Journal of Health Informatics in Africa

Improving Collaboration Among Healthcare providers in Resource Constrained Healthcare Facilities: An Enterprise Architecture Approach

Samuel Walusimbi [a] *, Joseph Wamema [b]

[a] Faculty of Science, Information Technology, Uganda Martyrs University, Kampala, Uganda
[b] School of Computing and Informatics Technology, Makerere University, Kampala, Uganda

Background and Purpose: Application of an Information System that can provide a seamless flow of patient information and medical guidelines is highly desirable in the practice of Evidence Based Medicine (EBM). Information systems in Resource Constrained Health Facilities including Uganda have been found to be inadequate in supporting collaboration among healthcare providers. This study aimed at optimising collaboration and information sharing among healthcare providers by developing an architecture for a collaborative mobile application.
Methods: The study adopted a case study research design and qualitative data was collected from 32 informants using a series of data collection methods including; interviews, focus group discussions, observation and document reviews from the hospital's resource centre, published articles and online informatics journals.
Results: Findings from this study showed that there were various information and communication systems including computers, e-mails, internet access and suffice to note, telephone calls for both landline and mobile were still being used for collaboration. Collaboration challenges that were identified include system integration issues, infrastructure limitations, data quality issues, system usability and geographical dispersals of both healthcare providers and healthcare facilities among others. The study further established that current systems focus more on monitoring and evaluation, surveillance of chronic diseases and data capture; less is done towards optimisation of collaboration.
Conclusions: Healthcare providers ought to make decisions based on the most up-to-date, solid, reliable and scientific evidence, this study proposed a collaborative mobile application architecture to improve collaboration among healthcare providers at any point of care. The architecture was developed using enterprise architecture principles taking cognizance of its four crucial C's; connection, collaboration, communication and customer.

Keywords: Collaboration, Resource-Constrained Healthcare Facilities, Evidence-Based-Medicine, Architecture.

1 Introduction

Nations that have inadequate health systems are liable to experiencing poor economic growth since the productivity of the labour force is bound to be affected by poor health [1]. They have to deal with the expectations of their citizens to resolve the challenges in persistent inequities in accessing healthcare among different communities [2]. More interventions are desirable and also essential world over since health systems are increasingly facing tough and complex challenges that partly originate from new pressures such as the prevalence of chronic illnesses, fragile populations and the intensive use of expensive yet vital health technologies [3]. To overcome these challenges, various nations have taken substantial steps in developing Health Information Systems (HISs) that can enhance the provision of healthcare service delivery[4] [5]. HISs are capable of improving collaboration and healthcare service delivery [6] as systems enable communication between and among healthcare providers even in hard-to-reach areas; and enable them to get access to critical information for decision making [7].

*Corresponding author address: walusimbisam@gmail.com
 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

With the influence of donor aid, Resource Constrained Healthcare Facilities (RCHFs) have implemented HISs to provide access to quality and equitable healthcare. Systems such as Electronic Patient Records (EPRs), Electronic Medical Record (EMR) [4], Electronic Health Record (EHR) [8], and District Health Information System (DHIS) [9]. These programs are influenced at the national level through various International donor funding such as WHO, USAID and DFID [10].

Whereas significant potential for HISs to positively influence optimal collaboration among healthcare providers exists, it is imperative to note that collaboration has been hindered by; individually operating entities, each generating its own silo of information and this makes interaction minimal [11] [12]. Healthcare systems in RCHFs greatly rely on donor funding in the pilot stages because of the huge costs involved,[4] and when there is need for scalability, institutions have to devise ways of getting funding yet this is costly. Donor systems are customized to target specific programs such as data collection and reporting on HIV/AIDS, malaria and tuberculosis, hence result in fragmented systems which hinder collaboration [13]. Focus is put on monitoring and evaluation, disease surveillance, chronicle diseases, patient registration, data capture and billing; very little is done towards optimization of collaboration [14]. These systems are a "cut and paste" solutions [15], though they are effective in mother countries, they are not in RCHFs; because of the design-reality gaps [16][17].

Those systems are further aggravated by other challenges common to most RCHFs [18] [19] including; financial and structural constraints; insufficient digital infrastructure due to high costs [20] unreliable electricity,[21]; low-quality and expensive Internet access,[22]; geographical proximity which hinders healthcare providers from getting to know each other and innovate together[23], a big number of the populace in rural areas which is aggravated by lopsided ICT implementations, inadequate information exchange mechanism across institutional boundaries, moreover they are hospital and departmental centred [24], and are inward facing to organizational units yet they should be outward facing to enhance collaboration [4], hardware acquisition [25], and lack of regional integration.

Amidst the prevalent adoption of ICTs, ICT systems that can execute a seamless flow of information through healthcare business processes are not widely used in healthcare environments [26]. It is common to find healthcare organizations still using manual systems, e-mails, telephones (landline and mobile handsets) as means of communication and collaboration [27]. This hinders collaborative prompt response to emergencies such as outbreak of diseases that lead to increased mortality and morbidity in RCHFs.[28].

Besides those challenges, it is worthy to note that, healthcare service delivery has two characteristics which make the deployment of HISs challenging as well as potentially highly helpful. First, healthcare is a key example of **collaborative work;** and this involves partnerships and shared decision making [29] secondly, contrary to other disciplines, healthcare work is often **non-routine**, which makes it difficult to pre-schedule clinical procedures and activities. Issues such as emergencies and exceptions are so common enough and impede standardization of clinical practices. These two characteristics call for dependency on communication and critical information sharing to achieve optimal collaboration but they also provide justification for deployment of seamless communication technologies to coordinate clinical workflow [30] [31]. Without workable architecture that can enhance collaboration and information sharing, the gap between empirical evidence and clinical workflow would continue to exist and this would have a negative impact on the quality of care [32] [33]. [34] specifically cites collaboration and communication limitations as the leading root cause for medical errors, delays in treatment, duplication of tests, wrong-site surgeries, or even unexpected death.

Despite the various interventions with different technologies, collaboration shortfalls as mentioned earlier still exist and a big portion of the HISs research had concentrated on initiatives relating to HIV/AIDS, tuberculosis, and malaria. Few studies had been carried out in information systems that focus on point-of-care collaborative architectures; so, this study aspired to explore existing healthcare information systems, the collaborative challenges that healthcare providers encounter in healthcare service delivery and the existing opportunities available that call for communication and collaborative technology architecture [35]. Thence, designing and developing a mobile tool architecture that would bridge the information gap and improve up-to-date information sharing on an anytime and anywhere basis was highly desirable.

Notably, the application of wireless networks and the wide implementation of mobile phone applications play a great role in overcoming these issues. According to [36] [37] [20]., the adoption of mobile phones is increasing year by year, this provides chances to implement systems that require minimal resources in

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

innovative ways. For these reasons, the architecture could bridge the gaps that arise from such fragmented systems and inadequate ICT infrastructure, geographical dispersals of healthcare providers [38] [39] [40]; [41] [25] and the poor and remote rural communities with challenging healthcare access.

