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Electronic information capturing, processing and reporting of routine health data using smartphone-based application

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ELECTRONIC INFORMATION CAPTURING, PROCESSING AND REPORTING OF ROUTINE HEALTH DATA USING SMARTPHONE-BASED APPLICATION

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master's in Information and Communication Science and Engineering of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

The primary health facilities are the core source of health data in the current health system. As a core source there is a need for an effective capturing, processing and reporting of this sensitive and crucial data for the smooth functioning of the health sector. In Tanzania, the routine reporting of health data from the primary health facilities to the district level is a manual system in which hard copies of different report forms are physically submitted to the district hospital, a computerized system is being implemented from the district level to the national level.

The data collected from the primary health facilities delays and reaches the districts late due to different challenges among them being the remoteness of health facilities to the district hospitals. The delay causes the districts to fail in utilizing the collected data effectively to make evidence-based decisions. The research aimed to bridge the technological gap that exists in the utilization of Information and Communication Technology in the health sector and thus address the late reporting problem by enabling data transfer through a smartphone-based application.

A qualitative research methodology is carried out coupled with agile development methodology for mobile applications in the design and development of the mobile phone reporting application

As a result, a smartphone-based application for reporting routine health data is developed which will facilitate on time submission of reports, improvements on the reporting frequency and reduction on the cost for reports submission. The reporting officers will no longer travel physically to the district hospital to submit the reports.

Keywords: Smartphone-based application, routine health data, reporting, mobile phone, mobile reporting.

DECLARATION

I, **LUBA PASCOE** do hereby declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

LUBA PASCOE

April 12, 2016

Name and signature of candidate **Date**

The above declaration is confirmed

Joseph W. Mwangoka **April 12, 2016**

Name and signature of supervisor **Date**

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CERTIFICATION

The undersigned certify that has read and found the dissertation acceptable by the Nelson Mandela African Institution of Science and Technology.

Joseph W. Mwangoka 	April 12, 2016
Name and signature of supervisor	**Date**

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DEDICATION

This work is humbly dedicated to my lovingly parents for their interminable efforts in moulding me, to be whom I am today. My beloved son, Lincoln and the love of my life Raphael for their unyielding love, care, support and prayers.

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LIST OF ABBREVIATIONS

API	**Application Program Interface**
AFP	**Acute Flaccid Paralysis**
ANC	**Antenatal Care**
CTC	**Care and Treatment Clinic**
DHIS	**District Health Information System**
EPI	**Expanded Program on Immunization**
ERD	**Entity Relationship Diagram**
GPS	**Global Positioning System**
HMIS	**Health Management Information System**
ICT	**Information and Communication Technology**
IDWE	**Infectious Disease Week Ending**
IPD	**Inpatient Data**
MoHSW	**Ministry of Health and Social Welfare**
NNT	**Neonatal Tetanus**
ODK	**Open Data Kit**
OPD	**Outpatient Data**
SDK	**Software Development Kit**
SMS	**Short Message Service**
STI	**Sexually Transmitted Infections**
UI	**User Interface**
VCT	**Voluntary Counselling and Testing**
VHF	**Viral Haemorrhagic Fever**
XML	**Extensible Mark-up Language**

CHAPTER ONE

Introduction

This chapter describes the general introduction of the study focusing on the background information, the use of mobile technologies for health as presented by different literatures and a summary on how mobile phones are currently being used in the health sector in Tanzania and other developing countries. Furthermore the chapter presents the research problem and justification for carrying out this research as well as the research objectives and the approach that has been employed for carrying out this research.

1.1 Background Information

The Ministry of Health and Social Welfare (MoHSW) is the main agency in Tanzania that is responsible for the provision, monitoring and evaluation of the health services to the Tanzania's population. The primary health facilities, which are, dispensaries, health centres and hospitals are the sources of data that is used by the MoHSW for making evidence-based decision. The health sector reporting system for routine health data from the primary health facilities to the MoHSW is both manual and computer based. The reporting is on weekly, monthly, quarterly and annual basis depending on the importance and urgency of the data. The primary health facilities report to the district hospital, district hospital to the regional hospital and the regional hospital reports to the national level and the MoHSW.

The weekly report on infectious diseases is submitted every Friday of the week providing information on the infectious diseases. The reported infectious diseases are cholera, Acute Flaccid Paralysis (AFP), measles, yellow fever, plague, animal bite, anthrax, rabies, bloody diarrhoea, human influenza, kerato conjuctivitis, Neonatal tetanus(NNT), small pox, trypanosomiasis and Viral Haemorrhagic Fever (VHF). The report is known as the Infectious Disease Week Ending (IDWE) report, it is a crucial report as it gives information on the health status of the community regarding the infectious diseases which are so dangerous to the community and need to be contended once they occur.

The monthly reports from the health facilities include an overall monthly report on Notifiable Infectious Diseases. It reports data on diseases such as malaria, diarrhoea, typhoid, NNT, pneumonia, bacillary dysentery, severe pneumonia and all the diseases that are included in the IDWE. Other monthly reports are the Voluntary Counselling and Testing (VCT), Expanded

Program on Immunization (EPI), Sexually Transmitted Infections (STI), Care and Treatment Clinic (CTC) and the Health Management Information System (HMIS)-which includes Postnatal, Child health, Antenatal Care (ANC), Family planning, Inpatient Data (IPD) and Outpatient Dara (OPD).The report forms are submitted to the data file at the district medical office. After submission, data sorting is done, then the data is fed into the District Health Information System (DHIS-2) database. The quarterly reports are only the CTC reports which are submitted after every three months. There are also annual reports that are submitted once per year.

A manual, paper based reporting system is used to transfer data from the primary health facilities to the district level while a computerized system (DHIS-2) is used for reporting of the data from the district to the national level. The manual reporting cause delay in submission of the reports especially from the remotely located facilities, reports do not reach the districts on the set deadlines. This causes the decision making on the health sector not be based on the collected data. Thus, there is a need to ensure that the reports from the primary health facilities reach the districts on the set deadlines while they are accurate and up-to-date. This opens up an opportunity for utilizing the emerging vibrant technology of mobile phones, whereas, a mobile phone reporting application can be used for reporting of the health data from the health facilities to the district level. Mobile phones use in the health sector can enable the health workers avail to their duties in an effective, accurate and efficient manner. In Tanzania, for example, more than 31 million people have exploited the mobile phone technologies as it can be clearly observed in Figure 1(TCRA, 2014).Studies show that, the number of mobile phone subscribers in the world is increasing very fast as the cost of mobile phones are declining rapidly due to several efforts being made to reduce the component count and hence the cost of mobile handsets (Chakraborty, 2005), thus the increase in the possession of mobile phones among the Tanzanians means that, technology can be utilized in a more beneficial way, for instance, in the health sector for reporting of routine health data.

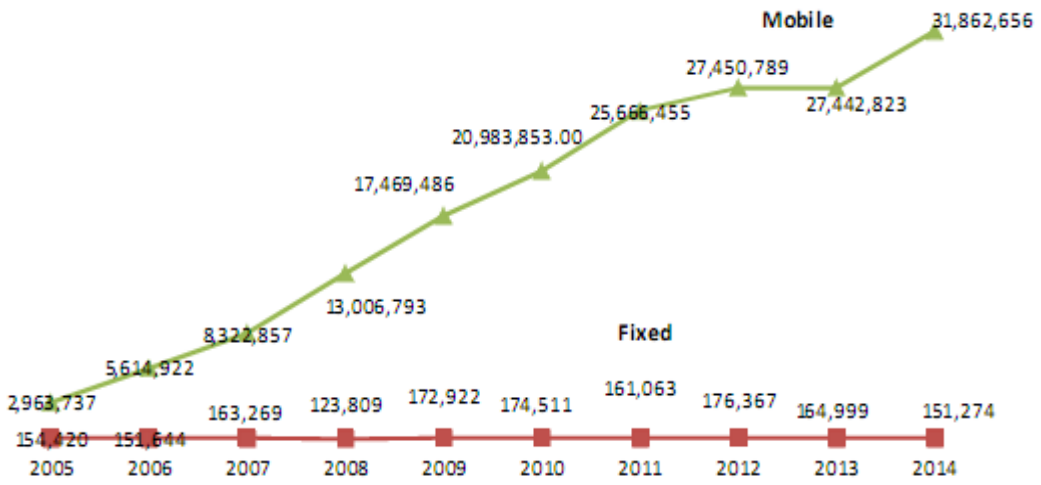

Figure 1: Trend of Mobile and Fixed Users' Subscription by 2014

Source: TCRA, Quarter statistics report 2014

1.1.1 Use of Mobile Technologies for Health

Mobile technology is used to promote health; it provides remarkable opportunities for developing countries to progress and save meager resources by making health systems more efficient (Qiang, Masatake, *et al*., 2011). Mobile technologies also improve the ability to diagnose and track diseases, thus offering timelier as well as more actionable public health information (Vital Wave Consulting, 2009).Thus a number of key applications for mobile technology in health in developing countries have been identified such as: education and awareness, remote data collection, remote monitoring, communication and training for healthcare workers, disease and epidemic outbreak tracking and diagnostic and treatment support (Mechael *et al*., 2010; Rolim *et al*., 2011; Barton 2012).

Mobile phones have various useful features that can be utilized differently to improve information capturing, processing and dissemination. These features are the Short Message Service (SMS), voice service, developed specialized tools (Software applications), GPS and Camera (Mwabukusi, *et al*., 2014; Ouma*et al*., 2011; Thirumurthy & Lester, 2012; Vital Wave Consulting, 2009) that have been widely utilized by different projects and applications related to health. In Tanzania, different mobile apps have been developed to improve the health sector such as the CommCare, iPath, Sms for Life, and "Wired Mother" project but have not covered the reporting of routine health data as elaborated in Table 1.

Table 1: Current Use of Mobile Phones in the Health Sector in Developing Countries

#	Mobile Application	What it does	Strength	Weakness
1.	CommCare (Mhila *et al*., 2009; Svoronos *et al*., 2010)	Used on pregnant women , patients with HIV+ and other chronic diseases Mobile phones are used to record patient's information in every visit and send the report over the cellular network to the server.	Collects data in real time, manage clients, supports decision and behavior change communication	Reports only data on pregnant women, HIV+ patients and data on chronic diseases.
2.	SMS for Life (Barrington *et al.*, 2010).	A mobile and electronic mapping technology is used to track and manage delivery and stock levels of anti-malarial drugs in rural health facilities. -Weekly automated SMS are sent to the healthcare facility staff reminding them to check the stock level, staff replies with an SMS that contains detailed stock levels.	Eliminate the persistent problem of stock-outs of anti-malaria drugs.	Reports only stock levels of anti-malaria drugs
3.	iPath (Krüger&Niemi, 2012).	Online consultation providing specialist doctors with patient information, x-rays, tissue samples and other radiological data for remote analysis	Addresses the acute shortage of specialists especially in rural areas.	For patient consultation and patient data analysis only.
4.	"Wired mother" project(Lund, 2009; Tamrat & Kachnowski, 2012).	SMS reminders are sent to pregnant women for antenatal care appointments and the pregnant women can call the primary healthcare unit in case of severe or non-severe problems.	Helps to ensure safe motherhood.	Reminds pregnant women on antenatal care appointments only.
5.	mCenas!(Pathfinder International, 2015)	Provides Sexual Reproductive Health information (SRH) to youths aged 15-24 in Mozambique. SMS functionality sends role model stories, information messages on contraceptive methods; interactive "Frequently Asked Questions" functionality is provided	Provides SRH information to youth tailored to their needs.	SMS functionality is used. Has limitations on the amount of information delivered, it is costly.

Table 1: Current Use of Mobile Phones in the Health Sector in Developing Countries

#	Mobile Application	What it does	Strength	Weakness
6.	Mobile referral systems(Pathfinder International, 2015)	Use of mobile tools to increase facility-based deliveries and accurate referrals to appropriate facilities for emergency obstetric care in Shinyanga and Sengerema regions in Tanzania. Algorithms, stored information and communication tools are used.	Communication between facility and community; interaction between the health system and community is strengthened	Targets only maternal mothers
7.	CommCare, MCCT and Text2Speek (Pathfinder International, 2015)	A mobile based decision support application in Nigeria which has four modules; client registration and collection of relevant medical history, client follow-up, lab/examination MCCT is a mobile application that enhances services provided by CommCare. It registers women eligible for conditional cash transfer, track and verify their progress and distribute payments via mobile money. SMS campaign (Text2Speek) provides feedback from beneficiaries of antenatal and postnatal care services received.	Support health providers in facilities to provide ANC Client tracking, thus women can attend ANC services -Security of money transfer	Targets to capture and provide information related to maternal health only
8.	Frontline SMS(Freifeld *et al*., 2010)	-Mobile platform for collecting and communicating information through SMS. Broadcast messages can be sent to request for information or emergency warning messages. It is an open source system used in countries such as Malawi, Burundi, Honduras and Bangladesh.	-Provides alerts which save lives as well as facilitate post/disease control	-Uses SMS service only which has limitations to number of characters

1.2 Research Problem and Justification

1.2.1 Research Problem

Reports that are generated from the collected health data are very crucial for the daily functioning and provision of health service. They provide information on the need for supply of medicines, type of medicines that are mostly required, reveal any outbreak of diseases, and arrange measures to address the outbreak of diseases. Considering the infectious diseases, these diseases need real time tracking so as to aid in prevention and containment of the outbreaks (Barton, 2012; Mechael *et al*., 2010; Rolim *et al*., 2011).

Unfortunately, this collected routine health data is delayed and reaches the districts late due to different challenges that are mostly influenced by the remoteness of the primary health facilities to the district hospitals. This causes the districts to fail in effectively utilizing the collected data to make evidence-based decisions that can improve health service provision and thus enhance the health status of the community.

Thus, this research aimed at providing an ICT based solution to address the untimely reporting problem from the primary health facilities to the district level. The research solution is a smartphone-based application to capture data from the paper reports and immediately send this data over the available network (mobile network or Wi-Fi over the internet) to the DHIS 2 server or can be stored in the application and later submitted to the server.

1.2.2 Research Justification

Effective operation of the health system and evidence based decision making process can be hampered by an inaccurate and an untimely reporting of the health data (Hoogeveen *et al.*, 2014). There is a need to ensure that weekly, monthly, quarterly and annually reports are submitted on time for smooth functioning of the health sector in Tanzania.

Thus, this research aimed at providing a smartphone-based solution to improve the data capturing process that improves routine reporting of the health data; exalts task coordination and guide health services delivery at the facility level. The solution addresses the challenges such as errors on the reported data, poor infrastructure, and remoteness of the primary health facilities to the district hospital which are the major causes for the inaccurate and untimely reporting of the weekly and monthly reports (Brovelli & Minghini, 2008; Brunette *et al.*, 2013).

Escalated penetration of mobile devices is among the reasons for the interest since they facilitate timely delivery of essential health services in developing countries. Owing to their pervasiveness

and comparative affordability, mobile phones have been perceived as a more advantageous technology for e-health(Rashid & Elder, 2009).

Mobile communication technologies benefit individuals' communication regardless of time and place. One can communicate while in motion. This has particularly benefited those working in remote areas where the mobile phone, and now increasingly wireless infrastructure, is able to reach more people and faster.

1.3 Objectives

1.3.1 General Objective

The research aimed to develop a smartphone-based application to capture and report routine health data from the primary health facilities to the district level in a cost effective and timely manner.

1.3.2 Specific Objectives

1. To identify the requirements for the smartphone-based reporting application to be developed.
2. Design and implementation of the smartphone-based reporting application.
3. Verification and validation of the smartphone-based reporting application.

