UNIVERSITY OF NAIROBI

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ENHANCING REALTIME REPORTING OF MATERNAL AND NEW-BORN MORTALITY THROUGH DHIS2

BY

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A project Submitted as a partial fulfilment for the requirements of the award of the Degree of Master of Science in Applied Computing of the University of Nairobi

DECLARATION

I hereby declare that this Research Proposal is my own work and has, to the best of my knowledge, not been submitted to any other institution of higher learning.

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This Project has been submitted as a partial fulfilment of requirements for the MSc in Applied Computing of the University of Nairobi with my approval as the University supervisor.

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Abstract

Background: An audit by WHO (2010) revealed that there were low levels of maternal deaths reporting, lack of reporting forms, and lack of understanding of classification of various causes of death according to the International Classification of Diseases. An analysis of DHIS2 (2017) data was done and a comparison of the number of deaths reported on the Integrated Disease Surveillance and Response (IDSR) and MoH 711, discovered that IDSR is under-utilized and inaccurate. This data analysis revealed that on average only 39% and 11% of maternal and neonatal deaths respectively, are reported as emergency events in the four counties.

Problem: In the earlier years there has been an underreporting of maternal and neonatal deaths, poor compliance with the MoH MPD notifications circular, and lack of supporting evidence on actions taken after MDR recommendations, reported at the national and facility levels. MPDSR forms were incorporated into the DHIS2 but the system still has gaps and not all maternal deaths are adequately captured on DHIS2.

Aim: The aim of the study was to unearth the workflow challenges which hinder the prompt reporting of maternal and neonatal deaths and to understand the surveillance cycle in use then propose a suitable solution. Digitization of the maternity register was explored as a solution.

Methods: A purposive sampling was used to select the research participants and regions to collect the data from. The staff directly involved in the reporting of maternal and new-born deaths were targeted. They included maternity ward-in-charges, surveillance focal persons, health records personnel, and the county health management teams. The awareness of the standard operating procedures and notification policies on zero-reporting was evaluated, as well as the preparedness of reporters, the availability of IDSR reporting tools, and the reporting process.

Results: The pre-study conducted in Kwale, Kisumu, Vihiga and Siaya indicated that the maternity staff were not aware that they were required to send death notifications to the IDSR office within 24 hours after the death occurs, only 3 (8%) respondents had seen a maternal and perinatal death standard operating procedure (SOP), the weekly reporting tool was not readily available in 15 (38%) facilities, only 8 (20%) facilities had a clear reporting cycle. Taking advantage of this potential, we designed and piloted a digitized maternity register for the maternity unit nurses and assessed its impact to improve timeliness in reporting, arithmetic accuracy, and data completeness in St. Marys Langata Hospital, Mbagathi

Hospital, and St Patricks Health Centre. The web based register helped reduce time spent collating the data by 84%, eliminate manual aggregation which was inaccurately done according to the 100% of users in agreement as well as tools unavailability barrier which previously affected submission of the reports.

Conclusions: The digitized maternity register was seen to improve the reporting process of the maternal and new-born deaths in Kenya. This research therefore recommends the use of such registers in health facilities to ensure efficient and easy data collection, transmission and analysis systems for quicker response.

DEDICATION

To my late mother Jane Kina Wamiti, who passed away just at the start of my master's studies, your strong love for education will forever remain my source of inspiration.

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List of Abbreviations

API - Application Programming Interface
CDR – Clinical Data Repository
CHRIO – County Health Records Information Officer
CRS – Civil Registration System
CRVS – Civil Registration and Vital Statistics
CSS - Cascading Style Sheets
DHIS2 – District Health Information System 2
DSS – Decision Support Ssystems
eHEALTH – Electronic Health
EIDSR – Electronic Integrated Disease Surveillance and Response
ERD – Entity Relationship Diagram
GSM - Global System for Mobile Communications
HIS – Health Information System
HLR – Home Location Register
HRO – Health Records Officer
HTML - Hypertext Markup Language
ICD – International Classification of Diseases
IDSR – Integrated Disease Surveillance and Response
ISAD – Information Systems Analysis and Design
mHEALTH – Mobile Health
MNCH – Maternal, Newborn and Child Health
MoH – Ministry of Helth
MPDSR – Maternal and Perinatal Death Surveillance and Response
MSC – Mobile Switching Centre
NIST – National Institute of Standards and Technology
PHP – Hypertext Preprocessor
RAD – Rapid Application Development
RDBMS – Relation Database Management System
SDD – Software Design Document
SDLC – System Development Life Cycle
SMPP – Simple Messaging Peer-Peer
SMS – Short Message Service
SPSS – Statistical Package for Social Scientists
SRS – Software Requirement Specification
URL - Uniform Resource Locator
USSD – Unstructured Supplementary Service Data
WHO – World Health Organisation

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Chapter 1 - Introduction

In the past years much research has focused on various ways of reducing neonatal and maternal deaths. According to the World Health Organization (WHO) (2010), an audit report of the maternal death reviews implementation identified weaknesses such as low levels of maternal deaths reporting, lack of reporting forms, and lack of understanding of classification of various causes of death according to the International Classification of Diseases. This weaknesses illustrate that maternal and neonatal health workers face difficulties in offering specific services in order to drastically reduce preventable deaths of new-borns and women. In order to track the preventable neonatal and maternal deaths there is need to provide these data in a precise and real-time manner so as to get the appropriate effective response.

Maternal and Perinatal Death Surveillance and Response (MPDSR) is an important unit in the Ministry of Health (MoH) that identifies, notifies, quantifies, and determines the causes and avoid-ability of all maternal and perinatal mortalities, and the use of that information to effectively respond with actions that will avert future deaths. Recent statistics show that up to 85% of maternal mortalities are not recorded in Kenya's routine health reporting system DHIS2; and up to 40% of all perinatal and maternal mortalities are not captured by the civil registration system due to the DHIS2 data gaps (Kenya Service Provision Assessment Survey 2010, 2011). Where these are reported, they are not accurate and the exact cause of death and its code is not included.

It remains unclear why these mortalities are not reported according to the policies set by the maternal and perinatal death surveillance and response unit. Recent estimates illustrate that annually we lose between 7,000 – 8,000 mothers in the course of pregnancy, delivery, or soon after; 23,000 stillbirths happen; and 40,000 babies die within 28 days after birth (Owino et al., 2017). According to 2015 data provided by world bank it shows that among the developing countries Rwanda reported 1100 maternal deaths, Tanzania 8200, and Ethiopia 11000, whereas for a developed country like United States they reported only 550 maternal deaths ("Number of maternal deaths | Data", 2017). For neonatal deaths Rwanda leads with the least deaths at 6121, United States 14943, Tanzania 46117, and Ethiopia 89867, according to the 2016 statistics ("Number of neonatal deaths | Data", 2017).

Available policies clearly state that deaths occurring in any health facility must be acknowledged and notified to the applicable authorities within 24 hours, and those happening within the community in homes, within 48 hours ("Maternal Death Surveillance and Response: Technical Guidance Information for Action to Prevent Maternal death", 2013). The notification of the deaths must include zero reporting, that is whether or not any death occurred. However, this is not the case which could probably be attributed to lack of proper implementation of the policies. Data that is of poor quality from the routine Health Information Systems (HIS) known as the District Health Information System 2 (DHIS2), together with low and incomplete reporting makes planning and monitoring for the vital statistics difficult. Data on maternal and neonatal deaths from the DHIS2 are habitually late, of low quality and incomplete (MoH, 2016). Due to this, the data is hardly ever used to plan, manage and monitor the coverage and quality of services. The Ministry of Health in a report dated 2016 noted that despite past efforts to improve Civil Registration and Vital Statistics in Kenya, the coverage rates realized have remained low.

In the technical guideline new amendments were also made to existing reporting tools. As part of these changes the reporting form MoH 505 which is one of the surveillance weekly reporting tools added maternal and neonatal deaths in the list of events on the form. There are other tools used in various ways at the health facilities: birth and death notification forms are used to register persons who were born or died, MoH 333 is used to collect data at the maternity and delivery ward, MoH 711 is an integrated summary tool for reproductive health, child nutrition, HIV/AIDS, malaria, and TB. Maternal audit forms and D1 forms are used to register patients who have died.

1.1 Use of mHealth for health interventions

Mobile health (mHealth) is the use of unwired communication equipment to provide support clinical practice. mHealth is taken to be a health empowering tool that brings positive outcome to the health system by enhancing the access and value of health care, and reducing the amout spent on health services (Fortuin, Salie, Abdullahi & Douglas, 2016). Health supporting tools comprise of health information systems (HIS), decision support systems (DSS), and health promotion and preventive programmes. In mHealth the systems that are commonly used oftenly are: client training and behaviour change, vital incident tracking, sensors and point-of-care devices, data gathering and reporting, electronic health (eHealth)

records, and electronic decision support (Fortuin, Salie, Abdullahi & Douglas, 2016). Quality health refers to the delivery of safe, equitable, effective and timely healthcare.

1.2 Mobile Health interventions in real time reporting

Real time reporting allows the monitoring of activities and events as they happen. Many health providers are not leveraging the huge amounts of data that is collected at the facility to advance the quality of care, reduce costs and increase patient satisfaction. It is certain that most of the information available to the health care managers and workers is still backdated. For example, many health facilities produce reports on outbreaks, maternal and neonatal deaths, and other incidences on a monthly basis yet this reports only reveal what has already happened, not what is occurring now or is expected to occur in the future. In order to maximise on this data, health providers should embrace IT systems that collect the data in real time, facilitating them to make better and effective decisions.

The majority of maternal and neonatal deaths can be avoided by using the wide variety of cost effective public health interventions as well as the use of mHealth technologies. The mHealth field offers technology integration in the health sector which endorses enhanced health through improved communication and better health care decision making. Having seven billion people estimated at 95% of the global population with access to mobile phones, mobile technology presents a scalable and cost effective solution that promotes early interventions to avert the maternal and neonatal deaths ("Press Release: ITU releases 2016 ICT figures ...", 2017). Mobile devices supports mHealth interventions since they are used to improve care delivery, point of service data gathering and the use of unwired equipment for real time monitoring and adherence support.

The most explored mHealth technologies consist of Short Message Service (SMS), Unstructured Supplementary Service Data (USSD), mobile telephony, SMS short-code service, Bluetooth, WiFi, and mobile apps providing an assorted range of services like tracking, treatment, behaviour change, and mother and child health interventions. Goel et al. (2013), notes that using mHealth technologies in the health sector solves the human resource shortage problem and makes health care service delivery more efficient.

1.3 mHealth challenges

World Health Organisation notes that mHealth holds a high chance to transform the delivery of health services worldwide as well as introduce a paradigm shift in the delivery processes. Therefore it can be confidently stated that enhancements in the technological inventions is capable of improving the clinical and operational processes that ensure operative and efficient healthcare services are provided. For that reason, the changes cannot occur without hitches, many challenges should be expected. Some of the challenges expected to be faced by a person who plans to design and implement a mHealth intervention are as follows:

I. Usability

This is the efficiency, effectiveness and fulfilment with which an identified user can accomplish the set objectives of a certain environment. The usability challenge could be things like font size, color combinations used on the display, cell phone screen size, or the ability of a person to use a cell phone for other functions other than phone calls. As usability improves other challenges like interoperability and data security which bring about the issues of confidentiality and integrity.

II. Interoperability and integration of technologies used

For an mHealth intervention to be termed usable it must be made a part of the larger information system through interoperability which is difficult because some of the smaller information systems may not have initially designed for healthcare purposes. This means that integrating this systems is very difficult. A solution to this problem is ensuring that developers use the clinical decision support systems standards that have been developed to ensure that health care systems are interoperable (Gurupur & Wan, 2017).

III. Data security and privacy

Ensuring data security is difficult when dealing with data transmissions across many devices and storing it using wireless media. mHealth uses data that is transmitted via wireless networks hence making the data not de-identifiable thus presenting several complex challenges linked to data security (Gurupur & Wan, 2017). De-identifying healthcare data as defined by the National Institute of Standards and Technology (NIST), stands for processes that are practical to a dataset with the aim of averting or limiting informational threats to

individuals, protected groups, and establishments, while still allowing for the creation of aggregate statistics (Stead, 2017).

It is crucial to ponder on the dire requisite of training users when bearing in mind methodological aspects like passwords management, building the capacity of users on technology, and management of data containing personal health data. If users are not trained on mHealth interventions it becomes challenging to interact with technology thus bringing an undesirable effect that is likely to be amplified in a healthcare setup. Transmission of protected information using unsecured wireless networks is another challenge faced. This situation makes it easy for a cyber-criminal to access private health records which is a risk to the security and privacy of a patient's data (Gurupur & Wan, 2017).

Data storage especially with the onset of cloud computing and application service providers is also another barrier. The main problem with cloud computing is the unknown locations where this data is stored. Data storage should be a key consideration to any mHealth implementation and the common regulation is to have the patient data kept in tenable server rooms with limited access to only approved personnel.

IV. Reliability

This can be described in simple terms as a device or application working when you want it to. One of the factors is available network connection and the value of the content programmed in an application (Gurupur & Wan, 2017). The readily available apps give data that is not evidence based from research and they are likely to provide inaccurate information which users presume to be correct. Approval from responsible bodies is required for mHealth interventions to be used.

1.4 Problem statement

Studies conducted in the earlier years revealed that there was underreporting of maternal and new-born deaths, poor compliance with the Ministry of Health (MoH) circular on perinatal and maternal death notification, as well as lack of evidence of responding to the Maternal Death Review (MDR) recommendations at the national and facility levels. Ameh et al. (2017) further revealed that despite the Maternal and Perinatal Death Surveillance and Response (MPDSR) notification and evaluation forms being incorporated into the DHIS2, the system still had gaps, and not all maternal deaths were adequately captured by the DHIS2 system. Manual tools are currently in use for reporting and they create challenges in achieving complete coverage because of untimely report submissions, incomplete and poor data quality

(Evaluation, 2017). Evidence-based interventions at health facility levels can only be made possible if there is timely, complete, and accurate reports on these mortalities.

Obstacles to effective data use in health facilities for purposes of decision making arise from poor data quality, weak human resource capacity and insufficient organization support in analysing, disseminating, interpreting and utilizing data, and delays in information release. Poor data quality inhibits stakeholders' ability to timely use data for evidence-based interventions which stems from complex reporting procedures which negatively affect data timeliness, accuracy and completeness. The use of manual registers increases the rate of errors, great workload for health workers at health facilities leaving inadequate time for operative data collation and reporting thus contributing to a weak surveillance information system (MOH, 2010). This is a hindrance to the success of surveillance in reducing maternal and new-born mortalities.

Reduction of maternal and new-born deaths at all levels of health care can only come down if reports submitted are timely, complete and accurate for the interventions to be effective enough. Numerous partner sponsored programmes have been implemented in selected counties but reporting and notification of the maternal and new-born deaths have not shown an improvement. However, despite a lot of health data existing, this information is rarely used by stakeholders for effective interventions because reporting is habitually late.

1.5 Aim of study

This study aims at defining and developing a working prototype that will strengthen the already developed policies and systems aimed at improving maternal and neonatal death surveillance with real time data submitted to DHIS2.

1.6 Research objective

The general objective of this research was to develop and implement a working prototype of a real time reporting health application for neonatal and maternal mortalities.

1.7 Specific objectives

The specific objectives include:

- To establish the current reporting work flow process for new-born and maternal mortalities
- To evaluate the challenges hindering timely reporting of neonatal and maternal mortalities

- To design and develop a prototype for reporting the maternal and neonatal deaths in real time
- To test the prototype for timely and complete reports

1.8 Research questions

To address the above objectives, this research wishes to answer the following Research Questions (RQ).

I. What is the current reporting work flow process for new-born and maternal deaths?
II. What are the challenges hindering timely reporting of neonatal and maternal mortalities?
III. How will the prototype be designed and developed to enable reporting maternal and neonatal deaths in real time?
IV. How will the prototype be tested for delivering timely and complete reports?

1.8 Study justification

Instant notification of a maternal or neonate death in the facility and the community within 24 – 48 hours, a true real time magnitude of the mortality burden in a country can be estimated with real time monitoring trends. Consequently, this will allow a country to have a proper evaluation of the impact the health programs aimed at reducing the maternal and neonatal mortality have and improving maternal health ("Maternal Death Surveillance and Response - background", 2017). The following benefits will therefore be provided to the users and key stakeholders by the proposed solution:

i. Enhance reporting to the DHIS2 since users will be able to send the death occurrences in real time using the proposed solution
ii. Provide a fast and secure tool that has interactive menus and is cost effective to the users
iii. Aid stakeholders especially the decision makers to access complete and good quality data in a timely manner, which will then be used to inform planning, management and monitoring coverage of services.

1.9 Scope of the study

The study was conducted successfully in 39 health care facilities spread out in four partner counties supported by GIZ, which use DHIS2 as their main reporting system. Since DHIS2 is the national reporting system the research and solution was conducted around it.

Chapter 2 - Literature Review

2.1 Mortality

Mortality is referred to as the number of death by cause, place and time. The most universally used indicator for analyzing mortality is life expectancy at birth. Life expectancy is defined as the mean number of years a person expects to live at birth if subjected to the current mortality conditions for the rest of his or her life ("Mortality and life expectancy statistics - Statistics Explained", 2018). Looking at life expectancy at birth is a powerful way of showing the advances in mortality.

The number of years that a newborn is expected to live, with the risks of mortality remaining constant, has since increased by 24 years from 1950-2015 (World Mortality Report, 2017). This increase represents a 3.6 years increase per decade for the past 65 years. The reduction of mortalities has a great impact on life expectancy as seen in the period between 2010 and 2015. During this period the reduced mortalities impacted on the percentage of the population living in countries with a life expectancy of below 60 years decreased to only 8.5%.

The World Mortality Report (2017) revealed that, since the early 1950s the world has gained 23.7 years of life expectancy reaching 70.5 years from 2010 to 2015. In the same period less developed countries gained 27.2 years of life expectancy, twice the number gained in more developed countries. This was attributed to the reduction in child mortalities which was a huge problem in the under developed countries. Improvements in life expectancy have had a great variance among the less developed countries as shown on the figure below.