To accomplish the objective, this study sought to answer this research question: How can collaboration among healthcare providers in RCHFs be enhanced to improve healthcare service delivery. This question was broken down into sub-questions as follows:

a) How do the existing Health Information Systems enable the sharing patient information and medical knowledge with regards to healthcare?
b) What collaboration and information sharing challenges do healthcare providers in RCHFs face?
c) What ICT Systems requirements must be met to optimize collaboration among healthcare providers?
d) How can the existing architecture development methodologies be used to develop a collaborative mobile application architecture?

2 Research Methodology

Research Design. This study was based on a case study research design in order to have an in-depth understanding of phenomenon under investigation. The case study research is an intensive study of a single unit with an aim to generalize across a larger set of units[42]. The design was also motivated by its ability to allow the generalisation of data collected from a single source. It has been known to be relevant in situations where one seeks to understand the relationship between information technologies and organisational context [43].

Sampling Method used: The study utilized purposive sampling in determining both the case study and key informants. The decision to use purposive sampling was motivated by the fact that, it would enable the researchers to choose informants that were capable of responding to an area of interest [44]. Secondly, it was the appropriate method since there was a limited number of primary data sources that could contribute to the study.

Inclusion Criteria for the Study Site*:* Lubaga hospital was adopted because it is one the largest hospitals in Uganda and was easily accessible. It had also implemented e-health systems namely clinical master and DHS2 though limited in scope, these would provide insights on the collaborative challenges and the opportunities they offer for improvements. Secondly, the hospital has Community Health Workers (CHW) under a home care department called ACT who face a variety of collaboration challenges and information access barriers hence the need to explore the associated access challenges and opportunities. The informants for this study were selected from the administration and management department because these support strategic and administrative processes; the front-office area which supports the admission of inpatients, outpatients, emergency/first aid patients; the clinical area which supports the core healthcare processes (the processes through which healthcare organizations provide treatment to patients); the IT department because this handles the management of health information systems; the resource centre since this is responsible for acquisition , dissemination, and utilization of medical knowledge and patient information; the research department which grants permission for doing research and has the documentation of the hospital.

Data Collection Tools: The study adopted two sets of data collection including primary data and secondary data. To collect primary data, three common qualitative methods were used including, in-depth interviews because they focus directly on case study topic, and they are insightful since they provide and perceive causal interfaces and explanations. Secondly, they enable the researcher to understand the phenomena in depth of what the interviewee says. The interviewer also has the benefit of following up on incomplete or unclear responses by asking additional probing questions and it has a high response rate since most informants will agree to be interviewed [45] [46]. Focus groups, and participant observation were also used and the three types of data that were generated from the three methods were field notes, audio recordings and transcripts. Purposive sample sizes were used and determined basing on theoretical saturation which is

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

an approach that is used to investigate empirically until no further themes emerge [47]. To collect secondary data, documentary analysis using the hospital's resource centre was used basing on internal annual reports, existing system documentation, and strategic plan.

Data Analysis: ATLAS.ti 9 (Windows) was used to code, analyse and clean up the data that was collected basing on themes that were derived from research questions. The researcher read the responses of each informant that participated in the study to gain in-depth understanding. Secondly, the statements were extracted that bore meaning to the research questions. To ensure data accuracy, direct quotations from the informants were used. During the analysis of the responses, the researcher articulated what the responses meant and recorded the emerging themes. Similar themes were categorized and grouped together. And audio recordings were replayed for verification. Several sub-themes were classified per every theme. A thematic framework basing on thematic analysis technique was developed by moving codes into their respective thematic headings.

Figure 1: Shows the thematic framework for the presentation of the results for both the existing systems and collaboration challenges.

Figure: 1 Thematic Framework Analysis of the existing healthcare information systems and the collaboration challenges

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

2.1 Statement of Ethical Approvals

The purpose of the study was explained to the Lubaga hospital research department and a research proposal was shared with them as a requirement. Besides, an informed consent form was submitted together with a payment of a research fee. A letter of approval numbered **LHREC/2018/012** permitting the researcher to conduct the study was obtained.

3 Results

3.1 Characteristics of Informants

Table 1 below shows the characteristics of informants.

Data Collection Method	Informants	Department	Frequency
Interviews	Top Management	Administration	3
Interviews	IT Staff	IT Department	4
Interviews	Medical Doctors	Medicine, Surgical & Children's Wards	5
Interviews and Focus Group Discussions	Nurse/Midwife	Medicine, Surgical & Children's Wards	15
Interviews	Laboratory Chemist	Laboratory	1
Interviews	Radiologist	Radiology	1
Interviews	Information Scientists	Records Department	2
Documentary Review	Information Scientist	Research Department	1
	Total		32

3.2 Existing Healthcare information sharing systems

Almost all informants reported that there were various information and communication systems including computers, e-mail, internet access, although internet use is becoming increasingly essential, telephones for both landline and mobile were still being used in collaboration. Besides there was a largely used system called Clinic Master as shown in Figure 2 to capture patient information and generate reports (Figure 2) and clinical management across inpatient/outpatient, laboratory, surgical and radiology units. Illustrative responses on the use of clinic master appear below.

> *"The hospital's current information and communication infrastructure includes computers, e-mail, internet access, and, telephone for both landline and mobile. Besides there is a system called Clinic Master that is currently used and this is basically for clinical management but at the back there is a government system called DHS2 that is used in aggregating statistical data collection, validation and analysis". (Interview held with the HCSP-01 on 24th May, 2018).*

> *"I use Clinic Master System to do most of my work but some services are still done manually" We also use phones to communicate among ourselves and the doctors. (*Interview held with the HCSP-02 on 24th May, 2018).

> *"We capture Bio data of patients, patient's medical history and the doctors pick notes from patients and feed them into the system. As the doctor talks to the patient, that information is directly entered into system and after typing it into the system it is saved, reports can be generated and shared with support from the IT department" (*Interview held with HCSP-03 on 24th May, 2018)