1.4 Research Questions

1. What are the requirements for the development of the smartphone-based application for easy reporting of routine health data?
2. What are the building blocks for the design and implementation of the smartphone-based application that can enable efficient reporting of routine health data?
3. What techniques can be employed for the verification and validation of the smartphone-based reporting application to enhance its usefulness?

1.5 Research Approach

The research was carried out in Tanzania in Kisarawe and Arumeru districts. During the research, a qualitative research methodology was used which involved the following methods for gathering information: field notes, observation, structured and unstructured interviews and questionnaires as well as analysis of documents and materials. Thus, data was collected through interviews, questionnaires, analysis of texts and documents collected in the field, together with observation technique. Research was carried out in collaboration with health stakeholders in the case study

districts and evaluation was carried out through discussions and demonstration on the use of the reporting smartphone-based application with the routine health data reporting personnel.

1.6 Personal Motivation

A lot more people in Tanzania have been linked by mobile phones over the recent few years than fixed line phones have been able to in decades. Proliferation of mobile phones has been an engrossing factor for carrying out this research believing that pessimistic effects will not be realized from the Tanzania's meager ICT infrastructure. A thorough exploitation of mobile phones with their allied services facilitate the growth of pioneered mobile solutions. The promise that mobile phones encompass towards contributing to developmental actions in Tanzania and other developing countries has been a fascinating factor for conducting the study. The research also intended to support ongoing health sector projects that use mobile phones to enhance information access. Ultimately, there is a contribution to existing literature on how mobile phones are utilized in developing countries.

1.7 Intended Stakeholders

The research is targeted to healthcare professionals, graduate students, Ministry of Health and Social Welfare (MoHSW) and computer software engineering professionals. The research contributes to the understanding of the theoretical and practical views in the design, development and implementation of smartphones in reporting of routine health data in the health information systems in developing countries.

1.8 Organization of the Dissertation

The dissertation is structured in the following order. Chapter one is an overview of the research work covered in this dissertation. It covers the introduction of the study; the problem domain; objectives of the study; research approach; personal motivation and states, who can read and benefit with this dissertation. Chapter two presents the first specific objective on identifying the requirements for the developed smartphone-based reporting application where the system requirements of a smartphone-based reporting application for routine health data have been presented. The chapter answers the research question: "what are the requirements for the development of the smartphone-based application for easy reporting of routine health data?" This chapter offers an understanding on the methods used for the data collection and requirements

analysis of the smartphone-based reporting application. Chapter three presents the system analysis, design and development of a smartphone-based reporting application. The chapter covers the second objective on the design and implementation of the smartphone-based reporting application. It presents modelling and design of the smartphone-based reporting application as well as the findings from the research work. The chapter unveils the analysis and discussion of the findings in connection with to the study problem and to what is found in the literature to date. The chapter offered answers to research question: "what are the building blocks for the design and implementation of the smartphone-based application that can enable efficient reporting of routine health data?" Chapter four presents the verification and validation of the smartphone-based reporting application in which the different testing techniques used have been shown as well as usability and acceptance findings have been presented. The chapter offered answers to research question: "what techniques can be employed for the verification and validation of the smartphone-based reporting application to enhance its usefulness?" Chapter five provides the concluding remarks, research contributions to knowledge, possible further research works on the problem area and recommendations. References and various appendices referred to during the discussions have been presented at the end of the dissertation.

CHAPTER TWO

A Smartphone-Based Reporting Application for Routine Health Data: System Requirements[1]

Summary

Mobile phone technology has invaded the daily routine of the people's lives. The improvements in this technology have facilitated its use in different areas including the health sector. As a result, mobile phones are found to be more useful in areas where the use of road or postal systems often delay or are unsuitable for data communication. This study analyzed and documented the functional and non-functional requirements needed for the design and development of a smartphone-based application that is used for reporting of routine health data from the primary health facilities to district level in a sub-Saharan country. The study answers a research question: "what are the requirements for the development of the smartphone-based application for easy reporting of routine health data?" In the study, qualitative data collection methods have been used to gather correct, consistent, unambiguous, complete, relevant and testable system requirements.

2.1 Introduction

Mobile phone reporting refers to the utilization of the mobile phones as reporting tools for various data such as health data, educational data, government and non-government data and all forms of data that need to be transferred from one level to the next. A mobile phone can be used as a reporting tool due to its enormous benefits that it possesses such as real time delivery of information, cost effective means of communication and provision of communication from anywhere, anytime(Kaplan, 2006; Yang *et al.*, 2009). Utilizing the opportunity ripped from Information and Communication Technology (ICT), the emergent of smartphones has enhanced and made life in mobile phones reporting much easier.

Routine health data refers to the health data that is collected in a routine basis and reported after a given period of time. Reporting of routine health data is crucial in the health sector as it is the core source of information that can be used for evidence-based decision concerning the health status of

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Paper 1: [1]Pascoe, L. and Mwangoka, J. W. "A smartphone-based reporting application for routine health data: system requirements, analysis and design", Int. J. Telemedicine and Clinical Practices. Paper accepted for publication in the forthcoming issue.

the community from which the data originate. This routine data is basically numerical data that is reported on a weekly, monthly, quarterly and annual basis. The weekly report from the primary health facilities furnishes the district hospital with information on the infectious diseases such as cholera, acute flaccid paralysis (AFP), measles, plague, yellow fever, animal bite, rabies, anthrax, bloody diarrhoea, human influenza, keratoconjuctivitis, Neonatal Tetanus (NNT), small pox and trypanosomiasis. Weekly report, also known as Infectious Disease Week Ending (IDWE) report is among the vital reports that enlightens on the health status of the community regarding the infectious diseases. Infectious diseases are so harmful and once they occur, need immediate containment. It reports on the number of cases and deaths for both males and females who are below and above 5 years within a given reporting week. The monthly reports from health facilities include an overall monthly report on Notifiable Infectious Diseases, reporting data on diseases such as malaria, diarrhoea, typhoid, pneumonia, NNT, bacillary dysentery, severe pneumonia and all the diseases that are included in the IDWE. Other monthly reports are the Voluntary Counselling and Testing (VCT), Expanded Program on Immunization (EPI), Sexually Transmitted Infections (STI's), Care and Treatment Clinic (CTC) and the Health Management Information System-HMIS (including Postnatal, Child health, Antenatal Care (ANC), DTC, Family planning, Inpatient Data (IPD) and Outpatient Dara (OPD)). All those reports record numerical data. An effective and cost-efficient provision of health care to the population is possible when the health workers are capable of collecting, analysing and utilizing accurate, reliable, and up-to-date health data. Similarly, policy makers need timely and accurate information to assist them in making well-informed decisions that can improve national health care (Hoogeveen *et al*., 2014). However, data routinely collected at health care facilities and submitted to district offices is done manually and oftentimes appears to be unreliable (Garrib *et al*., 2008). The unreliability of data is caused by the incompleteness, untimeliness, inaccuracy and inconsistency of the data among other things.

The manual reporting of routine health data from the primary health facilities to the district level in the Tanzania's context is the major cause of unreliability of information in the higher levels of the health sector. Lack of ICT based solution for the reporting of routine health data at the lower level of the primary health facilities may inhibit smooth and proper functioning of the computerized system at the higher levels (from district level to national level). Thus, this study provides an ICT based solution for reporting of routine health data from the primary health facilities to the district level by utilizing the now emerging smartphone technology. There is a

rapid increase on the number count of mobile phone subscribers globally within a remarkably short period of time; this has made the mobile phones to be seen as a crucial economic tool for both less developed and developing countries. As a result there is a swift decline in the cost of mobile phones ownership due to several efforts being made to decrease the component count and therefore the cost of mobile handsets (Chakraborty, 2005; Das & Saxena, 2012; Lee & Gardner, 2011).

In the developing world, mobile phones are more useful in areas where the availability of other forms of communication such as roads, postal systems or fixed line phones is often limited. (Pundir & Kanwar, 2012) states that "mobile phones can reach areas where there are infrastructure constraints for internet service or where wired phone service is not a viable option". For a developing country like Tanzania, which faces the challenges of poor communication infrastructures and unreliable power supply, the use of mobile phone reporting is an ideal solution so as to facilitate evidence-based decision making at the district level and higher levels by ensuring that the information will be accurate, up-to-date and on time. This is also applied in other developing countries in the sub-Saharan Africa where mobile phone-based mHealth approaches are intensively utilized for public health surveillance and as data collection tools (Brinkel *et al.*, 2014; Tomlinson *et al.*, 2009). On the other hand, developed nations whose communication infrastructures are advanced and have reliable power, the reporting of routine health data is through computerized systems right from the primary health facilities to the higher levels of reporting. For example in a study by Morrato and others (Morrato *et al.*, 2007) population based routine health data have been used for setting and evaluating national health policies in Australia, UK and USA right from the community through a well-structured ICT infrastructure that exist in these countries.

A qualitative research coupled with agile development methodology for mobile phone applications has been carried out to collect the requirements, design and develop a smartphone-based reporting application that enable transfer of routine health data from the primary health facilities to the district level and eliminate the manual reporting system that was being employed at the primary health facilities. Smartphone is used as a reporting tool and links directly with the District Health Information Software (DHIS 2). The completed data is automatically uploaded to the DHIS 2 server and can be accessible by other users. If there is no mobile network coverage, data are stored securely in the smartphone application, whenever network signals are detected the locally stored data are uploaded to the server.

Agile development methodology has been preferred over the traditional development methodologies such as waterfall model due the iterative and incremental model of the agile methods, flexibility of the methods in which changes can be accommodated at any stage of the development, the face to face communication with the customers which is a crucial process in ensuring that the customers are able to give their views on the different working versions of the software until the final version of the software is developed (Amir *et al.*, 2013; Ferdiana, 2012; Haikara, 2007; Lucia & Qusef, 2010). Also a study by Flora and Chande (Flora & Chande, 2013) identified agile approach as a natural fit for mobile application development due to its ability to meet the mobile application requirements such as the short development cycles, high environment volatility, small development teams, identifiable customers and object-oriented development environment. Furthermore, Khalid and others(Khalid *et al.*, 2014) in their study admitted that "All characteristics which are identified and all the requirement found for application development for mobile phone application showed that agile methodologies are far better for mobile application development than any other traditional methodology". By adapting agile development methodology the smartphone-based reporting application was developed to meet the reporting need of the health data and changes were welcomed and adopted respectively up to the stage when the reporting officers accepted that the app could now fulfil their reporting need of the routine health data.

The rest of the chapter is arranged as follows: section 2.2 states the problem governing this research, section 2.3, gives the system overview of the designed and developed smartphone-based reporting application, section 2.4 presents the requirements discovery elaborating on the various qualitative techniques that have been used to capture the research data and system requirements, these are interviews, questionnaires, discussion, document analysis and observation/ethnography. Section 2.5 elaborates on the characteristics of requirements and section 2.6 presents the requirements specification: the functional and non-functional requirements of the smartphone-based reporting application. Lastly, section 2.7 concludes the chapter.

2.2 Research Problem

Reporting of routine health data from the primary health facilities to the district level faces a number of challenges which are mostly influenced by the remoteness of primary health facilities to the district hospital. The remotely located facilities have poor communication infrastructure such as poor roads which are only passable during the dry seasons, lack of fixed telephone lines,

unreliable sources of power as well as shortage of resources. These challenges have made the reporting process a burden to the personnel responsible for reporting and have sometimes resulted to lateness in submission of the routine health data reports. Poor reporting affects evidence-based decision making at the higher levels that solely depend on the information obtained from the primary health facility as the core source of data. Thus, this research aims to use the emerging smartphone technology to solve the problem of untimely reporting which affects decision making at higher levels by providing an application that can be used for reporting of routine health data from the lower levels to higher levels of the health system.

2.3 System Overview

This chapter presents system requirements for the smartphone-based reporting application of the routine health data from the primary health facilities to the district hospital. The system employs smartphone technology to provide a reporting platform that is linked with a computerized system, DHIS 2 at the district hospital. The system is designed to capture all the data that is currently being fed into the paper report forms at the primary health facilities before being physically submitted to the district hospital. The smartphone-based reporting application is used by the health facility reporting officer who is legally registered into the system and provided with a secure login credentials. The reporting officer can use the smartphone-based reporting application to send weekly or monthly reports to the DHIS 2 server at the district hospital. Figure 2 shows the current manual reporting system and the proposed smartphone-based reporting application which solves the problems associated with manual reporting of routine health data. The smartphone-based reporting application eliminates the need to physically travel from the primary health facilities to the district hospital especially for the remotely located facilities, this is a gain for them as they only need the application to send the data to the district from their remote locations. Also using the application reduces the cost that they incur in submission of these reports as well as getting enough time to perform other clinical duties. Due to the benefits of the application, the routine health data reporting officers have rated the application as essentially useful in their service provision as reporting officers.

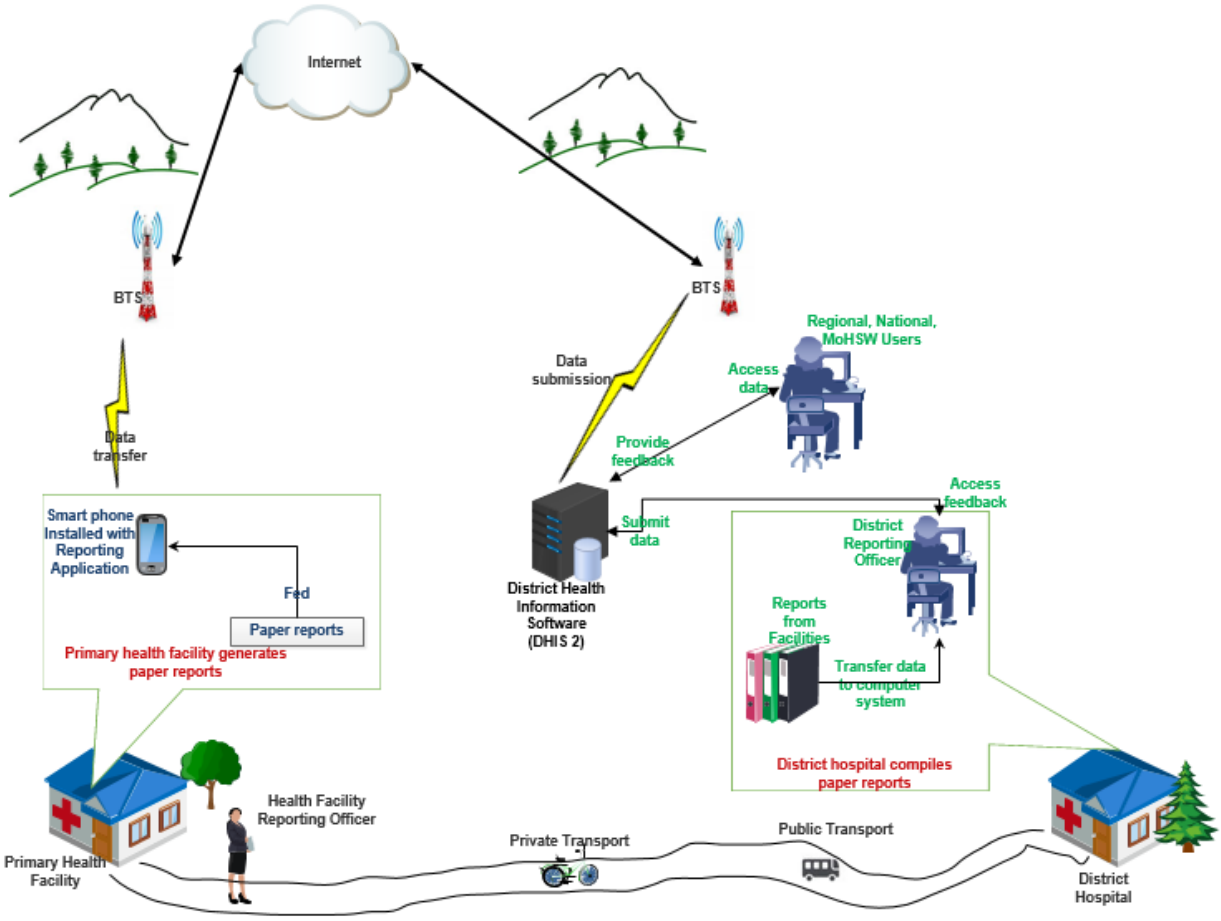


Figure 2: Figure Showing the Current Manual Reporting System and the Proposed Smartphone-based Reporting Application.

