UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING AND INFORMATICS

MSc Project Report

COMMUNITY HEALTH WORKERS MOBILE APPLICATION FOR HOUSEHOLD REGISTRATION;

DANGER SIGNS IDENTIFICATION AND REFERRAL

Submitted by:

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DECLARATION

DEDICATION

I dedicate my MSc project report work to my family, especially to my wife, colleagues and friends. I will always appreciate all they did to support me in this journey and their words of guidance will always be remembered. May the good Lord reward you.

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First and foremost, I would like to thank the Almighty God for giving me the gift of life without which this work would not have been possible.

I am highly grateful to my supervisor, Dr. Evans K. Miriti, for the guidance and support he gave in every step of this work. It helped me develop a deep understanding of this undertaking. I would like to thank him for all the valuable discussions we had and the helpful feedback he continuously offered me as I was doing this project. His contribution to this work is invaluable.

Finally, I would like to offer my thanks and regards to all those who supported and helped me in any way for the completion of this project.

ABSTRACT

Access to health care in low resource settings like slums is usually a major challenge and this is due to a variety of reasons ranging from poverty, illiteracy and distance to providers of health care. However, with healthcare providers at the community level known as Community Health Workers (CHWs) this challenge is alleviated. CHWs are meant to address shortage of health workers coming in to give health services to communities they come from an approach that has been in existence for a many years. In many communities of Kenya and around the globe, Community Health Workers are continuously collecting household and individual level data, which is rarely being used to make timely informed decisions. Data collected from households has no linkage with data captured at the health facility.

The main objective of the study was to develop a CHW mobile application that helps in capturing information and promptly using it, in making correct and timely decisions for cases in the community. To be able to develop the CHW Mobile application, requirements were collected through talking to different stakeholders who work closely with community health workers. They included sub county focal persons for Baba Dogo and Isiolo sub-counties, Community Health Workers, Research Officers from APHRC as well as Software developers. These requirements were also supplemented by looking at different literature which expound on the work done by Community Health Workers. This was done to help understand how CHWs work and the tools they use for their daily operations.

Through agile Software methodology that allows development of medium size software applications, the CHW Mobile application was developed. It was an iterative process where the most important aspects of the application were prioritized and developed. Others were also integrated tested and adopted thereafter.

The objectives set out at the beginning of this undertaking were achieved through; looking at literature and talking to different stakeholders that help community health workers in their work. The main objective of the study was achieved by developing the CHW Mobile application and linking it to a web application for uploading and downloading of data as well as for data visualization.

DEFINITION OF IMPORTANT TERMS

Acceptance criteria – this is notes about what a software product must do for it to be accepted by the client / user.

Case – a case can be a child or mother that has any danger sign.

Community Health Workers – these are individuals who assist individuals and communities to adopt healthy behaviors.

Health Service – this is a patient contact for diagnosis and treatment provided by a health professional.

Household - Members who eat and live together.

Implementation Research - This is research done with the aim of doing intervention for the condition in focus i.e. bringing solutions to address challenges learnt in earlier research studies.

Longitudinal Data - Routine collection of vital statistics from a defined population over time.

mHealth (**Mobile Health**) - This is the use of portable electronic devices with software applications to provide ***health services*** and manage ***patient information*** (Källander et al., 2013). This is the utilization of short messaging service (SMS), wireless data transmission, voice calling, and smart phone applications to transmit health related information or direct care. In simpler terms, it is the use of mobile communication in the provision of health information and services.

Primary Health Care – is a set of prescribed services falling within the skill base of a professional nurse, technician, mid-level worker, counselor, community health worker, midwife or emergency medical practitioner.

Research - This is the systematic investigation into and study of materials and sources in order to establish facts and reach new conclusions.

Selection bias - This is distortion of estimation results due to non-random patterns of loss to follow up (Alderman, Behrman, Watkins, Kohler, & Maluccio, 2001).

Service Oriented Architecture (SOA) – This is an architectural style where services are provided between different components through a communication protocol.

Study Validity (**Precision**) - This is the truthfulness of the conclusions made from the findings in a study. It depends on the comparison of similar groups. There may be differences between the people completing a study from those who are loss to follow-up.

Study Generalizability - This is the extent to which conclusions made from a trial are accurate when applied beyond the study setting. If applied in a different area, how accurate will these conclusions be for that setting?

Study Reliability (**Consistency**) - This is the extent to which the research measure is a consistent and dependable indicator of medical investigation (Suresh, Thomas, & Suresh, 2011).

User Acceptance Testing (UAT) - It is validating a product in a real setting by the intended audience.

User Story – as defined by Wikipedia, a user story is an informal way of describing what a system should be able to do, or capabilities a system should give to a user.

ABBREVIATIONS

APHRC	-	African Population and Health Research Center
API	-	Application Programming Interface
ART	-	Antiretroviral Therapy
CHW	-	Community Health Worker
CHV	-	Community Health Volunteer
DSS	-	Demographic Surveillance System
ECD	-	Early Childhood Development
HDSS	-	Health Demographic Surveillance System
MoH	-	Ministry of Health
MNCH	-	Maternal, Newborn and Child Health
REST	-	Representational State Transfer
SCRF	-	Sick Child Recording Form
SES	-	Social Economic Status
SOA	-	Service Oriented Architecture
SRH	-	Sexual and Reproductive Health
URI/URL	-	Universal Resource Identifier / Universal Resource Locator
WWW	-	World Wide Web

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1. CHAPTER ONE: INTRODUCTION

The health of an individual is of paramount importance as it determines how good a life that person will lead and to what extent they will be productive in the community. There have been quite a number of interventions that have been carried out with an aim of improving health outcomes as the ultimate goal in different communities, especially with regard to maternal and neonatal health (DeRenzi, Sims, Jackson, Borriello, & Lesh, 2011). However, there are gaps in the coverage of health care / provision of services for health, especially in settings with few resources like slums found in most urban centers (Bakibinga et al., 2014). Because of this, it becomes a farfetched idea for an individual from such a community to realize health and its benefit as healthcare is not accessible.

Note that the health of a person and the well-being of any community are determined by a number of actors, who have a responsibility of responding to what health needs there are in that community. Since health is of such importance to the development of any community, each actor needs to have a way of promoting health by whatever means possible. Primary health care relies on different health care workers e.g. doctors, midwives, nurses, auxiliary and community health workers, at local and referral levels, on health workers as a health team in response to the needs of a community (World Health Organization, 1978). The actors need to be given an enabling environment to work in. Healthcare and health services should be made accessible by hospitals complemented by other players in the health sector. There is need to have people that are constantly in contact with community members and that is where the role of CHWs and CHVs come in, they help extend the reach of primary health care (Khalala, Makitla, Botha, & Alberts, 2013).

Some of those actors at the community level are community based health (CBHS) providers who provide services through Community Health Workers (CHWs), Community Health Assistants (CHAs) or Social Health Activists who are Accredited (ASHA) as stated by ("Community Health Management Information System|DHIS2 based mHealth," n.d.). They act as links between health systems and communities. They enhance the cultural competence of medical care with an emphasis on preventative and primary care.

Evidence has shown that, community health workers can really assist in improving health care access, health outcomes, fortify health teams and greatly improve the quality of life for poor people in low resource settings. There are a number of roles they can undertake which includes case management of childhood illnesses, immunization, promote healthy habits in the community and in carry out community mobilization. The CHWs are identified as providers of healthcare, education and enrollment in primary healthcare. They are service extenders and facilitators for community improvement. They build capacity for individuals and communities through giving them health knowledge and teaching them how to be self-sufficient. They also provide social support. They also build peer-to-peer relationships with community members rather than client relationships and thus improve health care and access. They teach individuals how to take care of their health and navigating the healthcare system. It is also very important to have in mind that community health workers are not a solution or a cure for weak health systems, they need to be given focused tasks, trained well as well as given an enabling environment.

Combining CHWs' efforts with m-Health could be one of the ways of improving primary care services (Khalala et al., 2013; Schuttner et al., 2014). CHWs' major responsibility is to prevent illnesses rather than cure sicknesses as their skills can't allow.