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

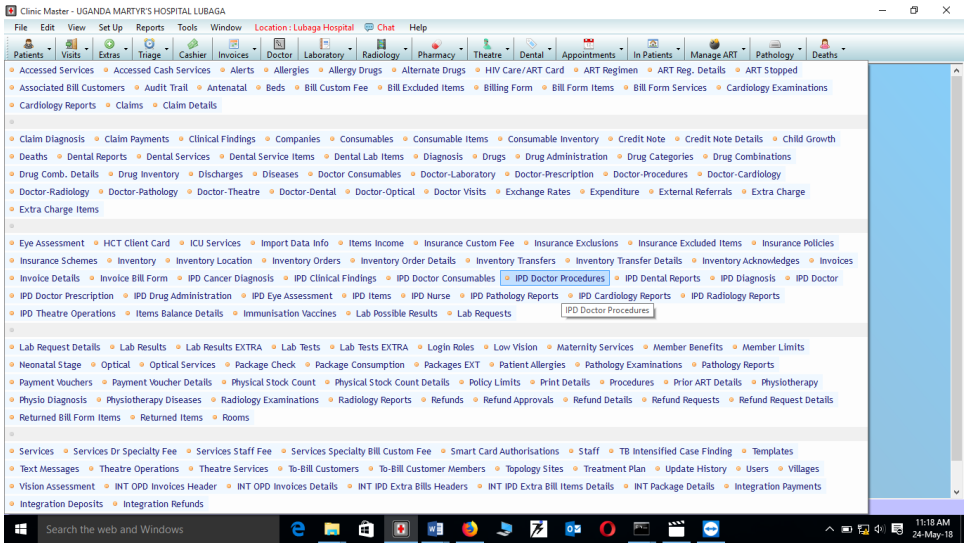

Figure 2: Showing Clinic Master System Generated Reports at Lubaga Hospital

3.3 Challenges faced in sharing of healthcare information

3.3.1 System Integration

Informants reported that there are system integration issues among the Catholic Church Founded Hospitals on one hand and the local internal systems of the hospital on the other. The illustrative example appears below:

> *"Kisubi and Nsambya hospitals do not have the Clinic Master System yet they are referral hospitals. In Kampala there is Lubaga which is using the system. There are also small units like Jinja Karoli they have a health center but they send patients to us but they do not have Clinic Master. So their bio data has to be captured from scratch when they are referred here. Nsambya Hospital is using a system called SAP, it is an ERP which is troublesome to customize. Kisubi is inquiring from us about the status of the integration of clinic master and Navision, then they will come onboard."* (Interview held with the HCSP-01 on 24th May, 2018, Lubaga Hospital).

When the informants were asked about how the current systems relate to each other and how they exchange information for collaboration, they noted that there are three systems i.e., Clinic Master, Navision and DHS2 systems within the hospital but are not connected to each other and so there is no seamless flow of information (Table 2). They indicated that they are detached; users pick data from clinical master and feed it manually into DHS2.

Category	**Patient Information sharing internally?**	**Patient Information sharing externally?**	**Medical knowledge sharing both internally and externally?**
Top Management	Yes but with limitations	Not possible	Not Applicable
Medical Doctors	Yes but with limitations	Not Applicable	Not Applicable
Nurse /midwives	Yes but with limitations	Not Applicable	Not Applicable
Computer Scientists	Yes	Not Applicable	Not Applicable
Information Scientists	Yes but with limitations	Not Applicable	Not Applicable

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

Table 2: System Functionalities in the Provision of Healthcare Information

3.3.2 Data Quality Issues

Informants also noted that there are data quality issues characterised by information completeness gaps. They reasoned that this is related to inadequate documentation as it is usually done manually especially from other health units when a patient is referred. In addition, some Healthcare providers might not always provide some clinical information that might be significant to clinical research. When referrals are done the information provided is not always complete and this makes it a time-consuming process before one makes a decision about which care to offer. It is sometimes difficult for Healthcare providers to figure out things from the manual medical record since there is no inter- automatic transfer of information from one health unit to another. Below is an illustrative example.

> *"The challenge is that currently we cannot be sure that the information given in the medical record will match the post treatment for the patient. So it is a bit tricky to figure out what has been previously prescribed as there is no interface between information systems that can provide the history in its entirety"* (Interview held with a HCSP-04 on 25th May, 2018, Lubaga Hospital*).*

3.3.3 Infrastructure Limitations

Informants also reported that there are infrastructure limitations as there are not enough information delivery channels for healthcare providers to access the current system. Each ward has one computer that is shared and when it is being used others have to wait; an indication that the implementation of clinic master was still largely at a pilot stage, and needed to be scaled up. Subsequently, there is low utilization of the technology by the Healthcare providers. Below is an illustrative example:

> *"The system is available, usually online but can be accessed on only the computers where it is installed and within the environs of the hospital" (Interview held with HCSP-01 on 24th May, 2018, Lubaga Hospital).*

3.3.4 System Usability

To further examine the implementation of clinic master, this study assessed the system usability as it is one of the critical factors in the successful implementation of any technology. It was found out that some users found it easy to use and others didn't. For this reason, there was always a switch between the manual and the electronic system which becomes tedious and ultimately hinders communication and collaboration. Below is an illustrative example

> *"There are issues with customization of the clinic master. The system does not fulfil all the users' expectations. The levels of customization facilitate about 60% of what they want to do and this retards the workflow as one has to switch between the system and the paper; recording here and there. Clinicians who were used to the books; turning them to the system makes it difficult for them and they usually wonder that if they have recorded in the book is there a need to record in the system*". (Interview held with HCSP-05 on 25th May, 2018, Lubaga Hospital).

3.3.5 Proximity

The study found out that there were healthcare providers who were full time, and consultants that came as and when they had appointments, there were services that were referred to other health units, for instance imaging centres for radiology and laboratory services. There was also a home care program which was partly clinical because its activities were related to inpatients, Healthcare providers also go to outreach to help in trainings in good hygienic conditions, there was a home care department called ACT which

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

physically picked patient's results from the laboratory moreover in a paper-based form. All these brought about a geographical dispersion of health services characterised by communication gaps.

4 Proposed Architecture for a Collaborative Mobile Application.

This section presents the architecture vision, goals and principles of development and implementation, strategic standards and objectives that guided the design of the architecture. It also includes the user requirements that are crucial in the design. The section also addresses the last objective of this study (How can the existing architecture development methodologies be used to develop a collaboration mobile application architecture?). The method used to resolve this research question was based on both the literature review and enterprise architecture framework and in particular the most commonly used which is TOGAF, Version 9.1, a standard of The Open Group Architecture. This has been contextualized to suite the RCHFs. It helps in developing architectures that are consistent and reflect the concerns of the key stakeholders [48] .

4.1 The Architecture vision:

To provide an information system architecture that is capable of optimizing collaboration and information sharing among healthcare providers.

4.2 Goals and Principles of the Architecture derived from The TOGAF Standard, Version 9.1

Business Principles

Name	Statement	Rationale	Implications
Primacy of principles	Architecture principles to apply to organizational units within healthcare facilities	Healthcare providers to abide by the main principals of the enterprise for its business, technology and information architectures. This will enable the organization to provide reliable and quality information for decision making.	The architecture should have provisions for ensuring collaboration, consistency and continued alignment to business without undermining the management of technology, information and business processes for both internal and external healthcare providers
Maximize benefits to healthcare facilities	Decisions are made to provide maximum benefits to healthcare facilities	Decisions made from an enterprise-wide perspective have greater long-term value than decisions made from any particular organizational perspective.	Application components should be shared across organizational boundaries
Common use applications	Solutions that can be applied across the organization are preferred	The architecture should be able to integrate various applications in the rapid integration of dynamic and diverse hardware.	The architecture should enable data transmission between various software products that are secured and connected through APIs and web services
Information Principles			
Information is a business asset	Information is an asset that has a value chain from creation to information that provides new insights	The architecture should have provisions for combining information with other sources to create new information that is critical in decision making.	The architecture should ensure compliance with confidentiality, integrity and availability and ensuring timely correct information flow and access.
Information is shared	Healthcare providers can access and share information that is required.	The architecture should have a single source of information and have it shared in response to business needs	The architecture should allow easy access to most accurate and timely information on an anywhere-anytime basis.

