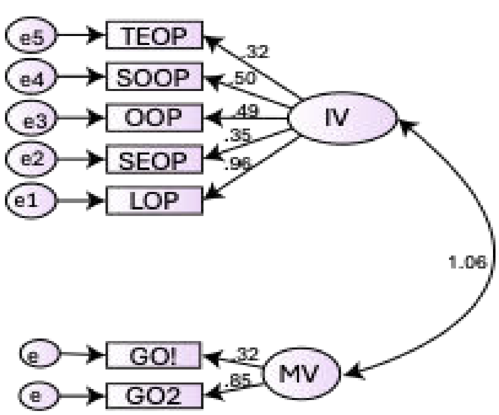


Figure 4.13: Confirmatory Factor Analysis

The model fit indices suggest an acceptable fit with a significance value for the default model 0.000 showing significance with a CMIN/DF ratio of 12.816, indicating a reasonable fit relative to the degree of freedom. The Comparative Fit Index (CFI) and Normed Fit Index (NFI) were 0.727 and 0.718, respectively, both indicating a strong model fit. Additionally, the Root Mean Square Error of approximation (RMSEA) was 0. 254 with a 90% confidence interval of 0. 220 to 0.289, and a PCLOSE value of 0.000, suggesting that the model fits well in terms of error approximation. Overall, these indices support the validity of the five latent factors in explaining the underlying factors that influence EMR interoperability implementation.

4.9 Findings from Quantitative Data

The study interviewed ICT managers and administrators on availability of EMR services, their utilization and level of integration in the Health sector. Manager two explained that;

> *"There is active facility wide EMR systems such as Clinical Care Classification System and MEDBOX. These systems work across the various service delivery points such as registration, cashier and to the wards. However, because of data protection from every facility and also the Data Protection Act of Kenya, the hospital is not able to do referrals or access patient data from other facilities."*

Manager 1 and 3 indicated that they understand what interoperability is. Manager 2 went ahead to explain that;

> *"Its components are foundational, structural, semantic, and organizational. He added that he understands the impacts on how the systems work".*

The interview established that the organizations would like to exchange data and specified the form of interaction required. Manager 3 stated that;

"There isn't intra facility data exchange and it is because it's very minimal as data is private."

Manager 2 indicated that;

"There is inter facility data exchange where hospitals can share relevant information to different departments through different systems that have been linked together".

All the managers agreed that the facilities do referrals where necessary within government hospital at the request of the patient and case at hand and data exchanged is purely approved by patient or next of kin. However, manager 2 stated that;

"Other healthcare facilities do not exchange patient data unless there is given permission from the patient that if it is intra facility".

The interview established that there are standards that guide interoperability in the facilities. Despite this positive response, manager 3 indicated that;

"Private facilities do not have interoperability standards because they focus on ISO certification".

The manager went ahead to explain that consent must be sought from the patient or next of kin there after data is shared. Manager 1 and 2 stated that

"Data is shared in form of Excel sheets, XML-based clinical document architecture and SQL database".

Manager 2 noted that;

"As data is shared, the facilities consider the following data security measures; firewall,

encryption of passwords, user accounts for users within the institution for data security".

The interview established that automation and trickle down or leaf type architecture are and good internet connectivity are favored in the facilities. Manager 4 stated that;

"In meeting the interoperability needs, the hospital use computers, switches, routers, ethernet cables, lab machines integrated to EMR".

The interview schedule also addressed the security issues and manager 4 stated that;

"To address security issues, the hospitals use antiviruses, encryption, passwords, unique log in prompt codes and firewall".

The interview schedule established that there are collaboration related factors that influence interoperability adoption. Manager 3 listed;

"Changes in technology, staff training, cost, availability of fast internet, technical infrastructure, cost and financial allocation as the factors".

The interview also established that there are challenges preventing the facilities from acquiring information from other hospitals with different EMR systems. Manager 1 stated that;

"Patient data protection, Data Protection Act of Kenya, privacy of patient and privacy of hospital data are some of the challenges that prevent the hospital from acquiring information from other hospitals with different EMR systems".

Lastly, the interview schedule established that the facilities have initiatives or collaborations aimed at enhancing interoperability between EMR systems. Despite the established initiatives, managers also noted that the initiatives are focused on inter facility not intra facility. Manager 3 stated that;

"Training of personnel, improving of internet speeds, installation of adequate and efficient systems and hardware, financial allocation and uniting departments are some of the major factors that will help to promote the implementation of interoperability of EMRs in the healthcare facilities".

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0.1 Overview

This chapter is a summary of findings, discussion, conclusions and recommendations. The summary of the study is presented. The section is further divided in five sections: summary of the results will be presented in the first part, summary of the findings will be presented in the second part, the third part will discuss the findings in relation to the study's objectives, the fourth part will present conclusions of this study, recommendations will be presented in the fifth part and lastly, the recommendations of the study will be presented in the sixth part.

5.1 Summary

The main objective of this study was to assess EMR services available, their levels of interoperability and formulate a Model for an interoperable EMR end-to-end implementation. To achieve this objective, the investigation was based on four objectives. The first research objective was to establish EMR services available, their utilization and level of integration in the Health sector. The second research objective was to determine the various EMR systems state of interoperability. The third research objective was to determine the strategies that have been used by successful implementer to address interoperability challenges. The fourth research objective was to develop an interoperability model for EMR implementation in Kenya.

This study employed a mixed methodology and involved a sample of 184 individuals from various healthcare facilities in Nandi and Uasin Gishu Counties, which varied in size and level. To ensure consistency and confidence in the results, other factors were kept constant across all study sites.

Objective 1: EMR services available, their utilization and level of integration in the Health sector.

This was done to establish EMR services available, their utilization and level of integration in the Health sector. The study used descriptive statistics to address this objective. The EMR services available, their utilization and level of integration in the Health sector were described as it existed at the time of study. Respondents were asked to indicate their level of agreement on a scale of 1 to 5 with 1 representing strongly disagree, 2 representing disagree, 3 representing not sure, 4 representing agree and 5 representing strongly agree.

Respondents agreed that EMR services are fully utilized in the facility, utilization of EMR service contribute significantly to improving healthcare delivery and patient outcome and the system offers an end to end coverage of all the service delivery points. On the other hand, respondents were not sure that EMR system is able to provide real time imaging, statistical outputs or visualizations, the features/functionalities of EMR services offered to healthcare providers are sufficient, patients interact with EMR service to schedule for appointment and EMR system sufficiently covers all administrative tasks within the facility including staff schedules, leaves and rosters.

The study established that the EMR services available were fully utilized to improve healthcare delivery through end to end coverage of all the service delivery. Contrary to this, Safi et al., (2018) stated that utilization of EMRs in the healthcare space, continues to lag. This statement does not stand with regard to findings of this study. Hence, this significantly enhances patient care by providing accurate and up-to-date information, improving coordination among providers, and enabling patient engagement through access to personal health data. EMRs streamline administrative workflows, reduce redundancies, and lower operational costs, while also facilitating compliance with regulatory standards and improving billing accuracy. Additionally, EMRs support data analytics for research and predictive healthcare. However, challenges such as privacy concerns, initial implementation costs, and interoperability issues must be addressed to fully harness the benefits of EMR systems.

The study also agrees with Safi et al., (2018) that utilization of EMRs in the healthcare space continues to lag since respondents were not sure of service provision of EMR system, sufficiency of features and services of the EMR system. This is not good to the healthcare facilities in this region since this can lead to inefficiencies, poor patient care coordination, limited data accessibility, and challenges in compliance and reporting. It hinders interoperability, increases operational costs, and results in potential revenue loss. Additionally, it negatively impacts patient satisfaction due to longer wait times and fragmented care, and limits the facility's ability to utilize data for analytics and research, ultimately affecting the overall quality of healthcare services provided.