	Life expectancy at birth (years)			
	1950-1955	2010-2015	Absolute change	Percentage change
World	46.8	70.5	23.7	50.6
More developed regions	64.7	78.3	13.6	21.1
Less developed regions	41.5	68.8	27.2	65.6
Least developed countries	36.1	62.2	26.0	72.0
Other less developed countries	42.3	70.2	27.9	65.8

Figure 1: Life expectancy at birth by development group and region, 1950-1955 and 2010-2015 (Source: World Mortality Report, 2017)

2.1.1 National Mortality Trends

The national life expectancy for Kenya in 2000 was 51.751 years and in 2017 it was 67.3 years (Kenya | Data, 2018). Life expectancy for Kenya increased from 66.7 years to 67.3

years in the period 2015-2017, showing an annual growth rate of 0.45% on average. The annual number of deaths per 1,000 total population for Kenya stood at 6 in the year 2017 (Population Reference Bureau, 2018). Death rate is a component of population change along with net migration and birth rates. Having high mortalities in a country for the young age groups would significantly lower the life expectancy at birth. But if an individual survives their childhood of high mortality, they are likely to live much longer (Kenya | Data, 2018).

2.1.2 Under 5 mortality trends

Under-five mortality is viewed as the possibility of a child dying amid birth and the age of five. According to the Millennium Development Goals report of 2011, most of the under-five death are found in the sub-Sahara region in Africa, it is estimated that at least one in eight children die before attaining the age of five or, in other words, 129 births per 1000 live births. The figure is two times the average of the low income countries and almost 8 times the average of the developed countries (UNICEF, 2011). The position is not different in Kenya albeit the registered decline in mortality among the under-five children. Up to the 1980s, the annual mortality motility rate is estimated rate of 4 percent per year Data from the 1998 Kenya Demographic and Health survey report indicate that the mortality rate increased to approximately 24 percent in the period between mid-1980s and mid-1990s. However, from 2009, the mortality rate reflected a declining trend.

2.2 Maternal and neonatal mortality trends

Goal four of the Millennium Development Goals (MDGs) purposes to decrease infant and child transience by two-thirds between 1990 and 2015. The MDGs have however, been replaced by the Sustainable Development Goals (SDGs) Agenda. The SDGs have 17 goals among which the assurance of healthy lives and promotion of the well-being for all is guaranteed. An example of the implementation of the SDGs includes the promotion of the implementation of the universal health coverage initiative. Another example is the Beyond Zero initiative that is aimed at promoting mother and child access to health care across the country. The strategy is driven by the National Health Sector Strategic Plan II as well as the Vision 2030 Medium Term Plan which aims at reducing the inequities that exist in the healthcare sector while improving the child health indicators (National Council for Population and Development, 2015).

2.2.1 Causes of Death for both Maternal and Neonatal Death

In most developing countries, the maternal death rate, which is often defined as the demise of a mother either during birth or within42 days after birth, is approximated at 100 times higher than high income countries. The rate of neonatal mortality, which is defined as the death of a baby within a period of 28 days of life, is also reported to be 10 times higher than in the developed countries (lack, Laxminarayan, Temmerman, Walker, 2016).

Most of the maternal mortalities are caused by cultural customs, beliefs, and practices which often influence women behaviors during the prenatal period. These customs may also increase the likelihood of maternal death during childbirth. In order to prevent such adverse outcomes, it is essential to understand how the culture beliefs surrounding childbirth influences the mothers behavior (National Council for Population and Development, 2015). Such knowledge can immensely assist the nurses, health care workers or midwives in the provision of culturally competent care that helps in the reduction of maternal deaths.

Poor women residing in remote areas may suffer from maternal mortality due to lack of adequate health care especially in regions with few skilled health care attendants. In other areas, the health workers may be overworked due to lack of hospital facilities as well as understaffing because of poor funding of the health care system. Other causes of maternal and neonatal mortality include poverty, distance from the health facilities, and lack of evidence, scarce services, and cultural practices (World Health Organization, 2016). In order to advance maternal health, it is vital to identify the obstacles that limit the provision of quality maternal health care and resolve them at all stages within the healthcare system.

Maternal mortality in Kenya varies markedly along geographic regions. An analysis of the 2009 population census data indicate that the highest maternal mortality was registered in the North Eastern Province with 2,o14 per 100,000 live births, Nyanza with 546 per 100,000 live births. The regions that have registered significant reduction of maternal mortality include Kakamega County which has introduced a number of programs in the maternal healthcare sector by the county government since the inception of devolution. The maternal mortality has reduced from 800 per 100,000 live births to approximately 460 per 100,000 live births. The commendable reduction of maternal mortality can be associated to the partnership with UNICEF and AMREF which offer technical support. Additionally, the county has a cash transfer program where mothers are given Ksh. 12,000 when the child reaches 18 months to take care themselves and the infants.

Makueni County has also registered considerable reduction of maternal mortality through largely educating women on the need to give birth in the hospitals. Where they can access skilled medical care. The county has engaged the services of community health workers to mobilize women to attend antenatal care and give birth in hospitals and hence, the maternal related complications are averted. The County of Mombasa has also put in place programs aimed at reducing maternal mortality. The county is working in partnership and support of Danish Red Cross and the European Union, through the Kenya Red Cross Society. The program is particularly targeted at the vulnerable communities (National Council for Population and Development, 2015).

2.3 Universal Health Coverage

Universal Health Coverage (UHC) often refers to the access or the provision of the needed health care services as well as financial risk protection in the health care system. Universal Health Coverage is a major commitment by the global health care community whose objective or goal is to ensure that all the people are able to acquire the health care amenities they require devoid of suffering adverse monetary hardship when meeting the cost of health care. The Universal Health care coverage concept was developed during the 58th World Health Assembly held in 2005. The World Health Organization (WHO) members committed to the provision of affordable Universal coverage and access to health services for everybody on the basis of equity. It is however, acknowledged that achieving the Universal Health Coverage goal is not simple thing. The available data or evidence show most nations are struggling to make some progress mostly because the UHC requires a well-managed health system that is strong and efficient. It also requires a significant investment that many countries have found difficult to make or is unwilling to commit.

In Kenya, the constitution that was passed in 2010 recognizes health care as a right and tasks the health care industry with the responsibility to achieve the right. The people's right to health care is also provided for in other policy documents including the Vision 2030 as well as the Kenya Health Policy 2015-2030 which seek to provide affordable and equitable quality health care to the Kenyan population. The policy and other legal documents signal the government commitment to make sure that the citizens have adequate access to affordable and quality health care. However, despite these commitments, there are recognizable disparities in the access to health care particularly driven by residence such as urban versus rural, wealth, gender, and regional variances.

2.4 Reporting is currently not optimal

A Maternal Death Review System was evaluated by WHO in 2014 showing that the system seemed to be operating well under partner sponsored programmes in selected counties, but reporting and notification of the maternal and new-born deaths had not improved (Ameh et al., 2016). The situation has not changed as seen on data reported on the District Health Information System (DHIS2) used in all facilities as a national reporting tool. In DHIS2 a data element defines the actual recording in the system for example, number of maternal deaths or number of immunizations. A comparison of the number of deaths reported on the surveillance and the maternity & delivery data elements, revealed that the surveillance element is under-utilized and inaccurate (DHIS, 2018).

2.5 mHealth

According to Van Doornik (2013), it is important that the essential technological infrastructure is in place since the success of the implementation of e-health depends on it. Accordingly, (Mushamiri et al. (2015), opines that the building of the submarine optic fibre cables as well as the laying of the national optic fibre backbone is a positive development and is likely to have a significant impact on e-health. Additionally, coupled with the increasing mobile telephoning infrastructure and the introduction of the 3g and 4g technology, the necessary infrastructural impetus for e-health is already in place (Juma et al., 2012).

2.5.1 Mobile Phones and Signal Coverage Pervasiveness

In Kenya, a country with an estimated population of 45.4 million, the mobile subscriptions rose from 41.0 million recorded in the first quarter to 42.8 million subscriptions, marking a growth of 4.4% for the 2017/18 financial year. The mobile penetration level also went up to 94.3% from 90.4% recorded in the preceding quarter. The sector is still rapidly growing due to the low cost of handsets and calling or SMS services (*SECOND QUARTER SECTOR STATISTICS REPORT FOR THE FINANCIAL YEAR 2017/2018 (*OCTOBER –DECEMBER 2017*)*, 2018). Net additions for mobile subscriptions were at 1.7 million up from 768,831 subscriptions reported for the quarter under review and the preceding quarter respectively. A national cross-sectional study which was undertaken in the public health facilities found that the SMS use was widespread among health workers. Nevertheless, disparities exist in education, gender, age, as well as in levels of poverty. However, some of the disparities can be solved through the intervention of mHealth while the phone penetration can be addressed by the growth of mobile phone ownership.

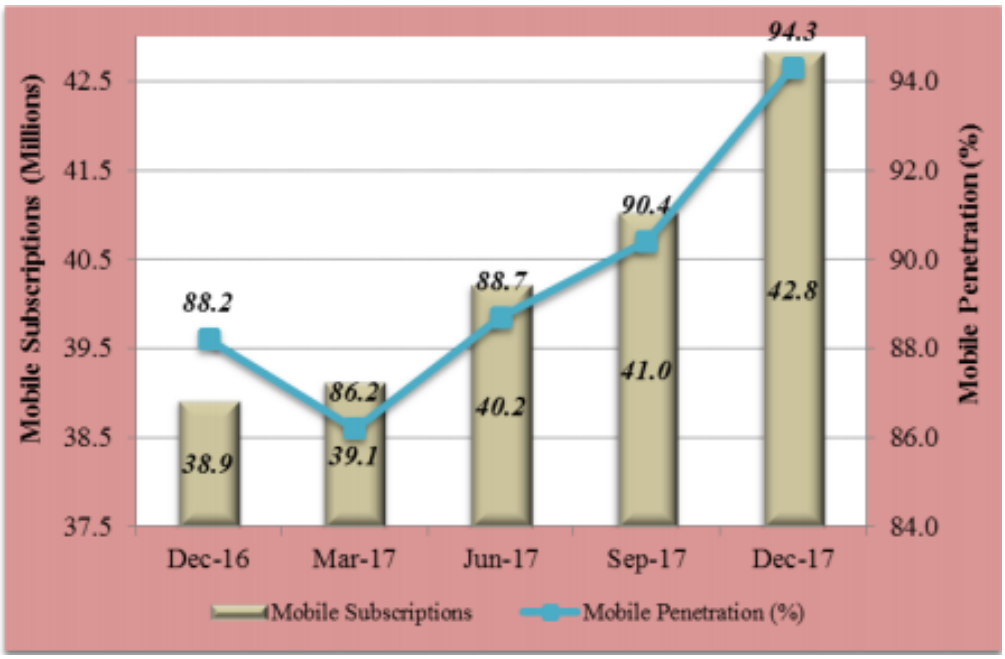

Figure 2: Mobile subscriptions (Source: Communications Authority, Operators' Returns)

The usage of portable computing and communication tools in delivering public health and care is an increasing area of study and practice (Adibi, 2014). Malvey & Slovensky (2014) further opines that the M-health interventions apply mobile electronic devices (MEDs) such as mobile phones and personal digital assistants, to deliver a series of functions such as clinical support systems as well as data collection tools for healthcare workers. Anastasius (2016) further observed that the use of the mobile electronic devises is also used to support health behavior change and the management of chronic disease management by patients.

According to Liu, Zhu, Holroyd, Seng (2011), Africa bears the highest disease burden in the world; however, the authors are of the opinion that the emergence of technological advancements provides opportunities for the development of sustainable mobile health solutions aimed at improving the delivery of health care. According to the Deloitte Open Mobile Survey, the growth of the mobile health technology should be viewed as a way of providing quality and accessible care at low costs (Kratzke & Cox, 2012).

In regions where basic access to health care is challenging, such as rural Kenya, M-health provides remarkable opportunities (Mushamiri et al., 2015). Due to the weak health care systems in Kenya, financial and organizational, quick and effective remote care management is limited, however, M-health can improve and strengthen the current health care systems in

the country and it has the prospective to health care interventions to patients in remote areas (Mushamiri et al., 2015).

Mobile phone technologies have several structures that provide them an advantage over the additional communication technologies in some specific activities within the health care sector. Many MEDs operate with the cellular wireless capabilities which provide the potential to have a continuous and interactive communication even in remote areas (Viljoen & Sowah, 2015). Such capabilities include calls, texting, and multimedia messaging (Kratzke & Cox, 2012). The MEDs also have internet access. Additionally, the mobile phones are portable due to their small size, low weight, and the rechargeable long life battery power (Kratzke & Cox, 2012). The MEDs also have computing capacity that can support software applications. Viljoen & Sowah, (2015), However, observed that a combination of the features may vary from one specific device to the other and their importance may also change depending on the specific health activity they are in use. Nevertheless, with the advances being made in technology, the devices may hold all the needed functions.

2.5.2 Other interventions that have used mHealth

The GSMA Mobile m-health program links the mobile and the health institutions with the objective of developing commercially viable and sustainable m-health services which addresses the public health needs (GSMA, 2016). The program is a partnership between GSMA m-health program and UK aid with the support of DFID and NORAD. The program is aimed at targeting maternal and child health as directed by the Millennium Development goals (GSMA, 2016). The GSMA program prioritized several countries including Ghana, Malawi, Kenya, and Tanzania among others (GSMA, 2016). The mobile application is aimed at offering content to improve individuals' knowledge that would modify their attitude and radically change their behavior. One of the services that have been effectively implemented is the Healthy Pregnancy, Healthy Baby (HPHB) in Tanzania (GSMA, 2016). The text messaging service is also called Wazazi Nipendeni (GSMA, 2016). Essentially, the service delivers reminders and other information through text messages to pregnant women or mothers with new born babies up to age five. The main objective is to promote healthy pregnancy as well as supporting early childhood care behaviors (GSMA, 2016). The service, additionally, helps the health professionals in disseminating information that is shared during the antenatal care visits.

There are other technologies that have been used to harness maternal care such as the Open Data Kit (ODK) and DHIS2 tracker. The ODK is a set of popular free and open source tool that allows for the gathering of data using the mobile phone technology and devices. It features an active online support base and community. The technology has been tested and tried and mostly works best with Smartphone that run on the Android mobile operating system (Quiros, 2014).

In Kenya, the ODK technology has been used by the Academic Model Providing Access to Healthcare (AMPATH). AMPATH is a partnership between Moi University, Moi Teaching and Referral Hospital, Kenya Government, and Indian University. The AMPATH health workers use the technology to collect data during home visits for HIV consoling. The data collected using ODK Is used by clinicians to make better and faster decisions abo7ut health care.

DHIS2 tracker, which is also known as DHIS2 Community module, is an integrated tracking module which is designed to support community health systems while facilitating the smooth integration between a given community health data and the aggregate health data management (Quiros, 2014). The tracking module facilitates the health workers in individual treatment follow up through the recording of all the treatment related to the treatment and the effective monitoring of different health services accorded to the individual. The DHIS2 technology has so far been implemented in over 87 countries across the world with 53 having a national operation.

2.6 IDSR departments

The major goal of the Integrated Disease Surveillance and Reporting (IDSR) is to strengthen the disease surveillance and response capacities at all the levels of the health system through the development of local capabilities to detect, confirm, and offer responses to any emerging public health threats (Momanyi, 2016). IDSR is born out of the need to offer responses to the emergence or outbreaks of diseases in Africa during the 1090s. A meeting of the 46 member States of the WHO Africa Region was convened in Zimbabwe in 1998 with the aim of adopting the Integrated Disease Surveillance and Response as a regional framework for the strengthening of the national health surveillance system in Africa (Momanyi, 2016). The IDSR framework delineates the functions, activities, and the skills required at every level of the health system in order to implement a comprehensive surveillance, coordination, and response system. The IDSR designates the activities for each level of the health system for the purpose of disease detection, reporting, investigation, response, monitoring, communication, evaluation, and preparedness. The framework also specifies the African

health priorities disease that affect African communities. However, when a country adopts the IDSR, it has the leeway to fix its national priorities according to the country's epidemiological profile.

2.6.1 IDSR in Kenya

In 2011, Kenya Ministry of Health with the support of World Health Organization and other health partners such as the Clinton Health Access, innovated the eIDSR, an internet based system as a way of meeting the challenges of transmitting the surveillance data from the district or sub-counties to the national level (Momanyi, 2016). Currently, the data from the hospitals are transmitted in paper-based standard tools to the sub-county at the sub-county, the information is transformed into web- based eIDSR platform and then forwarded to the county and national levels. The system, however, proved to be slow and prone to errors. To address the gaps in the eIDSR system, the government, in corroboration with various partners developed a mobile SMS-based disease outbreak alert system (mSOS).

2.7 Adoption of systems

Kenya has adopted the Health information System as a way of managing the delivery of health care to the citizens. The National Health Management Information System aims at establishing an integrated health management system at the national and county level as one way of realizing the Vision 2030 (Kihuba et al., 2014) health goals. Through the integrated health information system, the government aims at building capacity that contribute meaningful information that can be used to deliver quality health care and treatment to those seeking health services. The adoption of the Hospital information system has been viewed as a key component of the national health information system (HIS). The system is used to support the generation of health information as articulated in the health policy documents (Kihuba et al., 2014). However, despite the important role that the system is expected to play, various studies have raised concern regarding the performance of the health management system (HMS).

The studies indicate that the system produces poor quality data that are characterized by low reporting rates which is a result of a lack of a policy framework to guide the activities of the Health Information System particularly in the face of demand for performance information that are linked to specific indicators for various vertical programs such as maternal mortality rates (Kihuba et al., 2014). However, the government has of late invested in policy

development as well as the implementation of national scale through the computerization of District Health Information Systems.

2.8 Data Quality

Most of maternal and neonatal deaths happen in developing countries due to inequalities in access to health services, cultural practices, challenges in collecting and sharing clinical information, error reduction, and communication barriers between patients and clinicians due to varied cultures. There exists numerous solutions to these problems but the implementation is constrained by lack of access to quality maternal care. The available solutions vary from immediate application of interventions to learning from the mistakes and applying the lessons to avoid similar occurrences in future. Lack of resources at the facilities, inadequate knowledge, unclear operating procedures, and poor documentation contribute highly to loss of expectant mothers. It is, therefore, important that these critical health issues are addressed.