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

Information security	Data is confidential and shared in harmony with legislation and data policies	The architecture should have measures for restricting information from unauthorized users	Provision of access to information as well as maintenance of its security should be taken care of at the information but not at the application layer
Application Principles			
Technology independence	Applications are not dependent on specific hardware and operating systems software.	The architecture should ensure that the application can run on various technology platforms.	The architecture should incorporate interfaces that will enable legacy applications to interoperate with other applications.
Ease of use	The technology should be simple, efficient, effective and easy to execution tasks	The architecture should enable collaboration within an integrated environment.	The architecture should have an interface that accelerates usability
Technology Principles			
Requirements-based change	Technology should be implemented in harmony with business needs	The architecture should be developed in accordance with healthcare providers' collaboration needs instead of having the business change in response to IT changes	Changes in implementation of the architecture must comply with full examination of the proposed changes using the enterprise architecture

Table 3: Showing principles of the Architecture- The TOGAF Standard Version 9.2

4.3 Business requirements (User Requirements) to optimise Collaboration

This section presents the business / user requirements; These requirements were identified basing on the challenges that healthcare providers faced. The challenges were identified from both the field findings and literature review and were used as a basis for determining the stakeholder's needs for the proposed system and entailed the institutional requirements in general.

The following is a summary of user requirements that were gathered for the target architecture. The architecture should be able to:

(i) Display a list of available business start-up resources from the database to the users according to their access rights and privileges. And for this study this entailed links to the patients' database, call for help (collaboration), user's profile, medical guidelines and logout.

(ii) Have user-friendly interfaces and user guides understandable by Healthcare providers with basic computer skills.

(iii) Provide access to healthcare information from multiple sources such as access to patient bio data, history database, medical guidelines and instant online consultations among healthcare providers

(iv) Evolve to meet changing requirements both in terms of functionality as well as operation and specification since policy in healthcare is subject to review and updates

(v) Be easy to maintain - Maintaining health information systems is prone to high rate of change over time. Modifications in software is inevitable after the product has been deployed and this includes, corrections, improvements or adaptation to changes in environment, requirements and functional specifications [49].

(vi) Work with existing approaches – as indicated in the literature review of this study, the proposed architect in this study was based on the Agile Enterprise Architecture where customer satisfaction is the highest priority; change in requirements is welcomed and is no longer an obstacle; and architect is modified regularly in consecutive releases.

These requirements were validated by 20 potential users of the collaborative tool and the results of the validation are presented in figure (3) below:

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

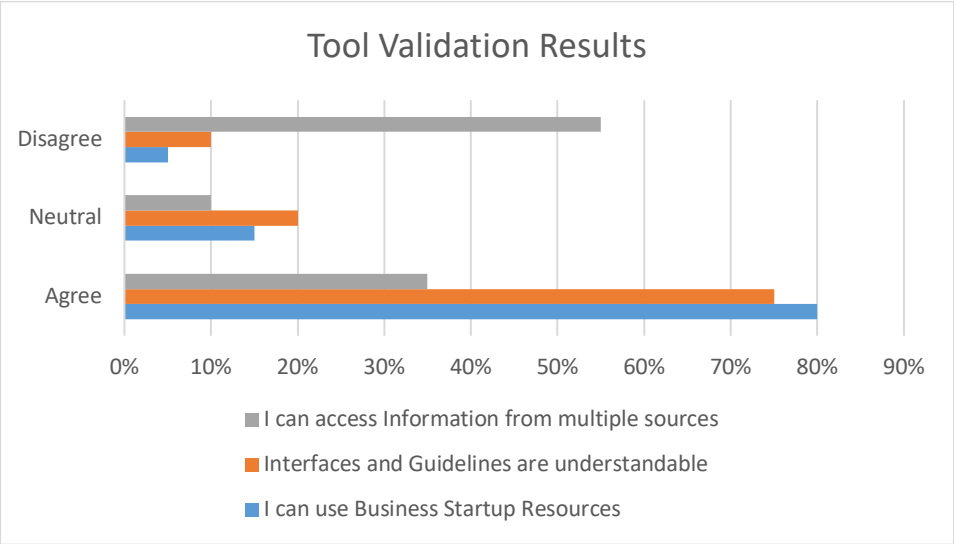

Figure 3: Shows the tool validation results

The validation of the tool indicates that 80% of the respondents strongly agreed that the tool provides start-up menus that are easy to use in their day-to- day work, 15% took a neutral position 5% disagreed. The 5% of the respondents may have been top management who do not use the tool frequently. All in all, the usability of business start-ups is highly acceptable. 75% of the respondents agree that the interfaces and guidelines are understandable, 20% took a neutral position and 10% present disagreed and these may have been ICT officers who do not use guidelines. 35% of the respondents can access information from multiple sources, 10% remained neutral and 55% disagreed and this is attributed to the fact that users needed more training on traversing through different menus to access information from multiple sources.

4.4 Proposed enterprise architecture for a mobile collaboration tool for Resource Constrained Healthcare Facilities

Below is a detailed model of the various architecture domains that make up the target Enterprise Architecture including the Business, Application, Data, and Technology that were constructed basing on the archmate language notations in figure (5).