Source: Researcher, 2015

2.4 Requirements Discovery

A requirement refers to an expression or a desired behavior, it deals with objects or entities, the states they can be in, and the functions that are performed to change states of object characteristics (Pfleeger & Atlee, 2009). In this study, discovering of the requirements involved the process of gathering information about the smartphone-based reporting system and the manual reporting system of the routine health data from the primary health facilities to the district hospital. The process provided valuable information from which both system and user requirements were distilled. As suggested by different studies in (Jung & NOMAD, 2011; King *et al*., 2014; Sommerville, 2011), sources of information in the requirements discovery process included

documentation, system stakeholders and specification of other smartphone-based applications such as Open Data Kit (ODK) and CommCare

In this study, a qualitative research methodology has been used with the intention of gaining an in-depth understanding of the reporting practices of the routine health data at the primary health facilities and access of that information at the higher levels of the health system. During the process of information gathering different methods have been suggested by literatures, these include observation, field notes, reflexive journals, structured and unstructured interview, questionnaires, prototyping, domain analysis, brainstorming, analysis of documents and materials (Aurum & Wohlin, 2005; Davis, 2013; Frankel & Devers, 2000; Moriarty, 2011; Myers, 1997). In this study, observation, field notes, interviews, questionnaires, prototyping, domain analysis and analysis of documents and materials have been used. In software design these methods are referred to as sources of requirements (Al-Hothali *et al.*, 2012) and have been used so as to capture the desired requirements. (Al-Hothali *et al*., 2012), defines requirements elicitation as a practice of collecting the requirements of a system from the users. This process involved eliciting the requirements by communicating with the customers, system users and others who had a stake in the system development so as to discover the system requirements (Al-Hothali *et al*., 2012; Davey & Cope, 2008; Tastle *et al.*, 2010). Tastle and others in (Tastle *et al*., 2010) states that "One can never really be sure one has all the requirements in spite of using interviews, questionnaires, personal observation, brainstorming techniques, use cases, prototyping and so forth". Due to this, when collecting the requirements for the smartphone-based reporting application, there was an active involvement of the stakeholders especially the health facility and district reporting officers so as to minimize the reasons for errors in the developed smartphone-based application. Also the use of agile methodology in the development of the mobile phone application has facilitated the development of a prototype of the smartphone-based reporting application which has then been given to the facility and district reporting officers and their views and comments on the improvements of the prototype have been captured and this has facilitated in the successful development of a full functional smartphone –based reporting application for the routine health data reporting form the primary health facilities to the computerized system at the district level.

2.4.1 Interviews and Questionnaires

Interviews were a good tool for getting an overall understanding of what the stakeholders do, how they might interact with the smartphone-based reporting application as well as a means of knowing

what difficulties they faced with the current manual reporting system. Interviews and questionnaires have played a great role as they provided a clear picture of the research domain. During the study, questionnaires and unstructured interviews have been used to obtain information on respondents' knowledge with the available mobile phone services, their experience in using mobile phone services, their frequency of reporting and their willingness to use the mobile phone reporting service that the developed smartphone-based reporting application offers (Al-Hothali *et al*., 2012; Kothari, 2009).

Informants were the facility reporting officers and the district health officers. The informants provided information on the reporting system used, the means of transport used in submission of the reports, time taken for report submission and challenges faced, cost involved in the reporting process, possession of a mobile phone and what network is used, their ability to use the developed smartphone application for reporting and their view on the usefulness of the application on reporting of routine health data.

Through the interviews and questionnaires conducted, the following are some of the findings that have been established after analysis of the collected information.

2.4.2 Findings from Interviews and Questionnaires

2.4.2.1 Cost Involved in the Reporting Process

Findings indicated that lateness in reporting was caused by transport problems in which in some remote facilities there were no public buses thus they had to hire public motor bikes and during the rainy season the transportation was worse. This made the reporting process costly.

"[Normally] I spend around four thousands Shillings [1USD ~ 2000TShs] to or from the facility to the district to submit the reports. During rainy season the roads are slippery and one cannot dare to use the motor bikes, instead I walk to the district hospital." Health facility reporting officer

On the other hand some facilities were able to submit the reports on time because they were provided with transport fees otherwise they had to wait until the time one goes to collect their salary from the district

2.4.2.2 Challenges Faced in Submission of Reports

Reporting health officers said to face a number of challenges in their duty, these include: unreliable transport especially during the rainy seasons and poor roads, which made transportation rather rough. During the rainy season, most of the roads are slippery and almost impassable making movement difficult. For the remotely located health facilities, a lot of time is wasted for the report submission process. This is experienced more with the weekly reports which have to be submitted every week.

"Some facilities bring reports late as they have to submit paper reports and sometimes they fail to submit all the required reports on time, that is, they may forget some of the report forms and have to go back and bring them as in a facility it is only one person who brings all the reports to the district" [District health reporting officer]

"I have to travel to the district to submit the reports, time is wasted unnecessarily traveling every week to the district. Otherwise I have to incur cost of calling the district officer and read to him/her the weekly data. Sometimes I may send an SMS but [one] cannot be sure that the information is received" [Facility reporting officer.]

2.4.2.3 Time Taken to Submit the Reports and Rating of the Reporting Process

Findings indicated that 40% of the reporting officers used 2-3 hours for the submission of reports from the primary health facilities to the district hospital while 30% used one hour or less as shown in Figure 3. Figure 4 shows the rating of the existing reporting process based on user friendliness, cost involved, time consumption and knowledge needed for the reporting process. Based on the cost involved, 70% of the reporting officers rated the existing manual reporting process from the primary health facilities to the district as inefficient, 20% efficient and 10% satisfactory.

Whether the paper based reporting is user friendly or not, 50% of the respondents rated it as efficient, that is, it is friendly to use. 40% rated it as satisfactory for the reporting process while

only 10% said it is unfriendly, that is, inefficient. Based on the time needed to learn the reporting process, 60% of respondents rated it as satisfactory while 40% said it is efficient. On the other hand, 50% of the respondents said that the time consumed for the reporting process was inefficient.

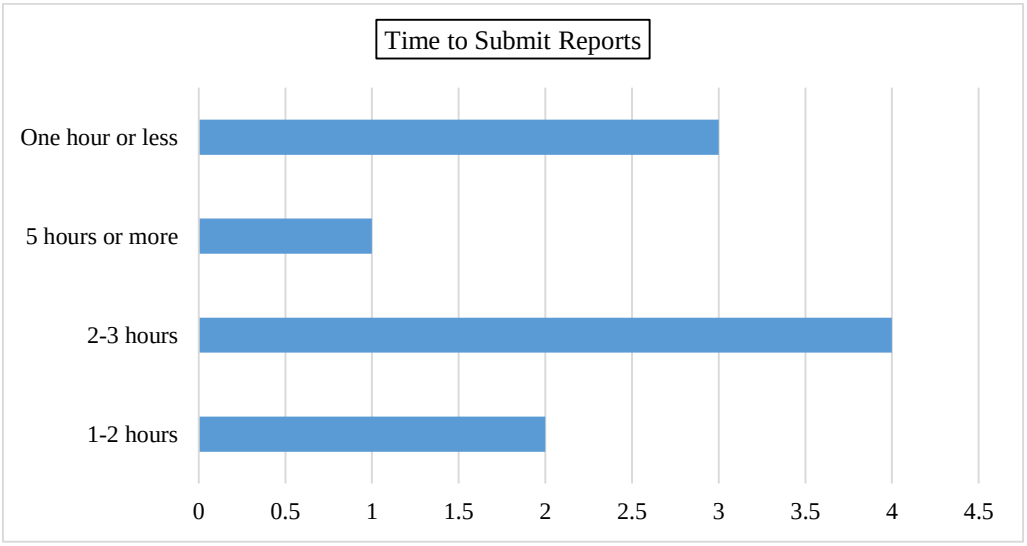


Figure 3: Time Taken To Submit Reports from the Primary Health Facilities to the District Hospital

Source: Researcher, 2015

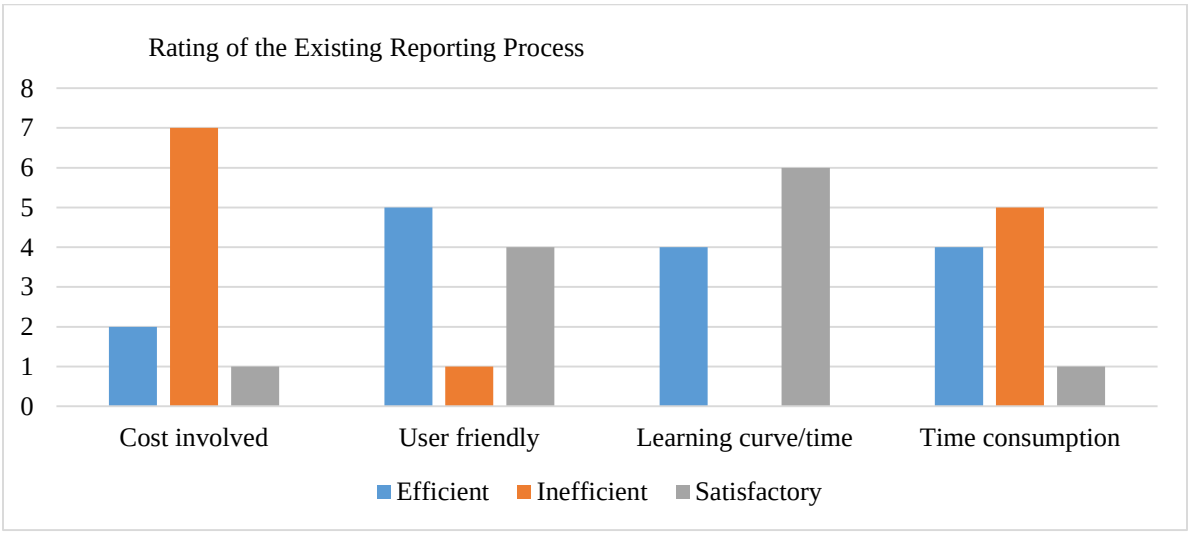


Figure 4: Rating of the Existing Reporting Process Based on the User Friendliness of the Process

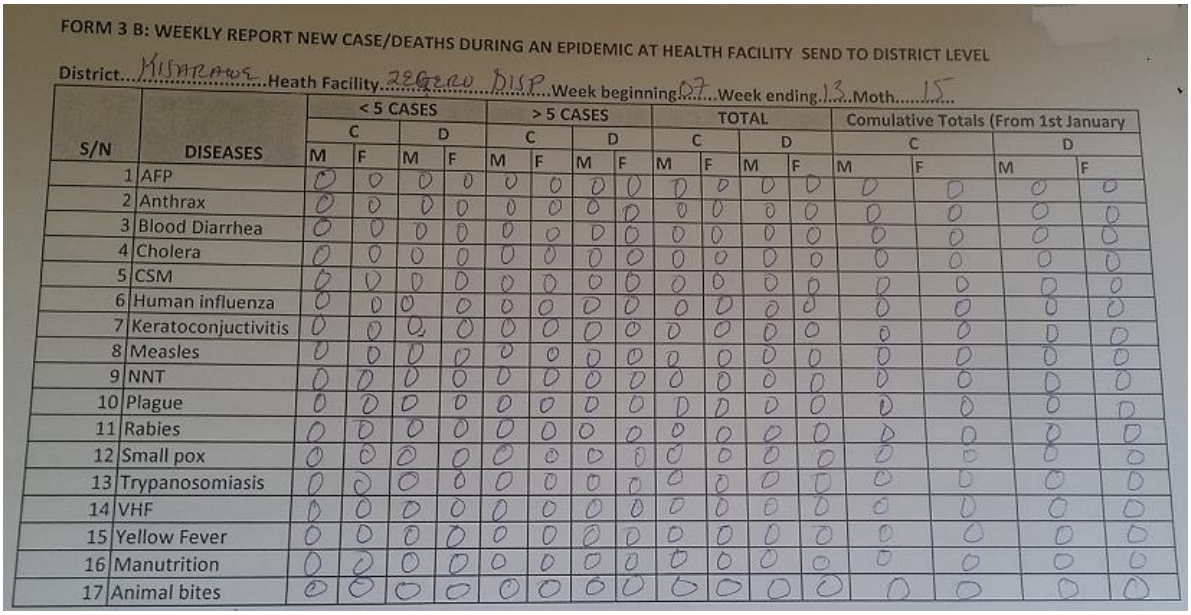
Source: Researcher, 2015

The findings have indicated the costliness of the current paper based system, based on the cost involved, time consumed for reporting, learning time and all the associated factors that complete

the reporting process. As a result there was a need for a new system for reporting health data from primary facilities to higher-levels of the hierarchy to ensure timely availability of health data in a very cost effective means which was accomplished by utilization of the mobile phone technology.

2.4.3 Document Analysis

Document analysis is explained as a systematic investigation of written documents or other art work such as photographs, films and videos. Written data sources consisted of published and unpublished documents, newspaper articles, health facility reports, memos, faxes, letters and so forth(Frankel & Devers, 2000; Myers, 1997). During the research, the facility level reporting tools such as ad hoc forms, registers and checklists were analyzed and have assisted in the implementation of the developed smartphone-based solution. Analysis of document was advantageous due to its unobtrusiveness and reusability nature. The sample of a currently paper report form presented in Figure 5 facilitated in the identification of the diseases that are reported on in weekly and monthly basis and have helped to identify the data that is collected based on each category. In addition, for reliability purposes the documents obtained from the primary health facilities and district hospital could be checked and re-checked without imposing on the routine health data reporting officers. This has been used as a basis in designing the smartphone-based reporting application interfaces that capture the routine health data.



FORM 3 B: WEEKLY REPORT NEW CASE/DEATHS DURING AN EPIDEMIC AT HEALTH FACILITY SEND TO DISTRICT LEVEL

District..KISARAWE..Heath Facility..ZEGEREDI DISP..Week beginning..07..Week ending..13..Moth..15..