Quality maternal care can only be ensured if the underlying challenges are resolved. Information technology is one of the ways that can be applied to advance quality of care (QoC). The automation of patient information is essential for timely decision-making (Crossing the quality chasm: a new health system for the 21st century, 2003). This automation offers the potential to enhance coordination of care across settings, which is critical to the effective management of maternal and new-born fatalities. Information technology also contributes to the reduction or errors by aiding in detection of possible errors.

Information technology in health can be described as technology and structure used to record, evaluate, and shape patient health records. There are numerous technologies including health record systems, paper and automated; individual health tools that include smart devices and apps; and communities that share and deliberate information. The goal of Health IT (HIT) is to offer better care for sick people and help realise health equity (Neiman, 2017). Health IT supports capturing of patient data to advance healthcare delivery and to permit for exploration of this data for both healthcare practitioners and the ministry of health or government agencies. The data is further used for implementing policies so as to better treat and avert the spread of infections.

Health IT develops the quality of service delivery, increase patient safety, decrease medical errors, and strengthen interaction among sick people and healthcare providers. As part of HIT, Mobile health (mHealth) has been proved to have the potentiality to significantly reduce

the inequality of maternal health care through various technological applications that aim at facilitating the communication between the patient and the health providers as well as promote women's behavior change. The applications can also assist in the collection of data with the overarching objective of enhancing access to quality maternal health care.

2.9 Interoperability in HISs

Interoperability can broadly be as the ability of two or more systems or their components to share or exchange information. When situated in the healthcare contexts, interoperability attains the ability of the healthcare information and technological systems, to work together across institutional boundaries, in order to enhance the delivery of healthcare (Malvey & Slovensky, 2014). Interoperability, therefore, is a fundamental component of supporting the desired cross-institutional point of care access to robust data that can enhance better patient care outcomes. (Mushamiri et al. (2013) opined that the attainment of interoperability, therefore, requires coordination and cooperation among the stakeholders. In Kenya, significant steps have been taken in developing the Standards and Guidelines for Electronic Medical Records in 2010. The guidelines are meant to guide the application developers as well as other solutions providers in coming up with interoperable systems.

2.9.1 Opportunities to Inter Connect and Share Data

Health Information Systems (HISs) include concepts and data in health services rendered to ill people with an aim of improving the supervision of such services. HISs have four key tasks namely: data generation, synthesis and analysis, compilation, and communication and use (SHAHMORADI & HABIBI-KOOLAEE, 2016). These functions provide the foundation for making decisions. HISs are essential sources for the collection of data in health sectors because it ensures the data is of high quality.

HISs ensure that information is shared across the systems for continuous patient care. Failing to integrate this systems leads to insufficient data flow between them. Integrated HISs are considered to deliver higher performance in safety and quality (SHAHMORADI & HABIBI-KOOLAEE, 2016). Information systems provide fast and appropriate access to healthcare services, cover diverse geographic regions, and lessen costs. Additionally, ISs are potential tools to health promotion (Heidemann, 2015).

SHAHMORADI & HABIBI-KOOLAEE (2016), identified three categories of health promotion that can benefit from HIS integration: health education, disease prevention and health screening. In health education the integrated HISs gives support to the healthcare providers to control some health conditions for example, obesity, FP methods, diet and

hypertension. For disease prevention HISs provide assembly, analysis, dissemination, promote and evaluate health promotion and disease prevention programs. The data about incidences and disease mortalities, trends, prevalence and identification of risk factors is shared between these systems. In health, screening well-being promotion programs are premeditated to manage prolonged conditions such as, heart diseases, cancer, and stroke. HISs aggregate the demographic data, data on the risk factors of ailments, and other associated data. This aggregation is of help to decision makers since it helps them to manage the screening programs.

2.9.2 Similar Interventions/efforts

An establishment by Population Health Implementation and Training (PHIT) partnerships in five sub-Saharan African countries (Ghana, Tanzania, Rwanda, Zambia, and Mozambique) to strengthen the district health systems was initiated. Through the African Health Initiative, PHIT tested novel approaches to improve data systems and used the HIS outcomes to drive decision making and improve health systems performance (Mutale et al., 2013). There were design differences that were described across the PHIT partnerships that reflected various theories of change for each project. The various theories put into consideration the information required, the users of the information to effect change, and how the change was expected to manifest.

As reported by Mutale et al. (2013), Ghana and Tanzania simplified the paper registers that integrated data on community service provision, and in Ghana took up a resource allocation tool initiated in Tanzania for supporting district managers in decision making. Mozambique worked on strengthening the existing national HIS, providing data summaries for health system managers, identify problems easily, allocate resources and evaluate solutions. Zambia and Rwanda implemented ICT approaches for improving data quality, providing timely information to clinicians and managers.

Rwanda

Rwanda implemented an enhanced version of OpenMRS as an electronic medical record system in the three districts supported by the PHIT partnership. The EMR held patient records for 33 health centers with a catchment area of 800,000 people. The EMR provided clinicians with patient visits summaries and laboratory test results. Through this the clinicians were able to get reports on at-risk patients, administrative matters, resource allocation, infectious diseases, and quality improvement (QI). The MOH also implemented a nationwide

comprehensive EMR system to ensure that no parallel systems were created, but have one national system to integrate across EMR components and feed into the national HIS reporting requirements.

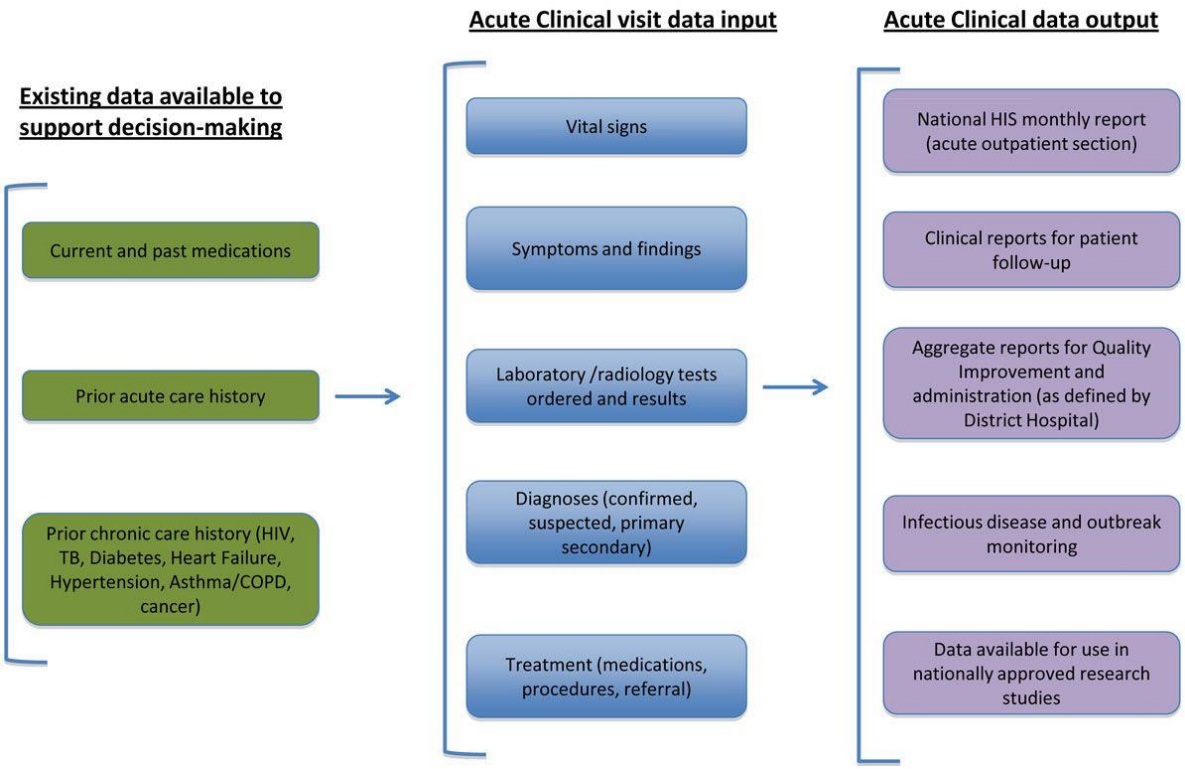

Figure 3: Framework for the health information intervention -Rwanda

According to Moturi & Kinuthia (2014), Rwanda has rolled out a national Electronic System for Disease Surveillance (elDSR) that has significantly enhanced the country's preparedness in identification and response to outbreaks and prevent outbreaks. According to the researchers, it has been demonstrated that the use of Smartphone applications has the potential of generating real-time disease surveillance data that can be used to augment the current methods. For instance, in Kazakhstan, they have developed a free Smartphone application, ClickClinica, which is used to escalate the identification of communicable diseases as well as other severe medical presentations which helps expand clinical practices (Moturi & Kinuthia 2014).

There have been comparative studies for the existing notification disease surveillance systems in the United Kingdom and Sri Lanka. The study recommends the use of

notifications from various sources and the involvement of laboratories in the disease surveillance activities. The study specifically recommends the computerization of the existing system to augment the comprehensiveness and timeliness of reports.

Zambia

A project in Zambia known as the Better Health through Mentorship and Assessment (BHOMA) uses Electronic Data Capture Systems (EDCS) and mobile technology to improve on the quality of data captured in their target districts. The BHOMA system utilizes touch screen data entry terminals that are attached to a miniature data processing server, into which patients visit information is fed. The system enables the generation of indicator performance reports which are used by the QI team to mentor facility staff on how to improve the quality of clinical care. Prior to the implementation of the new system, poor quality data was a source of concern throughout Zambia because the data was never used for evidence-based planning.

Lessons learned from the implementation of the PHIT was that training alone was not sufficient to build capacity for facility health workers. The most important thing was to have stakeholders meetings, data reviews, engaging health workers and managers to demonstrate the value of data, and owning the summary tools and guided decision making. A second lesson was how critical it was for HIS interventions to be developed in the national HIS context to ensure the programs' sustainability beyond the project lifespan. Finally the increased availability of mobile phones facilitated the use of EMR systems in resource constrained environments.

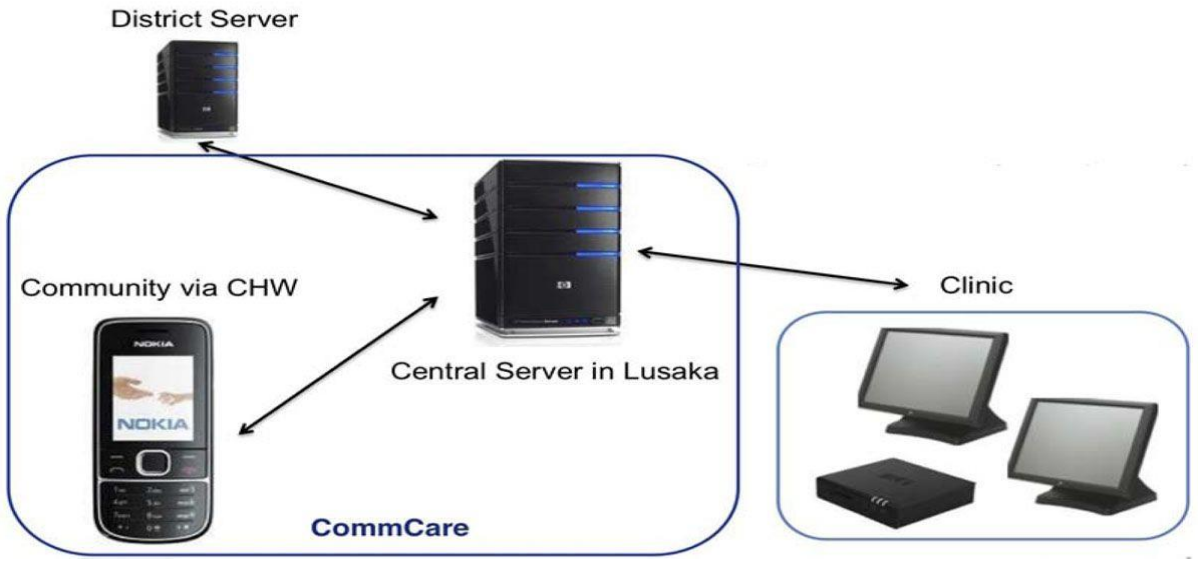

Figure 4: Framework for the health information intervention - Zambia

Kenya

Moturi & Kinuthia (2014) observe that there are several mHealth applications that are already in use in Kenya such as the Jamii Smart Kenya which is a collaboration between world vision mHealth initiative and Safaricom (a mobile service provider), AMREF, and CARE organizations. The Aga Khan University has provided the research and evaluation of the initiative in order to offer strategic guidance for the implementation. The Jamii Smart Kenya mobile phone initiative uses web based portals and SMS services to deliver the clinical component for the mothers with children aged less than 5 years and links them to a community health monitoring system (Moturi & Kinuthia, 2014). Kenya Integrated Mobile MNCH Information Platform is a nation-wide mHealth initiative that is aimed at offering pregnant women in Kenya wider choices, control and care during the pregnancy period and during and after delivery.

mHealth technology has also been used in Indonesia, a country that relies on midwifes, to facilitate communication among midwifes and obstetricians. The midwives reported a significant enhancement in their confidence to solve various problems as well as storing the patient data. The mobile phone technology application was positively associated with access to institutional as well as peer-network resources (Huaman, Araujo-Castillo, Soto, Neyra, Quispe, & Fernandez, 2009).

2.10 Summary

Health care information systems' major purpose is to facilitate the smooth running and interoperability of health care delivery with the aim of ensuring effectiveness and efficiency. However, the complexity and diversity of the health care sector provides some challenges particularly in relation to the integration of the systems. In Kenya, the application of information systems in the public health sector is relatively low, nevertheless, the government has initiated reforms through the Ministry of Health which are aimed at the development and integration of information technology.

Some of the initiatives that have worked include the innovation of the eIDSR, an internet based system as a way of meeting the challenges of transmitting the surveillance data from the district or sub-counties to the national level (Momanyi, 2016). Additionally, In Kenya, the ODK technology has been used by the Academic Model Providing Access To Healthcare (AMPATH). AMPATH is a partnership between Moi University, Moi Teaching and Referral Hospital, Kenya Government, and Indiana University. The AMPATH health workers use the technology to collect data during home visits for HIV consoling.

2.11 Conceptual Framework Design

The diagram below shows how various actors relate in the conceptualized architectural design. The proposed prototype aims at availing data from the healthcare service provision at the right time thus enabling policymakers, managers and individual service providers to make informed choices about everything.

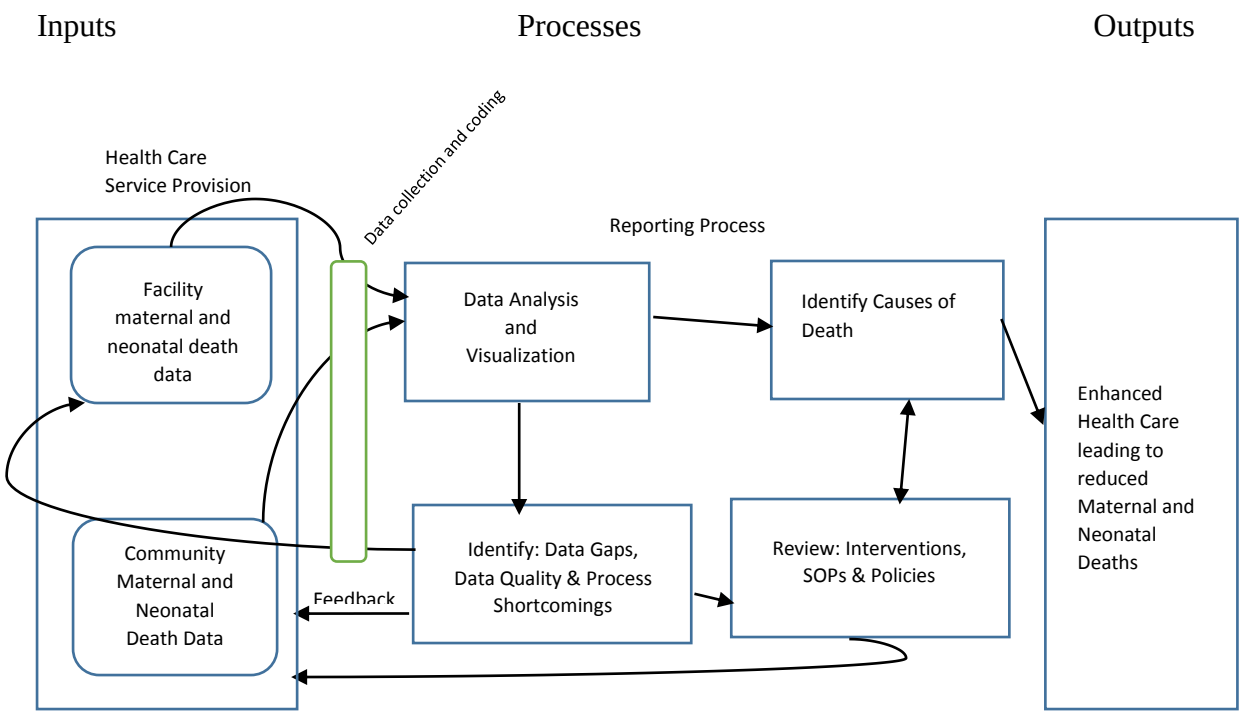

Figure 5: DHIS real time reporter conceptual framework

Chapter 3 - Methodology

3.1 Introduction

This chapter will define how the study was conducted by discussing the methodologies that were used to achieve the stated objectives, design and test the prototype, the source of data, requirements gathering, data collection and analysis techniques used. This section will also demonstrate the organisation of conditions to collect, measure and analyse the data that is in line with the stated objectives.

To better understand the factors that influence timely submission of data within the routine M&E systems in Kenya, an assessment was conducted of the data management and reporting systems involved in capturing and transferring health data from the point of generation at the health facility to the point of incorporation into national health statistics. The objective was to identify strengths and weakness related to the completeness and timeliness of the data management system. This was done through the use of interviews and focus group discussions.

Interviews are a qualitative research technique that involves intensive individual discussions to explore perspectives on particular ideas, programs or situations. The semi-structured interview format was used where an interview guide containing a set of questions was prepared prior to the interview sessions and additional questions asked in no particular order for further clarification and as a trigger to an open discussion.