Overall, the study established a high integration of the EMR services at the healthcare facilities which is supported by Akanbi et al. (2012; Haskew et al. (2015); Oluoch et al. (2014). Therefore, the facilities are at a position to enhance patient care by providing healthcare providers with immediate access to comprehensive patient information, improving decision-making and reducing errors. This would streamline administrative and clinical workflows, facilitates better communication among departments, and supports data analytics for population health management. Additionally, it simplifies regulatory compliance, engages patients through accessible portals, and can lead to long-term cost savings. Integrated EMR systems also ensure robust security and interoperability with other healthcare systems, promoting efficient and effective healthcare delivery.

Objective 2: EMR systems state of interoperability. This was done to determine the various EMR systems state of interoperability. This objective was also addressed by the use of descriptive statistical analysis. The study established that the existing EMR systems are able to communicate. This signifies a streamlined healthcare environment where patient data flows seamlessly across departments and facilities. This interoperability enhances patient care by enabling comprehensive access to medical histories, improving diagnostic accuracy, and supporting better treatment decisions. It boosts efficiency by reducing duplication of tests and procedures, enhances coordination among healthcare providers, and ensures patient safety through timely access to critical information like allergies and drug interactions. Additionally, it supports regulatory compliance, lowers costs through improved operational efficiencies, and ultimately enhances both healthcare quality and patient satisfaction.

Challenges and barriers in achieving interoperability stem from technical incompatibilities in data formats and protocols, concerns about data security and patient privacy, high costs and resource constraints for implementation, difficulties integrating new technologies into existing workflows, regulatory compliance requirements, and resistance to change among staff. Overcoming these obstacles requires collaborative efforts to standardize data formats, strengthen cybersecurity measures, streamline workflows, and ensure compliance with healthcare regulations, ultimately enhancing the efficiency and effectiveness of healthcare delivery. However, the healthcare facilities experience notable improvements in the healthcare delivery demonstrating that the EMR is crucial for improving patient care, reducing costs, and enhancing operational efficiency.

Overall, the study established a major interoperability of EMR systems within the health care facilities. This signifies that these systems can effectively exchange and integrate patient data within the healthcare providers setting.

However, it is noted that respondents were not sure if the facility's EMR system is capable of exchanging data with other EMR systems within and without an indication of lack of interoperability with other facilities. This was further confirmed by the ICT personnel who mentioned that "*Other healthcare facilities do not exchange patient data unless there is given permission from the patient that if it is intra facility".* Interoperability with other facilities enhances patient care by ensuring healthcare professionals have comprehensive and timely access to medical histories, test results, and treatment plans, thereby improving decision-making and care coordination. It also promotes efficiency through streamlined workflows, reduces costs by minimizing duplicate tests and procedures, enhances patient safety by reducing errors, and facilitates advanced data analytics and research opportunities. Overall, interoperability EMR systems contribute to a more integrated and effective healthcare delivery system.

Objective 3: Strategies used by successful implementers to address interoperability challenges. This was done to determine the strategies that have been used by successful implementers to address interoperability challenges. This objective was also addressed by the use of descriptive statistical analysis. The study established that there is awareness of common data standards and latest development and advancements in EMR system as a strategy used by successful implementers to address interoperability challenges. This signifies a strong grasp of how medical information should be structured and shared, adhering to protocols. It also involves being knowledgeable about current trends in EMR technology, including AI integration, telemedicine capabilities, and mobile access to medical records. This awareness ensures compliance with regulatory requirements, fostering efficient healthcare delivery, improved patient outcomes, and secure management of medical information within electronic systems.

However, the respondents were not sure of security measures, capacity building, government regulation, trust, cooperation and investment in technology as strategies used by successful implementer to address interoperability challenges. This signifies significant risks and challenges.

Without adequate security, patient data is vulnerable to breaches and privacy violations. Insufficient capacity building leads to inefficiencies and errors in system use. Absence of government regulation can result in legal non-compliance and data misuse. Trust issues arise, affecting patient confidence and willingness to share information. Lack of cooperation and interoperability hinders seamless data exchange between healthcare providers. Insufficient investment in technology leads to system inadequacies and inability to support evolving healthcare needs. Addressing these gaps is critical for ensuring secure, efficient, and trustworthy EMR systems that support high-quality healthcare delivery.

Objective 4. To develop an interoperability model for EMR end to end implementation. From the results of the study, a model of Electronic Medical Records End to End Implementation was formulated tested and validated. The study used Confirmatory Factor Analysis, a statistical approach applied to test hypotheses about the relationships among observed and latent variables. Latent variables also referred to as unobserved/underlying variables or factors. Thus, the study also applied (EFA), to extract the observable and latent variables to help confirm the validity of the model. Different software was however used for the two different cases; for EFA, SPSS was used, while for CFA, AMOS was used.

5.2 Conclusions

With reference to the findings, the study was in a position to conclude that all the objectives of the study were met. The researcher therefore made the following conclusions as per the objectives of the study.

EMR services available were fully utilized to improve healthcare delivery through end to end coverage of all the service delivery. There is a high integration of the EMR services at the healthcare facilities.

The existing EMR systems are able to communicate. The is a major interoperability of EMR systems in the health care facilities.

There is awareness of common data standards and latest development and advancements in EMR system as a strategy used by successful implementer to address interoperability challenges.

Overall, the results of the research study contributed, through the creation of a modified model for interoperability of EMR end to end implementation (fig. 4.8.3), by extending and modifying EIF, Lopez and Blobel's Interoperability frameworks.

This was therefore used as a lens to guide the study. The model developed from the study can be relied on to provide guidance on fundamental items that must be addressed for successful implementation of EMR end to end interoperability. The model will guide the policy makers and implementing groups on the use of the model

5.3 Recommendations

With reference to the findings of this study, the researcher was in a position to make the following recommendations:

Challenges such as privacy concerns, implementation costs issues must be addressed to fully harness the benefits of EMR interoperability.

The facilities to invest on security measures, capacity building, compliance to government regulation, technology as strategies to address interoperability challenges.

5.4 Future Studies

This study was focused on assessing EMR services available, their levels of interoperability and formulate a Model for an interoperable EMR end-to-end implementation in Kenya, other studies are therefore recommended to be done that include software designers, policy makers who understand the factors of interoperability, NGO's faith-based institutions and diverse stakeholders.

REFERENCES

1. Adebesin, F., Foster, R., Kotzé, P., & Greunen, D. V. (2013). A review of interoperability standards in e-health and imperatives for their adoption in Africa. *South African Computer Journal, 50*(1). https://doi.org/10.18489/sacj.v50i1.176

2. Adler-Milstein, J., & Pfeifer, E. (2017). Information blocking: Is it occurring and what policy strategies can address it? *The Milbank Quarterly, 95*(1), 117–135. https://doi.org/10.1111/1468-0009.12247

3. Agbo, C., Mahmoud, Q., & Eklund, J. (2019). Blockchain technology in healthcare: A systematic review. *Healthcare, 7*(2), 56. https://doi.org/10.3390/healthcare7020056

4. Aguirre, R. R., Suarez, O., Fuentes, M., & Sanchez-Gonzalez, M. A. (2019). Electronic health record implementation: A review of resources and tools. *Cureus, 11*(9), e5649. https://doi.org/10.7759/cureus.5649

5. Ajami, S., & Bagheri-Tadi, T. (2013). Barriers for adopting electronic health records (EHRs) by physicians. *Acta Informatica Medica, 21*(2), 129–134. https://doi.org/10.5455/aim.2013.21.129-134

6. Akanbi, M. O., Ocheke, A. N., Agaba, P. A., Daniyam, C. A., Agaba, E. I., Okeke, E. N., & Ukoli, C. O. (2012). Use of Electronic Health Records in sub-Saharan Africa: Progress and challenges. Journal of Medicine in the Tropics, 14(1), 1–6.