In reality, CHWs seldom carry out their responsibilities as they are most of the time engaged in doing side jobs, collecting data for the government and non-governmental organizations. They rarely make use of the data they collect from household. CHVs and CHWs are expected to manage patient's information as well as provide health care. They are faced with the immense task of managing so much information from the different households they are allocated (DeRenzi et al., 2011). The information collected from people in households is entered in big books provided by the Ministry of Health (MoH). They have to keep track of what is happening in every household. As they go about visiting women and children in their homes they have to determine if they have any danger sign, that needs to be referred to a health facility or whether it is an issue that can be managed at home (case identification).

1.1. Problem statement

Based on studies done, performance of a CHW is at its peak moments after training. At this time, they are able to identify danger signs easily and thus make correct judgment since their memory is still fresh. But this decreases with time. Experience of a CHW also plays a major role in being able to effectively make correct judgements on danger signs, but then there is always need to replace old CHWs with younger ones.

With the above in mind it is good to note that there would be a number of consequences as a result of making wrong judgement about cases. This would range from, under-prescription, over-prescription, small number of referrals or the converse. In cases that have serious danger signs and are not identified, it could lead to worsening of the clinical conditions and therefore lead to expensive evacuations and treatment in the long run. Bad prescriptions could also lead to unnecessary expenses to families. It could also lead to running out of stocks of necessary medicines if they tend to be misused.

1.2. Objectives of the study

This study's main objective was, to develop a Smart Community Health Workers mobile application that enables Community Health Workers (CHWs) register households with pregnant mothers and children, identifying of danger signs and processing referrals.

Specific objectives,

1. To identify existing methods through which CHWs record household information, identify danger signs, process referrals and pick out weaknesses of these methods.
2. To build an application that mitigates the weaknesses of existing methods.
3. To build a web system that visualizes data collected at the community level and link it back to the CHWs.
4. Test usage of the mobile application to ensure that setout objectives have been fulfilled.

1.3. Significance of the study

The Mobile application will help in collection of accurate information from the households. It will also help in ensuring data quality and security as CHW will only be able to send complete data. The application will also help in profiling of cases i.e. determining if a case needs specialized treatment at the health facility or can be managed at home. Whether a CHW is new or has experience working in the community will no longer be important, all CHWs will be equal to the task as long as they have skill in using smart phones. The application will be able to download incomplete referrals reminding CHWs of home visits and appointments to make, thus helping the community health worker in better management of their work and time. A CHW will also benefit through the continuous use of the system as it will help them in understanding more and more about the danger signs that exist. As they interact with people in the community they will dispense knowledge of danger signs.

2. CHAPTER TWO: LITERATURE REVIEW

2.0. Introduction

The following section is grouped into the following sections, background of healthcare service delivery by community health volunteers and workers, danger signs, related works, and the proposed solution.

2.1. Healthcare service delivery by Community Health Workers

Many developing countries in the world use Health Workers of the community (CHWs) programs to improve the health of the community. This is done through education, advocacy and direct assistance (Callan, Sundin, Suffian, & Mehta, 2014). In low-resource settings, community health workers (CHW) usually bear the burden of providing health services to the community. They help mitigate most barriers to health and are in the first tier of providing health care to their communities (Braun, Catalani, Wimbush, & Israelski, 2013; Gustafson, Atkins, & Rusch, 2018).

There are different aspects that are looked at when measuring the quality of healthcare provision. A number of issues were highlighted;

- Medical adherence
- Patient monitoring
- Healthcare worker communication
- Emergency and disaster response
- Accessibility to patients' information

There are a number of challenges for mHealth implementation which include; operating costs, knowledge, infrastructure, and policy framework (Betjeman, Soghoian, & Foran, 2013).

2.2. Community Health Worker

A CHW is a fellow community member and therefore has a great understanding of the community they serve in (Hynes, Buscemi, & Quintiliani, 2015). This closeness to the community

or as a result of being a part of the community, helps them to act as the go between health services and the community, smoothing access to health services and improving the quality of the services delivered. CHWs most of the time are engaged in health promotion service as opposed to curative services that are handled by the more professional nurses, clinical officers and medical doctors (Lewin et al., 2010).

Most countries in Africa have used these CHWs to advance a broad range of health aims including maternal and child health, HIV/AIDS, sexual and Reproductive health. It is estimated that Africa and Asia alone have deployed over a million community health workers (MacLeod, Walji, Phillips, Awoonor-Williams, & Stone, 2012). They play a key role in promoting health and providing medical care especially in areas where government services are weak. CHWs help circumvent the challenge faced by different African countries that have weak systems of health, dropping out of trained health workers from employment, few numbers of trained health workers, burden of disease arising from avoidable and curable conditions (Mwai et al., 2013).

In Kenya CHWs are recognized as an integral part in delivery of the National Health Sector Strategic Plan II of Kenya (NHSSP 2005-2010) which was rolled out in 2005 (Aridi, Chapman, Wagah, & Negin, 2014). It was about taking Kenya Essential Package for Health (KEPH) to the community and providing improved health services at the lowest level. One of the pillars of this was training members of community on how to provide health services that are basic and as a result enabling communities of Kenya to take control of their health. This included agreeing that the level one unit of primary health care is a Community Unit (CU) supposed to serve a substantial number of people, around 5,000 with a well-trained CHW giving services to 20 households. A CHA is supposed to supervise a group of 25 CHWs giving support in form of supervision of the CHWs. CHEWs are employees of MoH. They were charged with linking Community Health Workers and health facilities. They were also charged with training the community. Community Health Committees (CHCs) are expected to organize dialogue sessions to raise awareness of maternal and child health issues with the help of displaying data on community chalk boards. The CHCs together with the village are tasked with recruitment of CHWs.

CHWs are used by both the government and Non-Governmental Organizations to roll out different community interventions. CHWs have been instrumental in aspects like exclusive

breastfeeding (EBF), encouraging people in following immunization schedules and also in reducing the number of children getting high fever, diarrhea and pneumonia (Lewin et al., 2010). The government of Kenya has a National CHW programme (MoH sponsored CHW programme), which has been implemented in a number of districts countrywide.

2.2.1. Duties of a CHW

There are quite a number of tasks or roles played by CHWs which revolve around patients in the community and provision of health service. They carry out patient support which entails counselling, giving patient care at home, education, medical prescription observance and general life support. In health service provision they look for the presence of danger signs, refer the ones that are in serious need of seeing a health professional, health service organization and surveillance.

Work done by a community health worker (CHW) can be grouped into, identification and proper handling of childhood illnesses (malaria, pneumonia, infection contracted at birth), training of caregivers on how to prevent illnesses through immunization, encouraging healthy behavior among caregivers) and mobilization of communities (Haines et al., 2007).

The major/greatest role of a CHW is to build bridges between communities they work in and health services (Liu, Sullivan, Khan, Sachs, & Singh, 2011; van Heerden, Sen, Desmond, Louw, & Richter, 2017). They have a shared community membership with the population they serve, or their residencies are in close proximity to the community.

CHWs are tasked with collecting data from households in the community and making referrals whenever there is need, to the health facilities in case they identify danger signs. They usually use very large books for the different exercises i.e. household registration, pregnant mothers' registration, children registration. They visit household members at intervals in their homes to deliver health services.

Other CHW tasks are, enrollment of pregnant women and their children, assisting in the registering newborns, following up child growth and immunization schedules, and also recording

diseases and deaths. CHVs/CHWs are usually the first people to provide health care to community members for different health problems. They are also involved in guiding mothers on where to get ANC services during their pregnancy terms (Grossman-Kahn et al., 2018). They are trained to provide non-communicable chronic diseases and selected childhood diseases.

They mobilize families and communities on the uptake of healthy feeding behaviors, appraise communities on resources that are readily available, advocating for individual and community health needs, giving different services like first aid and measurement of blood pressure while collecting data with an aim of knowing what community needs in health are.

2.2.2. Danger Signs

Danger signs in healthcare are problems associated with lack of health in pregnant women, neonates, and even children. Danger signs are an important aspect as they help in recognition of illnesses amongst different groups. They could be broken further into other smaller groups like obstetric danger signs (potential problems associated with pregnancy), neonatal danger signs (fever, chest in-drawing, irritability, weakness, abdominal distension/vomiting, slow or rapid breathing, continuous crying, poor sucking, jaundice, lethargy/unconsciousness, convulsion, hypothermia and diarrhea) (Awasthi, Verma, & Agarwal, 2006; Doctor, Findley, Cometto, & Afenyadu, 2013; Kibaru & Otara, 2016; Sandberg, Pettersson, Asp, Kabakyenga, & Agardh, 2014).