Focus group discussions provide an opportunity for the respondents or participants to engage in a discussion regarding the field of study with the facilitator guiding the discussion. A few questions focusing on the main area of interest were prepared and tabled before the participants for discussion in a group. The discussions triggered further questions within the participants which they were able to answer. They were also able to share their experiences and views on the MPDSR reporting process and challenges faced at the higher levels.

Qualitative analysis was performed on the open-ended questions from the interviews because this kind of data cannot be quantified. The data from the different respondents was analysed so as to draw meaningful conclusions and recommendations. Phrases and words from diverse participants were studied to recognise the differences and similarities, then create a pattern.

Quantitative analysis was also performed on closed-ended questions which could not take numerical values and had predefined responses. This made it easy to create statistics describing the measurements or distribution of scores with few indices. After the analysis conclusions and recommendations were made.

3.2 Research Design

This section illustrates the research process and methods that were used in this study. The following table illustrates how each of the research objectives was achieved. In table 4 we present the mapping of the research objectives to the research methods.

Research Objective	Research Method
To establish the current reporting work flow process for new-born and maternal deaths	We reviewed literature and conducted a pre-study.
To identify the needs of the stakeholders in neonatal and maternal mortalities	We conducted a pre-study to understand their problems better, and designed the prototype, deployed and let the participants submit data with it for a period of 2-days and adjusted as per their feedback using Agile development method.
To design, develop and assess the usability of a prototype for reporting the maternal and neonatal deaths in real time	We used questionnaires at the end of the testing activity to determine if the system had helped address data accuracy, completeness, and time reduction by the maternity unit nurses.

Table 1: Mapping research objectives to the research methods

The nature of this research was to design a prototype for electronic health data transmission, aggregation and analysis using open source tools for rural areas in Low and Medium Income Countries.

3.3 Population and Sample Size

In this research a population was chosen from four counties namely Kwale, Kisumu, Vihiga and Siaya. A purposive sampling procedure was used to select the research participants from

the medical fraternity in 42 facilities spread out in the four counties. The choice of the respondents was guided by the participants' awareness of the maternal and child health issues including deaths, the reporting channels in use and the use of eHealth in managing the problem. Completeness of the data was also checked by looking at how the maternity registers were filled.

3.4 Sampling Techniques

The area of study was small which made it possible to collect information from each person. This study used purposive sampling technique to identify health personnel from health facilities.

3.5 Data Collection Tools

Mixed approach was used in this study (both qualitative and quantitative methods) because of the nature of the research questions and for allowing greater research flexibility.

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participants which they were able to answer. They were also able to share their experiences and views on the MPDSR reporting process and challenges faced at the higher levels.

3.6 Validity of Interview Questions

To ensure validity of the study a number of measures were undertaken; collecting data from the actual context; CHVs from the particular community unit. The survey questions were developed based on extensive literature review, other research experts' consultation and users view. Finally, the questionnaire was presented to some experienced researchers for approval. This was followed by a pre-testing using 10 selected CHVs each per village in order to ascertain the viability of the questionnaire.

3.7 Ethical Issues

The respondents' consent was sought before involving them in this research followed by the issuance of an approval letter. This was done through briefing the participants about the objectives of the research, and their roles in the research. The study also guaranteed the participants the confidentiality of the data recorded, how it would be analyzed and finally how it would be presented.

3.8 Data Collection Process

The process begun by obtaining a formal approval from the facility in charge of the 39 healthcare facilities after submitting an introduction letter gotten from the office of the director of School of Computing and Informatics. The hard copies of consent forms were issued for signing to all the respondents who had availed themselves at the maternity units. The data collection exercise involved an interview guide which was administered to all the participants of the study.

3.9 Data Analysis

After data was collected it was then prepared and processed by the following steps: the recorded information was transcribed on an SPSS data file; the data was then edited to check for errors and omissions; the closed-ended questions were coded, classified and tabulated to enable analysis; the open ended questions were transferred on excel where they were analysed. The data was analyzed using text format with the help of sketch drawings and tables. Since the focus of this study was on development of a prototype and evaluating its effectiveness in submitting timely and complete reports, quantitative and qualitative data analysis presented the best option for data analysis. Qualitative data analysis from focused group discussions and interviews was qualitatively analyzed with a view to identify emerging

themes and categories arising from the data. Quantitative data analysis from the interviews by the maternity unit nurses was analyzed using the Statistical Package for the Social Sciences (SPSS). The Median (Mdn) was calculated from the Likert-Scale results.

Chapter 4 - System Design

A digital maternity register system prototype for the maternity unit

This chapter aims at presenting the proposed prototype based on the findings of a pre-study conducted prior to designing the system, the understanding of the current data collection process flow within a health facility as well as from literature review.

4.1 Current health data collection system

Data collection is done using paper and pen methods: Maternity Register (MOH 333 Appendix 6). At the maternity unit, each of the nurses on duty is required to fill the MOH333 whereas every end month as they are required to submit their MOH 711 to the HRIO who is required to submit the data on the form to DHIS2. The MOH 711 is a summary extension form of the various Health Indicators reported in the facility. From the analysis of the interviews and discussions with the users and stakeholders the following was revealed

- 38% of the facilities were missing the IDSR manual reporting tool
- Only one facility had a well-defined MPDSR reporting flowchart
- 80% of the facilities were not completing the reporting process i.e. submitting their data on the IDSR data element in DHIS2 within the recommended 24 hours.

4.2 Proposed system requirements

It is from the gaps found in literature review as well as the findings gathered from the pre-study that was conducted which motivates us to design a prototype for facility health data collection, transmission, and processing using open source frameworks alongside existing and available technologies. The goal of the prototype is not only to bridge the gaps but in addition enhance timely and complete reporting in addressing facility health data management problems. The particular aspect that this research aims to address is facility data collection, transmission and processing directly from the maternity unit. In line with the objectives and findings of the pre-study, the following system features were envisioned

1) A system with the ability to validate all fields and send reminders to curb the poor filling of details before submission.

2) A system with the ability to generate daily, weekly and monthly summaries and reports

3) A system that digitizes the maternity register with minimal inputs to minimize errors and improve report completeness

The prototype aims at linking the reporting gap between the monthly service data and the IDSR immediate reportable events to allow timeliness, completeness and accuracy in reporting maternal and neonatal mortality data. We selected **DHIS2** which as an open source platform as the preferred choice of technology. The reasons behind this selection was motivated by: its ability to offer data collection through a computer, ease of its set-up on a computer to receive, and it is an existing technology already in use in the facilities. In addition, budget limitations which affect facilities in the devolved counties, make open source technologies solutions be more relevant and sustainable.

4.3 Requirement Specification of the Proposed Prototype

This section formally defines the requirements required to prevent occurrence of ambiguities during the development process of a given system. This section therefore presents the concerned stakeholders as well as functional and non-functional requirements of the proposed prototype.

4.3.1 Stakeholders

An important aspect of any software development process is identification of the relevant stakeholders because it helps shape the requirements engineering process. The following are the key stakeholders of the proposed digitized system of the maternity register for enhancing reporting of maternal and new-born mortalities.

i. **Maternity nurses:** these are the staff required to fill in the maternity registers at a facility maternity unit manually since they do not have access to the DHIS2. Their duties are to attend to patients, conduct deliveries, document on manual registers, conduct maternal/neonatal death reviews and document the same, and compile daily and monthly summaries.

ii. **Health Records Information Officers (HRIO):** these are health records personnel required to report into the DHIS2 at facility level. Their duties are to manage and keep track of patient files, collect data from all hospital departments, report to the DHIS2, conduct data review and analyse these data.

iii. **County IDSR focal person:** these are the surveillance personnel who monitor public health and immediate reportable events at county level. Their roles are to receive, compile and analyse public health events like maternal/neonatal deaths, outbreaks etc. they have access to DHIS2 that has IDSR data elements that they report to.

iv. **County Health Records Information Officer (CHRIO):** these are health records personnel in charge of all the facility HRIOs in the county with access to

DHIS2 for data management at higher levels. Their duties are to track, analyse and make informed decisions to improve the county health indicators as well as report to higher levels.

4.3.2 Use case diagrams

Use case diagrams model the user's characteristics to easily understand their roles and variations. It is used to show how the system stakeholders will interact with the system.

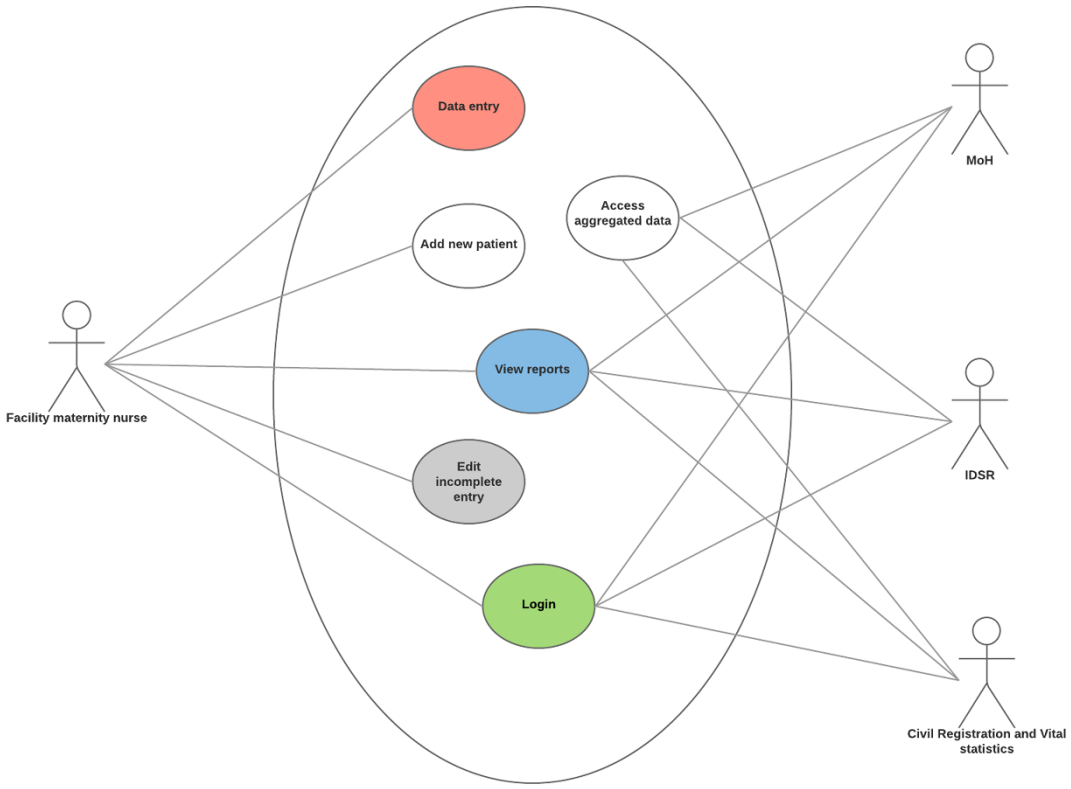

Figure 6: Use Case Diagram

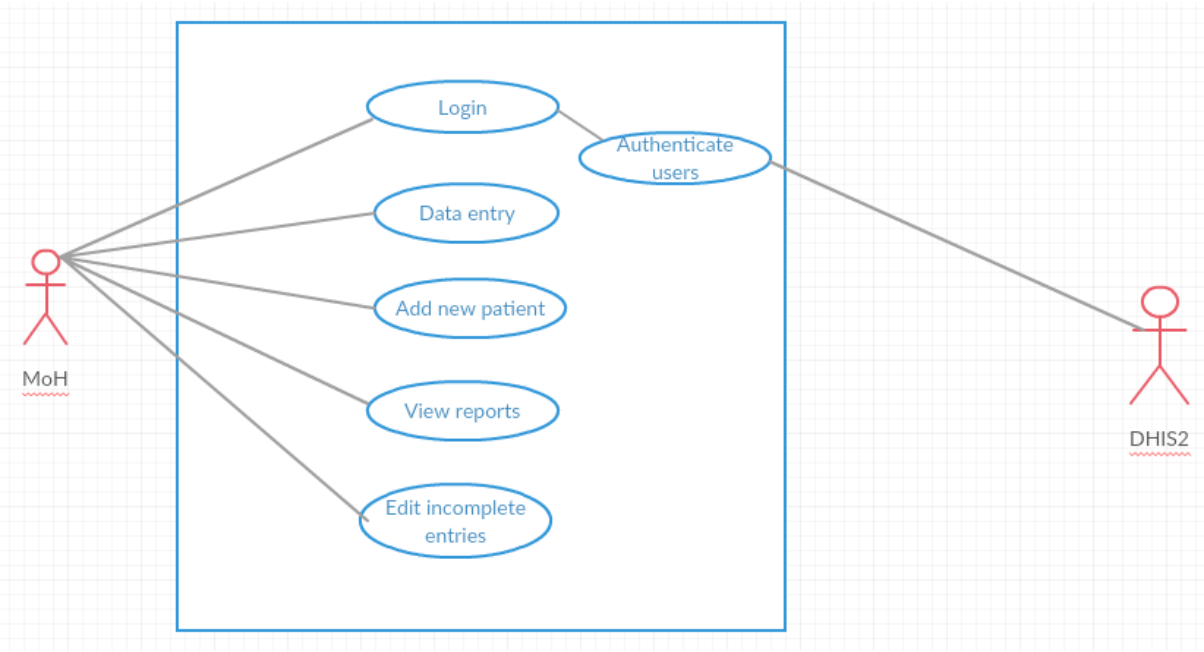

Figure 7: Maternity Nurse Use Case DiagramFigure 14: Maternity Nurse Use Case Diagram

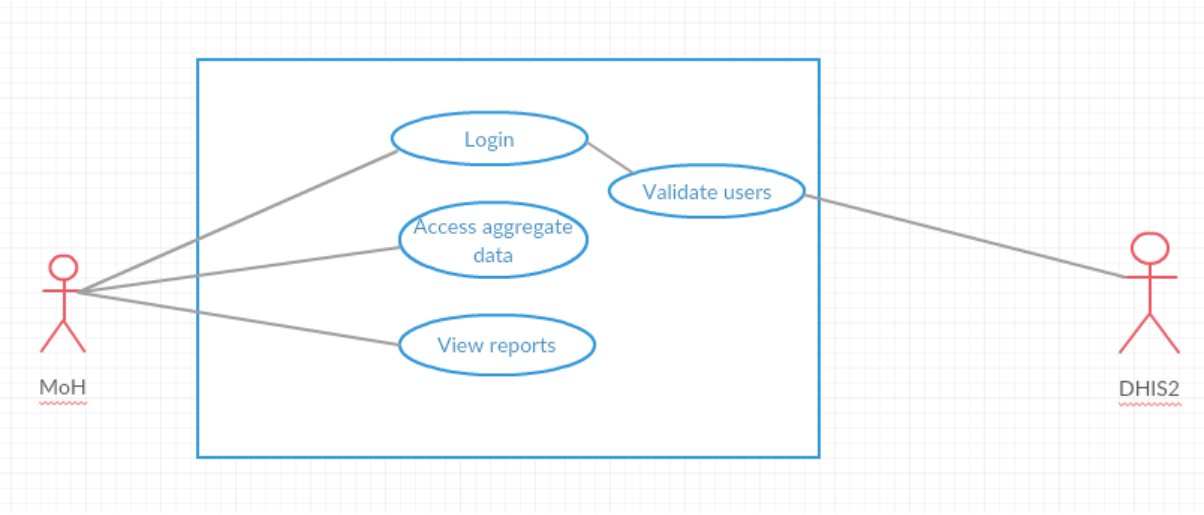

Figure 8: MoH Use Case Diagram

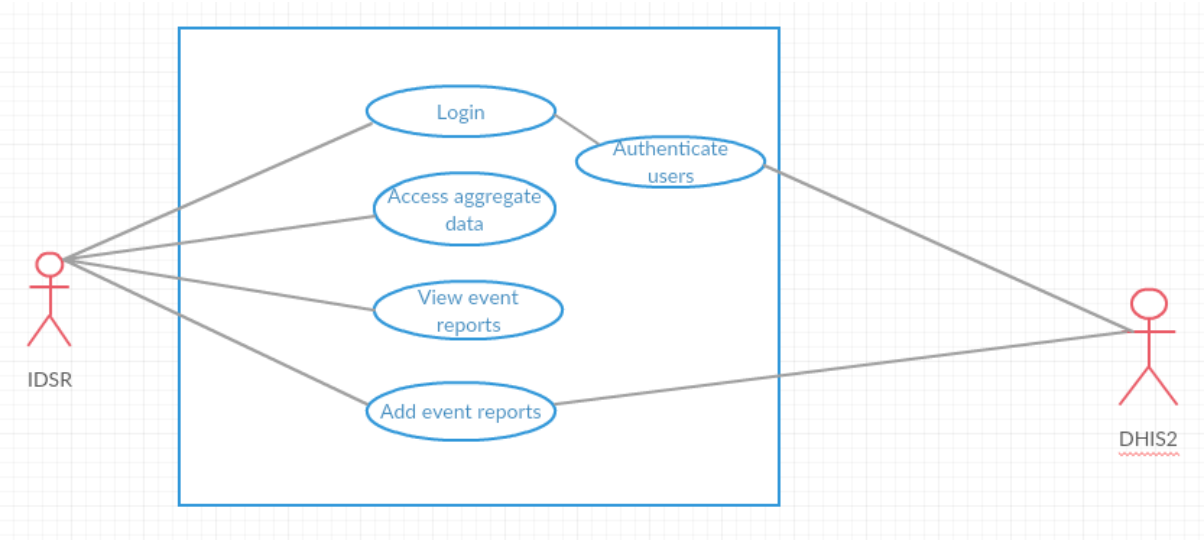

Figure 9: IDSR Use Case Diagram

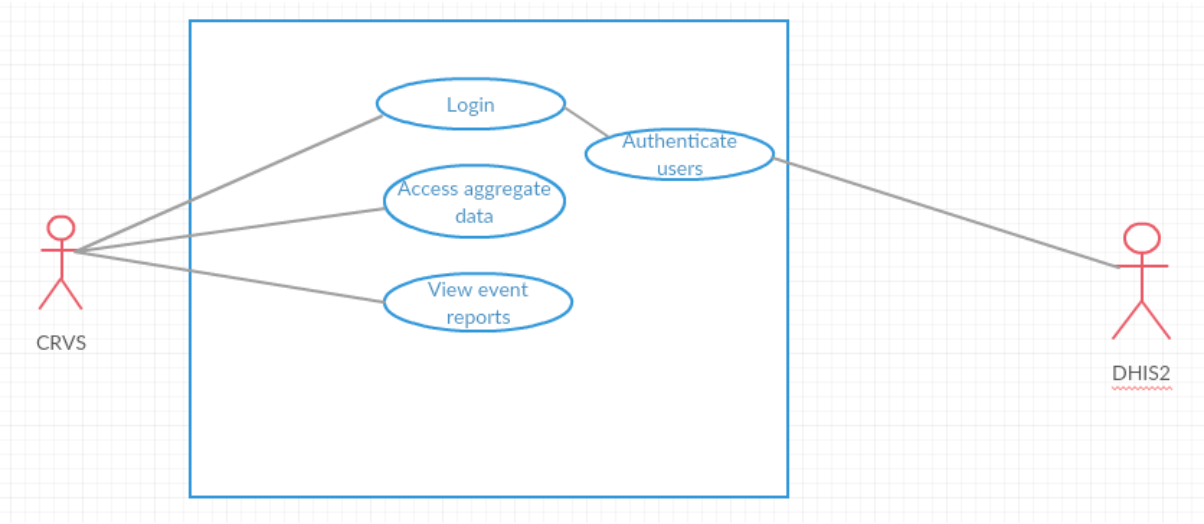

Figure 10: CRVS Use Case Diagram

The system consists of the data entry build.