7. Ambrosio, R., & Widergren, S. (2007, June). A framework for addressing interoperability issues. In 2007 IEEE Power Engineering Society General Meeting (pp. 1-5). IEEE.

8. Anderson, A. (2018). Retrieved from https://www.cs.dartmouth.edu/~trdata/reports/TR2018-854.pdf

9. Ayaz, M., Pasha, M. F., Alzahrani, M. Y., Budiarto, R., & Stiawan, D. (2021). The Fast Health Interoperability Resources (FHIR) Standard: Systematic Literature Review of Implementations, Applications, Challenges and Opportunities. JMIR Medical Informatics, 9(7), e21929. https://doi.org/10.2196/21929

10. Bates, D. W. (2005). Physicians and ambulatory electronic health records. Health Affairs (Project Hope), 24(5), 1180–1189. https://doi.org/10.1377/hlthaff.24.5.1180

11. Bates, D. W., & Samal, L. (2018). Interoperability: What Is It, How Can We Make It Work for Clinicians, and How Should We Measure It in the Future? Health Services Research, 53(5), 3270–3277. https://doi.org/10.1111/1475-6773.12852

12. Becker Hospital. (2015). The 3 levels of interoperability in healthcare. Retrieved November 14, 2019, from Becker Hospital website: https://www.beckershospitalreview.com/healthcare-information-technology/the-3-levels-of-interoperability-in-healthcare.html

13. Belletti, D., Zacker, C., & Mullins, C. D. (2010). Perspectives on electronic medical records adoption: electronic medical records (EMR) in outcomes research. Patient Related Outcome Measures, 29-37.

14. Ben van Lier, C. M. C., & Hardjono, T. W. Luhmann meets the Matrix Exchanging and sharing information in network-centric environments.

15. Bhartiya, S., Mehrotra, D., & Girdhar, A. (2016). Issues in Achieving Complete Interoperability while Sharing Electronic Health Records. Procedia Computer Science, 78, 192–198. https://doi.org/10.1016/j.procs.2016.02.033

16. Bhartiya, S., Mehrotra, D., & Girdhar, A. (2016). Issues in Achieving Complete Interoperability while Sharing Electronic Health Records. Procedia Computer Science, 78, 192–198. https://doi.org/10.1016/j.procs.2016.02.033

17. Blaya, J. A., Fraser, H. S., & Holt, B. (2010). E-Health Technologies Show Promise In Developing Countries. Health Affairs, 29(2), 244–251. doi: 10.1377/hlthaff.2009.0894

18. Bowman, S. (2013). Impact of Electronic Health Record Systems on Information Integrity: Quality and Safety Implications. Perspectives in Health Information Management, 10(Fall), 1c.

19. Capminds. (2020). The Strengths and Weaknesses of the HL7 FHIR Messaging Standard | Open Health News. Capminds. https://www.openhealthnews.com/story/2020-09-08/strengths-and-weaknesses-hl7-fhir-messaging-standard

20. Chawla, J., Ahlawat, A. K., & Gautam, J. (2020). Resolving Interoperability Issues of Precision and Array with Null Value of Web Services Using WSIG-JADE Framework. Modelling and Simulation in Engineering, 2020, e8862249. https://doi.org/10.1155/2020/8862249

21. Cho, Y., Kim, M., & Choi, M. (2021). Factors associated with nurses' user resistance to change of electronic health record systems. BMC Medical Informatics and Decision Making, 21(1), 218. https://doi.org/10.1186/s12911-021-01581-z

22. Clarke, J. M., Warren, L. R., Arora, S., Barahona, M., & Darzi, A. W. (2018). Guiding interoperable electronic health records through patient-sharing networks. Npj Digital Medicine, 1(1), 1–6. https://doi.org/10.1038/s41746-018-0072-y

23. Collier, R. (2017). Electronic health records contributing to physician burnout. CMAJ : Canadian Medical Association Journal, 189(45), E1405–E1406. https://doi.org/10.1503/cmaj.109-5522

24. Courbier, S., Dimond, R., & Bros-Facer, V. (2019). Share and protect our health data: An evidence based approach to rare disease patients' perspectives on data sharing and data protection - quantitative survey and recommendations. Orphanet Journal of Rare Diseases, 14. https://doi.org/10.1186/s13023-019-1123-4

25. Cowie, M. R., Blomster, J. I., Curtis, L. H., Duclaux, S., Ford, I., Fritz, F., . . . Leenay, M. (2017). Electronic health records to facilitate clinical research. Clinical Research in Cardiology, 106(1), 1-9.

26. Cresswell, K. M., Bates, D. W., & Sheikh, A. (2013). Ten key considerations for the successful implementation and adoption of large-scale health information technology. Journal of the American Medical Informatics Association : JAMIA, 20(e1), e9–e13. https://doi.org/10.1136/amiajnl-2013-001684

27. Dafny, L. S., & Lee, T. H. (2016, December 1). Health Care Needs Real Competition. Harvard Business Review, December 2016. https://hbr.org/2016/12/health-care-needs-real-competition

28. Dash, S., Shakyawar, S. K., Sharma, M., & Kaushik, S. (2019). Big data in healthcare: Management, analysis and future prospects. Journal of Big Data, 6(1), 54. https://doi.org/10.1186/s40537-019-0217-0

29. Davis, J. (2021, October 13). Critical flaws found in interoperability backbone: FHIR APIs vulnerable to abuse. SC Magazine. https://www.scmagazine.com/analysis/application-security/critical-flaws-found-in-interoperability-backbone-fhir-apis-vulnerable-to-abuse

30. De Benedictis, A., Lettieri, E., Gastaldi, L., Masella, C., Urgu, A., & Tartaglini, D. (2020). Electronic Medical Records implementation in hospital: An empirical investigation of individual and organizational determinants. PLoS ONE, 15(6), e0234108. https://doi.org/10.1371/journal.pone.0234108

31. de Mello, B. H., Rigo, S. J., da Costa, C. A., da Rosa Righi, R., Donida, B., Bez, M. R., & Schunke, L. C. (2022). Semantic interoperability in health records standards: A systematic literature review. Health and Technology. https://doi.org/10.1007/s12553-022-00639-w

32. Dehling, T., & Sunyaev, A. (2014). Secure provision of patient-centered health information technology services in public networks—Leveraging security and privacy features provided by the German nationwide health information technology infrastructure. Electronic Markets, 24(2), 89–99. https://doi.org/10.1007/s12525-013-0150-6

33. Dunskiy, I. (2021). Interoperability in Healthcare: Challenges, Solutions & Examples. Demigos. https://demigos.com/blog-post/interoperability-in-healthcare/

34. Dyb, K., & Warth, L. L. (2018). The Norwegian National Summary Care Record: A qualitative analysis of doctors' use of and trust in shared patient information. BMC Health Services Research, 18(1), 252. https://doi.org/10.1186/s12913-018-3069-y