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

4.5 Complete Enterprise Architecture for Resource Constrained Health Facilities

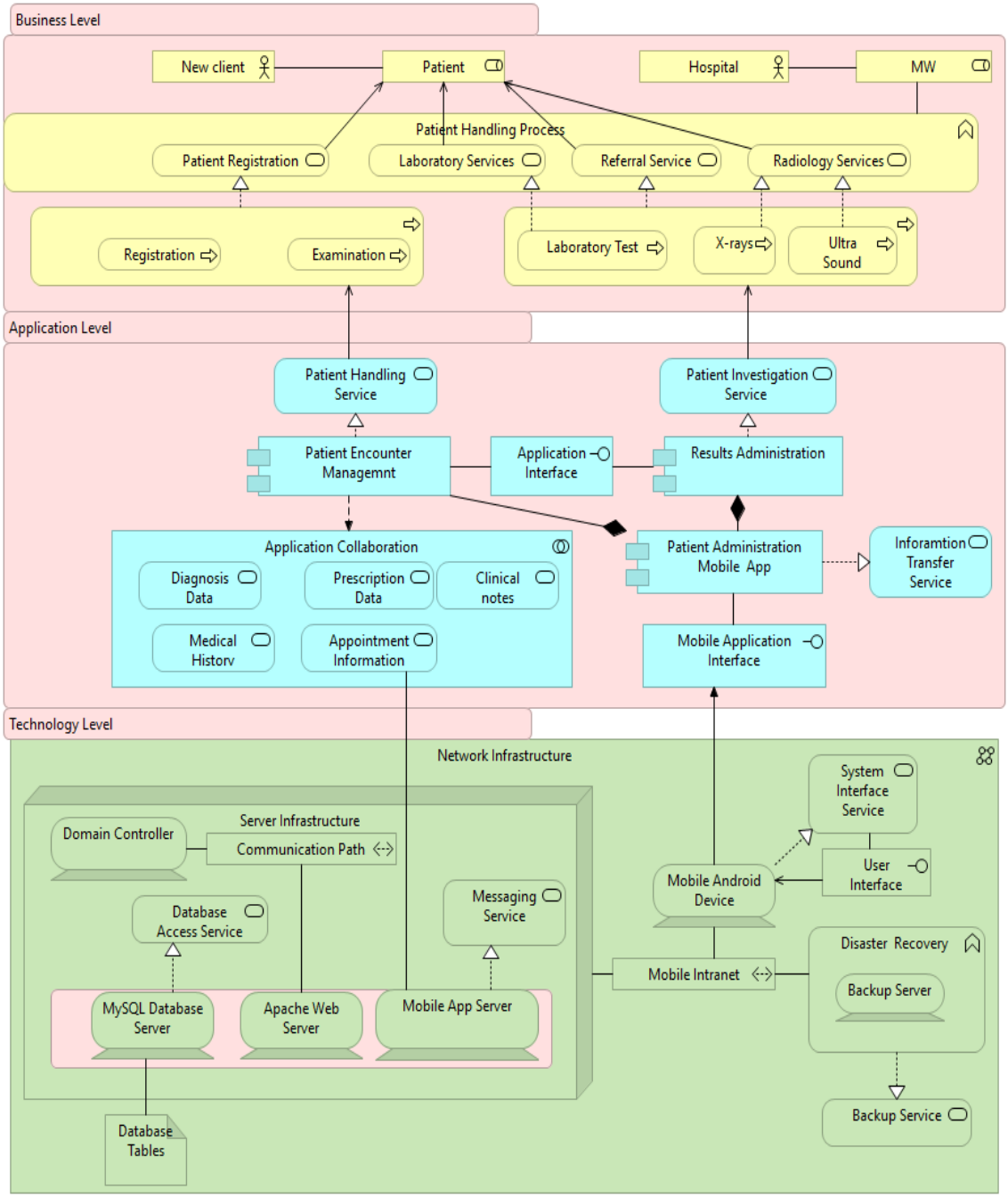

Figure 4: Enterprise Architecture Layers for Resource Constrained Health Facilities

Below is figure 5 that shows the archmate language notations that were used to develop the architecture in figure below:

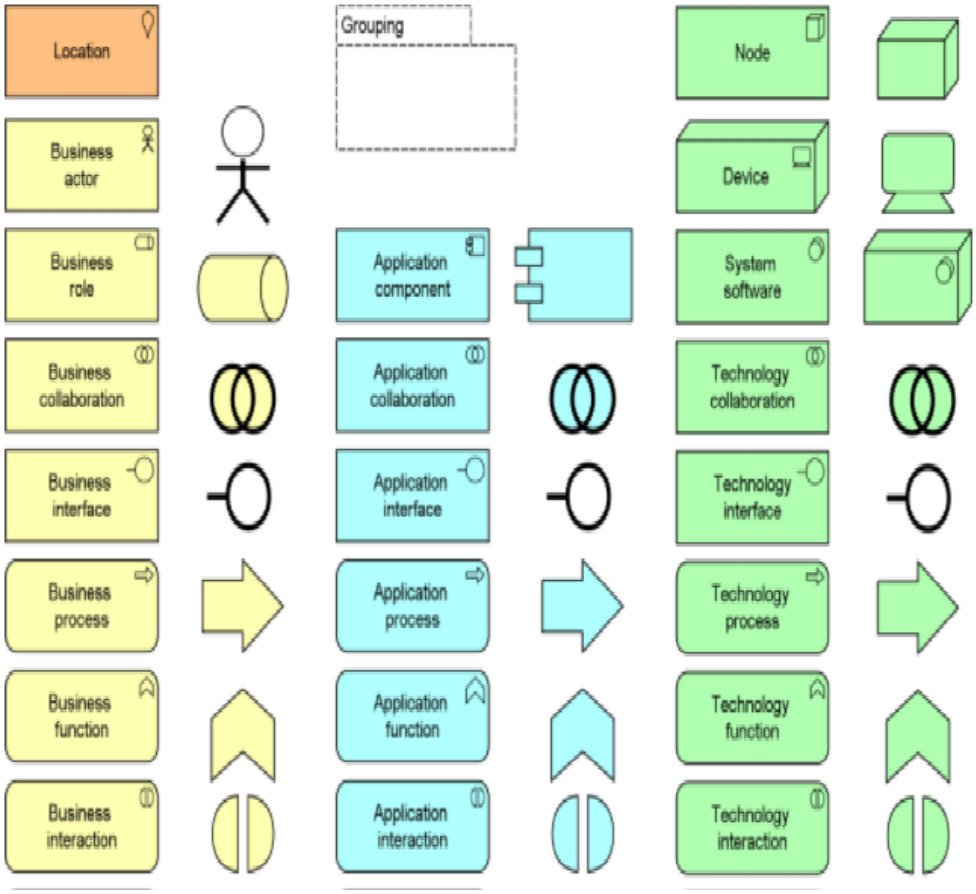

Figure 5: Showing Arch mate Annotations: Source: ArchiMate 3.0.1 Specification 2012-2017 The Open Group

The architecture comprises of the business level which encompasses the OPD, laboratory, referrals and radiology services. To reduce the length of stay, medical errors, duplication of tests and the associated problems with the existing method of patient handling, there was need to improve communication and collaboration among Healthcare providers.as illustrated in figure (4).

The application level was proposed in this study to primarily handle medical worker's interaction with the patients during the examination process. With this in place the patient's medical history is shared easily, diagnosis and treatment can be done in collaboration with other professionals and medical guidelines embedded in the patient administration application can be accessed online depending on a given condition.

The technology level architecture introduces the database server, apache web server and the mobile application servers to support collaboration. These servers are linked to the hospital network through the internet. These servers realize three services that are used in collaboration and these are the database access service, the messaging service and the backup service. This level emphasizes the need for technology that support the application and information sharing in the clinical workflows. This technology includes the servers, collaboration technologies, and storage and data recovery.