Roles: maternity unit nurse, Ministry of Health, CRVS, IDSR

Use case 1: Add new patient

Actors: Maternity unit nurse

Flow: The nurse registers a new patient in the system

Output: a new patient has been assigned an IP number

Use case 2: Add patient data

Actors: Maternity unit nurse

Flow: The nurse feeds more patient data pertaining services offered in the system

Output: A patient file has been updated

Use case 3: Edit incomplete entries

Actors: Maternity unit nurse

Flow: The nurse edits the patient file to complete the process in the system

Output: A patient file has been completed and submitted

Use case 4: View reports

Actors: Maternity unit nurse, MoH, IDSR, CRVS

Flow: The user selects the specific indicator for a specific facility and can see the statistics according to the indicator specification.

Output: The statistics are available

Use case 5: Access aggregated data

Actors: MoH, IDSR, CRVS

Flow: The user selects the specific indicator and can see the statistics according to the indicator specification

Output: The statistics are available

Use case 6: Login

Actors: Maternity unit nurse, MoH, IDSR, CRVS

Flow: The user logs in to the system

Output: The user is granted access to the system

4.3.3 Functional requirements

i. One of the modules of the prototype server will be responsible for displaying the interface of the data collection of the event data indicators.
   - Collection of the event data on the digital maternity register will ease the process of analyzing the data for informed decisions.

ii. The proposed maternity register for enhancing real time reporting prototype shall provide different ad hoc report formats to enable complete reporting right at the maternity unit.
   - The customisation of the event capture in DHIS2 and simplicity of filling the maternity register are some of the key features qualifying the digital register as a suitable technology for collecting and transmitting data in maternity units where there is a huge workload and the human resource is limited. Data collection through DHIS2 has the potential to reduce the number of errors compared to paper-based methods as well as reduce time required to prepare reports for decision making. The proposed prototype will thus provide a way of remotely transmitting the maternity unit data indicators from the facility units to the server module stationed at the national level.

4.3.4 Non-functional requirements

The following non-functional requirements were implemented

- Usability – the user interface will be similar to the existing DHIS2
- Security – the system will allow only authorised users
- Reliability – the system will be able to do the tasks it was designed for
- Integrity – the data will be designed in a way that it will be stored in a well organised manner ensuring integrity
- The user interface will use DHIS2 design standards.

Access Control - Each server has a different set of usernames and passwords, generated randomly and stored securely in KeePass.

Passwords are required across our infrastructure to consist of a minimum of 8 (eight) characters, and must contain a combination of Upper- and Lower- case alphanumeric digits. This means that our standard passwords are on average 46-bits in depth, and impossible to guess (i.e. because they are random, they do not contain birthdates or similar personal info). No two passwords are the same. KeePass ensures this.

Backup utility - Backups have been upgraded to include 46-bit encryption in all backup files, which are posted to a secure FTP server. Even if the FTP server were somehow compromised, attackers would then have to peel away the encryption on the data itself before they could get at any useful information.

Data fields Input validation - Data inputs will only complete if validation passes to mean that it **o**nly allows the Data Set to be marked complete if no Validation Rules are triggered.

4.4 Prototype Development Decision

While designing the proposed prototype, a decision was made on the choice of suitable technologies for the given context. One technology was chosen for development of the prototype which was the DHIS2 test instance. However since this prototype was developed using the existing open-source Java frameworks currently used by DHIS2, the prototype was limited to the implementation strategies of DHIS2. The following technologies were adopted for the development of the proposed prototype:

i. HTML is used for the user interface (UI). Underlying the UI is AngularJS which is an open-source client-server web application framework.
ii. CSS was used for the layouts and page frames
iii. PostgreSQL was used as the database management system because it was compatible with the Hibernate database abstraction framework

DHIS2 uses a three-tiered architecture that includes: a data layer, a business logic (service) layer, a presentation layer. The advantage of having a layered architecture is to allow for alternative display of data from the service layer.

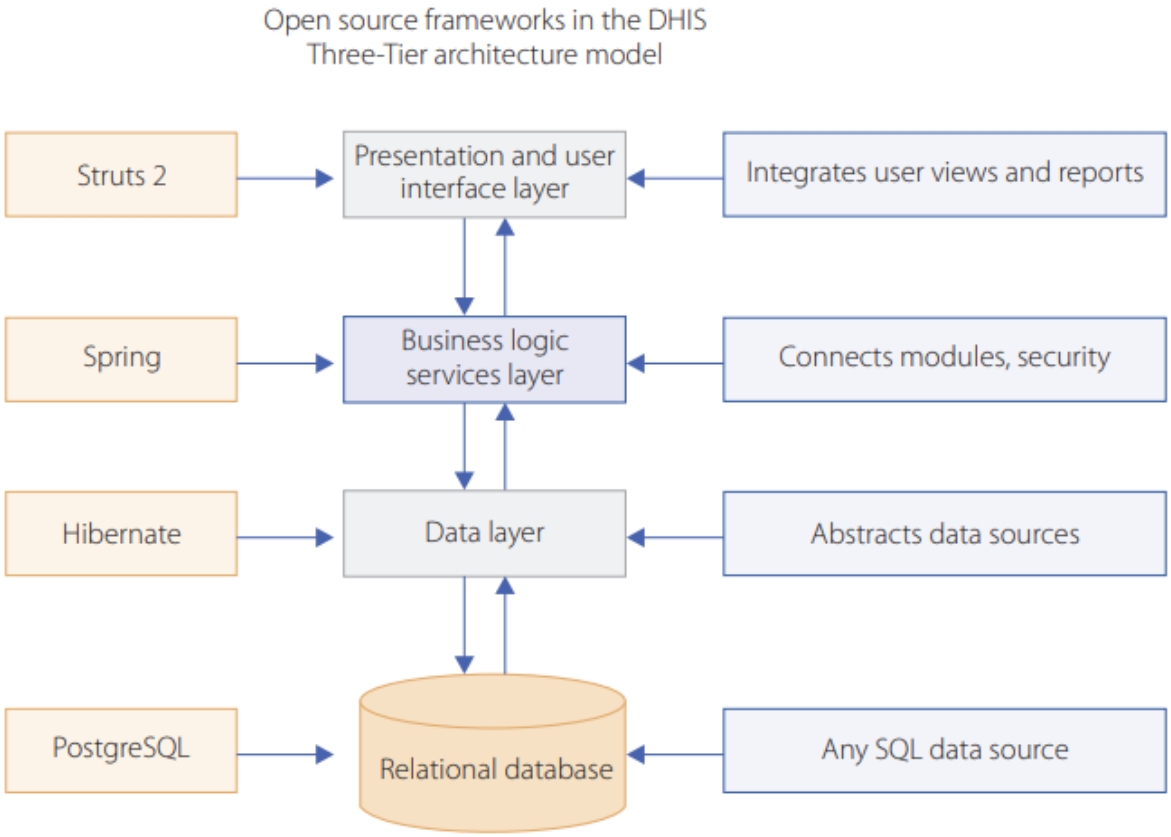

Figure 11: DHIS2 three-tier architecture model

Database design

The domain model of DHIS 2 is designed to be flexible in all dimensions in order to allow capturing of any type of data (see diagram below). The core unit is Data Value which can be captured for any Data Element, Period and Source. Hence, Data Value represents a captured item in a certain time period reported by a certain organisation unit. The Aggregated Data Value entity represent processed data from DataValue table.

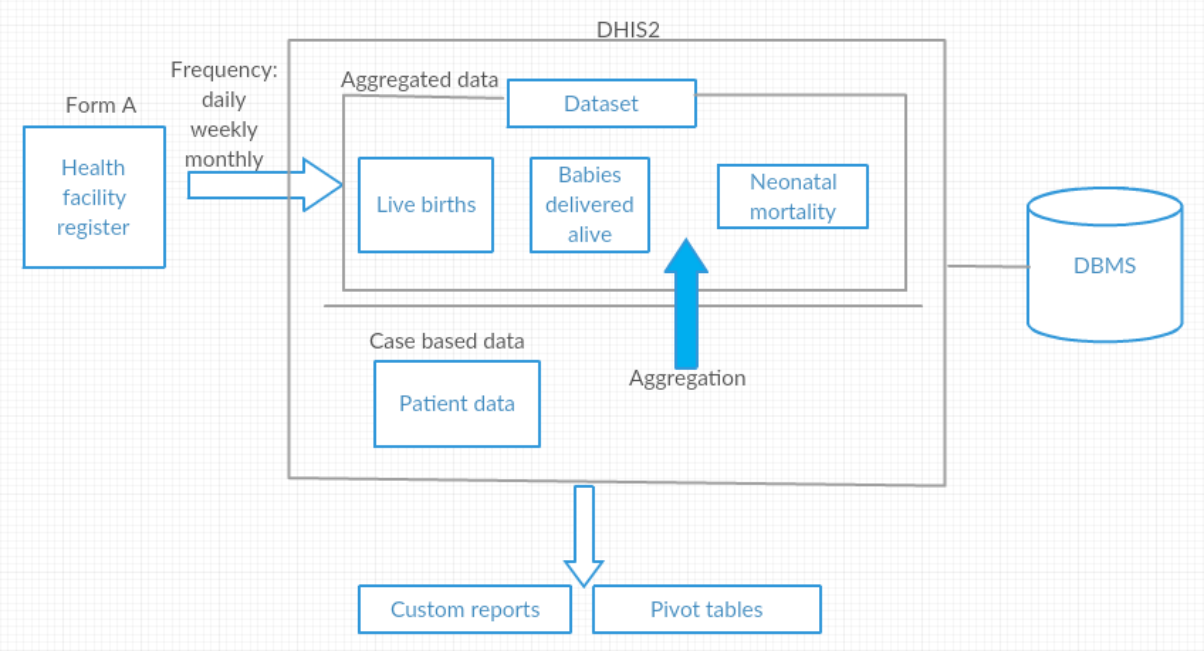

Figure 12: DHIS2 data model

For the data model the following data structures are needed:

I. HashSet<OptionSet> optionSets -- holds all OptionSet objects needed

II. HashMap<String,OptionSet> optionSetIndex -- maps from option_set_value_id to OptionSet object in optionSets

III. HashSet<CategoryCombo> catCombos -- holds all CategoryCombo objects needed

IV. HashMap<String,OptionSet> comboOptionLink -- maps from catCombos.Uuid to OptionSet object in optionSets to indicate linkage

V. HashSet<ReportData> dataElements -- holds all ReportData objects needed

VI. HashMap<String> dataElementIndex -- maps from element_id to ReportData object in dataElements

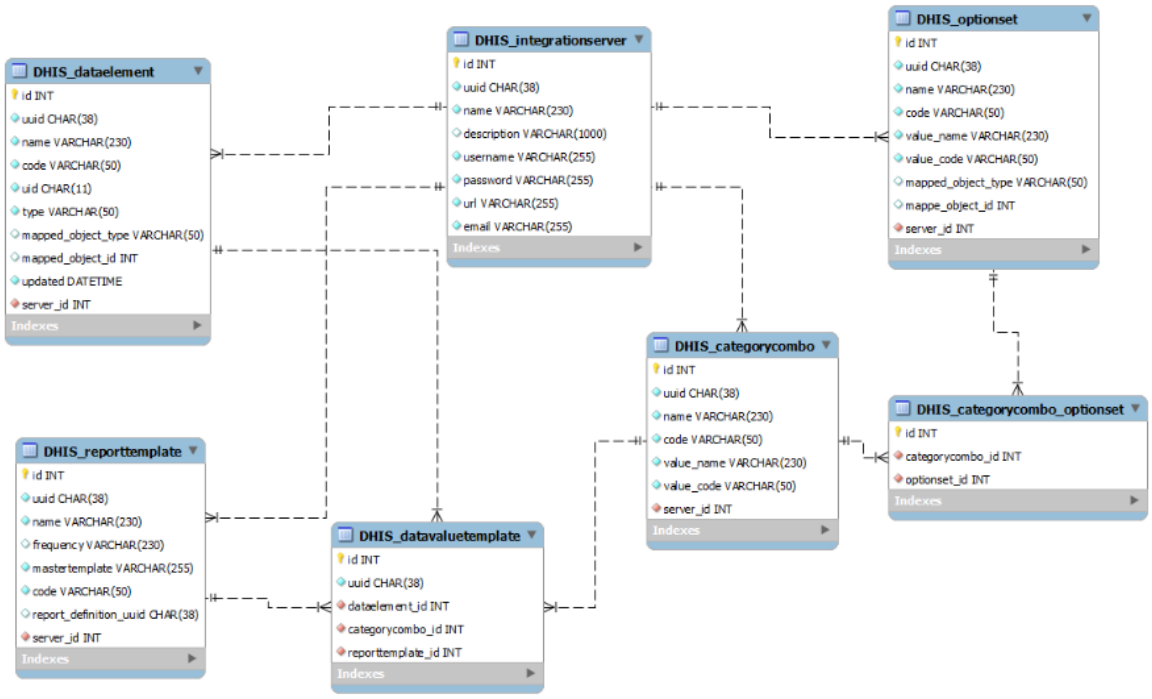

Figure 13: DHIS2 database designDHIS2 database design

System flow chart

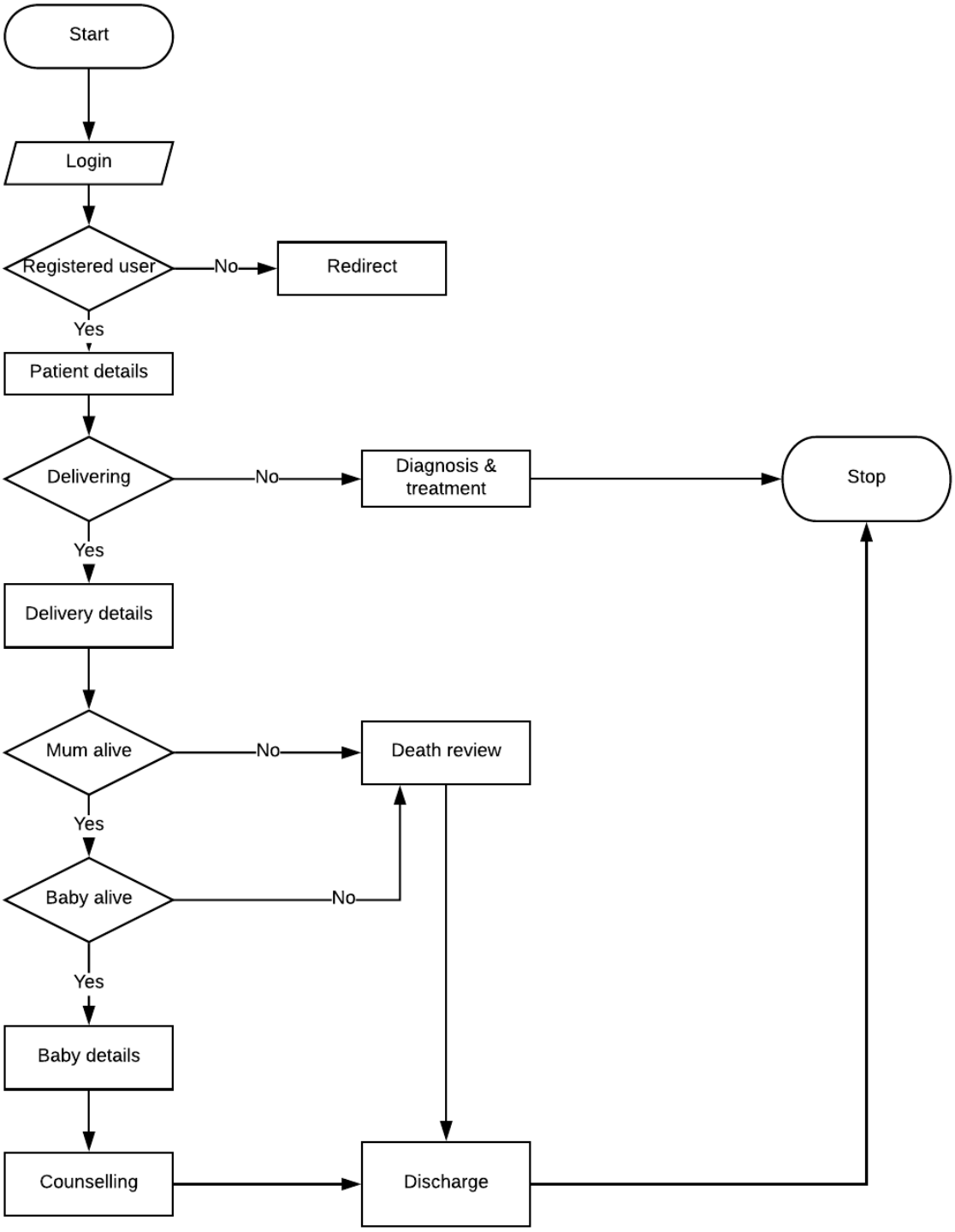

Figure 14: Proposed system flow chart

4.5 Prototype development

The agile methodology was used because it uses models that are iterative and incremental focusing on process flexibility and client satisfaction by delivering the software product rapidly. Agile methodology breaks a product into small builds which are delivered in iterations. Each build has its own schedule and scope. The release of the builds can be deployed to test (internally) or deployed to production (externally). The agile process ensures that the project still transitions through different life-cycle phases which include requirements analysis, designing, development, testing, deployment and releasing.