35. Ehrenstein, V., Kharrazi, H., Lehmann, H., & Taylor, C. O. (2019). Obtaining Data From Electronic Health Records. In Tools and Technologies for Registry Interoperability, Registries for Evaluating Patient Outcomes: A User's Guide, 3rd Edition, Addendum 2 [Internet]. Agency for Healthcare Research and Quality (US). https://www.ncbi.nlm.nih.gov/books/NBK551878/

36. Electronic Health Records Overview. (2006, April 1). National Institutes of Health. Retrieved February 20, 2012, from ncrr.nih.gov/publications/informatics/EHR.pdf

37. Elia, I. A., Laranjeiro, N., & Vieira, M. (2014). Understanding Interoperability Issues of Web Service Frameworks. 2014 44th Annual IEEE/IFIP International Conference on Dependable Systems and Networks, 323–330. https://doi.org/10.1109/DSN.2014.40

38. El-Sappagh, S., Ali, F., Hendawi, A., Jang, J.-H., & Kwak, K.-S. (2019). A mobile health monitoring-and-treatment system based on integration of the SSN sensor ontology and the HL7 FHIR standard. BMC Medical Informatics and Decision Making, 19(1), 97. https://doi.org/10.1186/s12911-019-0806-z

39. Esmaeilzadeh, P., & Mirzaei, T. (2019). The Potential of Blockchain Technology for Health Information Exchange: Experimental Study From Patients' Perspectives. Journal of Medical Internet Research, 21(6). https://doi.org/10.2196/14184

40. Evans, R. S. (2016). Electronic health records: then, now, and in the future. Yearbook of medical informatics, 25(S 01), S48-S61.

41. Evans, R. S. (2016). Electronic Health Records: Then, Now, and in the Future. Yearbook of Medical Informatics, Suppl 1, S48–S61. https://doi.org/10.15265/IYS-2016-s006

42. Evans, R. S. (2016). Electronic Health Records: Then, Now, and in the Future. Yearbook of Medical Informatics, Suppl 1, S48–S61. https://doi.org/10.15265/IYS-2016-s006

43. Ford, E. W., Menachemi, N., & Phillips, M. T. (2006). Predicting the Adoption of Electronic Health Records by Physicians: When Will Health Care be Paperless? Journal of the American Medical Informatics Association : JAMIA, 13(1), 106–112. https://doi.org/10.1197/jamia.M1913

44. Gariépy-Saper, K., & Decarie, N. (2021). Privacy of electronic health records: A review of the literature. Journal of the Canadian Health Libraries Association / Journal de l'Association Des Bibliothèques de La Santé Du Canada, 42(1). https://doi.org/10.29173/jchla29496

45. Garlapati, R., & Biswas, R. (2011). Interoperability in healthcare: A focus on the social interoperability (Master's thesis). Blekinge Institute of Technology, Karlskrona, Sweden. Retrieved from https://www.bth.se/com

46. Gordon, W. J., & Catalini, C. (2018). Blockchain Technology for Healthcare: Facilitating the Transition to Patient-Driven Interoperability. Computational and Structural Biotechnology Journal, 16, 224–230. https://doi.org/10.1016/j.csbj.2018.06.003

47. Halamaka, J. D., Lippman, A., & Ekblaw, A. (2017, May 18). The Potential for Blockchain to Transform Electronic Health Records. Retrieved October 31, 2019, from https://hbr.org/2017/03/the-potential-for-blockchain-to-transform-electronic-health-records.

48. Haskew, J., Rø, G., Turner, K., Kimanga, D., Sirengo, M., & Sharif, S. (2015). Implementation of a Cloud-Based Electronic Medical Record to Reduce Gaps in the HIV Treatment Continuum in Rural Kenya. PLOS ONE, 10(8), e0135361. https://doi.org/10.1371/journal.pone.0135361

49. Häyrinen, K., Saranto, K., & Nykänen, P. (2008). Definition, structure, content, use and impacts of electronic health records: A review of the research literature. International Journal of Medical Informatics, 77(5), 291–304. https://doi.org/10.1016/j.ijmedinf.2007.09.001

50. Health IT. (2021). What are the differences between electronic medical records, electronic health records, and personal health records? | HealthIT.gov. Health IT. https://www.healthit.gov/faq/what-are-differences-between-electronic-medical-records-electronic-health-records-and-personal

51. Heart, T., Ben-Assuli, O., & Shabtai, I. (2017). A review of PHR, EMR and EHR integration: A more personalized healthcare and public health policy. Health Policy and Technology, 6(1), 20-25.

52. Hevner, A.R., March, S.T., and Park, J. "Design Research in Information Systems Research," Mis Quarterly (28:1) 2004, pp 75-105.

53. HIMSS. (2016, March 9). What is Interoperability? Retrieved November 14, 2019, from HIMSS website: http://www.himss.org/what-interoperability

54. Hufford, MD, D. L. (1999, July 14). Innovation in Medical Record Documentation: The Electronic Medical Record. Uniformed Services Academy of Family Physicians. Retrieved February 19, 2012, from www.usafp.org/Fac_Dev/Orig_Papers/EMR-paper.doc

55. Hussain, M., Al-Haiqi, A., Zaidan, A. A., Zaidan, B. B., Kiah, M., Iqbal, S., Iqbal, S., & Abdulnabi, M. (2018). A security framework for mHealth apps on Android platform. Computers & Security, 75, 191–217. https://doi.org/10.1016/j.cose.2018.02.003

56. Imenda, S. (2014). Is There a Conceptual Difference between Theoretical and Conceptual Frameworks? Journal of Social Sciences, 38(2), 185–195. doi: 10.1080/09718923.2014.11893249

57. in: 26th Information Systems Research Seminar in Scandinavia, The IRIS Association, Haikko Finland, 2003.

58. Inge et. Al (2018) Attributes poor governance to lack on effective integration in the healthcare sector.

59. Inge Petersen, Debbie Marais, Jibril Abdulmalik, Shalini Ahuja, Atalay Alem, Dan Chisholm, Catherine Egbe, Oye Gureje, Charlotte Hanlon, Crick Lund, Rahul Shidhaye, Mark Jordans, Fred Kigozi, James Mugisha, Nawaraj Upadhaya, Graham Thornicroft, Strengthening mental health system governance in six low- and middle-income countries in Africa and South Asia: challenges, needs and potential strategies, Health Policy and Planning, Volume 32, Issue 5, June 2017, Pages 699–709, https://doi.org/10.1093/heapol/czx014

60. Jabbar, R., Fetais, N., Krichen, M., & Barkaoui, K. (2020, February). Blockchain technology for healthcare: Enhancing shared electronic health record interoperability and integrity. In 2020 IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIoT) (pp. 310-317). IEEE.

61. Jennett, P., Jackson, A., Healy, T., Ho, K., Kazanjian, A., Woollard, R., Haydt, S., & Bates, J. (2003). A study of a rural community's readiness for telehealth. Journal of Telemedicine and Telecare, 9(5), 259–263. https://doi.org/10.1258/135763303769211265

62. Jha, A. K., Bates, D. W., Jenter, C., Orav, E. J., Zheng, J., Cleary, P., & Simon, S. R. (2009). Electronic health records: Use, barriers and satisfaction among physicians who care for black and Hispanic patients. Journal of Evaluation in Clinical Practice, 15(1), 158–163. https://doi.org/10.1111/j.1365-2753.2008.00975.x

63. Jung, S. Y., Hwang, H., Lee, K., Lee, D., Yoo, S., Lim, K., Lee, H.-Y., & Kim, E. (2021). User Perspectives on Barriers and Facilitators to the Implementation of Electronic Health Records in Behavioral Hospitals: Qualitative Study. JMIR Formative Research, 5(4), e18764. https://doi.org/10.2196/18764

64. Kariuki, E. G., & Okanda, P. (2017). Adoption of m-health and usability challenges in m-health applications in Kenya: Case of Uzazi Poa m-health prototype application. 2017 IEEE AFRICON. doi:10.1109/afrcon.2017.8095537

65. Katehakis, D. G., Kouroubali, A., & Fundulaki, I. (2018). Towards the Development of a National eHealth Interoperability Framework to Address Public Health Challenges in Greece. In SWH@ ISWC.