It is important to have knowledge about the different danger signs present among pregnant women, delivery and postpartum period. When a CHW has the above knowledge they will be able to correctly point out what needs to be done per case, whether treatment or referral, and thus improve the quality of care being given.

Awareness of danger signs is the first step in accessing appropriate and timely referral for any form of health care (Bogale & Markos, 2015; McConnell, Ettenger, Rothschild, Muigai, & Cohen, 2016). It is also important to do this in a timely manner (Sreeramareddy et al., 2006)

Early identification of danger signs is also an important step towards improving a number of health indicators; newborn survival, and timely care-seeking (Sandberg et al., 2014). Early identification of danger signs could also draw the line between life and death for the neonates and thus its importance.

Proper identification of danger sign would help in seeking appropriate health care in a timely manner thus eliminating the risk that accompanies delay in seeking health care (Anwar-ul-Haq, Durrani, Kumar, & Durrani, 2015; Rowe et al., 2007). The converse of this statement is also true, if errors are made during handling of a case this could lead to delay in seeking medical intervention and care at the health facility.

Getting the correct health care and on the right time can minimize deaths of children as reported through estimates by World Health Organization.

Due to the above reasons on the importance of having knowledge about danger signs, improving skills to recognize danger signs in child illnesses of people who interact with children or families of children may enhance health-seeking behavior and by extension better the lives of children (Taffa & Chepngeno, 2005). Little knowledge in danger signs of young children calls out for the need of complementary ways through which communities can have programmes to improve family's behavior of seeking health and the capacity to identify danger signs of children (Sreeramareddy et al., 2006).

2.2.3. Case Referral

Since CHWs are not medical professions, whenever they encounter cases with danger signs in the community they are supposed to refer them to health facilities that are in close proximity. A case in point is if they encounter a child who has been having diarrhea for a number of days, clearly such a child can be helped to seek help from a medical professional since its clear they have a danger sign. If a child has chest in-drawing or has been coughing for many days those should be considered danger signs. A pregnant mother may also have danger signs.

2.2.4. Limitations in the work performed by CHWs

Community health workers (CHWs) are tasked with the following responsibilities; collecting field based data, facilitating health education sessions for antenatal care (ANC), postnatal care (PNC), child nutrition and breastfeeding), conducting person-to-person communication, doing follow ups , (Braun et al., 2013). Their other responsibilities include, registering pregnant mothers, encouraging them to attend ANC sessions, recommending Health facility delivery, following up after delivery to encourage them to attend PNC sessions. They are instrumental in prioritizing areas in health care, including child undernutrition, maternal and child health, enhancing the reach of family planning services to the masses, controlling of communicable diseases, malaria, and tuberculosis.

However, the above tasks are conducted using paper based systems where they record members of households in books in case of new births or addition to the existing households they have been attending to. They also do follow up on cases identified in the communities and record their progress in the same books. The CHWs have to master the art of identifying danger signs or any associated complications thus making their work complex as they have to recall all the danger signs and what actions to take when they come across one (Rowe et al., 2007).

CHWs are also not incorporated in clinic flow and decision making (Grossman-Kahn et al., 2018).

There is also a problem when the communities CHWs work in don't understand the role and responsibilities played by Community Health Worker and thus are not able to value what they do. The community is yet to understand the value of preventative medicine.

Mobile technology is increasingly being used to facilitate the work done by different health care providers, some of them being community health workers (CHWs).

Multiple research works have shown that patient-care can be improved through the use of decision support systems and by extension mHealth in resource limited settings (Anokwa, Ribeka, Parikh, Borriello, & Were, 2012).

2.3. Related Work

2.3.1. Mobile Partnership for MNCH (mPAMANECH)

The objective of this study was to evaluate the feasibility of using a mobile app and smartphones in the identification and tracking of mothers and their children by community health workers (CHWs), aimed at reducing complications during pregnancy and deaths of neonates, and also contribute to the big aspiration of improving maternal and neonates survival (Bakibinga, Kamande, Omuya, Ziraba, & Kyobutungi, 2017). They were looking at how they would facilitate the work done by Community Health Workers (CHWs) in slum settlements, in the management of mothers and their children and also introduce an innovative way of handling referral mechanism.

One of the shortcomings of this app was that one needed to be continuously connected to the internet for you to have access to collected information and also get any verdict or conclusion made by the health facility personnel. This application didn't have a mechanism to store data locally in the mobile phone and only connect when there is need to download or upload data from the field.

2.3.2. AMREF mHealth App (LEAP)

This is an app that was used for training of Community-based health workers (Amref, 2016a, 2016b). It helped CHWs to continuously receive training through text messages unlike the way it has always been where a CHW receives training once in their lifetime. However, it is important to note that the app was leveraging on the use of short message service where information in form of messages would be sent to their phones.

Use of text for sending information was not considered as a shortcoming as it would make it quite cheap. There was also no guarantee that the message/information was delivered to the intended recipients. Systems should have a feedback mechanism to ensure that a message has been delivered to the intended clients.

2.3.3. Information for Action (IFA) Mobile App

The IFA application was developed to be used by community health workers (CHVs) from West Katweng'a sub location in Rarienda sub county. The app would enable them collect data routinely for monitoring and evaluation of Early Childhood Development (ECD) as well as give timely feedback whenever a challenge was faced (van Heerden et al., 2017). The data collected routinely would then be repackaged into useful information to help make informed decisions by caregivers and program managers. After data has been collected from caregivers, it was then looked at by experts and program managers, then feedback would be packaged and sent to caregivers, unlike what many organizations do, collect data and never go back to the respondents they collected data from. The end goal for this app was to improve how monitoring and evaluation (M&E) is done and by extension provide accountability, learning and correction. From the conclusion drawn, the app helped improve the relationship between the CHVs and the caregivers (client-provider) as it improved the quality of home visits. It gave the added benefit of helping make decisions based on visits made and data collected.

One of the strengths of the application is that it had a feedback mechanism. Data collected from caregivers would be looked at by experts and program managers, then feedback would be packaged and sent to them.

One of the shortcoming identified in the application is that data collected was not being promptly used by the CHW to make decisions.

2.3.4. Mwanzo Mwema Monitoring and Tracking Tool (MMATT)

This was a simple monitoring and tracking tool that was developed to enable Community Health Workers (CHWs) of four sub counties of Taita Taveta County, plan their workload and activities, identify women and children most in need of accessing critical maternal (prioritizing beneficiaries), newborn and child health, and improve key MNCH indicators (Avery et al., 2017). MNCH indicators includes; visits during pregnancy, delivery at health facilities, care after birth of the mother and child within two weeks of delivery, early breastfeeding, exclusive breastfeeding (EBF), and a complete package of care.

The apps shortcoming is that information collected would not be used there and then to help in making certain decisions e.g. making of referrals.

2.4. Summary of gaps

There are three important aspects that need to be addressed in the existing mHealth solutions namely; prompt (timeliness), appropriate (correct) and feedback (information linkage) using the data being collected by the CHWs. From literature reviewed it has been found that some solutions enable one to collect data but which is not promptly used to help in decision making. Others have a feedback mechanism which is a strength, however, that information is used at a later stage to arrive at conclusions.

Some projects use mHealth specifically as a tool that helps in sharing of knowledge and behavioral transformation, others use it as a bridge to important SRH services (family planning and counselling services, advised / guided abortion and care after abortion has taken place (PAC) and HIV care and treatment) (Ippoliti & L'Engle, 2017).

Other many projects use SMSs to send sexual and reproductive health information / advice to the youth. This shows us the wide use of it as a way of sending knowledge and knowledge sharing within different groups of the populations e.g. adolescent SRH.

Analysis of the different projects that have been carried out shows clearly the need to combine the different facets and strengths of the applications into an integrated system that would help synthesize data collected by the Community Health Worker and use it promptly (Carrion, Bradway, Vallespin, & Puigdomènech, 2016).