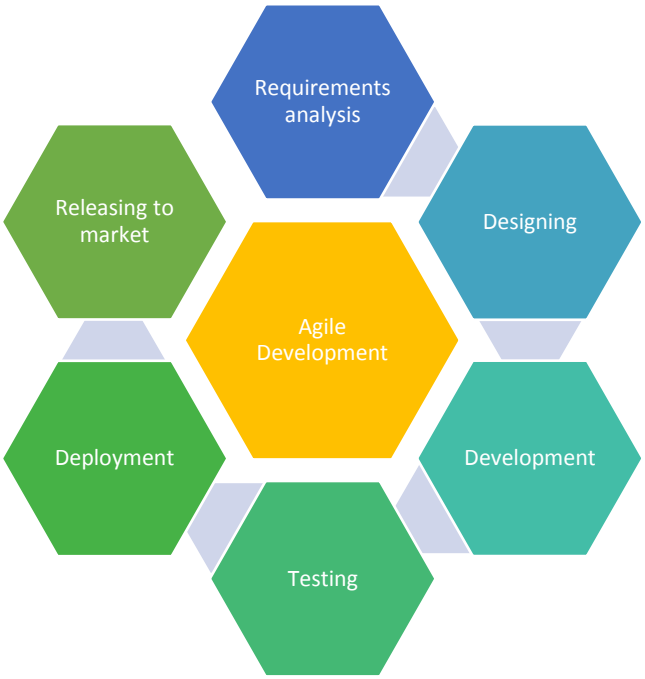

Figure 15: Agile development process (source: http://ixorasolution.com/process (dated: 2018))

4.5.1 Prototype Development Phases

1. **Requirements Analysis.** This phase looked at the current maternal and neonatal death reporting tools at the maternity ward. The process involved discussions with the users to create a roadmap in form of stories. The main purpose was to know and understand the client's requirements then map it to the proposed system.
2. **Designing.** The conceptualized processes, services and requirements were transformed into sets of related models and platform interfaces. The artefact designed conformed to design principles like coupling and cohesion which guarantee that the services developed in the proposed system are useful, effective and usable.

3. **Development.** The system models were converted to a working prototype for deployment. The system was developed based on the comprehensive system specifications elicited from the users.
4. **Testing.** This is where the software was tested to ensure that a software product of high quality was delivered, the users were satisfied, maintenance costs were lowered and more reliable and timely results achieved. As part of the user acceptance testing the nurses and records personnel were allowed to interact with the system so that issues could be identified and rectified before full implementation.
5. **Deployment.** The prototype was rolled out to the health facilities. Awareness creation was conducted coupled with user training. The system was closely monitored to ensure the users had a smooth experience.
6. **Releasing to users.** After the product was deployed to the users any errors or modifications required were implemented in this phase.

4.6 Prototype Testing

This is where the software is tested to ensure that a software product of high quality is delivered, the users are satisfied, maintenance costs are lowered and more reliable and accurate results achieved. The software is then rolled out to the stakeholders. As part of the training as well as user acceptance testing all the stakeholders (nurses, HRO and CHRIO) will be allowed to interact with the system so that issues can be identified and rectified before full implementation.

A total of 8 maternity ward nurses were provided with a user manual and allowed to use the prototype at their health facilities using tablet devices. The participants were requested to send sample data on the digitized maternity register. The users were to view the summary reports after successful submissions of the data. The nurses were thrilled to send their reports and later view the day's summaries in a click of a button. After the prototype was tested by the users they were issued with a questionnaire and the below are some of the results from the responses.

I. Type of tools used by participants

The participants were asked the type of tools they use for their reporting. The results in the figure below show that 44% of the respondents use manual registers while 44% of the participants use a desktop/laptop and 11% use a tablet device.

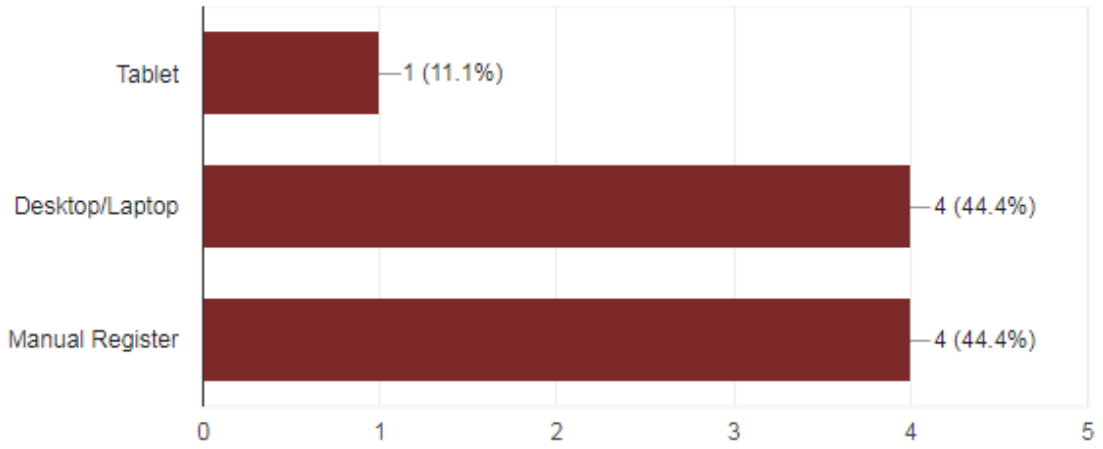

Figure 16: Tools used to report

A questionnaire was used to evaluate the usefulness of the prototype to the maternity unit staff after the end of the evaluation period. The prototype was evaluated for timeliness, completeness, and accuracy during data transmission, aggregation and analysis.

The responses were based on a 7-point Likert scale (*Strongly disagree, disagree, somehow disagree, neither disagree nor agree, somehow agree, agree, strongly agree*).

The following were the results from the analysis done using excel

	Strongly disagree	Disagree	somehow disagree	neither disagree or agree	somehow agree	agree	strongly agree
I can be able to navigate through the digital register without seeking any assistance					3	4	2
Overall, I am satisfied with how easy it is to use the digital register to submit my data					1	4	4
I find it easier submitting my data via the digital register instead of filling the registers manually					2	1	6
The use of the digital register to send my data has enabled me save on time which I can use to attend more to my patients.					2	2	5
I am more likely to submit my data on time than before when using paper-based forms					2	1	6
The training sessions have helped me understand how to navigate through the system and submit my data					3	1	5
It was easy to learn how to use the system to submit my data					1	6	2
I am able to key in patient data according to the provided format without requiring assistance.					1	6	2
Overall, I am satisfied with this system					3	3	3
I can recommend the use of this system to submit data to the DHIS2					2	1	6
I am likely to make a mistake while manually compiling our summary report from the manual registers and would prefer the system do it for me.						7	2
The use of the digital register to submit my data has motivated me to do my work unlike before					3	3	3

Table 2: Results from questionnaire

In evaluating the proposed prototype which relies on data submission through a digital device, it was necessary to assess users' ability to operate the tablet device without assistance. Majority of the participants indicated agreement with the statement of being able to navigate through the digital register without seeking help (Median=6). This is possibly because majority of the respondents confirmed to using similar devices for sending reports (56%). In

addition, assessment of ease of use of a digital version of the maternity register to submit data had majority of respondents expressing agreement as well as preference of submitting records.

II. Prototype Test Results

This was intended to get the overall users perception towards the prototype developed based on their satisfaction. The following were the results.

Overall satisfaction	Total number (N=9)	Percentage
Agree	4	44%
Strongly agr	4	44%

Figure 17: Usability results

This indicate that a large proportion of users recommended (N=9, 44%) satisfaction with the use of system whereas a similar proportion (N=9, 44%) recommended it too.

III. Results on usefulness

a. Timeliness

A total of 9 respondent were asked on the number of minutes they take to fill in the registers under the manual process and the time they also took to fill in the tablet for the same. The following were the results generated from the analysis.

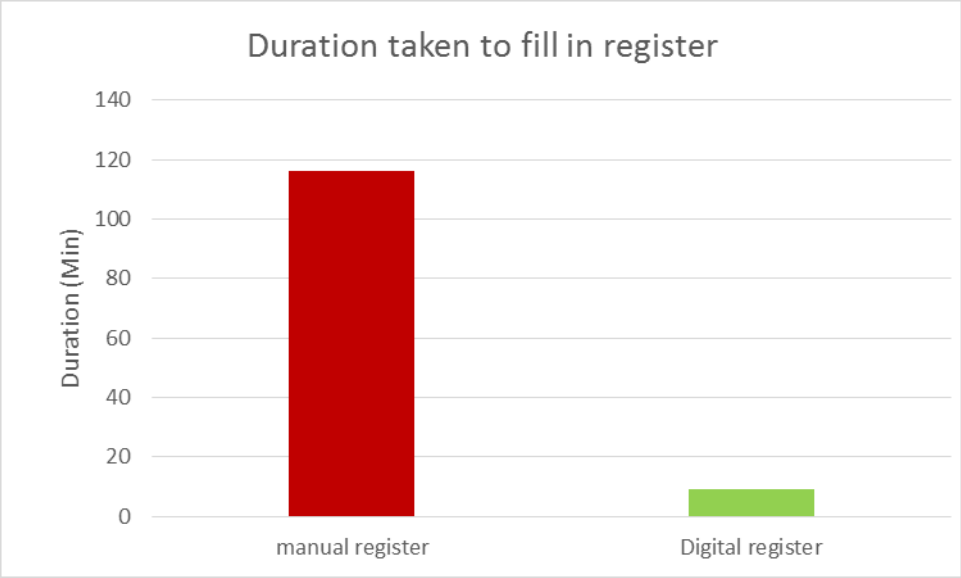

Figure 18: Duration taken to fill registers

The nurses acknowledged using an average of 116 Minutes or 1 Hour and 56 Minutes every day to fill in the registers after attending to the patients. Further evidence can be seen by the respondents' agreement that use of a tablet device has enabled them save on time to undertake other roles as well as submit the records on time (Median=7).

Accuracy

A review of past final reports by facilities showed a huge discrepancy in the values submitted to the monthly statistics and those submitted to the surveillance statistics showing a clear indication of inconsistent values being reported. This is further evidenced by high number of respondents agreeing (N=9, 78%), a small proportion strongly agreeing (N=9, 22%) to possibility of making arithmetic errors while doing aggregation (Median=6).

Completeness

A review of the manual registers which are filled at the maternity unit had blank spaces and wrongly filled fields. The proposed prototype was used in reporting and the report generated confirmed that all fields were correctly filled and had no blank spaces left. This is further confirmed by the respondents who said that using the digital register has enabled them submit their records on time (Median=7).

Maintenance

After the product has been deployed to the users any errors or modifications required are implemented in this phase. Awareness creation will be conducted coupled with user training.

i. Testing methodology

Upon successful completion of the development phase, the system will be tested as follows:-

a. **Program testing-** This testing was carried out after customisation of the event capture app to ensure that the events and data elements that had been coded for the program are tested as an integrated unit.

b. **Acceptance testing-**The system acceptance testing was carried out by helping participants to interact with the system so as to get their feedback. This feedback will be used to improve the system.

ii. **Assessment/Evaluation**

After a version of the prototype was built, it was evaluated by the stakeholder's to verify that it meets their needs. During the evaluation of the prototype the following sample of questions were asked to gain significant feedback through a survey:

- What is good about the prototype?
- What is bad about the prototype?
- What is missing from the prototype?

After evaluating the prototype, some parts may need to be scrapped off, modified, and even brand-new parts added as long as the feedback given in the survey contains important ideas.

4.7 Hosting the DHIS test instance

In this study, due to the environment within which this study was conducted, a cloud server was purchased for easy access in the various facilities visited.

Chapter 5 – Results

4.1 Sample description

There were 41 facilities selected to participate in the study. The data necessary for this research was obtained from 39 healthcare facilities which were accessible and the rest were inaccessible due to the bad road conditions. For this research, the participants were interviewed through a one on one interview. A separate group was also engaged in an open group discussion. Staff that are directly involved in the maternal and perinatal deaths reporting were targeted. Completeness of data recorded on registers was also checked on the maternity registers.

The target respondents included maternity ward in-charges, facility surveillance focal persons, health records personnel, and the county health management teams. Where the facility in-charge was not available the records person together with the surveillance focal person were interviewed. A few members of the County Health Management Team (CHMT) were also engaged in group discussions.

4.2 Analysis

This section focuses on the analysis of the study. The use of interviews, focus group discussions and observations. Interviews and FGDs were the main source of data collection instruments used.

4.2.1 Answering research questions

Research Question 1

What are the current reporting work flow processes of new-born and maternal deaths?

The study used a purposive sampling procedure to select the research participants and regions to collect the data from and this was in the specific hospitals where GIZ gives direct support: Kwale (11), Kisumu (12), Vihiga (11), and Siaya (8). The health facilities are run by private institutions, the ministry of health, and faith-based organizations. The staff that were involved directly in the maternal and perinatal deaths reporting were targeted. They included maternity ward in-charges, facility surveillance focal persons, health records personnel, and the county health management teams. Completeness of data recorded on registers was also checked on the maternity registers.

Literature from credible scholarly sources were reviewed focusing on similar cases, mortality trends, the importance of reporting maternal and neonatal mortalities, status of reporting, data quality, how health systems are structured in Kenya, universal health coverage status in Kenya, mHealth, IDSR departments, adoption of systems, and interoperability of HISs. A pre-study was conducted through the use of unstructured interviews administered to 39 interviewees located in the various health facilities. Focus group discussions were held with the CHMT members from the four counties.

i. Reporting process

Only one facility out of the 39 had a well-defined MPDSR flowchart pinned on the wall at the maternity ward; it was developed with the help of a development partner. 97% of the facilities were issued with MoH tools and in case of a maternal or perinatal death, the hospitals were able to send the written reports to the sub-county offices. There are only 8 (20%) facilities that have a clear reporting cycle and complete the process by submitting their data in DHIS2 although not within the recommended 24 hours.

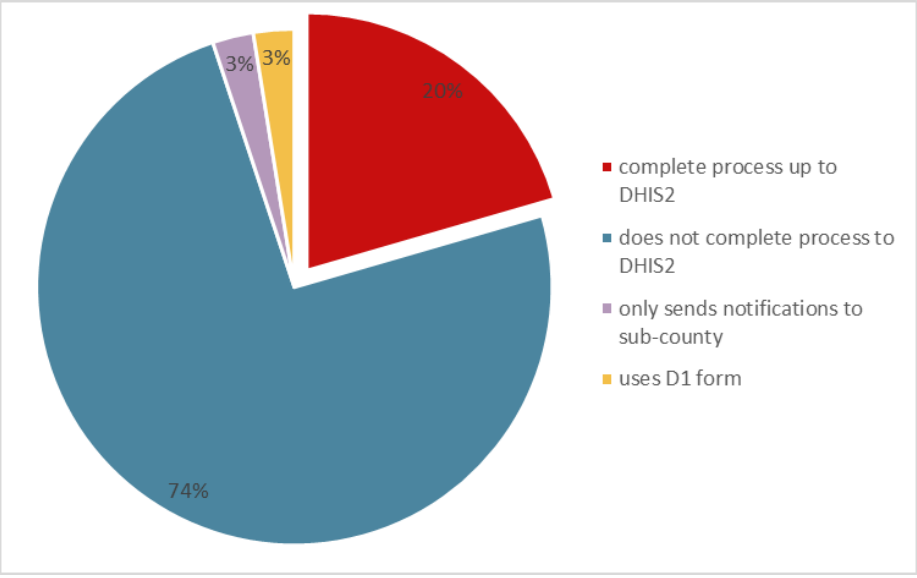

Figure 19: Complete reporting to DHIS2

Research Question 2

What are the challenges hindering timely reporting of neonatal and maternal mortalities?

The second objective was to evaluate the challenges hindering timely reporting of neonatal and maternal mortalities.

Challenges hindering reporting

The respondents stated that due to understaffing and other competing tasks the registers had many gaps, were incorrectly filled and incomplete. Upon checking the registers there was no single register in all the 38 facilities which were properly and completely filled as is required. One facility had an improvised general register for the whole hospital thus not checked for completeness. The registers had numerous misfiling with the wrong content/words instead of codes in some fields. The challenges faced in the current reporting workflows were broken down into 3 main themes namely: technical challenges, organisational challenges, and process challenges.

Technical challenges: weekly reporting was affected due to the unavailability of tools (MOH 505 in Appendix 7). This was worsened by the fact that the facilities were not aware they were expected to notify the surveillance office of all maternal and new-born death and submit the report on a weekly basis. A majority of the facilities would fill in a zero as the default value on the MOH 505.

Organisational challenges: the main focus for a majority of the facilities was reporting on indicators that are followed up on by partners. Withdrawal of partners from this facilities affects the continued reporting for the same thus affecting completeness of this data. The data collected is thus incomplete, inconsistently reported and not suitable for decision making. The data collected from the facilities are supposed to be used in decision making for an intervention back in the facility. However, a lack of resources like internet bundles have hampered facilities ability to undertake a timely intervention to the facility concerned. This means the intervention is made to wait when financial or human resource are available.

Process challenges: the data collection process is hampered by workload brought about by understaffing. The manual registers are incomplete and wrongly filled by staff who are overwhelmed by attending to patients with little or no help by colleagues. Filling the summary tool MOH 711 requires counterchecking from the many registers placed at the

maternity wards and are all required to be filled with various patient information. This aggregation process is time consuming and increases the chances of inaccuracies in the final report being generated.