The inference drawn from the discussion of the findings were such that it is imperative to streamline certain processes as well as introducing new ones in some areas. A mobile tool architecture was of paramount importance as it can act as interface between the current technology and service delivery at any

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

point-of-care. Therefore, an enterprise network architecture had to be done to streamline and align business processes to the overall objective.

5 Discussion

Basing on the results of the findings it was clearly evident that the development of an architecture that can support a mobile tool could resolve the mismatch between the actual and assumed information in clinical workflows thereby enhancing collaboration among Healthcare providers and ultimately improve healthcare service delivery in Resource Constrained Healthcare Facilities. To that effect it will enable Healthcare providers to work in agile collaborative manner as they will be able to innovate together and uncover new ways of service delivery in a way that reduces waste, patient-length-of-stay and missed handoffs which potentially lead to medical errors such as mistaken identity, improper diagnosis, and duplication of tests, wrong-site surgeries, inaccurate treatment and unexpected deaths.

During the study, a number of healthcare sharing information systems and the collaboration challenges that healthcare providers face were identified that are consistent with past research. The level of communication technology in the hospital and between hospitals was still at its infancy as the implementation of clinic master at the hospital was largely at experimental stage, with minimal collaborative features and therefore required to be scaled up. Subsequently, there was insufficient utilization of the communication technology by the Healthcare providers as there were still instances of manual information processing. These findings correspond with [40] [41] [25] as they point out that there is still lack of communication technology infrastructure in Resource Constrained Healthcare Facilities (RCHFs) and this has a great impact on data quality in regards to information completeness in clinical workflows. When referrals are done the information provided is not always complete and this makes it a time-consuming process before one makes a decision about which care to offer. It is sometimes difficult for healthcare providers to figure out things from the manual medical record since there is no inter- automatic transfer of information from one health unit to another. Secondly, there are issues with the outpatient clinical-information correctness. These findings correspond with [50] as she indicates that poor data quality caused by different issues such as lack of communication technology required in collecting the required data poses challenges to good data quality which ultimately affect decision making and quality service delivery.

More to that, the responses were in agreement with [51] who notes that there is no sub Saharan African country which has developed modern Health Information Technology that has improved online collaboration by providing timely health information. He further notes that with the influence of USAID DFID and WHO, there are emerging systems in RCHFs but these mainly focus on managing data collection and reports. Less is being done in improving online collaboration by providing patient information and medical guidelines in a concurrent and seamless manner at a point-of-care. Furthermore, the responses are indicative of [52] who note that, systems such as Electronic Patient Records (EPRs) are increasingly being considered to improve data storage, by storing and tracking medical data over the lifetime of a patient, typically across healthcare units. However various studies of such systems indicate that whereas the development and analysis of these western solutions is increasingly becoming important less is being done towards collaboration and innovations that are local in nature. This is principally true in RCHFs where IT infrastructure is still under-developed, as compared to developed countries. Many a time RCHFs look at developed ones for ICT solutions, yet local infrastructural issues can introduce drastic operational or performance challenges into the system. This is a clear manifest of a ‘design-reality’ gap [16]. There are cultural differences between the makers and the users of ICT technologies [48]. Factors of the real-world implementation differ from those considered in the design, leading to operational complications; this is a fact that is clearly manifested in the findings.

This study further revealed the user’s needs and these were elaborated in three scenarios; first, when a patient visits the hospital and when a patient is discharged from the hospital, secondly, when a facility is caring for a patient referred to them by another physician and thirdly, when they refer their patient to another physician. In that regard, this study revealed what type of information they want in the various care hand-

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

offs or transitions, how they like to receive or access it, and how quickly. It was noted that across all the three situations as outlined above the medical lists, relevant laboratory results and relevant imaging results from radiology are very vital types of information to receive and use during transition of care. This collaborates with [9] as she proposes an online and real-time knowledge sharing approach that can support Healthcare providers in the process of service delivery. However, the flow of information in the above scenarios especially with the referrals was still largely characterized by paper work. For example, in case referrals to the hospitals, patients manually carry the referral forms to the consulting Healthcare providers. The existing system does not interface with other systems from other health units, if any anyway. Besides, when hospitals are also making referrals to other health units or consultants, the process is mainly paper based due to lack of system integration with other health units. These findings correspond with [16] who states that Healthcare providers and institutions lack the adequate systems functionalities to deliver strategic change yet there is a sense of urgency on their part to make use of information technology.

Looking at the case study for instance, this study found out that there are three systems including Clinic Master, Navision and DHS2 systems but they are not connected to each other and so there is no seamless flow of information. They are detached, users pick data from clinical master and feed it manually into DHS2. This collaborates with [53] as he notes that when having multiple information systems within an organization, integration of information may be required across various business units/departments. By effectively integrating systems, organizations can reap the benefits of increased efficiency and effectiveness in their processes whilst decreasing the disruption caused by having all their information in different locations.

To understand the issue of proximity or geographical dispersal, this study explored the degree to which healthcare providers are distributed and how they keep in touch with their respective units. It was found out that that there are Healthcare providers who are full time, there are consultants that come as and when they have appointments, and there are services that are referred to other health units, for instance imaging centres for radiology and laboratory services. All this brings about a geographical dispersion of health services that calls for collaborative and communication architecture. There are also home care programs which are partly clinical because their activities are related to inpatients and they also go to outreach to help in trainings in good hygienic conditions, in outreach, at Lubaga hospital for instance, there is a home care department called ACT which picks patient's results from the laboratory physically, this further reveals that there are limitations in information sharing as there are Healthcare providers that deal with outreach programs who because of lack of proximity do not have access to information unless they move physically to the hospital and pick it manually in a paper based form. This matches with [50] as he contends that rural areas experience distinct challenges in gaining access to health care. And he proposes the implementation of ICT infrastructure can support rural health in overcoming geographic and historical healthcare barriers.

The study confirmed that there are infrastructural limitations since the hospitals do not have enough information delivery channels for Healthcare providers to access the current system. Each ward has one computer that is shared and when it is being used others have to wait; an indication that the implementation of clinic master was still hindered by infrastructural limitations. Subsequently, there is low utilization of the technology by the Healthcare providers. These findings correspond with [25] indicate that the use of Technology-Based Interventions (TBI) for healthcare delivery is hampered by poor infrastructure as the major barriers to communication and collaboration among Healthcare providers.

Moreover, RCHFs have substantial operational shortfalls in their physical networks because of the high costs, geographic dispersals, and a big number of the populace in rural areas. Thence the use of wireless networks and implementation of a well-structured mobile architecture can help to overcome this issue. This is in agreement with [54] as he contends that the adoption of mobile phones is increasing year by year, and this provides chances to implement systems that require minimal resources in innovative ways. For these reasons, connected collaborative healthcare (architecture) can bridge the gaps that arise from lack of adequate ICT infrastructure.