S/N	DISEASES	< 5 CASES				> 5 CASES				TOTAL				Comulative Totals (From 1st January			
		C		D		C		D		C		D		C		D	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1	AFP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Anthrax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Blood Diarrhea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Cholera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	CSM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Human influenza	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Keratoconjuctivitis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Measles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	NNT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Plague	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Rabies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Small pox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Trypanosomiasis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	VHF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Yellow Fever	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Manutrition	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Animal bites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 5: Figure Showing a Sample of a Filled Form That Is Used For Reporting Weekly Data on Infectious Diseases

Source: Kisarawe District, 2015

2.4.4 Observation /Ethnography

The technique exclusively involved the researcher making observations of the real enforcement of existing processes without direct interference (Al-Hothali *et al*., 2012). Observational findings are considered strong in validity because the researcher is able to gather a depth of information about particular manners (Davey & Cope, 2008). During the research a significant amount of time was spent in the primary health facilities and at the district hospital where the routine reports were generated and submitted respectively, and it was during that time that fieldwork notes were taken and a significant amount of information was collected that assisted in providing a technical solution to the existing manual reporting system. It was observed that at the primary health facility, the weekly and monthly reports were submitted physically to the district every week and month respectively. So, sometimes these reports were not all submitted on time because the primary health facility reporting officer would sometimes forget to pick all the required reports to be submitted at that particular time and this would require him/her to go back and bring them in the next day in case the facility was remotely located. However, an alternative of a mobile phone short message service (SMS) was used in which the facility reporting officers would send an SMS with the data on the infectious diseases to the district reporting officer, also they would sometimes call the district reporting officer and read the data to him/her, then the district reporting officer would enter that data into the computer system. The informal use of mobile phones to report through the SMS functionality had some shortcomings such as sender could not be sure that the SMS is correctly delivered to the intended recipient, SMS has the ability of sending a message with only 128 characters thus the full report must be sent as multiple messages which is costly. Due to the existence of this alternative, this highlighted an opportunity of formally utilizing the smartphone-based application for reporting of routine health data from the primary health facilities to the district level.

2.5 Characteristics of Requirements

High quality requirements must be correct, consistent, unambiguous, complete, relevant and testable to yield useful system specifications(Al-Hothali *et al*., 2012; Davey & Cope, 2008; Gröner, 2002; Pfleeger & Atlee, 2009; Sommerville, 2011). A study by (Tastle *et al*., 2010) states that "analysts are charged with the task of producing a set of requirements that are measurable, testable, actionable, and in sufficient detail such that system design can occur with the delivery of a system that truly does solve business needs." To ensure that the designed and developed

smartphone-based reporting application fulfilled the characteristics of the requirements, each characteristic was addressed as shown in Table 2:

Table 2: Characteristics of the Requirements for the Smartphone-Based Reporting Application

Characteristic	Description
Correct	The documented requirements for the smartphone-based reporting system adhered to the overall understanding of the requirements. The documented requirements and a prototype of the smartphone-based application were reviewed with the facility and district reporting officers in order to be satisfied that the correct requirements were captured.
Consistent	Consistency in the requirements for the smartphone-based reporting application aimed to ensure that there were no conflicting requirements that had been stated, this was achieved with the help of the health facility reporting officers who clearly clarified all the requirements to ensure consistency.
Unambiguous	The requirements for the smartphone-based reporting application were stated precisely to eliminate any misunderstandings that might have arose due to different interpretations. Any doubts in the requirements were clarified with the help of the health facility and district reporting officers.
Complete	The requirements had to be both externally and internally complete by stating all the states, state changes, inputs, products, constraints as well as lack of undefined terms among the requirements. The completeness of the requirements for the smartphone-based reporting application has been achieved during the conceptual modelling of the system requirements.
Relevant	The established smartphone-based reporting application requirements were relevant to the routine health data that was reported and were stated while ensuring that they did not restrict the developers unnecessarily or containing functions that were not directly related to the routine health data reporting needs.
Testable	The requirements for the smartphone-based reporting application have been stated in a way that at the end they would easily be measurable and could demonstrate that the eventual developed smartphone reporting application met the requirements.

2.6 Requirement Specification

Requirements specification was an important step in the design process of the smartphone-based reporting system, as it helped in specifying what the system would do as well as providing the essential and desirable properties of the system. At this stage there was a direct engagement with the end users and customers of the system who were the beneficiaries of the provided technical solution on their social problem. The requirements specification involved collecting both user

requirements and system requirements. User requirements are abstract statements of the system requirements for the customer and end user while the system requirements are the detailed description of functionalities that are to be provided by the system to the users (Davis, 2013; Sommerville, 2011). It is in requirements specification where the functional and non-functional requirements were derived. Functional requirements are the statements that described what services the system should provide, how the system should react to particular inputs as well as how it should behave in certain situations (Pfleeger & Atlee, 2009; Robertson & Robertson, 2013). The constraints on the system services or functions are what were referred to as non-functional requirements (Glinz, 2007), most of the time these arise through the user needs such as reporting officers' needs, organizational policies, need for interoperability such as linking the smartphone-based application with the DHIS2 server, PostgreSQL and use of certain operating systems. The requirements for developing a smartphone-based application for reporting of routine health data from the primary health facilities to district hospital are specified in the Tables 3 and 4.

Table 3: Functional Requirements for the Smartphone-Based Reporting Application

Actor	Requirements	Description
Facility reporting officer	Prepare report Submit report Update report	The facility reporting officer shall prepare the paper reports and enter the data into the smartphone-based reporting application. Once the data is entered in the smartphone-based reporting application the facility reporting officer shall submit the data to DHIS 2. The facility reporting officer shall be able to update the report that is, edit the report on the smartphone-based reporting application.
System administrator	Monitor system activities Register users Update profile	The administrator shall monitor the system. The administrator shall register the users to the system. The administrator shall be able to update the user's profile.
District Health Information Software (DHIS 2)	Receive reports Send feedback	The system shall receive the sent reports automatically. The system can send feedback to the facility reporting officers.

Table 4: Non-Functional Requirements

Requirements	Description
Usability/Ease of use	A user centered design method has been used in the design of the interfaces for the smartphone-based reporting application to provide a user friendly and easy to use environment. In designing of the application interfaces, emphasis was put to ensure that the developed smartphone-based reporting application was optimized on how the reporting officers could use it, would want to use it or even would need to use it rather than just designing an application that would force the reporting officers change their reporting behavior in order to accommodate the new smartphone-based reporting solution. Standardized colors and fonts have been used. Help links and about links have been designed to support the reporting officers. The interfaces have been designed with help facilities which enable the users add appropriate data at the appropriate place.
Reliability	The smartphone-based reporting application ensures that the reporting actions are performed correctly as the user requires. When a user enters invalid data the smartphone-based application is able to recover and react robustly with an error message that instructs the reporting officer the correct value to be entered. The reporting application ensured a 24-hours a day 7-days a week availability.
Performance	The number of health facility officers using the smartphone-based reporting application is not limited at any time because the application is installed on the individual user's mobile phone. Thus no restriction on the number of reporting users to be added in the database. Minimum response time is provided whenever a user accesses the system and the system will be available whenever it is requested by the user.
Security of the mobile phone reporting application	The health facility reporting officer is authenticated before using the application by using usernames and passwords. The access permissions are created by the system administrator and they are unique for each reporting officer.

2.7 Conclusion

The data collected from the primary health facilities is delayed and reaches the districts late due to different challenges which are mostly influenced by the remoteness of health facilities to the district hospitals. The manual reporting of routine health data from the primary health facilities to the district level contributes greatly on the challenges facing the primary health facilities as the

core source of data used in the health system. This causes the districts to fail in effectively utilizing the collected data to make evidence based decisions.

This chapter has analyzed and stated the requirements of a smartphone-based reporting application which aimed to bridge the technological gap that existed in routine reporting of health data from the primary health facilities to the computerized system at the district level and thus address the late reporting problem by enabling data transfer through a smartphone-based application.

CHAPTER THREE

Needs Assessment, System Analysis, Design and Development of a Smartphone-Based Application for Reporting Routine Health Data

Summary

In a hierarchical health care system, the primary health facilities are the core sources of data that is generated in the health sector. This information has to be transferred to the higher levels of the hierarchy. However, the remoteness of the facilities, use of manual reporting system and cost involved in physical submission of the paper based reports delay the information -- which negatively affects evidence based decision-making at higher levels. Therefore, there is a dire need for effective capturing, processing and reporting of this critical data for the smooth functioning of the health sector ecosystem. This work proposed a smartphone-based application to enhance the reporting of routine health data. In the conceptual modelling entity relationship diagram, class diagram, use cases, sequence diagram and data flow model have been used which have facilitated in the designing of the user interfaces of the smartphone-based reporting application. The study answers a research question: "what are the building blocks for the design and implementation of the smartphone-based application that can enable efficient reporting of routine health data?" Results have shown significant improvement in the speed of data collection, cost reduction in submitting reports; thus, enabling continuous accessibility of health officers to patients, leading to improved livelihood of citizens.

3.1 Introduction

In a hierarchical health care system, the primary health facilities are the core sources of data that is generated in the health sector, because they have direct contact with the people at the community level and thus collect all the useful information in their locality. For remotely located health facilities, the routine reporting of health data to the district level is a manual system where as hard copies of different report forms are physically submitted to the district hospital. However, a computerized system is being implemented from the district level to the national level. Figure 6 shows the reporting hierarchy of the health system.

The remoteness of the facilities, use of manual reporting system and cost involved in physical submission of the paper based reports lead to reports being delayed, incomplete or having errors; and lack of feedback. Consequently, decision-making and resource allocation processes are inefficient. Furthermore, healthcare officers who travel to submit the routine reports would not be available to attend patients, thus affecting the wellbeing of rural communities. Therefore, there is

a dire need for effective capturing, processing and reporting of this critical data for the smooth functioning of the health sector ecosystem.

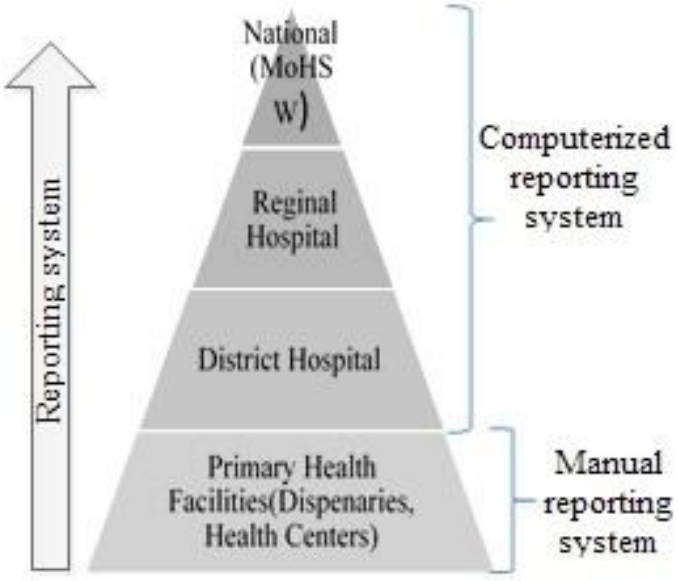


Figure 6: Routine Health Data Reporting System in Tanzania [MoHSW: Ministry of Health and Social Welfare]

Source: (Lungo, 2003)

Information and Communication Technologies (ICTs) present a range of new, quick and stronger opportunities for communication and information dissemination among different groups of people and organizations. Specifically, rapidly adopted mobile phone technology (Hassan & Semkwiji, 2011; Infodev, 2006) offers advanced computing capabilities and rich features for data collection. In Tanzania, for example, more than 31 million people own mobile phones, a period of nearly 20 years since its introduction in the late 1990's (Hassan & Semkwiji, 2011; TCRA, 2014).

The advent of smart phones has advanced computing and communication capabilities of mobile technologies, creating increased opportunities for the delivery of health information to the public (Infodev, 2006). Smart phones are portable, allow continuous data streaming, and support (development of) multimedia software applications (Free *et al*., 2010), thus creating a vibrant new industry (Boulos *et al.*, 2011). In addition, features like short message service (SMS), voice, global positioning system (GPS), and Camera can be utilized effectively to improve information capturing, processing and dissemination (Mwabukusi *et al*., 2014; Ouma *et al*., 2011; Thirumurthy

& Lester, 2012; Vital Wave Consulting, 2009). A wide range of projects and applications related to health have benefited from such features. Therefore, mobile technologies present a remarkable opportunity for improving health care data collection (Qiang*et al*., 2011).

In Tanzania, for example, several mobile apps have been developed to improve the health sector in projects such as CommCare, iPath, SMS for Life and "Wired Mother". However these works have not covered the reporting of routine health data from primary health facilities which are in remote areas and are not computerized (Barrington *et al*., 2010; Krüger & Niemi, 2012; Svoronos *et al*., 2010; Tamrat & Kachnowski, 2012).

This study proposed the use of mobile phone in transmission of health data from the primary health facilities, which are remotely located and not computerized, to higher levels, to achieve quick delivery of the data, reduce cost and save time of physical movement, thus improving the efficiency of the whole ecosystem.

The rest of the chapter is arranged as follows: Section 3.2 assesses the need for an improved reporting system in which the findings on the means of transport used, cost for reporting, reporting system used , availability of mobile phone and challenges faced in submission of reports has been discussed. Section 3.3 presents the methods used for developing the smartphone-based reporting application. The conceptual modelling of the smartphone-based reporting application is presented in section 3.4 where the Entity Relationship Diagram (ERD), use case model, class diagram, sequence diagram and the cross-functional flow chart of the smartphone-based reporting application are discussed. The User Interface (UI) design and its characteristics are presented in section 3.5. Section 3.6 presents findings on the usage, benefits and changes that would emerge due to the use of the smartphone-based reporting application. Section 3.7 concludes the chapter.

3.2 Need Assessment

In identifying the need for improving the current manual, paper based system, ten facilities in Arumeru and Kisarawe districts were visited, of which eight are primary health facilities, and two are district hospitals. Arumeru district receive reports from 59 primary health facilities of which 2 are hospitals, 8 are health centres and 49 are dispensaries. Kisarawe district receives reports from 31 primary health facilities of which 1 is a hospital, 3 are health centres and 27 are dispensaries.

The need assessment of the smartphone-based reporting application was done through questionnaires, interviews, observation, and discussions with both primary health facility reporting officers and district reporting officers. Information collected were: the amount of time used to

transfer reports from primary health facilities to the district level, monetary cost incurred through physical transfer, time wasted and time of deliverance of the routine reports. The findings are as follows:

3.3 Findings from Need Assessment

3.3.1 Means of Transportation

70% of the interviewed routine data reporting officers revealed to use public transportation as a means of sending the reports to the district as shown in Figure 7. 20% revealed to use foot while the other 10% used motorcycle as a means of transport during submission of the reports to the district depending on the seasons of the year. Use of public transportation indicated a challenge for the remotely located facilities of which most of their roads are impassable during the rainy season. Also the public transport is limited as most of these roads are rough and corrugated. For the health officers who have to submit the reports weekly, this can be a reason for the delayed submission of the reports.

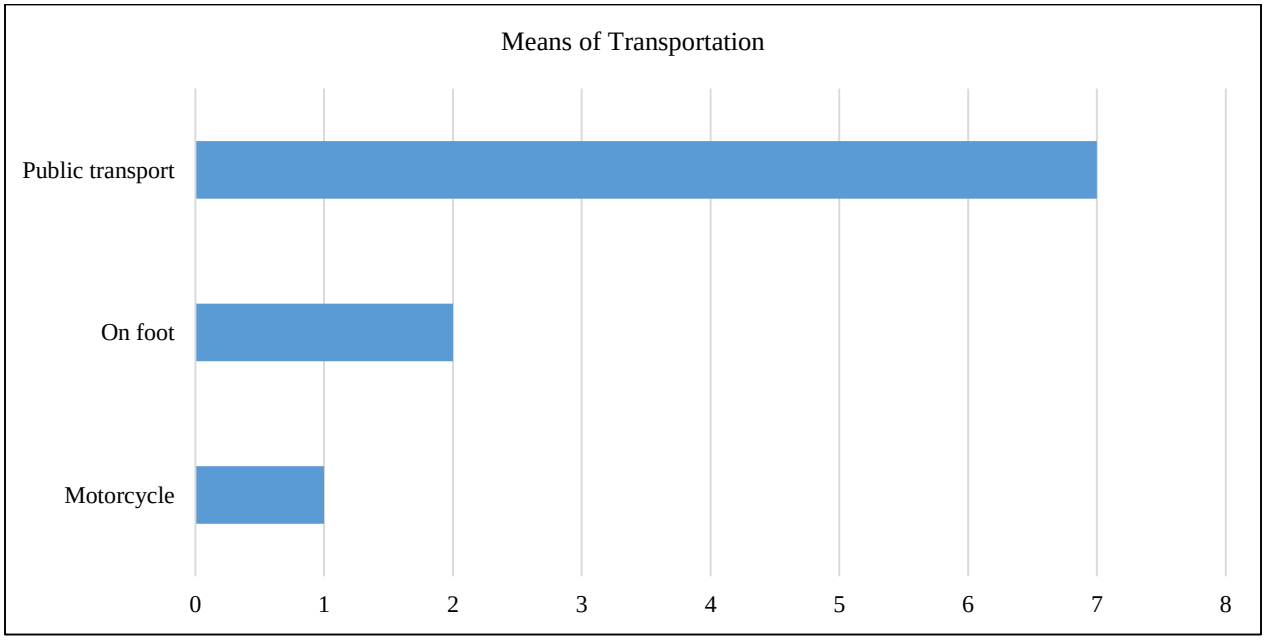


Figure 7: Figure Showing the Means of Transportation Used by the Routine Health Data Reporting Officers

Source: Researcher, 2015

3.3.2 Reporting System

All the primary health facilities declared to use manual reporting system while the district hospital declared to use a computerized system, which is DHIS-2 as shown in Figure 8. This indicated that

the primary health facilities which used paper based reporting needed to improve their reporting means through the use of mobile phone technology. Since most of the reports originate from the primary health facilities where their means of reporting is paper system, then it was obvious that the use of the proposed smartphone-based reporting application would benefit them.