66. Kennedy, M. (n.d.). Laboratory Interoperability Best Practices—Ten Mistakes to Avoid. 32.

67. Kent, J. (2018, December 3). Big Data to See Explosive Growth, Challenging Healthcare Organizations. Retrieved November 14, 2019, from HealthITAnalytics website:

https://healthitanalytics.com/news/big-data-to-see-explosive-growth-challenging-healthcare-organizations

68. Keshta, I., & Odeh, A. (2021). Security and privacy of electronic health records: Concerns and challenges. Egyptian Informatics Journal, 22(2), 177–183. https://doi.org/10.1016/j.eij.2020.07.003

69. Khan, S., Amin, M. B., Azar, A. T., & Aslam, S. (2021). Towards Interoperable Blockchains: A Survey on the Role of Smart Contracts in Blockchain Interoperability. IEEE Access, 9, 116672–116691. https://doi.org/10.1109/ACCESS.2021.3106384

70. Kimathi L. (2017). Challenges of the Devolved Health Sector in Kenya: Teething Problems or Systemic Contradictions? Africa Development, Volume XLII, No. 1, 2017, pp. 55-77 Council for the Development of Social Science Research in Africa, 2017 (ISSN: 0850 3907)

71. Kipruto, A. K., & Letting, N. (2017). Factors Influencing Provision of Health Care In A Devolved System of Government, Bungoma County, Kenya. Global Journal of Health Sciences, 2(1), 13–38. Retrieved from https://www.iprjb.org/journals/index.php/GJHS/article/view/310

72. Kouroubali, A., & Katehakis, D. G. (2019). The new European interoperability framework as a facilitator of digital transformation for citizen empowerment. Journal of biomedical informatics, 94, 103166

73. Kruse, C. S., Kristof, C., Jones, B., Mitchell, E., & Martinez, A. (2016). Barriers to Electronic Health Record Adoption: A Systematic Literature Review. Journal of Medical Systems, 40(12), 252. https://doi.org/10.1007/s10916-016-0628-9

74. Kyalo, C., Odhiambo-Otieno, G., Otieno, G., & Tenambergen, W. (2018). Technical Factors Influencing Integration of Health Management Information Systems in the Health System in Kenya. International Journal of Scientific and Research Publications (IJSRP), 8. https://doi.org/10.29322/IJSRP.8.8.2018.p8021

75. Lehne, M., Sass, J., Essenwanger, A., Schepers, J., & Thun, S. (2019a). Why digital medicine depends on interoperability. NPJ Digital Medicine, 2. https://doi.org/10.1038/s41746-019-0158-1

76. Lehne, M., Sass, J., Essenwanger, A., Schepers, J., & Thun, S. (2019b). Why digital medicine depends on interoperability. Npj Digital Medicine, 2(1), 1–5. https://doi.org/10.1038/s41746-019-0158-1

77. Li, E., Clarke, J., Neves, A. L., Ashrafian, H., & Darzi, A. (2021). Electronic Health Records, Interoperability and Patient Safety in Health Systems of High-income Countries: A Systematic Review Protocol. BMJ Open, 11(7), e044941. https://doi.org/10.1136/bmjopen-2020-044941

78. Lopez, D. M., & Blobel, B. G. (2009). A development framework for semantically interoperable health information systems. International journal of medical informatics, 78(2), 83-103.

79. Manca, D. P. (2015). Do electronic medical records improve quality of care? Canadian Family Physician, 61(10), 846–847.

80. Maphumulo, Winnie T., & Bhengu, Busisiwe R.. (2019). Challenges of quality improvement in the healthcare of South Africa post-apartheid: A critical review. Curationis, 42(1), 1-9. https://dx.doi.org/10.4102/curationis.v42i1.1901

81. Meehan, R. A., Mon, D. T., Kelly, K. M., Rocca, M., Dickinson, G., Ritter, J., & Johnson, C. M. (2016). Increasing EHR system usability through standards: Conformance criteria in the HL7 EHR-system functional model. Journal of Biomedical Informatics, 63, 169–173. https://doi.org/10.1016/j.jbi.2016.08.015

82. Menachemi, N., & Collum, T. H. (2011) Menachemi, N., & Collum, T. H. (2011). Electronic health records: Then, now, and in the future. Yearbook of Medical Informatics, 20(1), S48-S61. https://doi.org/10.1055/s-0038-1638747

83. Menachemi, N., & Collum, T. H. (2011). Benefits and drawbacks of electronic health record systems. Risk Management and Healthcare Policy, 4, 47–55. https://doi.org/10.2147/RMHP.S12985

84. Meyer, V. M., Benjamens, S., El Moumni, M., Lange, J. F., & Pol, R. A. (2022). Global overview of response rates in patient and health care professional surveys in surgery: a systematic review. Annals of surgery, 275(1), e75-e81.

85. Mkayula, N., Mbise, M., & Mahundi, M. (2022). Approaches Towards Interoperability of Electronic Medical Records Systems: A Case of Selected Referral Hospitals in Tanzania. Journal of Health Informatics in Africa, 9(1), 1-13.

86. Mooney, L., Knox, D., & Schachtt, C. (2007). The three main sociological perspectives. Understanding Social Problems, 1–2. Retrieved from https://laulima.hawaii.edu/access/content/user/kfrench/sociology/the three main sociological perspectives.pdf

87. Nagasubramanian, G., Sakthivel, R. K., Patan, R., Gandomi, A. H., Sankayya, M., & Balusamy, B. (2020). Securing e-health records using keyless signature infrastructure blockchain technology in the cloud. Neural Computing and Applications, 32(3), 639-647.

88. Ndlovu, K., Mars, M., & Scott, R. E. (2021). Interoperability frameworks linking mHealth applications to electronic record systems. BMC health services research, 21(1), 459.

89. Ndlovu, K., Mars, M., & Scott, R. E. (2021). Interoperability frameworks linking mHealth applications to electronic record systems. BMC Health Services Research, 21(1), 459. https://doi.org/10.1186/s12913-021-06473-6

90. Ndungu, L. W. (2020). Replication As A Way To Achieve Interoperability In Healthcare (Doctoral dissertation, University of Nairobi).

91. Ngugi, P. N. (2021). A Systematic Method for Evaluating Implementations of Electronic Medical Records Systems in Low-and Medium-Income Countries.

92. Ngugi, P. N., Were, M. C., & Babic, A. (2021). Users' perception on factors contributing to electronic medical records systems use: a focus group discussion study in healthcare facilities setting in Kenya. BMC Medical Informatics and Decision Making, 21, 1-14.

93. Ngugi, P., Babic, A., & Were, M. C. (2021). A multivariate statistical evaluation of actual use of electronic health record systems implementations in Kenya. PLOS ONE, 16(9), e0256799. https://doi.org/10.1371/journal.pone.0256799

94. Nunamaker, J.F., and Chen, M. "Systems Development in Information Systems Research," Journal of Management Information Systems (7:3) 1991, pp 89 - 106.