2.5. Proposed Solution

Mobile phones are increasingly becoming important in everyday life and work. Nowadays you cannot talk innovation while excluding mobile phones. They are becoming an important topic when discussing issues to do with patient information gathering, management of the information, monitoring of healthcare services, decision support and handling referrals. The primary goal of

this project was to come up with an innovative way of facilitating how CHWs collect data, use it promptly in making decisions and how they determine whether cases in the community have danger signs or not by applying mobile technology.

This system will help overcome the challenge of linking data collected by the CHWs and data collected at the health facility. Remember as the CHWs visit different households and come across a child or woman with a danger sign they fill a referral form. In the event that the referred child or woman does not present themselves to the recommended health facility, a message is sent to the CHWs phone to follow up with the person in the household that was supposed to visit the health facility

There are events that occur in the surveillance area qualifying an individual to be registered in the Community Health Workers (CHWs) registries. They majorly help in registering of pregnant mothers and young children. Sometimes they may also provide health care services to men of the households where CHWs work with or have been attending to.

3. CHAPTER THREE: METHODOLOGY

Overview

The following steps were undertaken to develop the CHW mobile application in its entirety. The CHW mobile app was developed by following agile software development methodology application development Model while the web service was developed using IT product Design method proposed by Papazoglou (Papazoglou, 2007).

3.1. System Development Methodology

There were a number of design methodologies that could have been used when developing this system, examples being; Spiral methodology (Extreme Programming techniques) which is suitable for big software projects, waterfall model, SSADM – Structured System Analysis and Design. The choice of, agile methodology was picked since it is appropriate for smaller projects. System Analysis Design development methodology was used for developing the proposed solution and specifically agile methodology. It combined Information Technology, people and data to support business requirements (Dubinsky, Hazzan, Talby, & Keren, 2008; Ramakrishnan S, 2012).

3.2. Phases of agile software development methodology

This methodology is a type of software development process (SDLC) methodology that is iterative in nature. It allows for incremental changes to the application/program being developed. With each iteration there are changes that are effected in the system as recommended by the user. Below is a diagram that highlights the steps that were taken. This method gives more importance to collaboration within the team and stakeholders.

The following steps of agile software methodology were undertaken in realizing the CHW mobile application system;

AGILE METHODOLOGY

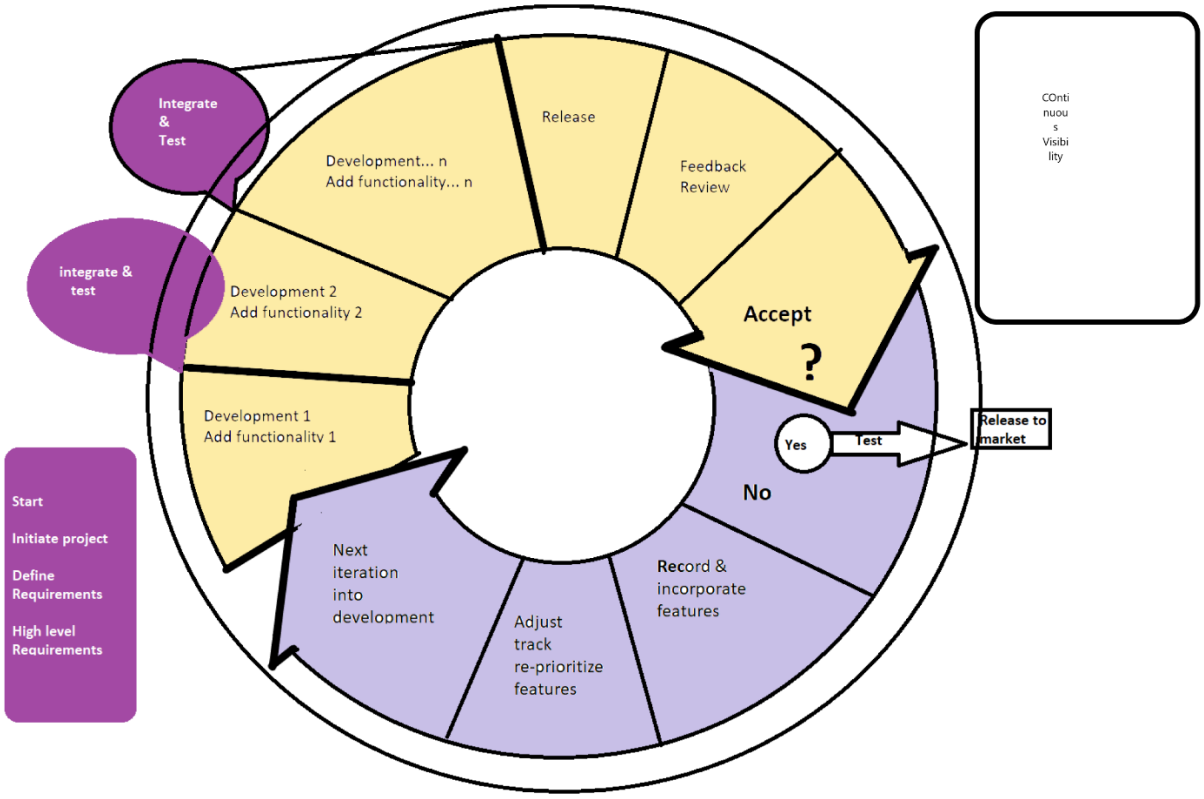


Figure 1 Agile Methodology (incremental)

As depicted in the picture below, this methodology allows the user to interact with the application / software at the end of each loop i.e. after a bunch of requirements grouped according to priority have been developed, a software package is released to the user. The method also allows the development team to take up changes and recommendations more easily and implement corrections that are needed.

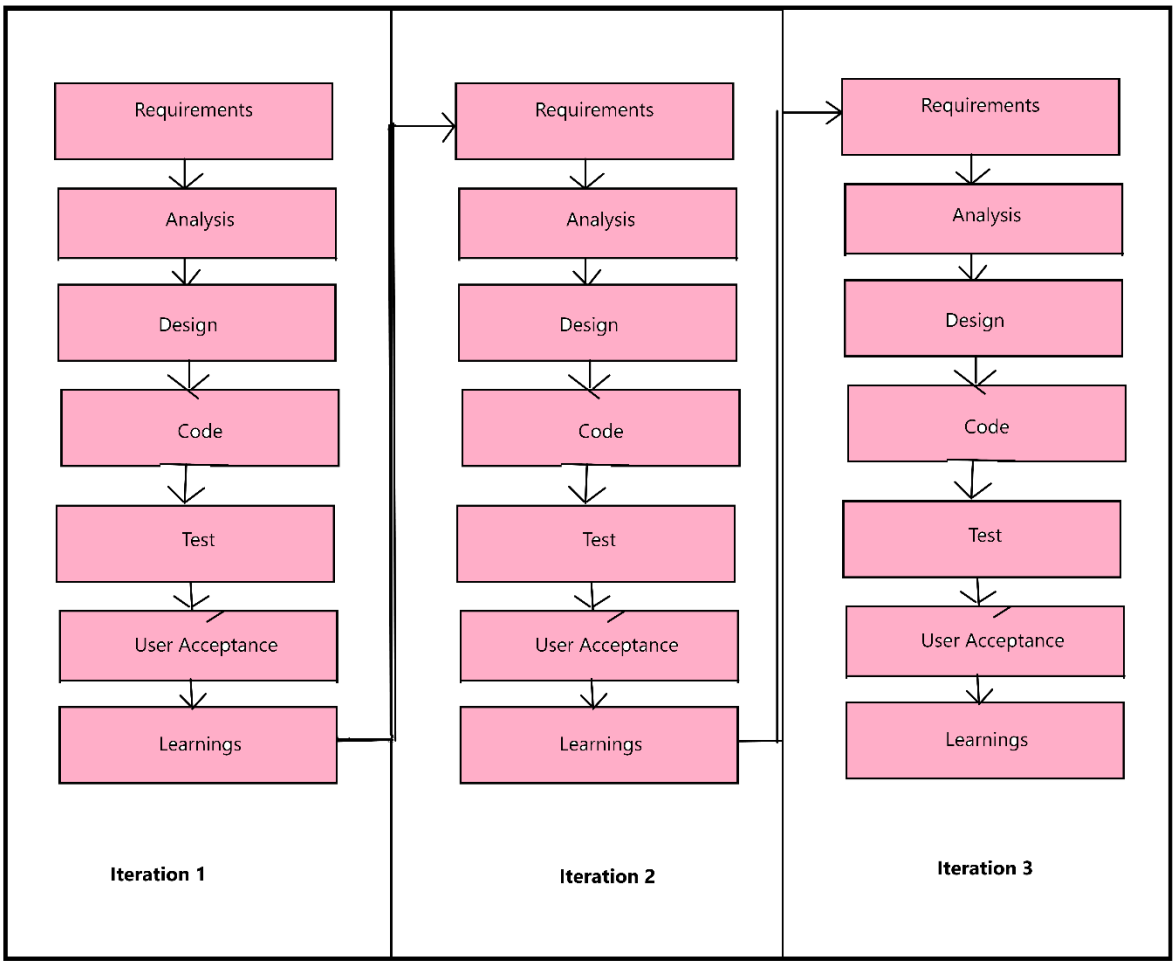


Figure 2 Agile Methodology Iterations

As explained above, with each iteration, there is significant improvement in the overall application as changes and recommendations are given and implemented.