The pre-study revealed a number of issues mentioned to be hindering the correct and timely reporting:

	Challenges hindering reporting		
		Responses	
		N	Percent
1	Not aware they are expected to report daily including zero reporting	27	16.8%
2	No reporting policies or SOPs available at the facility	24	14.9%
3	No training on MPDSR	19	11.8%
4	Priority is given to program driven indicators	15	9.3%
5	Unavailability of the standard booklets	13	8.1%
6	Documentation is incomplete	11	6.8%
7	Understaffing	8	5.0%
8	Not aware on the reporting process	6	3.7%
9	Competing tasks	5	3.1%
10	Political interference	4	2.5%
11	Inadequate resources	4	2.5%
12	No proper understanding of how to fill registers	4	2.5%
13	No feedback mechanisms	3	1.9%
14	A lot of time taken to confirm the incomplete registers	3	1.9%
15	Culture of communities	2	1.2%
16	Communication barrier	2	1.2%
17	Unstable network to send reports immediately	1	.6%
18	Too many registers	1	.6%
19	Lack of support from the top management	1	.6%
20	No access to DHIS2	1	.6%
21	Many home deliveries	1	.6%
22	Lack of supplies	1	.6%
23	Unable to audit some cases	1	.6%
24	No close monitoring	1	.6%
25	Revenue focused	1	.6%
26	Repetitive reports	1	.6%
27	Unable to identify some causes of death	1	.6%

Table 3: Challenges

The above listed challenges impact greatly on timely reporting and developing solutions to them would improve the quality of these data. The highest ranked challenges which are four in number are brought about by lack of awareness and the other challenges (23 in number)

are brought about by varied reasons. The below table and graph demonstrates how the challenges can be solved using various methods.

	Challenges	Solutions
1	Not aware they are expected to report daily including zero reporting	capacity building
2	No reporting policies or SOPs available at the facility	capacity building
3	No training on MPDSR	capacity building
4	Priority is given to program driven indicators	data capture tool
5	Unavailability of the standard booklets	data capture tool
6	Documentation is incomplete	field validation on a data capture tool
7	Understaffing	Reduced time on report compilation by a data capture tool
8	Not aware on the reporting process	data capture tool
9	Competing tasks	Reduced time on report compilation by a data capture tool
10	Political interference	data capture tool
11	Inadequate resources	data capture tool
12	No proper understanding of how to fill registers	capacity building
13	No feedback mechanisms	Work flowchart to include feedback channels for the report to be termed as complete
14	A lot of time taken to confirm the incomplete registers	data capture tool
15	Culture of communities	Facility dependent
16	Communication barrier	capacity building
17	Unstable network to send reports immediately	Infrastructure development
18	Too many registers	data capture tool
19	Lack of support from the top management	Incorporation of surveillance unit in facilty departments
20	No access to DHIS2	data capture tool
21	Many home deliveries	awareness creation during ANC visits
22	Lack of tools supplies	data capture tool
23	Unable to audit some cases	capacity building
24	No close monitoring	Work flowchart to include feedback channels for the report to be termed as complete
25	Revenue focused	Facility dependent
26	Repetitive reports	data capture tool
27	Unable to identify some causes of death	capacity building

Table 4: Challenges and their solutions

From an analysis of the above information, a number of solutions that would be appropriate to solve the challenges hindering timely reporting were discussed. Among the solutions (Figure 6) are capacity building handling 26% of the challenges; awareness creation during ANC visits for example using ANC visit drives would solve 4% of the challenges; incorporating the surveillance to be part of the health facilities department would solve 4% of the challenges cited; development of the IT infrastructure by equipping facilities with wired/wireless internet connections would solve 4% of the challenges; and finally the deployment of a data capturing tool at the maternity unit would solve 56% of the challenges cited by respondents.

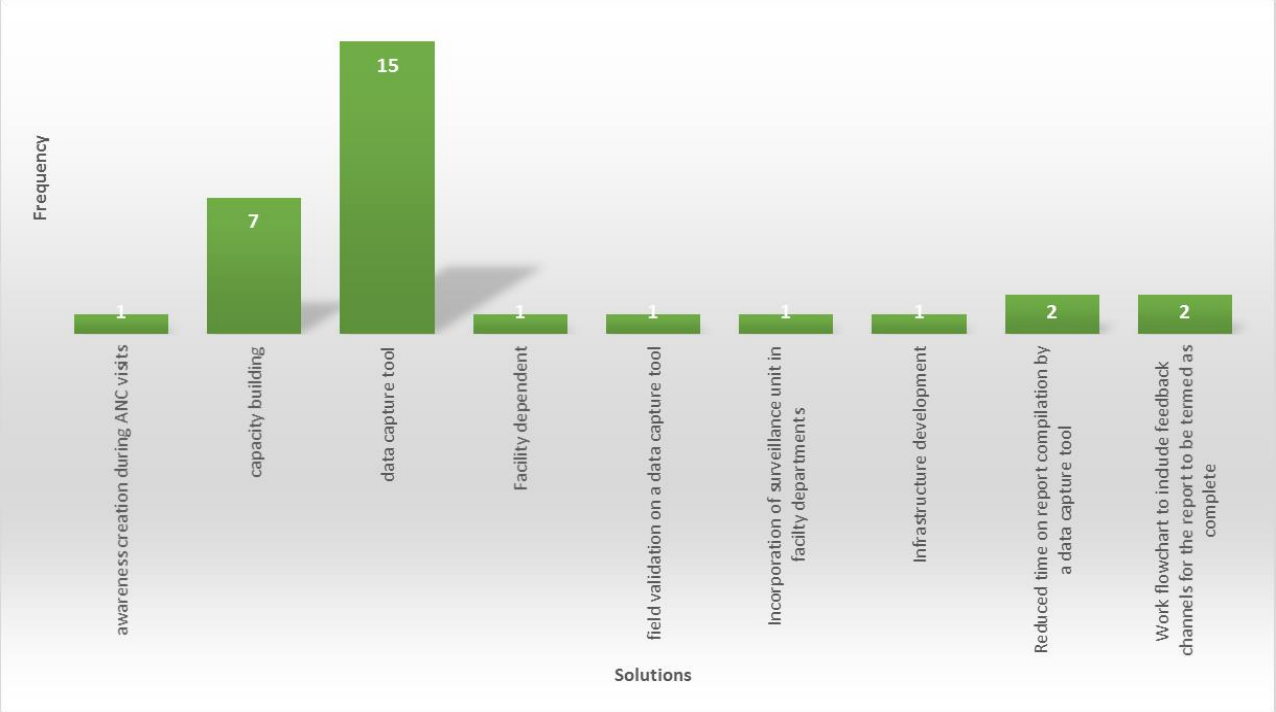

Figure 20: Frequency of each solution

What the stakeholders need to improve the reporting of new-born and maternal deaths?

The respondents suggested what they needed to support the reporting process and enhance the quality of the MPDSR data as below:

Needs	Frequency	percentage
Capacity building on filling the tools	15	38.5
Resources to be availed by the facility	15	38.5
Mobile-based system	11	28.2
Access to DHIS2 at the maternity	9	23.1
EMR	8	20.5
Availability of tools	6	15.4
More staff	6	15.4
Records person	3	7.7

Figure 21: Participants needs

Apart from stating their needs the respondents also disclosed the requirements of their proposed prototype: they wanted a system that would reduce their workload, a system that allowed them to report their data at the maternity unit for them to feel they own the data, a system that would make it easy to produce ad hoc reports, and finally a system that would eliminate the numerous manual registers used at the maternity unit. 71.8% of the participants needs were a system based solution, 38.5% for capacity building and resource availability, 15.4% for the availing of tools, and 23.1% for more personnel.

Research Question 3

How will the prototype be designed and developed to enable reporting maternal and neonatal deaths in real time?

The third objective was to design and develop a prototype for reporting the maternal and neonatal deaths in real time. Among the list of challenges as gathered from objective 2 and the proposed solutions as seen on figure 8 suggestions like field validations, reduced time during report compilation, and inclusion of feedback in the work flowchart, can be implemented in a data capturing tool. This informed the third objective of this research because it became evident that digitizing the maternity register would help curb these challenges as revealed by the research.

We designed and developed a maternity register as the prototype. The prototype was developed on a test instance of the DHIS2 platform, this enabled us to customise the event

capture app to suit the maternity register currently in use at the maternity units. During the development phase users needed to test the prototype so as to ensure that all the requirements were captured.

Research Question 4

How will the prototype be tested for delivering timely and complete reports?

From objective 3, after the iterations were completed there was need to test if the prototype was providing complete and timely reports.

Feasibility analysis

Operational feasibility. This looks at how the proposed system will be effectively used after development and deployment. A crucial guiding question is whether the system meets the intended functionalities and expectations of sending reports in real time within 24 or 48 hours to the DHIS2 web instance. Our analysis exhibited that the system would highly benefit the facilities since there is no similar system presently.

Technical feasibility. The technical feasibility study is concerned with specifying the software and hardware that will successfully satisfy the requirements of the user. The preliminary study showed that the project is technically viable because of the stakeholders' goodwill to improve the timeliness and quality of data.

Economic feasibility. The economic feasibility analysis is a frequently used technique in assessing the effectiveness of the proposed system. The analysis showed that it is more effective to implement and the benefits outweigh the design and implementation costs.

Schedule feasibility. This research is to be conducted in three milestones with fixed deadlines which will be adhered to strictly. A project schedule was prepared including the time allocations for each activity and since this is an academic project, we anticipate that it shall be completed within the stated time frame.

Legal feasibility. The necessary approval was sought prior to the start of the research because all the ethical issues, confidentiality of the data gathered, privacy of personal information and participants' rights needed to be protected throughout the research.

Chapter 6 - Conclusion & Recommendations

6.1 Summary

The first objective of this research was to establish the current reporting work flow process for new-born and maternal deaths, and it was achieved through a pre-study. The main purpose of the pre-study was to gain a better understanding of what is currently happening on the ground while sending reports for maternal and neonatal death.

The second objective was to evaluate the challenges hindering timely reporting of neonatal and maternal mortalities. This was achieved through a one-on-one interview session with 39 interviewees to understand their problems better, which would then inform the various solutions available and viable to solve their problems. Each interview was done separately and using thematic analysis process the challenges and needs were analysed. The county health management team was also engaged in focus group discussions. The FGD sessions were carried out in the county boardroom. Random questions were asked to the participants eliciting responses from everyone present.

The third objective was to design and develop a prototype for reporting the maternal and neonatal deaths in real time. From the analysis it was discovered that the development of a data capturing tool in the form of a maternity register was most appropriate to solve a majority (56%) of the cited challenges.

The testing phase informed the fourth objective of this research which was to test if the prototype had enabled real time access to complete maternal and neonatal death reports. Due to time constraints, testing of the prototype was done through the selection of three facilities in Nairobi (St. Mary's Langata Hospital, St. Patrick's Health centre and Mbagathi Hospital) to interact with the system. The prototype was evaluated by the users to verify that it met their needs. Users were asked to spend a few minutes to interact with the developed prototype after which they were issued with questionnaires to give feedback on the usability of the prototype.

6.2 Conclusion

The study established that the present MPDSR reporting cycle is very inefficient because it has not been circulated to the facilities hence not in use. This lack of use has led to the delayed reports not done within 24 hours of the death occurring. For the reporting cycle to be complete it is expected that feedback is given to the facilities by the surveillance focal

persons so that they can enhance the data quality. Consequently, this is lacking as only 26% of the facilities stated to have received feedback from the county management team and none from the surveillance teams placed at the sub-county or county level.

At the health facilities the quality of MPDSR data was found to be poorer than anticipated because there was an alarming lack of awareness of the reporting procedures and policies which were also missing from more than two-thirds of the facilities. Collection of MPDSR data is not a priority to the facilities since the results show that there was an intentional non-supporting from the facility management and the focus is mainly on partner-driven data needs like malaria, HIV, TB, and outbreaks. The persons who have been delegated to send the MPDSR data in facilities are weak and also absent in private hospitals as surveillance is treated as an external body.

It was also established that the health workers were inadequately trained on the job of reporting maternal and perinatal deaths to the surveillance team. 51% had attended formal training on events and disease surveillance over three years ago. There have been IDSR focal persons deployed to the sub-county and county levels and the facility in-charges act as the focal persons in small facilities. The study also established shortcomings with regard to the IDSR reporting tools: they were either not available at the facility or underutilized due to a lack of perceived ownership as the tools were seen as being donor driven. This underutilization of tools was also seen in the maternity registers which were highly incomplete.

The underreporting of maternal and new-born deaths as reported in previous studies still exists. Poor compliance with the Ministry of Health circular on perinatal and maternal death notification within 24 hours has also not improved as seen in the research results. In addition, the notification and reporting of the maternal and neonatal deaths have also not improved over the years as shown by the DHIS2 data. Despite the Maternal and Perinatal Death Surveillance and Response (MPDSR) notification and evaluation forms being incorporated into the DHIS2, the system still has gaps, and not all maternal deaths are adequately captured by the DHIS2 system. The reporting process for neonatal and maternal deaths has not been circulated to health facilities. There exists numerous challenges that are hindering emergency reporting of the neonatal and maternal deaths to DHIS2; whereas some can be resolved by building the capacity of facility staff, others need a system solution.

Facility based health information systems tools (MOH 333, MOH 711) are the current paper based methods of data collection and reporting in all the maternity units in Kenya. This poses a challenge as quality health management demands for timely and accurate data which paper-based reporting doesn't solve adequately. The use of manual reporting forms increases frequency of errors, high workload at health facilities by health workers leaving insufficient time for effective data compilation and reporting thereby contributing to a weak facility based information system and subsequently HMIS.

The proposed prototype achieved satisfaction from the users because of its use of open source tools which don't need installation of any application on the computers or mobile devices and thus supports even basic smart phones hence making it self-sustaining. In addition, the prototypes' design to fit the local context and its ability to fit within the existing process flow makes it easier for nurses to switch from paper-based reporting systems. The prototype further allows a remote based report generation which has a potential to greatly minimize the time lag from when the data is submitted to when it is available for use. The prototype has also shown how a digitized register can reduce time delays, inaccuracies and incompleteness. Therefore, the proposed prototype maybe used to capture different facility unit health data indicators depending on their requirements. The choice of prototype which is based on open source technologies (DHIS2) allows for future development to be done with less effort, reduced cost and within acceptable timelines.

6.3 Recommendations

Future research may perhaps be on the incorporation of the surveillance unit as part of the facility to ensure that there is a clear process workflow which takes into consideration feedback mechanisms that will enhance the timeliness of MPDSR data. It is recommended that the surveillance tools be distributed to all the facilities and training on how to use them be scheduled. It is also recommended that the reporting processes be improved by providing MPDSR SOPs, policies and guidelines to the facilities for their reference and use.

6.4 Limitations of the proposed prototype

The proposed prototype has been developed using specifications from the primary sources at the maternity unit gathered in our particular context, therefore, it can only be applied in similar settings. Additionally, the proposed prototype has been developed in dhis2 version 2.29 which is a work in progress and does not support the android event capture app at the moment so it can only work on the web module.

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Appendix

Appendix 1: Consent form

RESEARCH CONSENT FORM

Hospital or Clinic Name: _____

Background of student:

Hello! My name is…….. I'm here for a study on behalf of the University of Nairobi. Therefore, I would like to request approval of my admission on …… for the period of …….. on following reasons;

1- To conduct a one on one interview
2- To conduct interviews through a focus group discussion
3- To tally maternity registers

Motive:

We're talking with the maternity nurse in charge to gather information about their daily activities and to find out what they think about reporting mortalities within 24 hours. The information gathered will be used to create a report to enable the development of an intervention. This study wants to make sure that every mortality is accounted for and reported in real time. It will review the information and give recommendations about how real time reporting can be improved.

How this works:

We would like to ask you some questions in an interview that will take about 15 to30 minutes. I would like to talk to you alone, but if you would like, you can ask for a colleague to be present at any time. However, I would really appreciate it if you would answer the questions honestly and openly, so that we can find out what reporting challenges you are facing. Your answers are very important to us.

Precautions:

Some of these questions may talk about things that some people find quite personal, or may be difficult to answer. If any of the questions make you feel uncomfortable or you don't want to answer them, you do not have to.

Advantages:

If you decide to participate in this interview, you will have the chance to help make the reporting process seamless. Even though this isn't a quick process, your thoughts and

opinions are very valuable. You will also have the opportunity to learn what the policies require and how you can be an active member in your health facility.

Confirmation:

Remember, you do not have to talk about anything you don't want to. This will not affect your ability to receive any of the services that this study provides now or in the future.

Disclosure Policy:

If you agree to take part in this interview, the things you tell me will be confidential. That means they will be private between you and me. I want to let you know, though, that it is my responsibility to make sure that whatever you tell me will remain confidential.

Understanding:

Do you have any questions about what was just mentioned? If you think of any questions in the future can force to disperse the information, you may reject my admission.

Agreement:

Would you like to participate in the research? If so, how would you like to participate? Please indicate here with your name or a mark if you would like to participate.

Date:	_____
Interviewee:	_____
Researcher's Signature:	_____

Appendix 2: Interview Guide

Name of interviewer:

Place of interview:

Date of interview:

Questions:

1. What do you see as your most important responsibilities and tasks?
2. Can you tell me the things you like most about your work?
3. Do you find some things difficult about your work? Can you tell me about them?
4. How do you report maternal and neonatal deaths?
5. How involved are you in reporting maternal or neonatal deaths?
6. What is the process of reporting such an occurrence?
7. Do you feel you need additional training to prepare and send reports? Would you recommend a technological solution?
8. Do you have any reporting policies in place at the facility? Which ones?
9. Which system do you use to report this occurrences?
10. Which manual form do you use to capture this and for reporting?
11. Do you have access to DHIS2? Which form do you fill in DHIS2?
12. How would you consider the usability of DHIS2? Would you recommend simplification of the system?
13. Which other tools do you use to report?
14. Are you involved in coming up with mitigation measures? What mitigation measures are taken?
15. Are you aware that you are expected to report any maternal/neonatal death within 24hrs?
16. What challenges do you face that hinder you from reporting within the expected time? Are the challenges related to hardware (computer use, attitude or office politics) or software?
17. Are there any limitations in the tools? What are the limitations in the available tools?