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

6 Conclusion

Healthcare is a key example of collaborative work and contrary to other disciplines, it is often non-routine, which makes it difficult to pre-schedule clinical procedures and activities. Issues such as emergencies and exceptions are so common enough and impede standardization of clinical practices. These two characteristics call for dependency on communication and critical information sharing to achieve optimal collaboration but they also provide justification for deployment of a seamless collaborative mobile application architecture to coordinate clinical workflow. Healthcare providers ought to work in an agile collaborative manner that empowers them to innovate together and uncover new ways of service delivery in a manner that reduces waste, missed handoffs, patient length-of-stay, medical errors such as improper diagnosis, wrong medication, mistaken identity duplication of tests, wrong-site surgeries, inaccurate treatment and unexpected deaths. To that effect, this study investigated the existing systems and associated collaboration challenges faced by healthcare providers and also analysed those that were derived from literature review. All in all, there was need to develop an architecture that would connect healthcare providers and enable them to work and innovate together. The development of the collaboration architecture was based on enterprise architecture taking cognizance of its four crucial C's; connection, collaboration, communication and customer. The solution was based on the alignment of the hospital's strategic vision with its information technology. It connects different business units for synergistic communication and collaboration, creating a more seamless end-user experience. Future research that focuses on sociotechnical aspects of information security and privacy requirements when designing and developing a mobile application for collaboration among medical workers is essential and timely.

Acknowledgements

The researchers would like to recognize all the administrators of Uganda Martyrs Hospital Lubaga and informants who played a significant role in providing data that informed this study.

References

[1] D. M. Mugo and D. Nzuki, "Determinants of electronic health in developing countries," 2014.
[2] K. S. Mate *et al.*, "Improving health system quality in low-and middle-income countries that are expanding health coverage: a framework for insurance," *Int. J. Qual. Heal. Care*, vol. 25, no. 5, pp. 497–504, 2013.
[3] M. Herselman and A. Botha, *Designing and implementing an Information Communication Technology for Rural Education Development (ICT4RED) initiative in a resource constraint environment: Nciba school district, Eastern Cape, South Africa*. CSIR, 2014.
[4] D. Luna, A. Almerares, J. C. Mayan, F. González Bernaldo de Quirós, and C. Otero, "Health informatics in developing countries: going beyond pilot practices to sustainable implementations: a review of the current challenges," *Healthc. Inform. Res.*, vol. 20, no. 1, pp. 3–10, 2014.
[5] S. Zeadally, J. T. Isaac, and Z. Baig, "Security attacks and solutions in electronic health (e-health) systems," *J. Med. Syst.*, vol. 40, no. 12, p. 263, 2016.
[6] V. Minichiello, S. Rahman, T. Dune, J. Scott, and G. Dowsett, "E-health: potential benefits and challenges in providing and accessing sexual health services," *BMC Public Health*, vol. 13, no. 1, p. 790, 2013.
[7] H. C. Ossebaard and L. Van Gemert-Pijnen, "eHealth and quality in health care: implementation time," *Int. J. Qual. Heal. care*, vol. 28, no. 3, pp. 415–419, 2016.
[8] B. M. C. Silva, J. J. P. C. Rodrigues, I. de la Torre Díez, M. López-Coronado, and K. Saleem, "Mobile-health: A review of current state in 2015," *J. Biomed. Inform.*, vol. 56, pp. 265–272, 2015.
[9] J. Karuri, P. Waiganjo, O. Daniel, and A. Manya, "DHIS2: the tool to improve health data demand and use in Kenya," *J. Health Inform. Dev. Ctries.*, vol. 8, no. 1, 2014.
[10] V. M. Kiberu, J. K. B. Matovu, F. Makumbi, C. Kyozira, E. Mukooyo, and R. K. Wanyenze, "Strengthening district-based health reporting through the district health management information software system: the Ugandan experience," *BMC Med. Inform. Decis. Mak.*, vol. 14, no. 1, pp. 1–9, 2014.
[11] H. Rexhepi, "Improving healthcare information systems: A key to evidence based medicine." University of Skövde, 2015.