- Requirement gathering
    - This stage involved talking to the Community Health Assistant and Community Health Workers as the greatest users of the system.
- Analysis
    - Also as part of this stage the requirements were then grouped into functional and non-functional requirements which were further prioritized accordingly. A number of questions also were brought out e.g. will we be

continuously connected to the internet? How many people will be using the system? Where will the data collected through the system be saved? How many languages will the system support?

- System design
    - At this stage the software developer was fully involved and made other decisions that are important regarding the system. The need to have a backup of the data collected through the system and redundancy to make sure that the system is always available. Data flow diagrams and flowcharts were also drawn to help in developing the system sequentially.
- Implementation
    - Coding for the CHW android application was done using java and specifically following model-view-view-model (MVVM) architecture. The CHW Health Facility website was also developed using PHP. On the android app the local database was in SQLite while on the main server the database was MS SQL Server. This was to ensure security.
- Testing
    - Testing was done in phases, starting with individual components separately then after integration the entire system was tested to ensure that it worked as expected. Any defects identified were logged in and worked on accordingly. Regressions testing was also done to ensure that no new defects were introduced to the system.
- User acceptance
    - This testing is done a number of times with each incremental release of the software. Defects encountered are reported and fixed accordingly. The users are given any new application that is packages to interact with the new release and review the application.
- Deployment
    - An android package (apk) was built through which a CHW can install to their tablet or android phone. As for the server side which hosts the main database, MS SQL Server was installed. XAMPP webserver was also

installed that enables external parties post data to the server MS SQL database.

- Maintenance
    - Issues that were encountered after the system was developed for use were logged in and solved at this particular point. They were then tested to ensure that they had been solved.

3.3. Requirement Specification

The following process that was undertaken to develop the Requirement Specification Document (RSD) for the CHW Mobile Application. It was in two stages; the first step was talking to stakeholders of Community Health Strategy Process. The stakeholders included; Ministry of Health Sub-County Focal Person (Strategist), Community Health Assistants who were initially referred to as CHEWs who directly supervise the CHWs, Research officers from APHRC that were working closely with the CHWs in different projects as well as the CHWs themselves. This was done in Isiolo and also Baba Dogo in Nairobi.

The second step taken was that of determining the system needs of the stakeholders to successfully develop the system. It was found that CHWs use Ministry of Health (MoH) books to register households and collect health indicators for neonates, children and their mothers. MoH 513 books are used for registering households, MoH 514 books are used for weekly data collection and MoH 100 is used for referral of cases. The CHWs then use their experience in handling cases in order to determine if a case has danger signs or not. They also use notebooks to record dates of when they intend to visit those households for follow-up. This combined with the fact that they have to carry other tools for their work, proves quite cumbersome and a heavy load to carry around. This can prove a daunting task for a new CHW who is not used to the system. The CHWs are expected to use cards to determine danger signs in neonates.

Summary of the requirements (MoSCoW technique)

Requirements were ranked for importance and stability. Importance in this case referred to level of necessity or priority. MoSCoW technique was used to rank the requirements gathered.

MoSCoW technique defines “Must Have”, “Should Have”, “Could Have”, and “Won’t Have” requirements ranking.

After talking to the stakeholders and looking at the data collected, the following summary of requirements were arrived at which included, functional and non-functional requirements:

Functional requirements.

This group is composed of functions that a developed application / system or a system component / part of the system should be able to perform. Some of these requirements were captured as user stories i.e. very simplified functionality required of the system;

a) Should enable registration of households, individuals, follow-ups and addition of information in them.
b) It must be compatible with most android devices.
c) Security and audit requirements, ability to protect information from being accessed or tampered with, by users either accidentally or deliberately.
d) A functionality for report generation, - desire for a system that would help in generating work reports.
e) Function for downloading information from different health facilities.

CHW Mobile App Use Cases

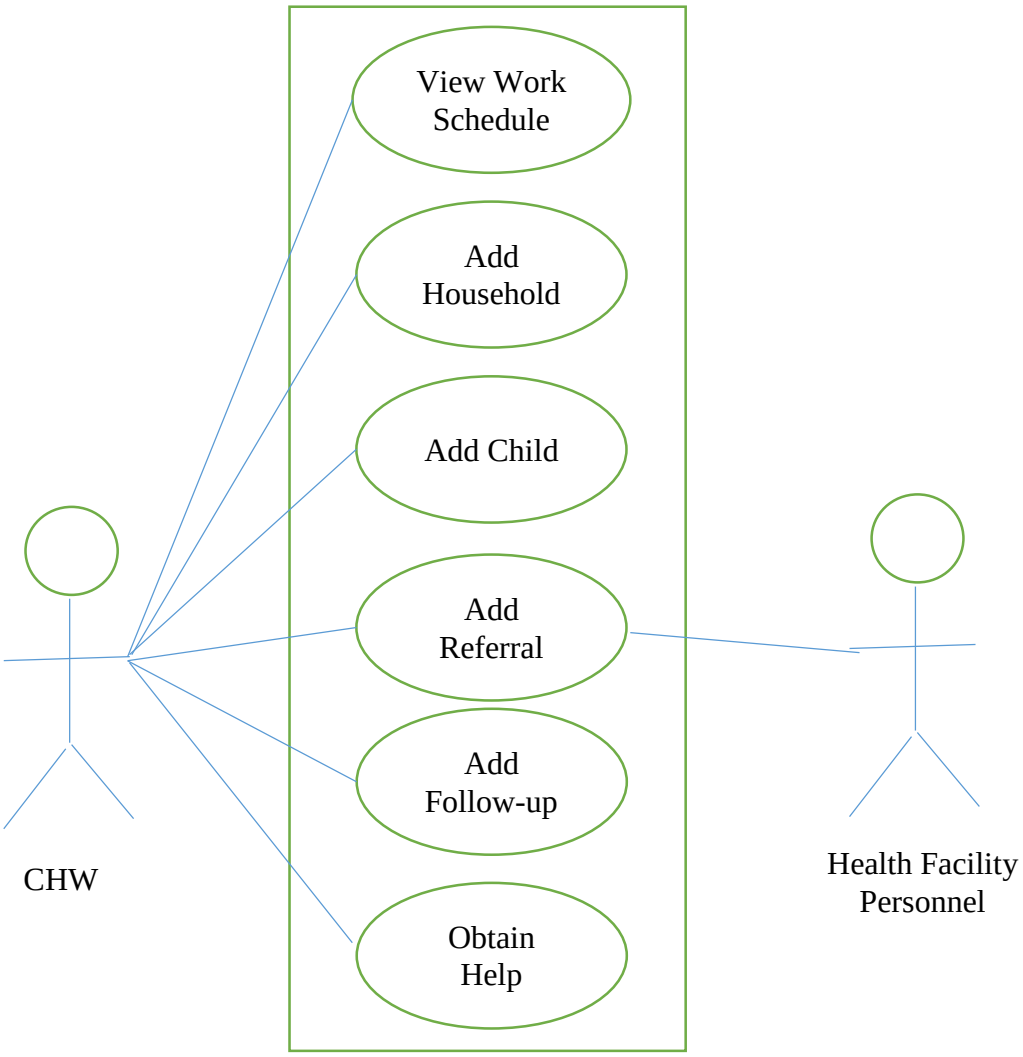


Figure 3 CHW Mobile App Use Case

Non-functional requirements.