Appendix 3: Prototype Testing Questionnaire template

(Please note, your information will only be used for this study and will not be shared with others. Please circle/tick the correct answer. Kindly provide extra information for some of the questions as provided for

1. What tools do you use to send your reports?

[ ] Tablet [ ] Desktop/Laptop [ ] Manual register

2. Have you ever used DHIS2 to send reports?

[ ] Yes [ ] No

3. On average how much time do you spend filling the registers per day?
_____

4. How much time have you spent compiling a report with the new reporting tool?
_____

5. To what extent do you agree with each of the following statements;

	Strongly disagree	Disagree	somehow disagree	neither disagree or agree	somehow agree	agree	strongly agree
I can be able to navigate through the digital register without seeking any assistance					3	4	2
Overall, I am satisfied with how easy it is to use the digital register to submit my data					1	4	4
I find it easier submitting my data via the digital register instead of filling the registers manually					2	1	6
The use of the digital register to send my data has enabled me save on time which I can use to attend more to my patients.					2	2	5
I am more likely to submit my data on time than before when using paper-based forms					2	1	6
The training sessions have helped me understand how to navigate through the system and submit my data					3	1	5
It was easy to learn how to use the system to submit my data					1	6	2
I am able to key in patient data according to the provided format without requiring assistance.					1	6	2
Overall, I am satisfied with this system					3	3	3

I can recommend the use of this system to submit data to the DHIS2					2	1	6
I am likely to make a mistake while manually compiling our summary report from the manual registers and would prefer the system do it for me.						7	2
The use of the digital register to submit my data has motivated me to do my work unlike before					3	3	3

6. The system can be improved by the addition of the following

i. ……
ii. ……
iii. ……
iv. ……..
v. ……

7. In your opinion, what other task do you think you would need the system help you perform?

Answer_____
_____
____

8. What advantages have you seen with filling the MOH 333 data using a computer?

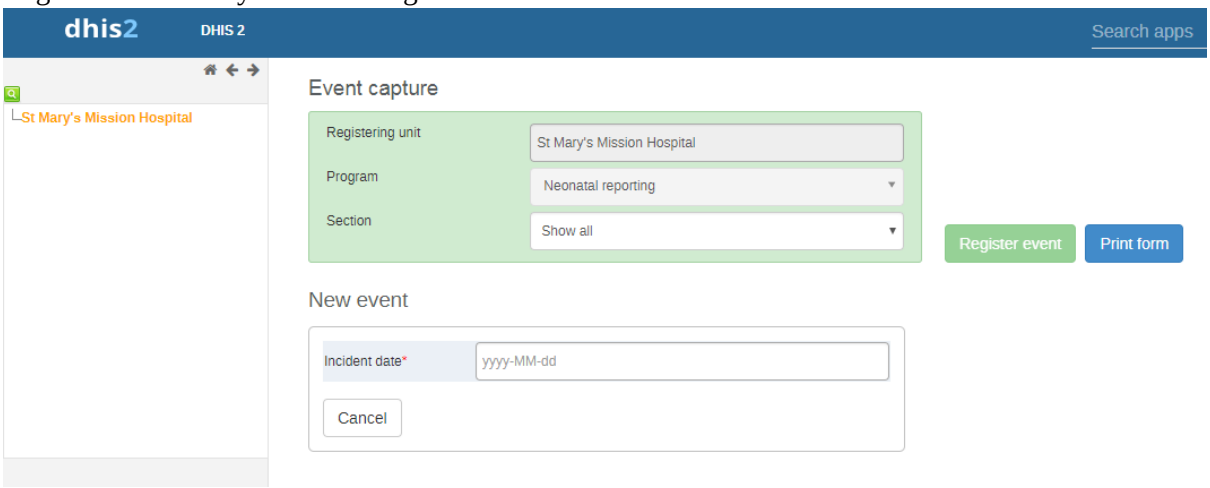
Answer(list as many as you can)
_____
_____
_____
_____

Appendix 4: User Manual

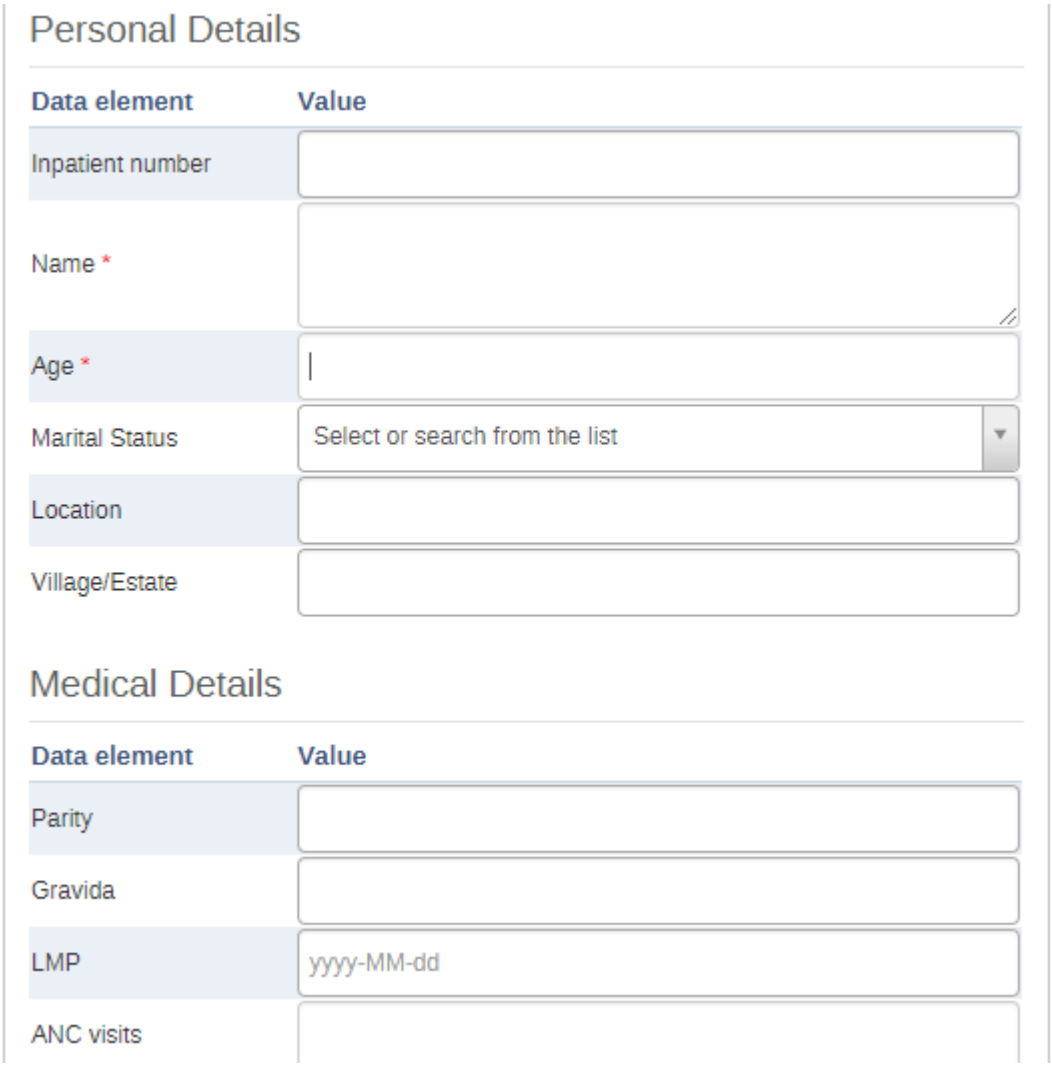
1. Click on this url to access the test DHIS2 version http://51.38.186.183/dhis/dhis-web-commons/security/login.action
2. Login using these credentials
   - Username St Patricks/ St marys/ mbagathi
   - Password Stpatricks1! / Stmarys1! / Mbagathi1!
3. On the far right corner click on the grid box as shown below

4. Select event capture

5. Register the event by first selecting the date the event occurred



6. Fill in the personal and medical details of the patient



7. In case of additional comments add them in the comments section.
8. Click on the button “save and add new” to save the event and add a new event
9. Click on the button “save and go back” to view the registered events for the day.

Appendix 5: Sample code

```
<?xml
version="1.0"
encoding="UTF-
8"?>
                    <!DOCTYPE struts PUBLIC
                      "-//Apache Software Foundation//DTD Struts Configuration 2.0//EN"
                      "http://struts.apache.org/dtds/struts-2.0.dtd">
                    <struts>
                      <include file="dhis-web-commons.xml" />
                      <package name="dhis-web-apps" extends="dhis-web-commons" namespace="/dhis-web-
                    apps">
                        <action name="index" class="org.hisp.dhis.commons.action.NoAction">
                          <result name="success" type="redirect">index.html</result>
                        </action>
                      </package>

                      <package name="dhis-web-visualizer" extends="dhis-web-commons"
                    namespace="/dhis-web-visualizer">
                        <action name="index" class="org.hisp.dhis.commons.action.NoAction">
                          <result name="success" type="redirect">index.html</result>
                        </action>
                      </package>
                      <package name="dhis-web-event-reports" extends="dhis-web-commons"
                    namespace="/dhis-web-event-reports">
                        <action name="index" class="org.hisp.dhis.commons.action.NoAction">
                          <result name="success" type="redirect">index.html</result>
                        </action>
                      </package>
                      <package name="dhis-web-pivot" extends="dhis-web-commons" namespace="/dhis-
                    web-pivot">
                        <action name="index" class="org.hisp.dhis.commons.action.NoAction">
                          <result name="success" type="redirect">#</result>
                        </action>
                      </package>
                      <package name="dhis-web-event-capture" extends="dhis-web-commons"
                    namespace="/dhis-web-event-capture">
                        <action name="index" class="org.hisp.dhis.commons.action.NoAction">
                          <result name="success" type="redirect">index.html</result>
                        </action>
                        <action name="cacheManifest"
                    class="org.hisp.dhis.appcache.CacheManifestAction">
                          <param name="appPath">dhis-web-event-capture</param>
                          <param name="i18nPath">i18n</param>
                          <param name="appCache">event-capture.appcache</param>
```

```
    <result type="stream">
      <param name="contentType">text/cache-manifest</param>
      <param name="inputName">inputStream</param>
    </result>
  </action>
</package>
```

Appendix 6: MoH 333

Table 11: MOH 333 MATERNITY REGISTER

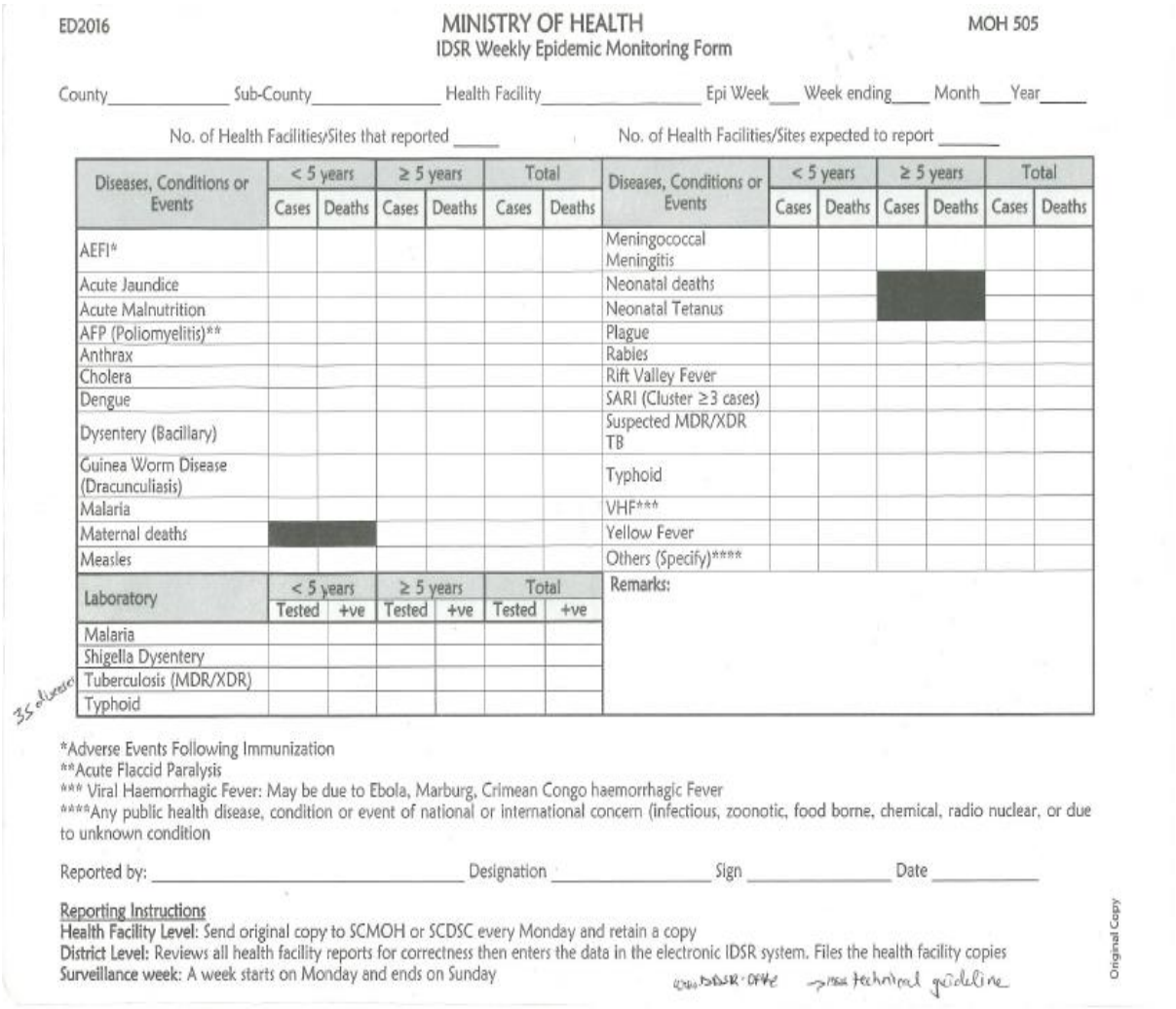
Date	No. Of anc visits.	In-patient no	Full names	Age	Marital status (1=m , 2=w, 3=d, 4=s, 5=se)	Sub location	Village/estate	Parity	Gravidae	LMP	EDD	Gestation at birth	Diagnosis	Date of delivery	Time of delivery	Duration from onset of labour	Mode of delivery	APGAR score	If baby dead: 1 =FSB; 2 = MSB	Baby weight (grams)	Sex of baby	Mother's conditions after delivery:	Blood loss (in mls)	Placenta complete (1= yes, 2 = no)
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y

Counselled and Tested HIV ANC Y/N	Counselled and Tested HIV MAT Y/N	HIV status 1 = Pos 2 = Neg	Partners (1=Counselled, 2=Tested, 3=Referred) for	Partners status: 1=Pos; 2=Neg	VDRL Serology Results (+ve/-ve)	ARV drug given (Mother) Y/N	ARV Prophylaxis given (Baby) Y/N	MT "A" supplementation to mother Y/N	Feeding Options (1=Exclusive, 2=Formulae)	Delivery conducted by (Name)	Birth notification number	Date of Discharge	Condition of baby on discharge (A/D)	comments
Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN

				Diagnosis	Alive:	Deaths		
				No. with APH:	_____	_____	No. of Normal deliveries:____	\No. of underweight babies (<2500gm) : _____
Total No. with 4 ANC visits: _____				No. with PPH:	_____	_____	No. of Caesarean sections:_____	No. of pre-term babies:_____
				No. with Eclampsia:	_____	_____	No. of Breech Deliveries:_____	No. of babies discharged alive:_____
				No. with Ruptured Uterus:	_____	_____	No. of assisted vaginal Deliveries:_____	Referrals:_____
				No. with Obstructed Labour:	_____	_____	Total Live births:_____	No. of Neonatal deaths (NND):_____
				No. with Sepsis:	_____	_____	No. of Still births:_____	No. of Maternal deaths:_____

No. Counselled for HIV: _____	No. initiated cotrimoxaxole (women) :_____	
No. Tested for HIV: _____	No. initiated cotrimoxaxole (infants) :_____	
No. found HIV +ve: _____	No. HIV+ referred for follow-up (mothers) :_____	
No. issued with preventive ARVs: _____	\No. HIV+ referred for follow-up (Partners) :_____	
No. of Infant Nevirapine administered : _____		
No. of Deliveries from HIV+ women :_____		

Appendix 7: MoH 505



ED2016

MINISTRY OF HEALTH
IDSR Weekly Epidemic Monitoring Form

MOH 505

County_____ Sub-County_____ Health Facility_____ Epi Week___ Week ending____ Month___Year_____

No. of Health Facilities/Sites that reported _____ No. of Health Facilities/Sites expected to report _____

Diseases, Conditions or Events	< 5 years		≥ 5 years		Total		Diseases, Conditions or Events	< 5 years		≥ 5 years		Total	
	Cases	Deaths	Cases	Deaths	Cases	Deaths		Cases	Deaths	Cases	Deaths	Cases	Deaths
AEFI*							Meningococcal Meningitis						
Acute Jaundice							Neonatal deaths						
Acute Malnutrition							Neonatal Tetanus						
AFP (Poliomyelitis)**							Plague						
Anthrax							Rabies						
Cholera							Rift Valley Fever						
Dengue							SARI (Cluster ≥3 cases)						
Dysentery (Bacillary)							Suspected MDR/XDR TB						
Guinea Worm Disease (Dracunculiasis)							Typhoid						
Malaria							VHF***						
Maternal deaths							Yellow Fever						
Measles							Others (Specify)****						

Laboratory	< 5 years		≥ 5 years		Total		Remarks:
	Tested	+ve	Tested	+ve	Tested	+ve	
Malaria							
Shigella Dysentery							
Tuberculosis (MDR/XDR)							
Typhoid							

35 diseases

*Adverse Events Following Immunization
**Acute Flaccid Paralysis
*** Viral Haemorrhagic Fever: May be due to Ebola, Marburg, Crimean Congo haemorrhagic Fever
****Any public health disease, condition or event of national or international concern (infectious, zoonotic, food borne, chemical, radio nuclear, or due to unknown condition

Reported by: _____ Designation _____ Sign _____ Date _____

Reporting Instructions
Health Facility Level: Send original copy to SCMOH or SCDSC every Monday and retain a copy
District Level: Reviews all health facility reports for correctness then enters the data in the electronic IDSR system. Files the health facility copies
Surveillance week: A week starts on Monday and ends on Sunday

Original Copy