95. Odekunle, F. F., Odekunle, R. O., & Shankar, S. (2017). Why sub-Saharan Africa lags in electronic health record adoption and possible strategies to increase its adoption in this region. International Journal of Health Sciences, 11(4), 59–64. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5654179/#ref11

96. OECD. (2020). The Future of Primary Health Care. OECD.

97. Oleribe, O. O., Momoh, J., Uzochukwu, B. S., Mbofana, F., Adebiyi, A., Barbera, T., Williams, R., & Taylor-Robinson, S. D. (2019). Identifying Key Challenges Facing Healthcare Systems In Africa And Potential Solutions. International journal of general medicine, 12, 395–403. https://doi.org/10.2147/IJGM.S223882

98. Oluoch, T., Katana, A., Ssempijja, V., Kwaro, D., Langat, P., Kimanga, D., Okeyo, N., Abu-Hanna, A., & de Keizer, N. (2014). Electronic medical record systems are associated with appropriate placement of HIV patients on antiretroviral therapy in rural health facilities in Kenya: A retrospective pre-post study. Journal of the American Medical Informatics Association, 21(6), 1009–1014. https://doi.org/10.1136/amiajnl-2013-002447

99. Ozair, F. F., Jamshed, N., Sharma, A., & Aggarwal, P. (2015). Ethical issues in electronic health records: A general overview. Perspectives in Clinical Research, 6(2), 73–76. https://doi.org/10.4103/2229-3485.153997

100. Park, J. H., & Park, J. H. (2017). Blockchain security in cloud computing: Use cases, challenges, and solutions. Symmetry, 9(8), 1–13. https://doi.org/10.3390/sym9080164

101. Payne, T. H., Lovis, C., Gutteridge, C., Pagliari, C., Natarajan, S., Yong, C., & Zhao, L.-P. (2019). Status of health information exchange: A comparison of six countries. Journal of Global Health, 9(2). https://doi.org/10.7189/jogh.09.020427

102. Peffers, K., Tuunanen, T., Gengler, C. E., Rossi, M., Hui, W., Virtanen, V., & Bragge, J. (2006). The design science research process: a model for producing and presenting information systems research. 1st International Conference on Design Science in Information Systems and Technology.

103. Peterson, K., Deeduvanu, R., Kanjamala, P., & Boles, K. (2010). A Blockchain-Based Approach to Health Information Exchange Networks. 1(1), 10.

104. Pfaff, E. R., Champion, J., Bradford, R. L., Clark, M., Xu, H., Fecho, K., Krishnamurthy, A., Cox, S., Chute, C. G., Overby Taylor, C., & Ahalt, S. (2019). Fast Healthcare Interoperability Resources (FHIR) as a Meta Model to Integrate Common Data Models: Development of a Tool and Quantitative Validation Study. JMIR Medical Informatics, 7(4), e15199. https://doi.org/10.2196/15199

105. Ratwani, R. M., Savage, E., Will, A., Fong, A., Karavite, D., Muthu, N., Rivera, A. J., Gibson, C., Asmonga, D., Moscovitch, B., Grundmeier, R., & Rising, J. (2018). Identifying Electronic Health Record Usability And Safety Challenges In Pediatric Settings. Health Affairs, 37(11), 1752–1759. https://doi.org/10.1377/hlthaff.2018.0699

106. Razzaque, A. (2020). Knowledge Management Infrastructure for the Success of Electronic Health Records. In Global Approaches to Sustainability Through Learning and Education (pp. 207-217): IGI Global.

107. Reinhardt, J., Fu, B., & Balikuddembe, J. Healthcare Challenges After Disasters in Lesser Developed Countries. Oxford Research Encyclopedia of Natural Hazard Science. Retrieved 22 Jun. 2021, from https://oxfordre.com/naturalhazardscience/view/10.1093/acrefore/9780199389407.001.0001/acrefore-9780199389407-e-337.

108. Reisman, M. (2017). EHRs: The Challenge of Making Electronic Data Usable and Interoperable. Pharmacy and Therapeutics, 42(9), 572–575.

109. Reisman, M. (2017). EHRs: The Challenge of Making Electronic Data Usable and Interoperable. Pharmacy and Therapeutics, 42(9), 572–575.

110. Rossi, M., and Sein, M.K. "Design research workshop: a proactive research approach,"

111. Rothstein ∗, M. A. (2007). Health Privacy in the Electronic Age. Journal of Legal Medicine, 28(4), 487–501. https://doi.org/10.1080/01947640701732148

112. Rothstein, M. A., & Tovino, S. A. (2019). Privacy Risks of Interoperable Electronic Health Records: Segmentation of Sensitive Information Will Help. Journal of Law, Medicine & Ethics, 47(4), 771–777. https://doi.org/10.1177/1073110519897791

113. Rudin, R., Volk, L., Simon, S., & Bates, D. (2011). What Affects Clinicians' Usage of Health Information Exchange? Applied Clinical Informatics, 2(3), 250–262. https://doi.org/10.4338/ACI-2011-03-RA-0021

114. Ryan, M. S., Shih, S. C., Winther, C. H., & Wang, J. J. (2014). Does it Get Easier to Use an EHR? Report from an Urban Regional Extension Center. Journal of General Internal Medicine, 29(10), 1341–1348. https://doi.org/10.1007/s11606-014-2891-0

115. Safi, S., Thiessen, T., & Schmailzl, K. J. (2018). Acceptance and Resistance of New Digital Technologies in Medicine: Qualitative Study. JMIR Research Protocols, 7(12), e11072. https://doi.org/10.2196/11072

116. Samarth, A. (2016). Final Report: Measurement of Interoperable Electronic Health Care Records Utilization. Clinovations.

117. Schopf, T. R., Nedrebø, B., Hufthammer, K. O., Daphu, I. K., & Lærum, H. (2019). How well is the electronic health record supporting the clinical tasks of hospital physicians? A survey of physicians at three Norwegian hospitals. BMC Health Services Research, 19(1), 934. https://doi.org/10.1186/s12913-019-4763-0

118. Schrepp, M. (2020). On the Usage of Cronbach's Alpha to Measure Reliability of UX Scales. Journal of Usability Studies, 15(4).

119. Seiedfarajollah, S., Safdari, R., Ghazisaeedi, M., & Keikha, L. (2019). Key security and privacy issues from implementing the National Electronic Health Record in the Islamic Republic of Iran. Eastern Mediterranean Health Journal, 25(09), 656–659. https://doi.org/10.26719/emhj.19.006

120. Seymour, Dr. Tom & Frantsvog, Dean & Graeber, Tod. (2014). Electronic Health Records (EHR). 10.19030/ajhs.v3i3.7139.

121. Seymour, T., Frantsvog, D., & Graeber, T. (2016). Electronic Health Records (EHR). American Journal of Health Sciences (AJHS), 3(3), 201–210. https://doi.org/10.19030/ajhs.v3i3.7139

122. Sittig, D. F., & Singh, H. (2015). A New Socio-technical Model for Studying Health Information Technology in Complex Adaptive Healthcare Systems. In V. L. Patel, T. G. Kannampallil, & D. R. Kaufman (Eds.), Cognitive Informatics for Biomedicine: Human Computer Interaction in Healthcare (pp. 59–80). Springer International Publishing. https://doi.org/10.1007/978-3-319-17272-9_4

123. Sprague, L. (2004). Electronic health records: How close? How far to go? NHPF Issue Brief, 800, 1–17.

124. Sürücü, L., & Maslakci, A. (2020). Validity and reliability in quantitative research. Business & Management Studies: An International Journal, 8(3), 2694-2726.