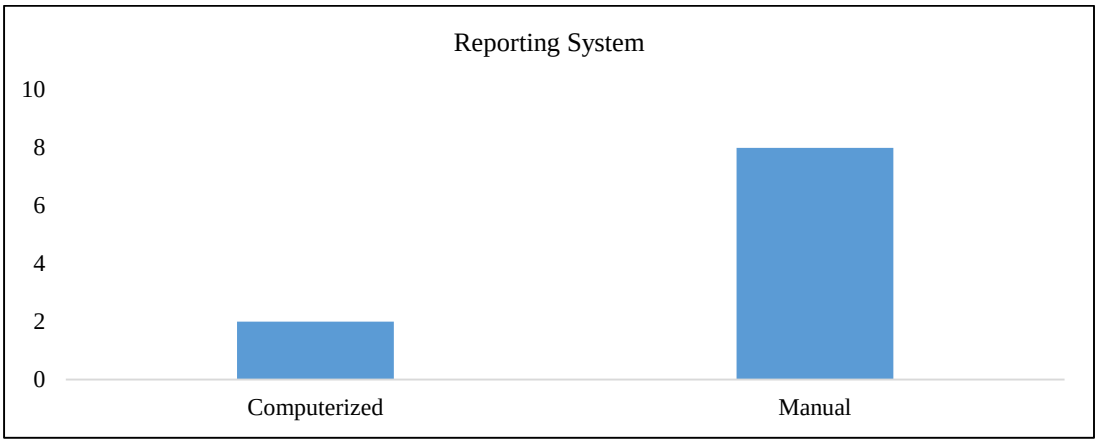


Figure 8: Figure Showing the Reporting System Used by the Reporting Officers

Source: Researcher, 2015

3.3.3 Availability of Mobile Phones and Mobile Network

In all visited facilities, reporting officers said to own mobile phones for three years or more. The phones were either smartphones (60%) or feature phones (40%). The available mobile networks accessible and mostly used by the reporting officers were Tigo, Airtel and Vodacom. This indicated the availability of mobile phones in the hands of reporting officers, thus introducing a smartphone-based reporting system would be relatively inexpensive.

3.3.4 Uses of Mobile Phones Specifically for Reporting

Previously, mobile phones have been informally used in reporting of health data. For the weekly reports, the reporting officer would call the district reporting officer and read the data to him/her. Alternatively, SMS was used; however, it was difficult to confirm that the information was received.

The district reporting officer also used mobile phone to contact the facilities reporting officers in case of missing report from the facilities or any errors that needed correction or clarification.

The costs involved in the use of mobile phones for reporting were incurred by the respective reporting officers.

Other findings on the needs assessment have been presented in chapter 2 section 2.4.2 which present the time taken to submit reports from the primary health facilities to the district hospital,

rating of the existing reporting process based on the user friendliness of the reporting process, challenges faced in submission of the reports and the cost involved in the reporting process.

3.4 Mobile App Development

The design and development of the smartphone-based reporting application employed an agile development methodology. A trimmed version of the routine reporting smartphone-based application was developed and then iterated over for the improvement on usability, ease of use, flexibility, availability and scalability. Agile methodology is adapted because; mobile applications need to be revised frequently to meet the end-user expectations while providing the intended functionality.

Agile development process requires operations be on top of infrastructure and systems to support frequent mobile application deployments and pushed updates (Spataru, 2010). Thus, development tools used for the routine reporting smartphone-based application were Window 7, Eclipse Juno, API 21, SQLite database, Android Software development Kit (SDK) tools version 23.0.2, Android SDK platform tools 20, Android SDK build tools 20, Android support library 20, Extensible Mark-up Language (XML), Java and GenyMotion virtual device.

The smartphone-based reporting application has two layers of security. The first layer is provided through user account authentication in which only registered users are able to send data and access the application. Users are provided with usernames and passwords to access the smartphone-based reporting application. The second layer enhances security through encryption of the transferred data and of the database.

Internet protocols are used for data transfer between the smartphone-based application and the DHIS-2 database. The source of internet can be the available mobile data services or Wi-Fi. The smartphone-based reporting application is elaborated in Figure 9.

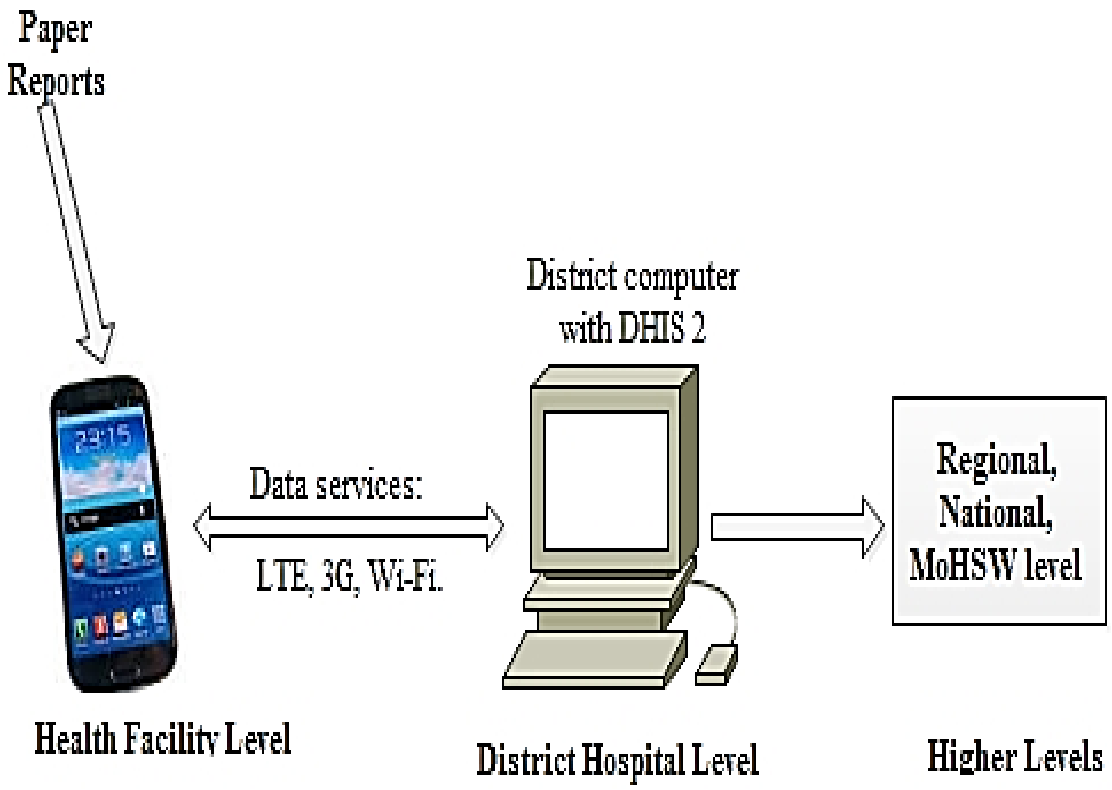


Figure 9: Proposed Smartphone-Based Reporting System

Source: Researcher, 2015

3.5 Conceptual Modelling

3.5.1 Use Case Modelling

In the process of requirements elicitation, a scenario-based technique has been employed to identify the type of interaction and the actors involved in the smartphone-based reporting system. In this technique, use cases have been used to model the business view of the scenarios by identifying the individual interactions with the system in which each type of interaction is represented as a use case. Use cases are very useful in modelling the system requirements from a user's perspective and are a starting point of object-oriented analysis with Unified Modelling Language (UML) (Engels *et al.*, 2001; Popkin Software, 1998). Figure 11 shows the use case diagram for the routine data smartphone-based reporting application.

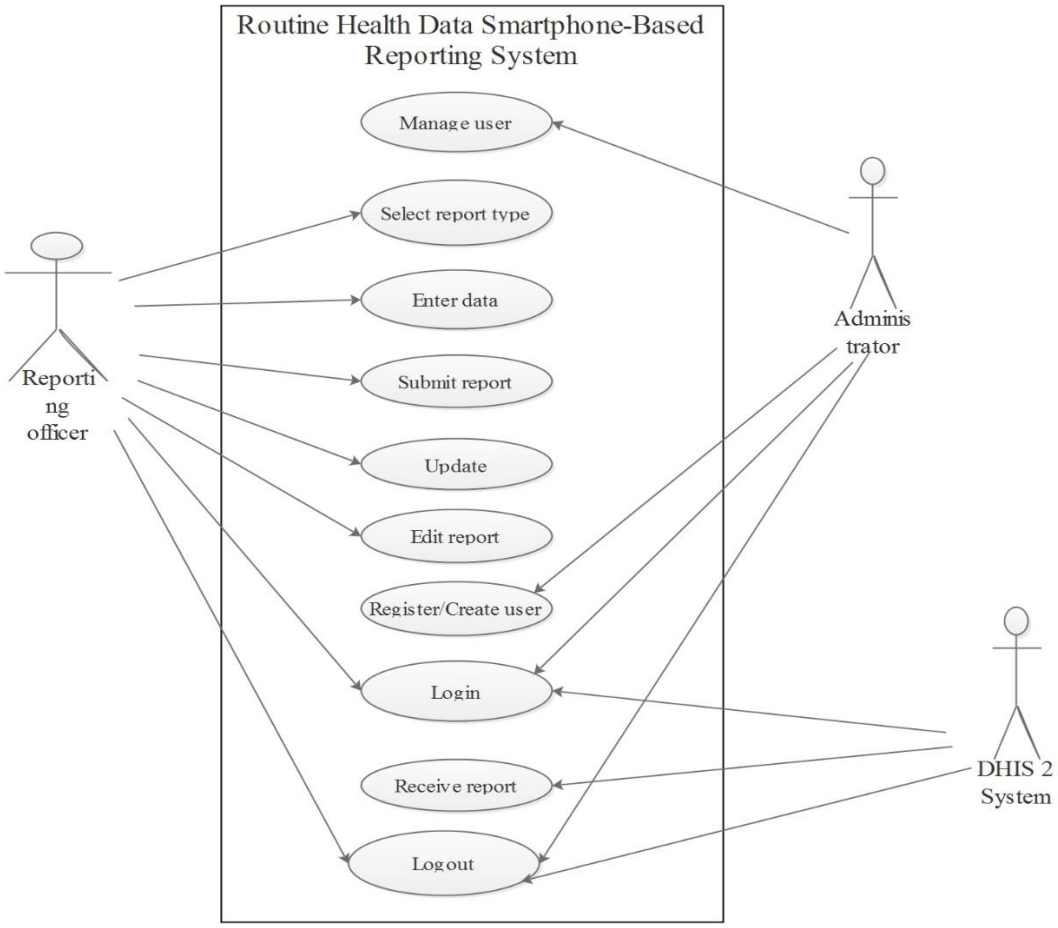


Figure 10: Use Case Diagram for the Routine Health Data Smartphone-Based Reporting Application

Source: Researcher, 2015

3.5.2 Entity Relationship Diagram (ERD)

This is a graphical representation of the smartphone-based reporting system which depicts the relationship between people, objects, places, concepts or events within that system. ERD has been used as a data modelling technique to assist in defining business processes, it was used in conjunction with other modelling techniques to ensure that the system was correctly defined. An ERD has three main components, namely entities which are objects or concepts about which data is stored, relationship which show the association between two entities and cardinality which define the relationship in term of numbers (Sommerville, 2011).

The smartphone-based reporting application had five entities; namely, the health facility, health facility reporting officer, report, smartphone app and DHIS 2. Figure 10 shows the ERD for the smartphone-based reporting application.

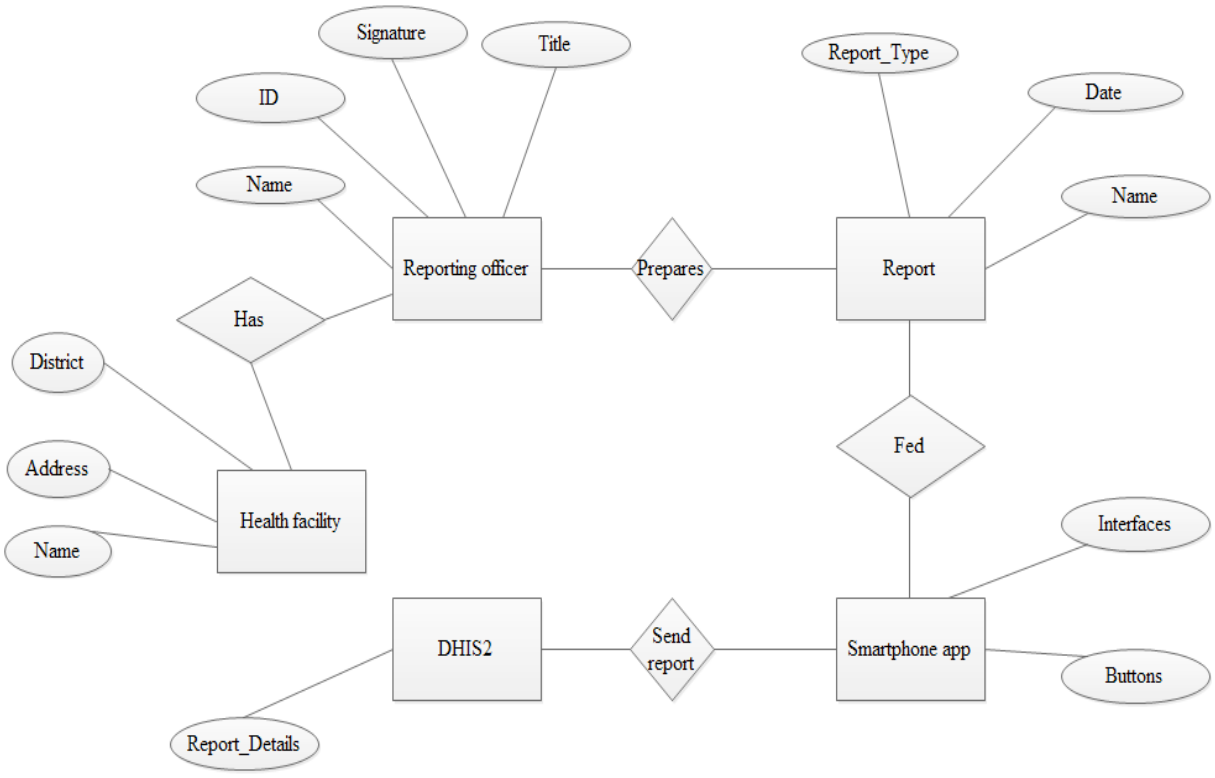


Figure 11: An ERD for the Routine Data Smartphone-Based Reporting Application

Source: Researcher, 2015

3.5.3 Class Diagram

The class diagram is considered as the main static analysis and design diagram of the system. It has been used to specify the system structure, relationships between the different classes and inheritance of the structures. In system design, the class diagram is elaborated so as to take into account the concrete details that can enable implementation of the system (Popkin Software, 1998). Figure 12 represents the class diagram for the routine data smartphone-based reporting application. The smartphone-based reporting application was made up of five classes namely, reporting officer class, report class, health facility class, smartphone class and the DHIS 2 class. For the health facility class attributes such as the facility name, address and the district in which the facility was found were captured. The health facility class defined the reporting officers whose attributes such as identity, name, signature and his/her title were captured. The reporting officer class had method create() which governed the registration of the reporting officer in the system. The report class had attributes such as report type, name of the report and the reporting date. This class had methods

such as update() report, create() report ad send() report. The smartphone application class is the one that governed the developed application based on the information gathered from use cases, sequence diagrams and collaboration diagrams. This class is linked to the DHIS 2 class which represented the computer system at the district level.