This group comprises of specifications on how well a system should perform its intended purpose and the ease with which a system should fulfill its work.

a) Users are technically unsophisticated and thus need a system that is not complicated (easy to use).
b) Desire for a system that clearly outlines the existing workflow of CHW (fits into the existing framework).

c) Security requirements, there is need to define who is authorized to access the system, its functionalities as well as the data collected using the system. This was because the system is meant to capture patients' information and ethically only authorized personnel should access this information.

3.4. System design

Below is the system architecture for the CHW Mobile Application system that was developed, the services it is linked to and the online database and system accessed by personnel at the health facility? The design was informed by the requirements gathered from the users of the system which in this case are the CHW.

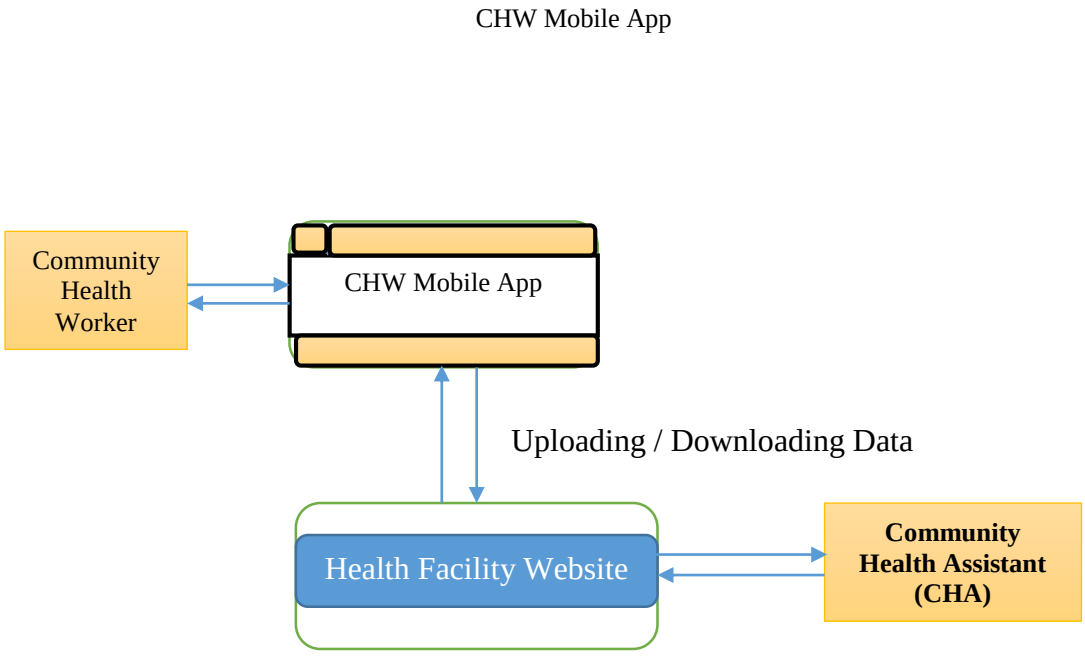


Figure 4 DFD Level 0 Context Diagram Whole System

The above context diagram is a simple representation of the whole system which is a combination of CHW Mobile Application, Health facility website and the interlinkages.

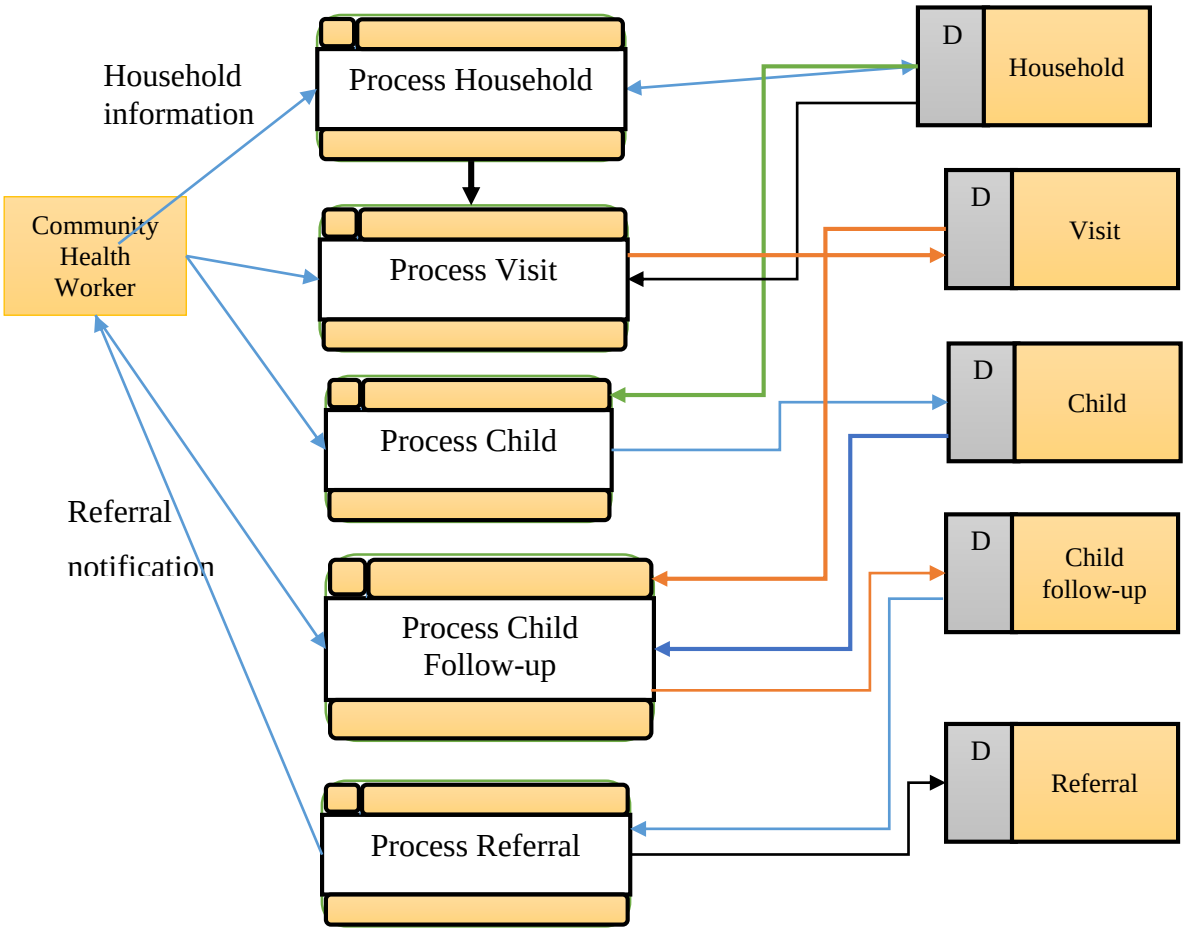


Figure 5 DFD Level 1 Mobile Application

Arrows show data flow from different data stores (D) and external entities. Before creating a household search has to be made in the database to confirm that it does not exist. The same case applies when a child is being added to a household.

Based on the requirements gathered, the system should be able to register households in a community unit. Household registration module is meant to fulfill this requirement. To be able to register visits to a household, observation module was added to the system. Whenever a visit is made to a household this module has to be invoked albeit once for the household per day and by

the same community health worker. It is after a visit to a household is registered that a CHW can be able to add new members of a household and follow them up.