125. Thompson, M. P., & Graetz, I. (2019). Hospital adoption of interoperability functions. Healthcare (Amsterdam, Netherlands), 7(3), 100347. https://doi.org/10.1016/j.hjdsi.2018.12.001

126. Thun, S. (2019). The Use of FHIR in Digital Health – a Review of the Scientific Literature. Studies in Health Technology and Informatics, 267. https://doi.org/10.3233/SHTI190805

127. Tsegaye, T., & Flowerday, S. (2021). A system architecture for ensuring interoperability in a South African national electronic health record system. South African Computer Journal, 33(1), 79-110.

128. Tyagi, K., Rane, C., & Manry, M. (2022). Regression analysis. In Artificial intelligence and machine learning for EDGE computing (pp. 53-63). Academic Press.

129. Underwood, W. S. (2011, June 1). Choosing the Right Hardware for Your Practice | EHR Blog | AmericanEHR Partners. American EHR Partners | EHR/EMR Vendor Ratings, Resources &

Comparison Tools. Retrieved February 23, 2012, from http://www.americanehr.com/blog/2011/06/choosing-the-right-hardware-for-your-practice/

130. USF Health. (2017, February 15). Differences Between EHR vs EMR and Why It Matters. USF Health Online. https://www.usfhealthonline.com/resources/key-concepts/ehr-vs-emr/

131. van Lier, B., & Hardjono, T. (2011). A systems theoretical approach to interoperability of information. Systemic Practice and Action Research, 24, 479-497.

132. Vos, J. F. J., Boonstra, A., Kooistra, A., Seelen, M., & van Offenbeek, M. (2020). The influence of electronic health record use on collaboration among medical specialties. BMC Health Services Research, 20(1), 676. https://doi.org/10.1186/s12913-020-05542-6

133. Weiner, J. P., Fowles, J. B., & Chan, K. S. (2012). New paradigms for measuring clinical performance using electronic health records. International Journal for Quality in Health Care, 24(3), 200–205. https://doi.org/10.1093/intqhc/mzs011

134. Wikina, S. B. (2014). What Caused the Breach? An Examination of Use of Information Technology and Health Data Breaches. Perspectives in Health Information Management, 2(1), 16.

135. Winter, A., Stäubert, S., Ammon, D., Aiche, S., Beyan, O., Bischoff, V., Daumke, P., Decker, S., Funkat, G., Gewehr, J. E., de Greiff, A., Haferkamp, S., Hahn, U., Henkel, A., Kirsten, T., Klöss, T., Lippert, J., Löbe, M., Lowitsch, V., … Löffler, M. (2018). Smart Medical Information Technology for Healthcare (SMITH). Methods of Information in Medicine, 57(Suppl 1), e92–e105. https://doi.org/10.3414/ME18-02-0004

136. Zaheer, S., Pimentel, S. D., Simmons, K. D., Kuo, L. E., Datta, J., Williams, N., Fraker, D. L., & Kelz, R. R. (2017). Comparing International and United States Undergraduate Medical Education and Surgical Outcomes Using a Refined Balance Matching Methodology. Annals of Surgery, 265(5), 916–922. https://doi.org/10.1097/SLA.0000000000001878

APPENDICES

Appendix I: Questionnaire

Demographic Information

The main aim of this questionnaire is to assess and formulate Interoperability Model For EMR end to end implementation. The questionnaire shall be completely by Medial personnel, ICT practitioners and medical health record practitioners. Practicing the privacy of the respondent is critical all personal information will be kept confidential and only used purely for academic purposes.

Please respond to all the questions by following the instructions:

Background Information

1.1 Gender

1. Male
2. Female

1.2 Age

1 <30
2 30 – 39
3 40 – 49
4 .>50

1.3 Personnel Specialty

1. Medical personnel
2. ICT practitioners
3. Medical Health Record Practitioners

1.4 Years of experience

1. 1-4
2. 5-8
3. 9-12
4. >12

1.5 Years of using EMR System

1. 1-4
2. 5-8
3. 9-12
4. >12

1.6 Name of the health facility: _____________________

1.7 What is the status of the health facility

1.Public
2.Private

1.8 Does the health facility have EMR services?

1.Yes
2.No

1.9 Do you perceive the EMR Services available effectiveness and efficiency?
1.Yes
2.No

1.10 Is the facility's EMR services interconnected with other external health facilities?
1.Yes
2.No

1.11 How long does EMR services been operated by this health facility
1. 1 – 4 Years
2. 4 – 8 Years
3. 8 – 12 Years
Above 12 Years

Consider the questionnaire below and provide candid response. Kindly rate the questions based on a scale of 1-5 based on your level of agreement to the individual items presented based on the study.

			5- Strongly Agree 4 – Agree 3 – Not sure 2 – Disagree 1 – Strongly Disagree		
Item			**Criteria**		
EMR services available, their utilization and level of integration					
EMR services are fully utilized in the facility.	5	4	3	2	1
The system offers an end-to-end coverage of all the service delivery points (SDPs) (Technical)	5	4	3	2	1
The features/functionalities of EMR services offered to healthcare providers are sufficient.(Technical)	5	4	3	2	1
Patients interact with EMR services to schedule for appointment (social)	5	4	3	2	1
EMR system sufficiently covers all administrative tasks within the facility including staff schedules, leaves and rosters. (organizational)	5	4	3	2	1
EMR system is able to provide real time imaging, statistical outputs or visualizations. (technical)	5	4	3	2	1
Utilization of EMR services contributes significantly to improving healthcare delivery and patient outcomes (social)	5	4	3	2	1
EMR systems state of interoperability					

My facility has different EMR systems and they are able to communicate with each other, or the EMR system available is able to communicate end to end throughout all service delivery points (Technical)	5	4	3	2	1
The facility has in the past encountered challenges and barriers in achieving interoperability between EMR systems and other healthcare systems	5	4	3	2	1
The facility's EMR system demonstrates semantic interoperability, as it can exchange data with other EMR systems both internally and externally while ensuring the meaning of the data remains consistent and understandable across systems (semantic)	5	4	3	2	1
I have observed notable improvements in the facility's healthcare delivery/patient outcomes as a result of achieving interoperability in the facility's EMR systems. (organizational)	5	4	3	2	1
I have encountered instances where the lack of interoperability between EMR systems has resulted in adverse events or delays in patient care	5	4	3	2	1
The effect of interoperability between EMR systems on workflow efficiency and productivity within the facility is over all good. (social)	5	4	3	2	1
strategies used by successful implementer to address interoperability challenges.					
My organization is aware of common data standards that make it easier for different EHR systems to communicate with each other (moderating)	5	4	3	2	1
Government has created regulations that mandate interoperability thus providing a framework for organizations to follow when sharing data (legal)	5	4	3	2	1
My organization has invested in the right technology like middleware, application programming interfaces (APIs), and cloud computing to enable interoperability (Technical)	5	4	3	2	1

There is trust and cooperation between healthcare organizations, which has made it easy to agree on standards and protocols for sharing data. (social)	5	4	3	2	1
My organization is capacity building the already existing workforce to handle the sharing of data/information through different levels of training. (organizational)	5	4	3	2	1
The hospital has put in place security measures for sharing patients' data/information(legal)	5	4	3	2	1
The facility's personnel are informed about the latest developments and advancements in EMR interoperability standards and practices (organizational)	5	4	3	2	1

In your opinion are there any other challenges to the utilization and integration of EMR services in healthcare facility?

1. Yes
2. No

If yes give the reason for your answer

____
____
____
____

Appendix II: Interview Guide

The objective of the interview is to establish the current state of interoperability, required state of interoperability and the adoption factors that will influence the adoption of interoperability of EMR in hospitals.