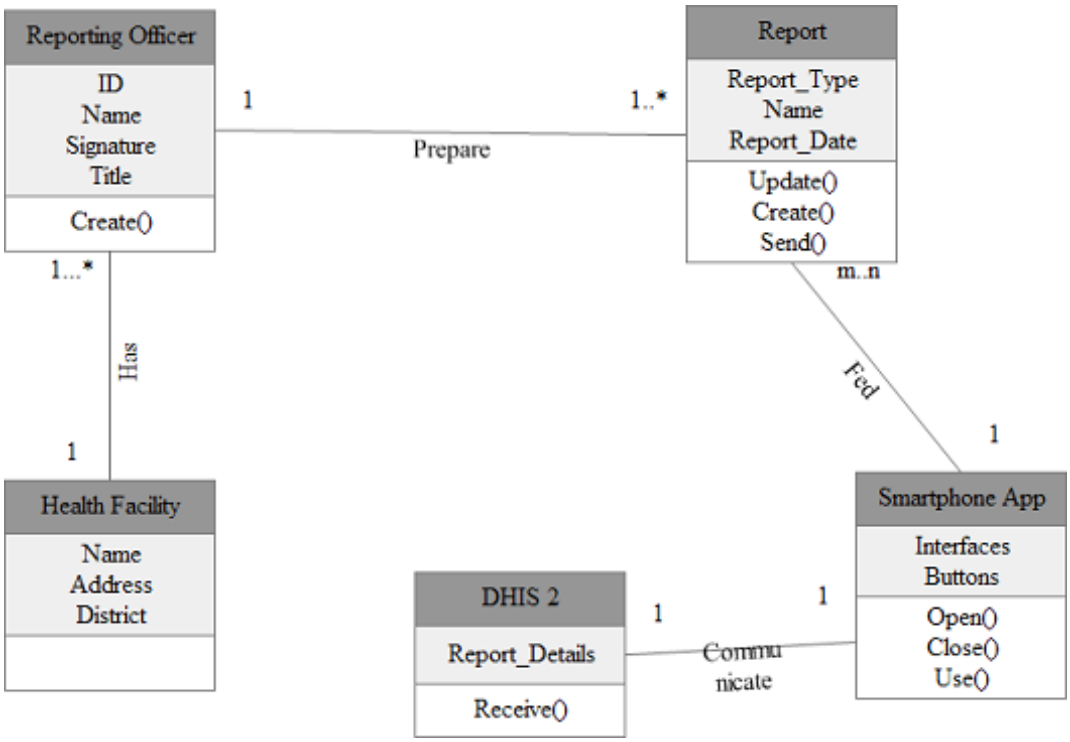


Figure 12: Class Diagram for the Routine Health Data Smartphone-Based Reporting Application

Source: Researcher, 2015

3.5.4 Sequence Diagram

Sequence diagram has been used to model the system interactions among objects in a timely manner, sequence diagrams add information to the use cases by showing the actor involved in the interaction, object which the actor interacts with, and the operations associated with these objects (Kambow, 2012). A sequence diagram is modelled for every use case, it contains the implementation details of each scenario including the objects and classes that are used to implement the scenario and the messages passed between the objects (Popkin Software, 1998). Figure 13 shows a sequence diagram of the reporting scenario.

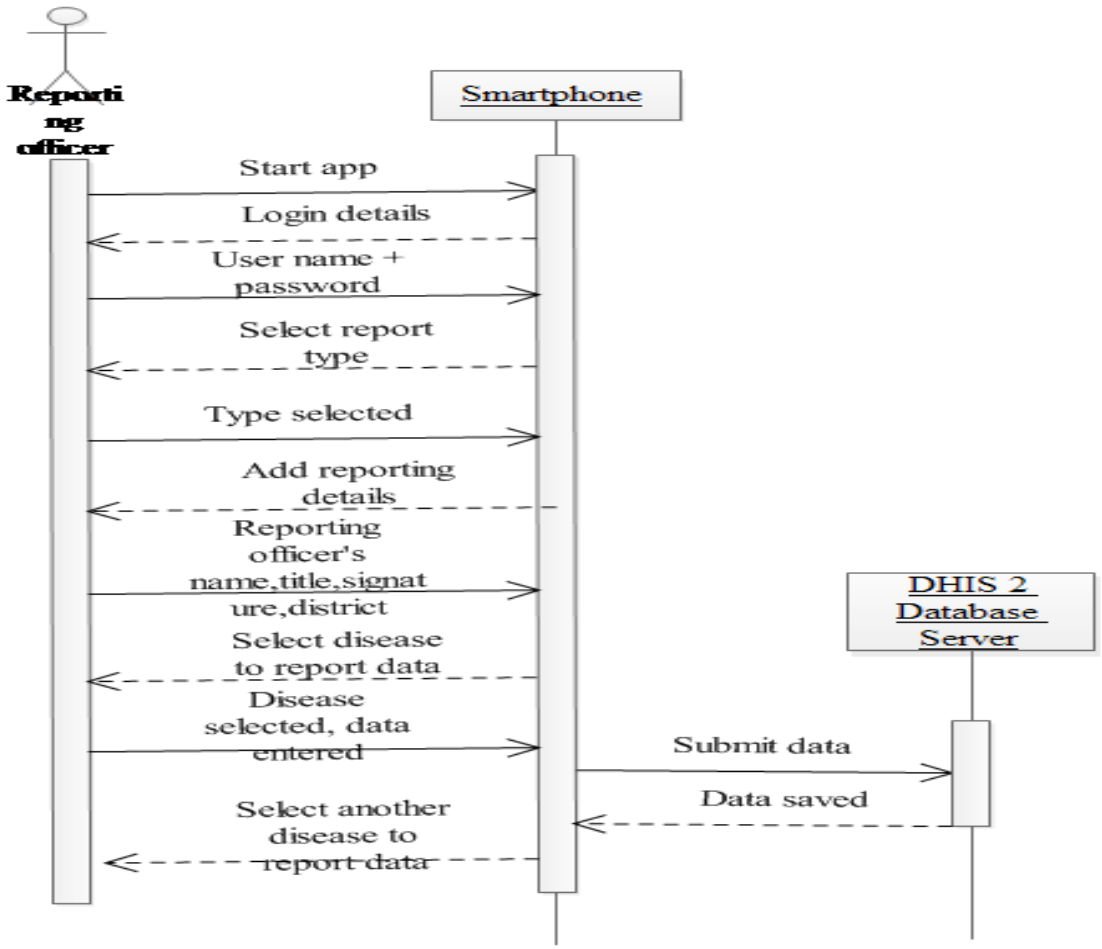


Figure 13: Sequence Diagram for the Reporting Scenario in the Routine Health Data Smartphone-Based Reporting Application

Source: Researcher, 2015

3.5.5 Cross-Functional Flow Chart

Cross-functional flow chart has been used to show the stakeholders of the system and how data is being processed. Cross-functional flow chart is valuable because it help to track and document how data associated with a particular process and user moves through the system. In this case the cross-functional flow chart showed how data flowed through a sequence of processing steps. The value provided by the cross-functional flow chart is very useful to show the relationship between stakeholders in addition to process flow as well as the interfaces between the individual stakeholders of the system. Figure 14 represent the cross-functional flow chart for the smartphone-based reporting application. Table 5 shows the symbols used in designing the cross-functional flow chart for the smartphone-based reporting application.

Table 5: Description of Symbols Used in Cross-Functional Flow Chart

Symbol	Meaning
	Start/End
	Process
Label	Data movements between functions
	Decision
	Document
	Database
	Return control

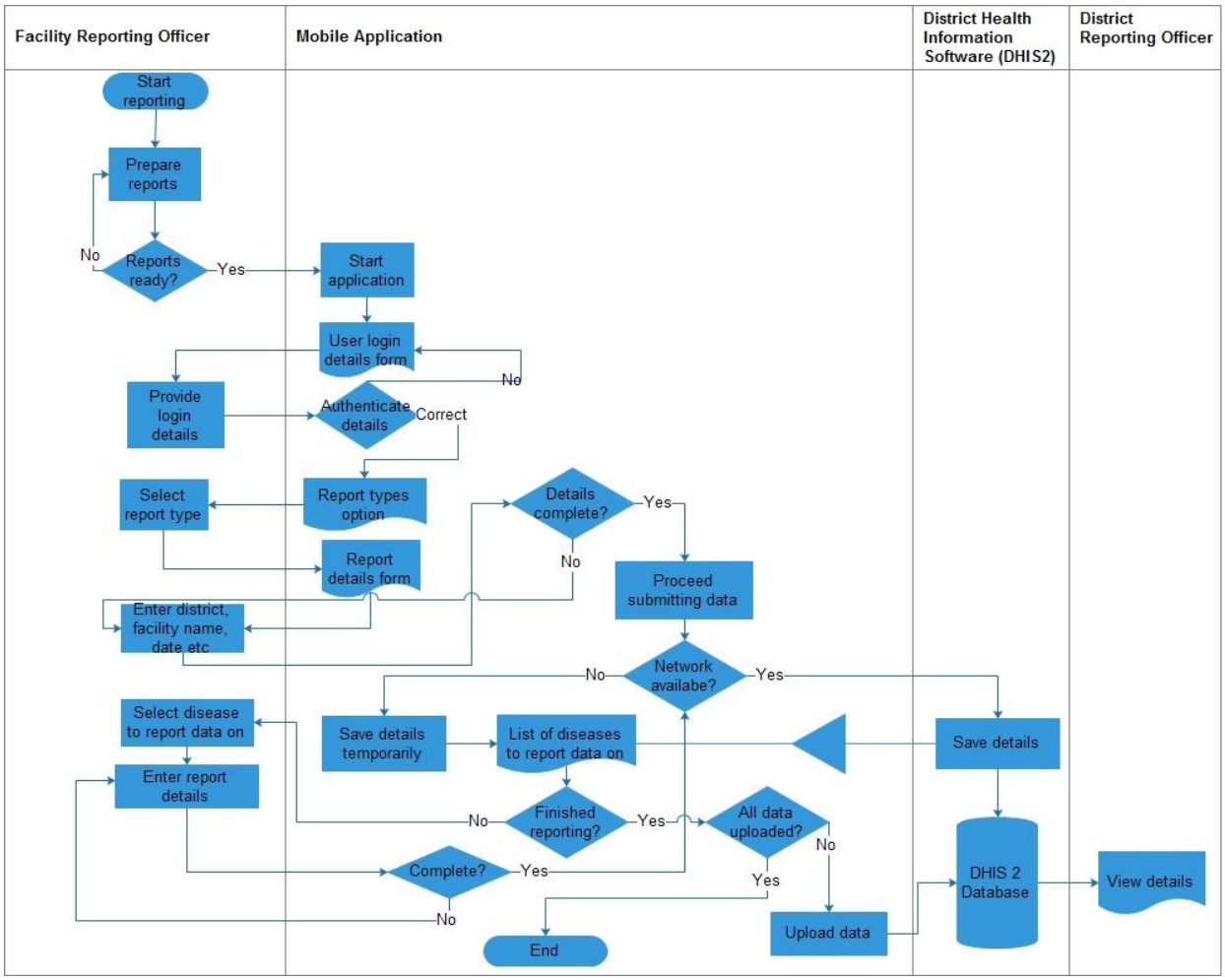


Figure 14: Cross-Functional Flow Chart for the Routine Health Data Smartphone-Based Reporting Application

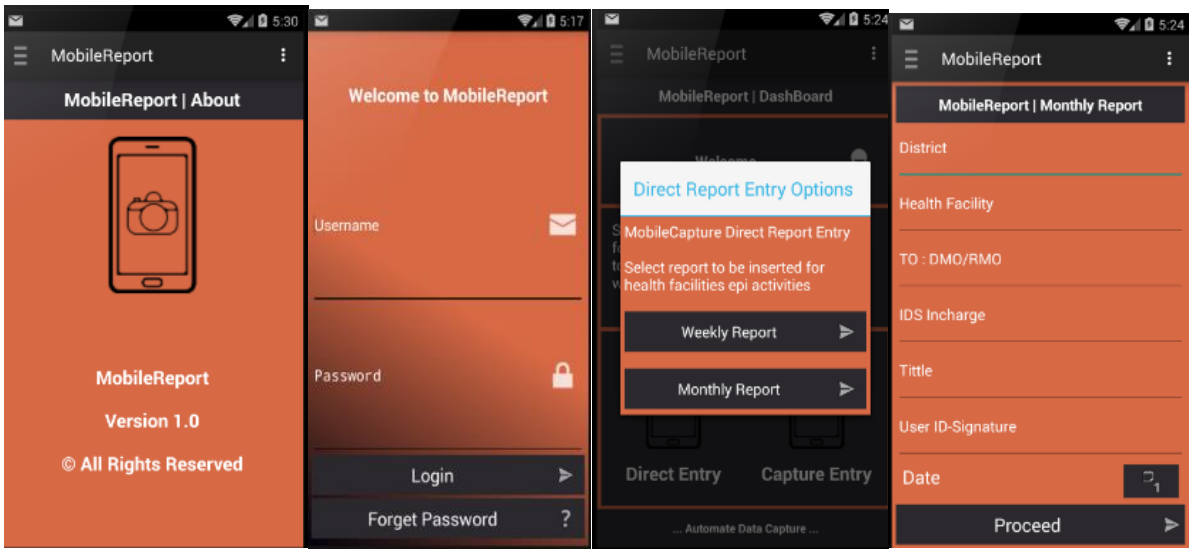
Source: Researcher, 2015

3.6 User Interface (UI) Design

Designing UI is an essential part of the overall software design process (Sommerville, 2011). For the routine data smartphone-based reporting application, the UI of the smartphone-based application as shown in Figure 15 have been designed to match the skills, experience and expectations of the facility reporting officers so as to increase system dependability of those users. Poorly designed UI may inhibit users from accessing some of the system features, may cause users to make mistakes, and the reporting officers may feel that the system hinders rather than help them in achieving the goal of reporting over the new mobile phone technology (Pfleeger & Atlee, 2009; Robertson & Robertson, 2013; Sommerville, 2011). When designing the UI for the smartphone-based reporting application, the physical and mental capabilities of the facility reporting officers have been taken into account. Table 5 shows the characteristics which have governed the design of the UI for the smartphone-based reporting application:

Table 6: Characteristics of UI for the Smartphone-Based Application

Characteristic	Description
User familiarity	The designed UI have implemented the concepts from the experience of the reporting officers who are expected to make the most use of the smartphone-based reporting application. The objects that are manipulated relate directly to the facility reporting environment
Consistency	The designed UI are consistent and comparable operations are activated in the same way. The system commands and menu have the same format parameters and are passed to all commands in the same way. This has been implemented with the intention of reducing the user learning time
Minimal surprise	The smartphone-based reporting application interfaces have been designed in a way to avoid any unexpected surprises by the reporting officers as well as enabling them see the current mode in which he/she is operating
Recoverability	The designed UI have the mechanism of enabling the reporting officers uncover from errors. This has been implemented by provision of an undo facility and asking users to confirm whenever they perform a destructive action
User guidance	Help facilities and user assistance has been provided to the users so as to clearly direct them on the system usage and operation to avoid making unnecessary errors.