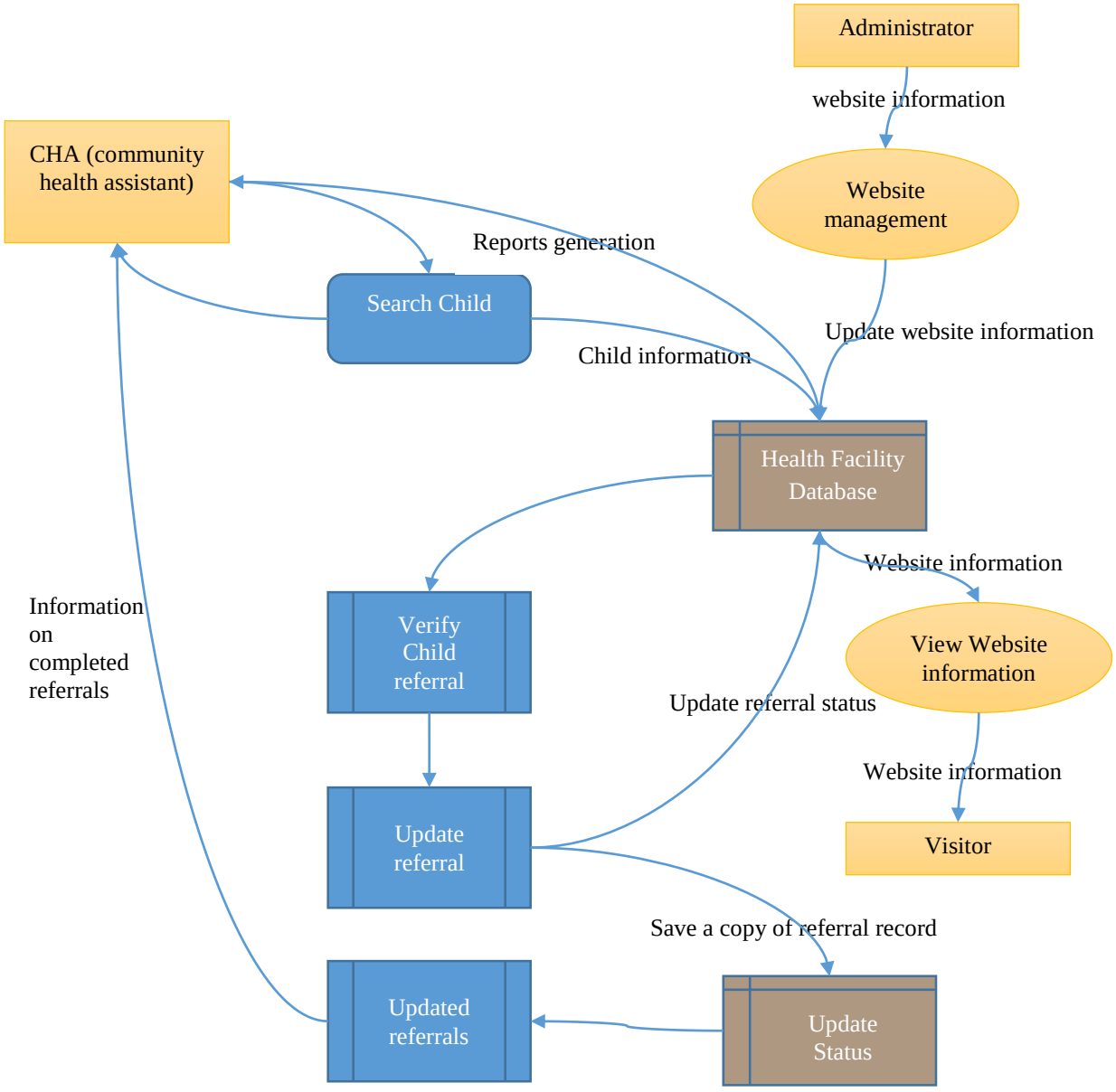


Figure 6 DFD 1 Health facility Website

The system designed and developed should fit into the current workflow and supervision for the community health workers.

User Interface Design

The user interface is modelled using classes that extend the Activity class. The user interacts with the application using the following activity classes;