Objective 1 – To establish EMR services available, their utilization and level of integration in the Health sector

- Which Information Systems are at present operational within your hospital?

- Which of these Information System(s) are exchanging data or information?

Section 2 - Required State of Interoperability -To determine the various EMR systems state of interoperability

Based on their interoperability needs, the questions centered on identifying the type of interoperability that enterprises will need in the upcoming years. We'll concentrate on elements including cooperation, standards, data, and infrastructure interoperability

2.1 Collaboration

Guiding questions meant to identify the organizations interested in exchanging data and the necessary type of cooperation.

- Which groups or entities is the organization interested in exchanging or sharing data with?

- Which information systems would most likely play a role?

2.2 Standards

Guiding questions pertaining to compatibility standards mandated by an organization or technical interoperability that is mentioned.

- Will your facility create or implement any compatibility or data interoperability standards for the necessary type of interoperability?

• Will your facility create or implement any compatibility or infrastructure interoperability standards for the necessary type of interoperability?

2.3 Data and Information

Guiding questions focused on establishing the form and class of data required or offered by an hospital?

What data presentation form is preferred for data interchange?

What form of data security would be required?

2.4 ICT Infrastructure

Guiding questions focused on describing the interoperability technology infrastructure and functionalities required by the organization.

- Which architectural style best meets the technological interoperability requirements of your facility?
  • What kind of electronic services for data sharing or exchange would your facility like to offer?
  • Which high-level communication protocol or protocols are recommended for data exchange between systems that are interoperable?
  • Which kind of network is best for facilitating communication between systems that are compatible?

Section 3 - Interoperability Adoption

Guiding questions directed at establishing the different factors that will influence the adoption of interoperability solutions.

- Are there are ongoing initiatives or collaborations aimed at enhancing interoperability between EMR systems within the facility
- What standards related variables will affect the adoption of interoperability?

- What informational or data elements will impact the adoption of interoperability?
- Which aspects of the infrastructure will have an impact on the adoption of interoperability?
- Will the adoption of interoperability be influenced by any factors connected to collaboration?
- What factors do you think would help promote implementation of interoperability of EMRs in your hospital?
- How often do you encounter communication breakdowns when sharing patient information across different EMR systems?
- What kind of training have you received on the interoperability features of the EMR system?
- How does interoperability between EMR systems impact the efficiency of your daily workflows?
- How do you perceive the ease of use of the EMR system when interacting with other EMR systems?

Appendix III: Sample letter to experts

Elaine Kansiime Pamela

Masinde Muliro University of Science and Technology

elaine2ug@gmail.com

0708114708

Dear Sir/Madam

REQUEST FOR EXPERT REVIEW OF MY QUESTIONNAIRE

Greetings. I hope you are ok. I am writing to request your assistance in the validation of a questionnaire that I have developed as part of my research titled '**INTEROPERABILITY MODEL FOR ELECTRONIC MEDICAL RECORDS END TO END IMPLEMENTATION'** Given your expertise in Medical field/ICT/Hospital Administration/ Health records Information, I believe your insights and judgment would be invaluable to ensuring the quality and effectiveness of this instrument.

The questionnaire has been designed to get users opinions in regards to EMR interoperability end to end implementation in health facilities. It is essential that the questions accurately reflect the constructs we aim to measure and are comprehensible and relevant to the target population. I would be grateful if you could review the attached questionnaire and provide your expert opinion on Clarity, Content validation, relevance of the questions to the research objectives and comprehensiveness in relation to necessary aspects of the topic.

If possible, please provide any additional suggestions or comments on how the questionnaire could be improved. Rate the questions on a scale of 1 to 5 where 1 is poor and 5 is excellent.

Your contribution to this process is highly appreciated. Thank you very much for considering this request. Your expertise will significantly improve the quality of this research, and I am looking forward to your valuable feedback.

Yours Sincerely,

Elaine Kansiime Pamela
Phd student
Masinde Muliro University of Science and Technology

Appendix IV: NACOSTI Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **727906**

Date of Issue: **15/April/2024**

RESEARCH LICENSE

This is to Certify that Ms.. Elaine Pamela Kansiime of Masinde Muliro University of Science and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Nandi, Uasin-Gishu on the topic: AN INTEROPERABILITY MODEL FOR ELECTRONIC MEDICAL RECORDS END TO END IMPLEMENTATION for the period ending : 15/April/2025.

License No: **NACOSTI/P/24/30824**

727906

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR
SCIENCE,TECHNOLOGY &
INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document,
Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix V: Research Ethics Letter

OFFICE OF THE CHAIRPERSON
INSTITUTIONAL SCIENTIFIC ETHICS REVIEW COMMITTEE
UNIVERSITY OF EASTERN AFRICA, BARATON
P.O. BOX 2500-30100, Eldoret, Kenya, East Africa

B1812092023

September 12, 2023

TO: Elaine Kansiime Pamela
Department of Information Technology
Masinde Muliro University of Science and Technology

Dear Elaine,

RE: An Interoperability Model for Electronic Medical Records End to End Implementation

This is to inform you that the Institutional Scientific Ethics Review Committee (ISERC) of the University of Eastern Africa Baraton has reviewed and approved your above research proposal. Your application approval number is UEAB/ISERC/12/09/2023. The approval period is 12th September, 2023 – 12th September, 2024.

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used.

ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by the Institutional Scientific Ethics Review Committee (ISERC) of the University of Eastern Africa Baraton.

iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to the Institutional Scientific Ethics Review Committee (ISERC) of the University of Eastern Africa Baraton within 72 hours of notification.

iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to the Institutional Scientific Ethics Review Committee (ISERC) of the University of Eastern Africa Baraton within 72 hours.

v. Clearance for export of biological specimens must be obtained from relevant institutions.

vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.

vii. Submission of an executive summary report within 90 days upon completion of the study to the Institutional Scientific Ethics Review Committee (ISERC) of the University of Eastern Africa Baraton.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and also obtain other clearances needed.

Sincerely yours,

Prof. Jackie K. Obey, PhD
Chairperson, Institutional Scientific Ethics Review Committee

University of Eastern Africa, Baraton
12 SEP 2023
P. O. Box 2500-30100, ELDORET
Research Ethics Committee

A SEVENTH-DAY ADVENTIST INSTITUTION OF HIGHER LEARNING
CHARTERED 1991

Elaine Kansiime Pamela

elaine2ug@gmail.com

0708114708

11/4/2014

The Administrator,

Hospital A

Dear Sir/Madam,

REQUEST TO CONDUCT RESEARCH IN YOUR HEALTH FACILITY

I hope this letter finds you well. My name is **Elaine Kansiime Pamela**, student at Masinde Muliro University of Science and Technology and I am writing to introduce myself and my research assistant **Levi Nyambati**

I am a Phd student in the department of Information Technology with a keen interest in Medical Informatics. After conducting preliminary research, I have identified Hospital A as a facility to carry out my research because it's one of the hospitals that have Electronic Medical Records my area of research.

The primary focus of my research is **To assess EMR services available, their levels of interoperability and formulate a Model for an interoperable EMR end-to-end implementation.**

I believe that allowing me conduct research in your facility will enhance the quality and scope of my work. I have the required permits from NACOSTI, Ethics committee and my university. I intend to use questionnaires and interviews to the medical personnel, IT staff, administrators and records officers to collect data about the availability and use of EMRs no patient data is required.

Thank you for considering my request.

Yours sincerely

Elaine Kansiime Pamela