UI-1 UI-2 UI-3 UI-4

UI-5 UI-6 UI-7 UI-8

Figure 15: User Interfaces UI of the Developed Smartphone-Based Reporting Application

Source: Researcher, 2015

From Figure 15, once the application is opened, the user is required to enter the login credentials in UI-2 and then click on the login button. Once logged in, the user selects the direct entry option, which opens up UI-3, where the user selects a weekly or monthly report. In case a monthly report is selected, the user is directed to UI-4 and has to feed in the names of district and health facility, date, title and all other required information. When completing, the user clicks the Proceed button

and opens up UI-6, which, contains the list of all the infectious diseases that has to be routinely reported. The same procedure applies in case of weekly report.

Upon selecting a disease to report on, UI-7 lets the user input the number of cases (C), number of deaths (D) for male (M) and female (F); for patients 5 years and below and then for above 5 years old. The tool automatically computes the total number of cases and deaths for that particular disease. When the user presses the submit button, the data is sent to the server and returns to UI-6 and where the user can proceed to input data for the other diseases in the list. In case there is no connectivity, the tool stores the data, and uploads it once the connection is restored.

3.7 Findings

3.7.1 Effectiveness of the Smartphone-Based Routine Health Data Reporting Application

The smartphone-based reporting application was described as an efficient and effective way of reporting especially when the application is capable of capturing all the data that was reported from the primary health facilities to the district level and other higher levels. This is presented below as one of the facility reporting officer stated.

"*This application can significantly simplify my reporting duties as at any time I can send the reports regardless of the season of the year or the condition of the roads.*" Health Facility Reporting Officer.

3.7.2 Expected Changes That Can Take Place as a Result of the Use of the Smartphone-Based Reporting Application

The smartphone-based application brought a number of changes in the reporting process as well as in the working experience of the health facility reporting officers. It was discovered that the application reduced the cost of reporting in terms of transport fees incurred during the physical submission of the reports, with the operation of the smartphone-based reporting application no need for physical movement of the reporting officers from their working stations to the district level. Thus the use of the smartphone-based reporting application also facilitated timely reporting, easiness in reporting, cost reduction and generally simplification of the reporting process.

3.7.3 Benefits Achieved with the Use of the Smartphone-Based Reporting Application to Report Routine Health Data

A number of benefits have been stated by the health facility reporting officers which correlate with the changes that have been expected as a result of the use of the new means of reporting. The different benefits were; time saving, the application is clearer than the use of paper forms, reduction in the transportation risks (this is obvious especially during the rainy season when the roads are impassable and others slippery, for the reporting facility officer who used motor cycles it was very risky for them), timely reporting, reduced burden in the reporting process and getting more time to perform other clinical duties.

3.7.4 Enhancement on Timely Reporting by Using Smartphone-Based Reporting Application

The findings indicated that the use of the smartphone-based reporting application improved timely submission of data to the district level and higher levels as there was no longer a need for the use of transportation infrastructure such as roads, or other means of transportations which were used in the paper based reporting. Data was directly sent to the DHIS server through the available data transfer services and thus it was an immediate and a fast means of reporting.

"*Data is sent directly to the server, no need to physically travel, so it is a cheap means of sending data and a cost effective one*." Health Facility Reporting Officer.

"*I am now capable of submitting the reports on time from my work station, thus no more excuses of poor roads, lack of public transport or rainy season. Transport is no longer an obstacle*" Health Facility Reporting Officer.

3.8 Conclusion

The remoteness of primary health facilities, use of manual reporting system and cost involved in physical submission of the paper based reports delay the critical routine health information in the health sector. Capitalizing on the increasing penetration of mobile phone usage, this research has

developed a smartphone-based application for reporting routine health data from primary health facilities to the district level, where a DHIS-2 system is being used.

The greatest advantage of the smartphone-based application is the ease with which it can be implemented in sending the routine reports in a cost effective way, thus enabling the health sector to collect a bulk of data on time and with minimum cost possible. As a result completeness and timeliness of the reports from the primary health facilities have potential improvement compared to the current manual based system. In addition, facility and district health workers will benefit, since they save time and funds for transport.

CHAPTER FOUR

Verification and Validation of a Smartphone-Based Routine Health Data Reporting Application

Summary

Verification and validation is a crucial process in any system design and development process. It is important to ensure that a right system is being designed and developed in a right way. The usefulness of the process is to provide the end users with a system that conforms to the specifications and produces the expected output. In this study a research question: "what techniques can be employed for the verification and validation of the Smartphone-based reporting application to enhance its usefulness?" has been answered. A routine health data reporting application was designed, developed and installed in an android-based Smartphone and used as a reporting tool, then different verification and validation techniques were employed to test the usability and acceptance of the system and how the application conformed to the requirements. The primary health facility officers who are the core users of the system rated the application as useful and usable after a short training on the application was conducted. Therefore through verification and validation it was possible to perform components testing and system testing and the errors that emerged from the process were corrected.

4.1 Introduction

Development of a system is a rigorous process involving a number of processes and steps to accomplish the design and development of an accurate, functional and completely full operational system. To ensure that the development process is successful, there is a dire need to run evaluation on the developed system. The evaluation process involves two major parts, namely verification and validation. Verification is the internal static check on the developed system or the developed components of a system, to determine whether the products of a given development process satisfy the conditions imposed at the start of the process. This process involves checking against the specifications to see that the product conforms to the stated system or component requirements specification (Gennip & Talmon, 1995; Oberkampf & Roy, 2010; Sommerville, 2011). Usually verification, is a phenomenon that defines how to get the system right.

Validation on the other hand is involved with getting the right system, that is, the tests performed to check the accuracy of the results given by the system. Validation is performed on the individual components or modules to check whether the component or module produce the intended results and at the level of integrated system to check whether all the modules or components when combined they can work together and produce the intended results. Usually, validation is

concerned on the question that need to outline whether the designed and developed system performs as intended by all stakeholders who are involved in the system or will benefit from the existence and operation of the system (Gennip & Talmon, 1995; Oberkampf & Roy, 2010; Sommerville, 2011).

4.2 Methodology

Agile development methodology for mobile phone applications was adapted in the design and development of the smartphone-based reporting application. Thus, the same methodology was adopted in the verification and validation of the system in which testing was carried out parallel to the development process. Each unit or component was tested individually and the preceding increments were also tested. This means the testing process was an incremental one (Gennip & Talmon, 1995; Oberkampf & Roy, 2010; Sommerville, 2011)

Carrying out verification and validation was a vital process for testing the performance of the designed and developed smartphone-based reporting application as well detecting any errors that needed correction to enhance its usability and usefulness to the health facility reporting officers. Initially the verification and validation of the requirements for the smartphone-based reporting application was carried out to ensure that the specifications were internally consistent, as well as certifying that the requirements were the correct representation of the users' (health facility reporting officers) intentions.

Verification was conducted to ensure that the developed smartphone-based routine health data reporting application conforms to the specification developed by the researcher in a close collaboration with the other stakeholders in order to ensure that the end product which is the reporting application meets the customer's expectations. Summerville states that "The verification and validation is performed to establish confidence that the software system is 'fit for the purpose'" (Sommerville, 2011).

The testing of the smartphone-based routine health data reporting application started right from the early stages of the development, that is, after the concession on the system requirements by the stakeholders. This facilitated the implementation of all the stages of testing, that is, unit/component testing, module testing, integrated testing as well as testing of the whole system to check whether it conforms to the specifications.

The verification process relied on the static techniques which facilitated checking of the correspondence between the various functionalities and their documented specifications. The

smartphone-based routine health data reporting application was tested over real data processing and whenever system defects were detected, the generated errors were corrected to ensure that the program generated the required output for the accurate, reliable and correct reporting of routine health data. Validation was carried out to find out whether the developed smartphone-based health data reporting application performed the reporting functionality as the facility reporting officers expected from the application.

The whole process involved requirement traceability which is a crucial component in the testing process because the users were mostly interested to see that the developed smartphone-based reporting application met its requirements. Through this the testing was performed against each individual documented system requirement.

4.3 Verification and Validation Techniques

4.3.1 Unit/Component Testing

Component testing refers to testing of the part of the system being developed. This can be soon after a component is complete or after all the components are fully developed ready for integration. Component testing was carried out during the development process by the developer so that any defects in the individual program components could be discovered and immediately corrected so as to ensure its accuracy and functionality. Each component of the smartphone-based reporting application was separately tasted during its development.

4.3.2 System Testing

This is the process of testing the system as a whole. In system testing the previously tested components were integrated to form two subsystems that is, the smartphone application subsystem and the DHIS 2 web based subsystem that comprised of the datasets and their web interfaces; all these subsystems were tested separately. Then the two subsystems were integrated to form the complete reporting system which was then tested. The complete system was tested to ensure its compliance to the functional and non-functional requirements while monitoring any signs of unexpected behaviour from the smartphone-based reporting application.

4.4 Usability and Acceptance Testing

The android application package (.apk) file of the application was installed to the android enabled smartphones. The application was then linked to the District Health Information software (DHIS-2) server through the DHIS-2 web API to enable direct submission of the reports from the primary

health facilities to the district level through a smartphone. The system testing was performed by the users of the system who are the primary health facility reporting officers. The smartphone-based reporting application was demonstrated to the reporting officers and a smartphone installed with the application was given to them to use the application for reporting then evaluate the reporting process in terms of system usability, as well as system meeting the functionalities. Qualitative data collection methods which included Questionnaires, interviews and observation were conducted, then the collected data was analysed. The response of the health facility reporting officers on the usability of the smartphone-based reporting application are reported in the following sections.

4.5 Findings on Usability and Acceptance Testing

4.5.1 Ability to Use the Developed Smartphone-Based Reporting Application

The findings as shown in Figure 16 indicated that 80% of the routine health data reporting officers were capable of using the smartphone-based reporting application for routine health data while 20% could somehow use the smartphone-based application. None of the reporting officers could not use the application.

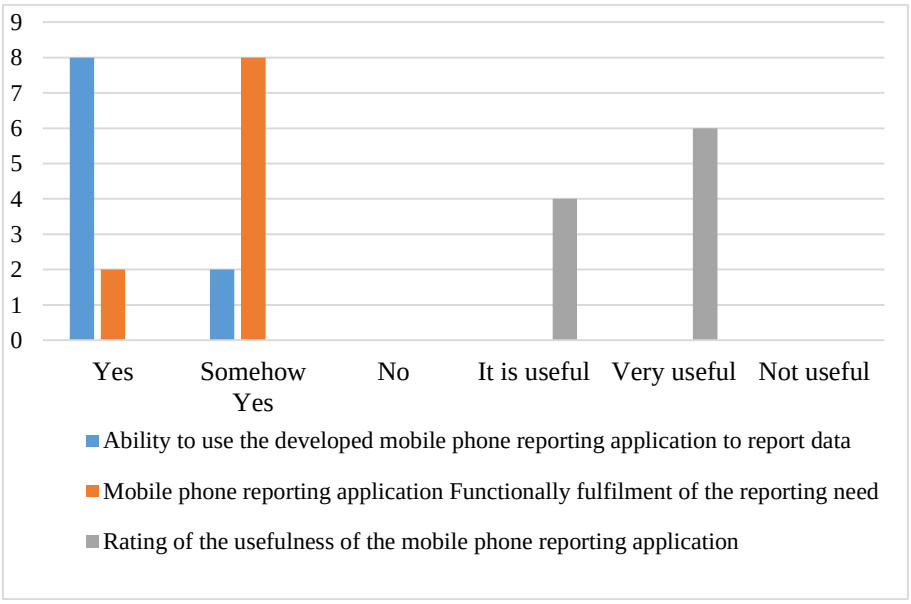


Figure 16: Usability, Functionality and Usefulness of the Smartphone-Based Reporting Application

Source: Researcher, 2015

4.5.2 Smartphone-Based Reporting Application Functionally Fulfilling the Reporting Need

80% of the reporting officers indicated that the application somehow fulfils the reporting need of the routine health data while 20% were satisfied with the reporting application as shown in Figure 16 above. Results indicated that the developed smartphone-based application somehow fulfils the reporting need because some of the diseases that were supposed to be reported on were not captured in the developed application and thus improvement on the design was required.

4.5.3 Usefulness of the Smartphone-Based Reporting Application

60% of the respondents rated the developed smartphone-based reporting application as very useful while 40% rated it as only useful. None of the respondents rated it as 'not useful at all', as indicated in Figure 16above; all respondents found that the developed reporting application was useful and helpful in the reporting process.

4.6 Conclusion

This chapter has highlighted the different verification and validation techniques that have been employed to test the smartphone-based reporting application for routine health data as well as the findings generated from the use of the application. Through the testing, the researcher, developer and the primary health facility reporting officers were convinced that the developed reporting application was usable and useful to the reporting officers. The application was good enough for operational use and would benefit them in the reporting process. Through this, it was possible to build confidence on the new reporting means proposed and thus the facility reporting officers would have confidence on the smartphone-based reporting application.

CHAPTER FIVE

5.1 General Discussion

This study was conducted in two districts, Arumeru in Arusha region and Kisarawe in Coastal region. In the study areas, a situational analysis of the reporting process used to report the routine health data from the primary health facilities to the district level was conducted and eventually usability test of the proposed solution was carried out. The needs assessment revealed a manual paper based reporting system at the primary health facilities to the computerized system that is being implemented at the district levels and higher levels in both study areas. The challenges associated with the manual paper based reporting system were assessed to enable the researcher gain an in-depth understanding of the reporting process and the underlying challenges, as a result a smartphone-based application was proposed that would assist in the reporting process without changing the reporting officer's perspective but rather simplify their reporting process.

A qualitative research was carried out and different qualitative data collection methods used resulted to needs assessment information as well as the usability testing of the prototype of the smartphone-based reporting application. The prototype was designed and developed based on agile mobile application development approach with the intention of providing the reporting officers with an immediate working prototype which was then iterated and incremented over time until the full functional prototype of the application was implemented.

The smartphone-based reporting application was linked with the DHIS 2 web application through the DHIS 2 web API. The developed smartphone-based routine health data reporting application has the capability of providing the reporting service both in offline an online mode. When there is no mobile network or Wi-Fi, the application has the ability to save the data in the phones SQLite database and whenever network signal is available synchronization takes place and the data is uploaded to the DHIS 2 server.

5.1.1 Generalization of the Research Findings

A mobile application is a designed software which can utilize the advantages of mobile technology (Qiang *et al.*, 2011). The mobile applications can as well be developed for technology besides mobile phones, meaning that the same apps can be used in other devices such as tablets and others of the kind. This study was based on the development of a smartphone-based application for reporting of routine health data from the primary health facilities to the district hospital to enable direct submission of the reports using the available data services in the area. The smartphone-based

application eliminates the need of the reporting officers to physically submit paper report forms to the district hospital for computerization.