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

[12] G. Hirsch, "Leaping Together Toward Sustainable, Patient-Centered Innovation: The Value of a Multistakeholder Safe Haven for Accelerating System Change," *Clin. Pharmacol. Ther.*, vol. 105, no. 4, p. 798, 2019.
[13] J. L. Drummond, M. C. Were, S. Arrossi, and K. Wools-Kaloustian, "Cervical cancer data and data systems in limited-resource settings: Challenges and opportunities," *Int. J. Gynecol. Obstet.*, vol. 138, pp. 33–40, 2017.
[14] H. B. Mwanyika, "Developing integrated health information systems in low income countries: An enterprise architecture approach," *PhD Thesis*, pp. 1–186, 2014, [Online]. Available: http://edoc.unibas.ch/33044/1/Henry Mwanyika Thesis Final.pdf.
[15] R. Matavire, "Health Information Systems Development: Producing a New Agora in Zimbabwe.," *Inf. Technol. Int. Dev.*, vol. 12, no. 1, 2016.
[16] R. Heeks, "Health information systems: Failure, success and improvisation," *Int. J. Med. Inform.*, vol. 75, no. 2, pp. 125–137, 2006.
[17] S. M. Chege, "Application of the design–reality gap model to enhance high availability of systems for health care providers in nairobi, kenya." University of Nairobi, 2015.
[18] J. A. Blaya, H. S. F. Fraser, and B. Holt, "E-health technologies show promise in developing countries," *Health Aff.*, vol. 29, no. 2, pp. 244–251, 2010.
[19] S. Scholz, B. Ngoli, and S. Flessa, "Rapid assessment of infrastructure of primary health care facilities–a relevant instrument for health care systems management," *BMC Health Serv. Res.*, vol. 15, no. 1, p. 183, 2015.
[20] J. O. T. A. Watkins, J. Goudge, F. X. Gómez-Olivé, and F. Griffiths, "Mobile phone use among patients and health workers to enhance primary healthcare: A qualitative study in rural South Africa," *Soc. Sci. Med.*, vol. 198, pp. 139–147, 2018.
[21] M. T. Latourette *et al.*, "Magnetic resonance imaging research in sub-Saharan Africa: challenges and satellite-based networking implementation," *J. Digit. Imaging*, vol. 24, no. 4, pp. 729–738, 2011.
[22] F. Shiferaw and M. Zolfo, "The role of information communication technology (ICT) towards universal health coverage: the first steps of a telemedicine project in Ethiopia," *Glob. Health Action*, vol. 5, no. 1, p. 15638, 2012.
[23] Y. B. Okwaraji and K. M. Edmond, "Proximity to health services and child survival in low-and middle-income countries: a systematic review and meta-analysis," *BMJ Open*, vol. 2, no. 4, 2012.
[24] O. Nov and W. Schecter, "Dispositional resistance to change and hospital physicians' use of electronic medical records: A multidimensional perspective," *J. Am. Soc. Inf. Sci. Technol.*, vol. 63, no. 4, pp. 648–656, 2012.
[25] M. A. Zayyad and M. Toycan, "Factors affecting sustainable adoption of e-health technology in developing countries: an exploratory survey of Nigerian hospitals from the perspective of healthcare professionals," *PeerJ*, vol. 6, p. e4436, 2018.
[26] A. Feroz, M. M. Kadir, and S. Saleem, "Health systems readiness for adopting mhealth interventions for addressing non-communicable diseases in low- and middle-income countries: a current debate," *Glob. Health Action*, vol. 11, no. 1, p. 1496887, 2018, doi: 10.1080/16549716.2018.1496887.
[27] W. Mutale *et al.*, "Improving health information systems for decision making across five sub-Saharan African countries: Implementation strategies from the African Health Initiative," *BMC Health Serv. Res.*, vol. 13, no. 2, pp. 1–12, 2013.
[28] O. O. Oleribe *et al.*, "Identifying key challenges facing healthcare systems in Africa and potential solutions," *Int. J. Gen. Med.*, vol. 12, p. 395, 2019.
[29] I. Supper, O. Catala, M. Lustman, C. Chemla, Y. Bourgueil, and L. Letrilliart, "Interprofessional collaboration in primary health care: a review of facilitators and barriers perceived by involved actors," *J. Public Health (Bangkok).*, vol. 37, no. 4, pp. 716–727, 2015.
[30] A. Doessing and V. Burau, "Care coordination of multimorbidity: a scoping study," *J. Comorbidity*, vol. 5, no. 1, pp. 15–28, 2015.
[31] H. Rexhepi and A. Persson, "Challenges to Implementing IT Support for Evidence Based Practice Among Nurses and Assistant Nurses: A Qualitative Study," in *Nursing Education, Administration, and Informatics: Breakthroughs in Research and Practice*, IGI Global, 2018, pp. 440–456.
[32] R. Zeuner, D. L. Frosch, M. D. Kuzemchak, and M. C. Politi, "Physicians' perceptions of shared decision-making behaviours: a qualitative study demonstrating the continued chasm between aspirations and clinical practice," *Heal. Expect.*, vol. 18, no. 6, pp. 2465–2476, 2015.
[33] G. Del Fiol, T. E. Workman, and P. N. Gorman, "Clinical questions raised by clinicians at the point of care: a systematic review," *JAMA Intern. Med.*, vol. 174, no. 5, pp. 710–718, 2014.
[34] E. Manias, "Effects of interdisciplinary collaboration in hospitals on medication errors: an integrative review," *Expert Opin. Drug Saf.*, vol. 17, no. 3, pp. 259–275, 2018.
[35] P. Mechael and S. Searle, "Barriers and Gaps Affecting mHealth in Low and Middle Income Countries : Policy White Paper," *mHealth Alliance*, vol. 54, no. March, pp. 1–79, 2010, [Online]. Available: http://www.globalproblems-globalsolutions-files.org/pdfs/mHealth_Barriers_White_Paper.pdf.
[36] T. Lewis, C. Synowiec, G. Lagomarsino, and J. Schweitzer, "E-health in low-and middle-income countries: findings from the Center for Health Market Innovations," *Bull. World Health Organ.*, vol. 90, pp. 332–340, 2012.

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299

[37] C. O. Buckee, A. Wesolowski, N. N. Eagle, E. Hansen, and R. W. Snow, "Mobile phones and malaria: modeling human and parasite travel," *Travel Med. Infect. Dis.*, vol. 11, no. 1, pp. 15–22, 2013.
[38] J. Braa, O. Hanseth, A. Heywood, W. Mohammed, and V. Shaw, "Developing health information systems in developing countries: the flexible standards strategy," *Mis Q.*, pp. 381–402, 2007.
[39] I. Asangansi and K. Braa, "The emergence of mobile-supported national health information systems in developing countries.," in *Medinfo*, 2010, pp. 540–544.
[40] H. W. Lee, T. Ramayah, and N. Zakaria, "External factors in hospital information system (HIS) adoption model: a case on malaysia," *J. Med. Syst.*, vol. 36, no. 4, pp. 2129–2140, 2012.
[41] Q. A. Qureshi *et al.*, "Infrastructural barriers to e-health implementation in developing countries," *Eur. J. Sustain. Dev.*, vol. 2, no. 1, p. 163, 2013.
[42] J. Gerring, "What is a case study and what is it good for?," *Am. Polit. Sci. Rev.*, vol. 98, no. 2, pp. 341–354, 2004.
[43] P. N. Rito, "WHAT ABOUT? CASE STUDY METHOD IN INFORMATION SYSTEMS," in *INTED2014 Proceedings*, 2014, pp. 2814–2821.
[44] I. Etikan, S. A. Musa, and R. S. Alkassim, "Comparison of convenience sampling and purposive sampling," *Am. J. Theor. Appl. Stat.*, vol. 5, no. 1, pp. 1–4, 2016.
[45] S. Knox and A. W. Burkard, "Qualitative research interviews," *Psychother. Res.*, vol. 19, no. 4–5, pp. 566–575, 2009.
[46] B. Gillham, *Research Interviewing: The range of techniques: A practical guide*. McGraw-Hill Education (UK), 2005.
[47] M. Saunders, P. Lewis, and A. Thornhill, "Research methods," *Bus. Students 4th Ed. Pearson Educ. Limited, Engl.*, 2007.
[48] T. Senator and P. Gramm, "I n t roduc t ion," *Terrorism*, pp. 1–222, 2010.
[49] K. Atalag, H. Y. Yang, and J. Warren, "Assessment of software maintainability of openEHR based health information systems-A case study in endoscopy," 2012.
[50] R. L. Richesson, M. M. Horvath, and S. A. Rusincovitch, "Clinical research informatics and electronic health record data," *Yearb. Med. Inform.*, vol. 9, no. 1, p. 215, 2014.
[51] F. Muriyesu, "Architectural Design of the National Health Information System for Rwanda," *Master's Thesis*, no. January, p. 63, 2016.
[52] S. P. Sood *et al.*, "Electronic medical records: A review comparing the challenges in developed and developing countries," in *Proceedings of the 41st Annual Hawaii International Conference on System Sciences (HICSS 2008)*, 2008, p. 248.
[53] T. Tossy, "Major Challenges and Constraint of Integrating Health Information Systems in African Countries: A Namibian Experience," *Int. J. Inf. Commun. Technol.*, vol. 4, no. 7, 2014.
[54] A. K. Kakkar, P. Sarma, and B. Medhi, "mHealth technologies in clinical trials: Opportunities and challenges," *Indian J. Pharmacol.*, vol. 50, no. 3, p. 105, 2018.

 J Health Inform Afr. 2022;9(1):14-30. DOI: 10.12856/JHIA-2022-v9-i1-299