An android-based smartphone was used in this research. Android is an open source mobile operating platform offering an open development environment which is built on an open source Linux kernel. It offers possibilities for the mobile applications development which have equal standing, that is, both native and third party android applications are written using the same API's and are executed on the same run time (Meier, 2012). Thus, android is more user and developer friendly making it preferable for the development of mobile applications for the health sector. Use of proprietary mobile phone operating systems might hinder smooth implementation of the application in the health sector since most of the proprietary operation systems run only on specific mobile phone devices and they may restrict or control the use of developed mobile phone reporting application on their platform.

5.1.1.1 Improvement in the Reporting Frequency

The use of smartphone-based reporting application for reporting routine health data from the primary health facilities to the district hospital improve the frequency of reporting due to the fact that in report submission, reporting officers no longer have to physically travel to the districts. To them it is a simplification of the reporting means because the mobile application has fields that capture the same data that is fed into the paper forms. This enables them to report as needed and as a result the district management teams can make beneficial decisions that require accurate, reliable and timely information. This will improve the availability of routine health data as a result information use will be perceived as more essential and useful for the health sector as the study by (Muschel, 1999) emphasizes on the benefits of information use and its availability.

With the continual use of the smartphone-based application for reporting of the routine health data there will be a tremendous improvement in the availability of data as reporting frequency will improve over time as the primary facility reporting officers continue to enjoy the benefits and easy of reporting data from their remotely located health facilities to the higher levels. The reporting officers have been very impressed with this technology as it minimizes the reporting burden that they have and they can get enough time to perform their clinical duties.

5.1.1.2 Timely Reporting

Based on the findings from the research, timely reporting is hindered by the existing poor infrastructure, remoteness of the primary health facilities to the district hospital as well as transport

costs incurred by health workers in order to submit the facility routine reports. The research has divulged that an easy, reliable and cost effective means of reporting health data can be achieved with the use of the smartphone-based application together with the DHIS 2 database. The use of mobile phones reporting will change the reporting trends of the primary health facilities as weekly and monthly reports will now be submitted to the district through the smartphone based reporting application and these reports can be accessed on time as required. In any Health Management Information System (HMIS) timely availability of data and information is an essential aspect so that appropriate reports can be generated whenever need. Thus, the smartphone-based reporting application helps to improve the HMIS by improving the means of reporting as well as the behaviour of the health workers who have to report data now and then as part and parcel of their daily responsibilities. The same is shown in a study by (Aker & Mbiti, 2010) in which findings indicated that mobile phone usage for agricultural market information in Niger has enabled the grain traders to obtain immediate and timely information on market prices through mobile phone calls thus reduce their personal travel cost which included long distances and poor roads. This point out how mobile phones have been beneficial since they are more accessible in terms of cost, geographical coverage as well as their ease of use. Though utilization of mobile phones technology timely health information can be obtained with low cost using the smartphone-based reporting application.

5.1.1.3 Cost Reduction

The use of smartphone-based reporting application for reporting of heath data will reduce the cost involved in the submission of reports. First cost in terms of time: the time that was spent to physically travel and submit the reports as the research findings indicated that reporting officers used an average of two to three hours to travel to and from the district hospitals in order to submit the reports. Worse enough remotely located facilities such as the facility which is 120KM from Kisarawe district, the reporting officer had to spend two days for report submission. Secondly, cost in terms of money, the money spent for transport fees can now be saved or utilized in another way such as being used for recharging the mobile phone credit. The advantage of the smartphone-based reporting application is its ability to send data in a bulk form through the data service that will be available such as through the mobile network or the wireless Wi-Fi. This will enable huge volume of data be sent at a low cost thus reduction in the reporting costs. Therefore, effective

utilization of the smartphone-based reporting application to report routine health data can be an effective reporting tool that will solve the challenges which have always been associate with timely availability of data especially form remotely located primary health facilities in the health system.

5.2 Conclusion

With the developed smartphone-based reporting application, its greatest advantage is the ease with which it can be implemented in sending the routine health data in a cost efficient way that bulk of data is sent on time with minimum cost possible. As a result completeness and timeliness of the reports from the primary health facilities to the district level will significantly be improved. Facility and district health workers will benefit, since they save time and funds for transport and be able to engage in other clinical responsibilities. (Archer, 2005) states that, in order to be adopted by health service providers, mobile phone solutions need to provide significant tangible benefits, as there are multiple competing demands. And this is what the smartphone-based reporting application will provide to the health facility reporting officers so that they can experience these benefits and make the reporting application as part of their working life.

5.3 Recommendations

Researcher recommends the use of the smartphone-based reporting application for timely reporting of routine health data. Use of the system can improve report process in a cost effective means and as a result a positive impact on the health services provision can be achieved. The use of the smartphone reporting application can ensure availability of accurate and up-ta-date data which the heath sector can rely on and this data can be used for planning and service provision as well as surveillance. Therefore, smartphones are effective tools in solving daily problems in the heath sector that directly benefits the community by enabling accurately and timely access to information in a very cost effective means that simplifies the daily operation of the service providers in the health sector.

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APPENDICES

Appendix 1: Questionnaires for Data Collection

Reporting Routine Health Data Using Smartphone-based Application

These research questions aim to collect information on the current practice on routine reporting of routine health data from the primary health facilities to the district hospital and evaluate the use of the proposed smartphone-based reporting application on the current reporting process.

Health Facility Name:.....

District:.....

Facility Reporting Officer Name:.....

1. What is your level of education?
    - ○ Primary Education
    - ○ Ordinary level education
    - ○ Advanced level education
    - ○ College
    - ○ University
2. What are your job responsibilities as a health worker?
3. What reporting system is currently being used to report routine health data?
    - ○ Manual
    - ○ Computerized
4. What mechanism/means do you use to send reports to the district?
    - ○ Public transport
    - ○ Office transport
    - ○ Motorcycle
    - ○ Bicycle
    - ○ On foot

5. How long does it take to submit the reports?

   - ○ One hour or less
   - ○ 1-2 hours
   - ○ 2-3 hours
   - ○ 3-4 hours
   - ○ 5 hours or more

6. At the end of each week/month, how many reports do you complete?
7. At end of each week/ Month what types of reports do you complete?
8. How do you rate the existing weekly reporting process?

	Efficient	Inefficient	Satisfactory
Time consumption	○	○	○
Cost involved	○	○	○
User friendly	○	○	○
knowledge needed	○	○	○

9. What challenges do you face in submission of the reports?
10. Are you able to submit the reports on time to the district?

    - ○ Yes
    - ○ No

11. From question 10, if yes how do you achieve that, if no what causes late submission?
12. What can be done to enhance the current reporting process?
13. Do you have a functional mobile phone?

    - ○ Yes
    - ○ No

14. In question 13 above, if the answer is YES, for how long?
15. What kind of a mobile phone is it?

    - ○ Feature phone
    - ○ Smart phone

16. What functions of the mobile phone are you conversant to use?

- ☐ Taking pictures/photos
- ☐ Voice call
- ☐ Voice message
- ☐ Text messaging
- ☐ Listen to music/radio
- ☐ Watching movie/video
- ☐ All functions

17. What network do you use?

- ☐ Tigo
- ☐ Airtel
- ☐ Vodacom
- ☐ Zantel
- ☐ Smart
- ☐ Other: _____

18. Based on your answer on Question 12, please tell me your experience with the network quality or its reception in your catchments area?

	Tigo	Airtel	Vodacom	Zantel	Smart	Other
Poor	○	○	○	○	○	○
Satisfactory	○	○	○	○	○	○
Good	○	○	○	○	○	○
Excellent	○	○	○	○	○	○

19. Can you identify any uses of mobile phones that belong to clinical work?

- ○ Yes
- ○ No

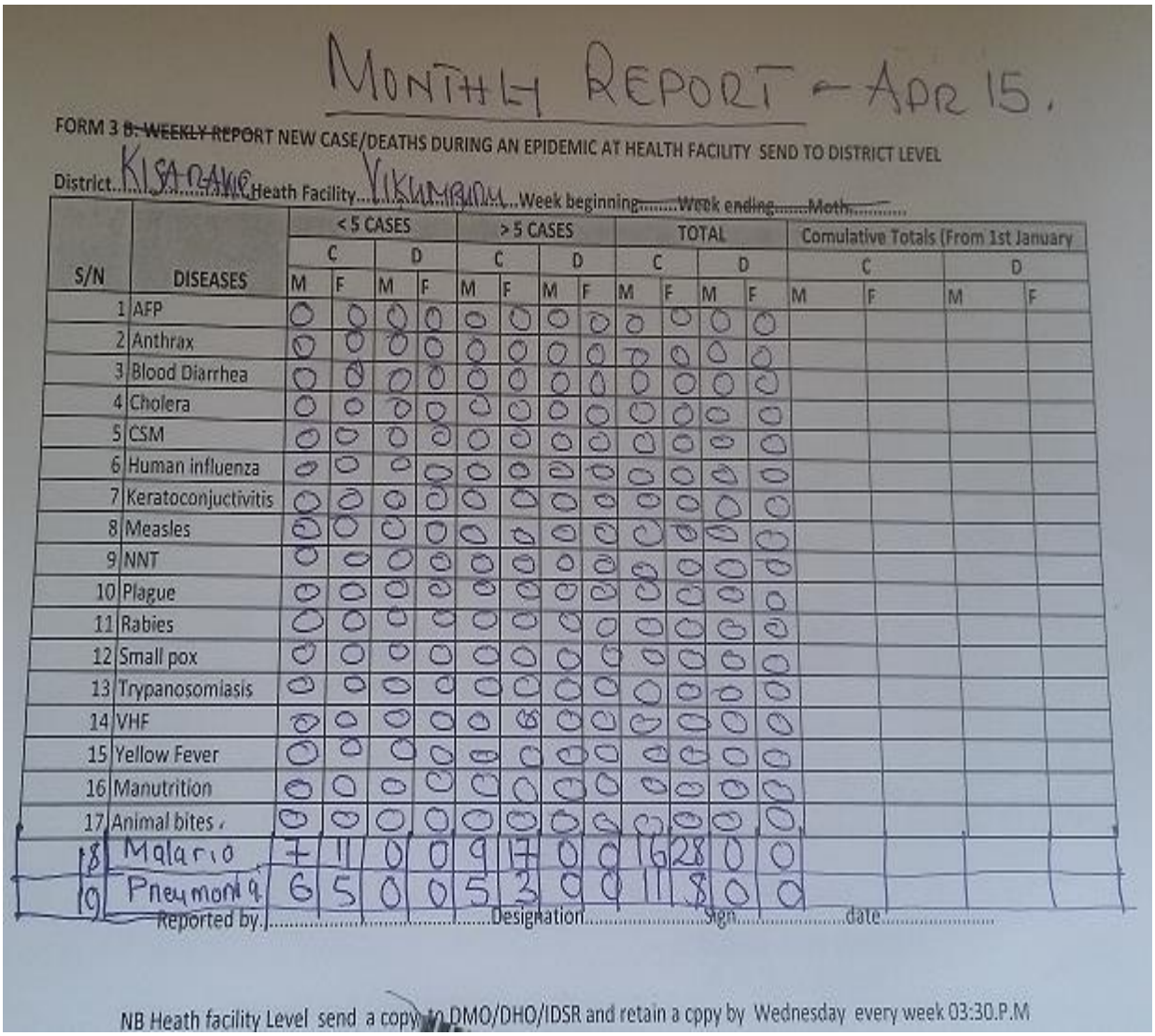
20. If yes, what are they?

21. Can you approximately tell the amount of money you spend per week on work related calls from your mobile phone?

- ○ Less than Tanzanian shillings 5000
- ○ More than Tanzanian shillings 5000

22. Who pays for it?
    - Myself
    - Office
23. How do you use mobile phone specifically for reporting?
24. Can you use this developed mobile app for reporting of health data?
    - Yes
    - No
    - Somehow yes
25. Does it functionally fulfill the reporting need of the infectious diseases report?
    - Yes
    - No
    - Somehow
26. Please explain your answer above
27. How do you rate the effectiveness of the developed mobile application in improving the efficiency of your reporting?
28. How do you rate the usefulness of the developed mobile application?
    - Not useful
    - It is useful
    - Very useful
29. What changes do you think can transpire from the use of mobile phone application in your workplace?
30. In what ways does mobile phone application complement/ replace forms?
31. In what other ways can mobile phones enhance reporting of health data?
32. What benefits can be achieved with the use of mobile technology in reporting of heath data?
33. How does the use of the developed mobile phone application in reporting enhance timely reporting?

Appendix 2: Form for Routine Data Collection



MONTHLY REPORT - APR 15.

FORM 3 ~~B. WEEKLY REPORT~~ NEW CASE/DEATHS DURING AN EPIDEMIC AT HEALTH FACILITY SEND TO DISTRICT LEVEL

District..KISORO Heath Facility..KIKUMIRO Week beginning..... Week ending..... Moth.....

S/N	DISEASES	< 5 CASES				> 5 CASES				TOTAL				Comulative Totals (From 1st January			
		C		D		C		D		C		D		C		D	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1	AFP	0	0	0	0	0	0	0	0	0	0	0	0				
2	Anthrax	0	0	0	0	0	0	0	0	0	0	0	0				
3	Blood Diarrhea	0	0	0	0	0	0	0	0	0	0	0	0				
4	Cholera	0	0	0	0	0	0	0	0	0	0	0	0				
5	CSM	0	0	0	0	0	0	0	0	0	0	0	0				
6	Human influenza	0	0	0	0	0	0	0	0	0	0	0	0				
7	Keratoconjuctivitis	0	0	0	0	0	0	0	0	0	0	0	0				
8	Measles	0	0	0	0	0	0	0	0	0	0	0	0				
9	NNT	0	0	0	0	0	0	0	0	0	0	0	0				
10	Plague	0	0	0	0	0	0	0	0	0	0	0	0				
11	Rabies	0	0	0	0	0	0	0	0	0	0	0	0				
12	Small pox	0	0	0	0	0	0	0	0	0	0	0	0				
13	Trypanosomiasis	0	0	0	0	0	0	0	0	0	0	0	0				
14	VHF	0	0	0	0	0	6	0	0	0	0	0	0				
15	Yellow Fever	0	0	0	0	0	0	0	0	0	0	0	0				
16	Manutrition	0	0	0	0	0	0	0	0	0	0	0	0				
17	Animal bites.	0	0	0	0	0	0	0	0	0	0	0	0				
18	Malario	7	11	0	0	9	17	0	0	16	28	0	0				
19	Pneumonia	6	5	0	0	5	3	0	0	11	8	0	0				

Reported by.....Designation.....Sign.....date.....

NB Heath facility Level send a copy to DMO/DHO/IDSR and retain a cppy by Wednesday every week 03:30.P.M

Figure 1: Figure Showing a Sample of a Filled Form that is used for Reporting Weekly Data on Infectious Diseases

Appendix 3: List of Publications

Pascoe, L. and Mwangoka, J. W. "A smartphone-based reporting application for routine health data: system requirements, analysis and design", Int. J. Telemedicine and Clinical Practices. Manuscript accepted for publication in the forthcoming issue.

Luba Pascoe and Joseph W. Mwangoka, "A smartphone-based reporting application: Need assessment, development, findings and usability testing." Manuscript

Luba Pascoe and Joseph W. Mwangoka, "Towards Enhanced Reporting Of Routine Health Data from Primary Health Facilities Using Mobile Phone Application" Pan *African International Conference on Information Science, Computing and Telecommunications (2015)* (Manuscript Accepted)