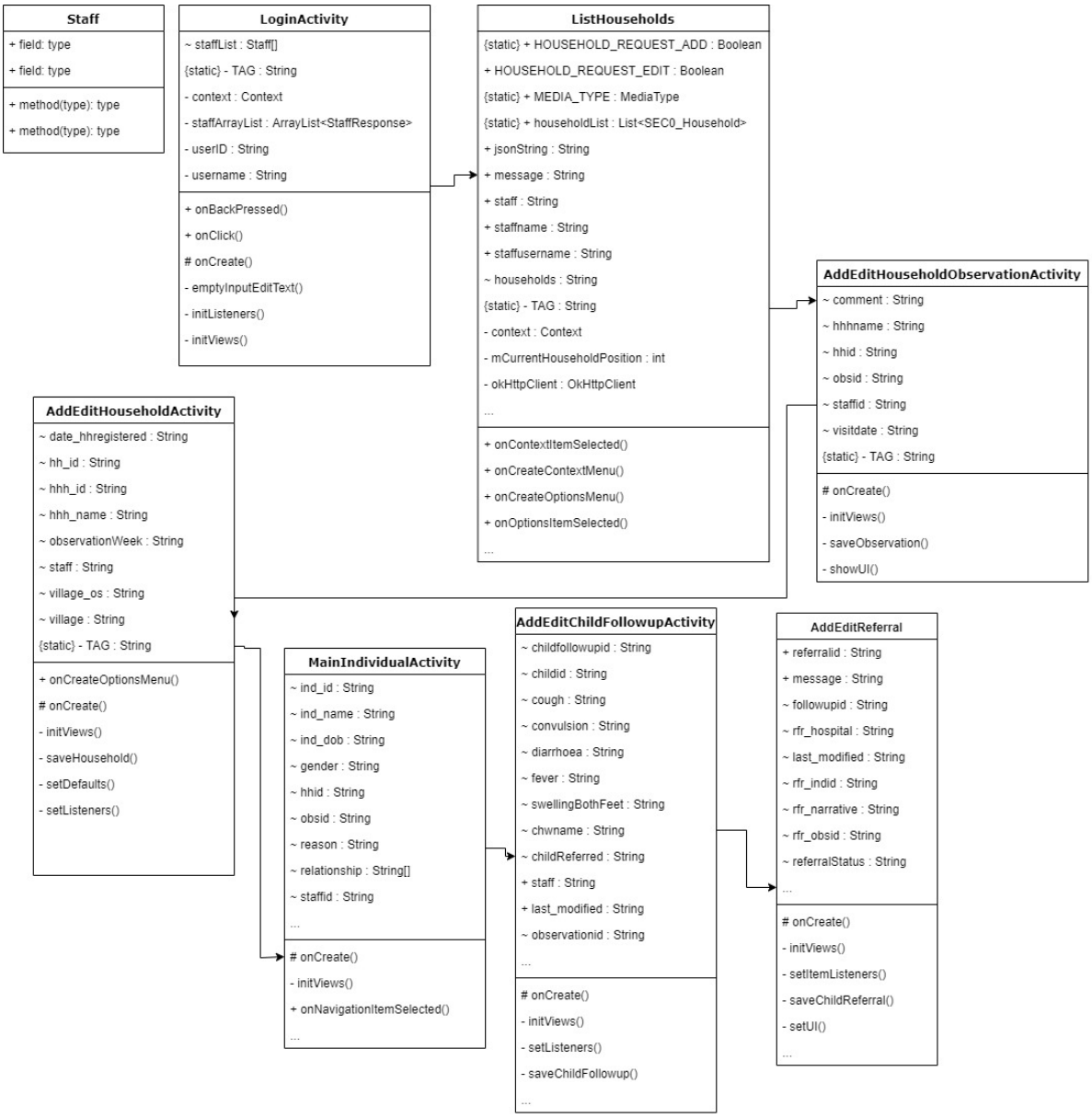


Figure 7 User Interface Activities

Login / Register User

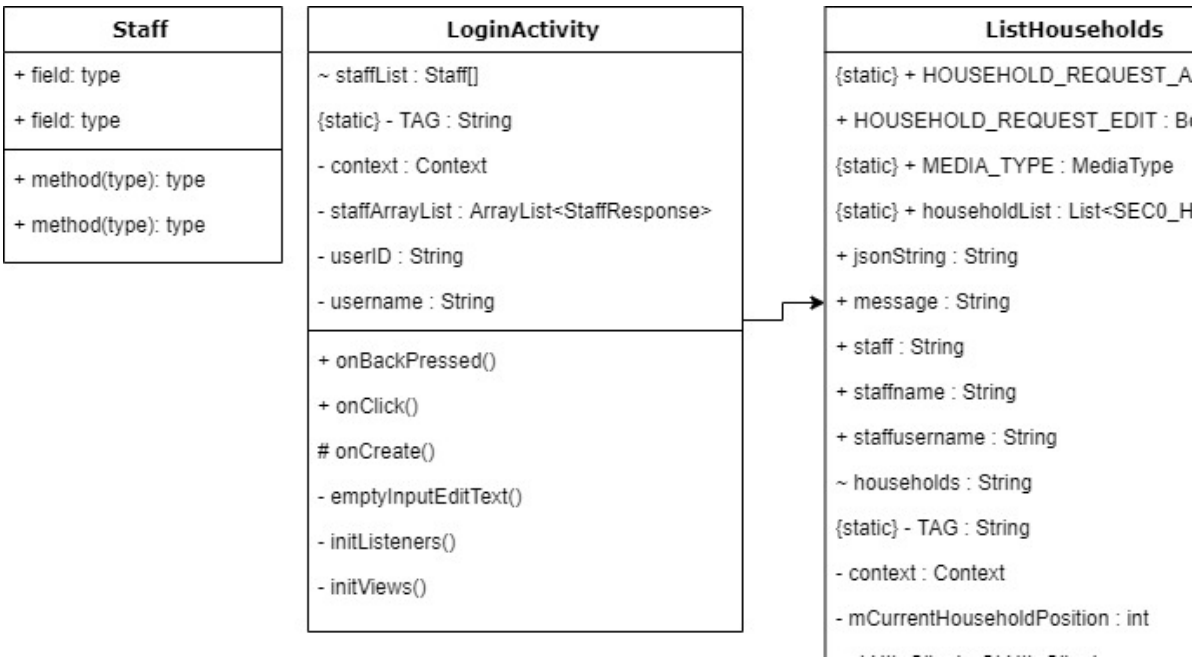


Figure 8 Login Activity

This is the first interface the user comes across after installing the application. They are required to Login to access the facilities of the application. Their user details must be entered in the system and access granted to them. If a person (CHV/CHW) is not in the system, they must be registered by an administrator who will then supply them with the required credentials.

Once a user is authenticated to use the system, they are allowed to access households assigned to them. This activity handles authentication of a user. It is the screen that a user interacts with after the application is set up.

Household Activity

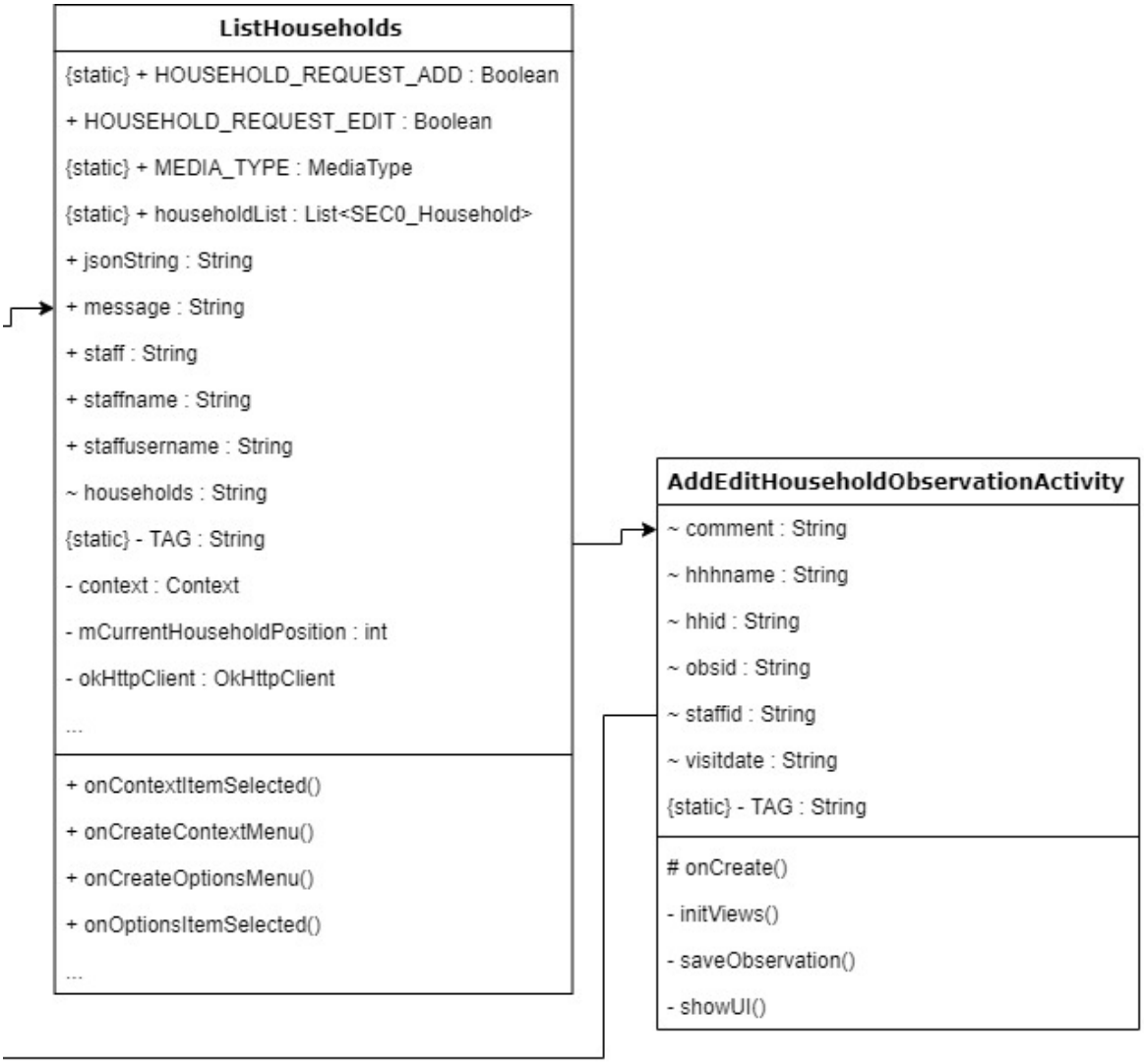


Figure 9 Household Activity

This class handles manual entry of new households or registering visits to the households. This is the screen that you access immediately you are allowed into the system. It is called by the Login activity handled earlier. It is this same screen through which a person will be accessing members of a household.

Individual Activity

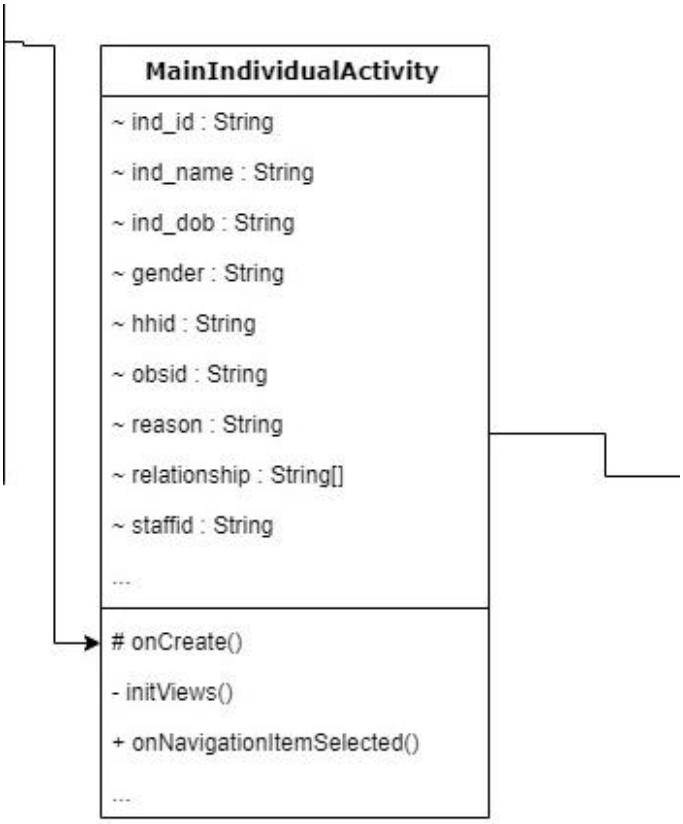


Figure 10 Individual / Child Activity

This is the activity that handles a respondent's information and processes accordingly what is fed into it. It is called by the household activity enabling a user enter or access individual data.

Child Follow-up Activity

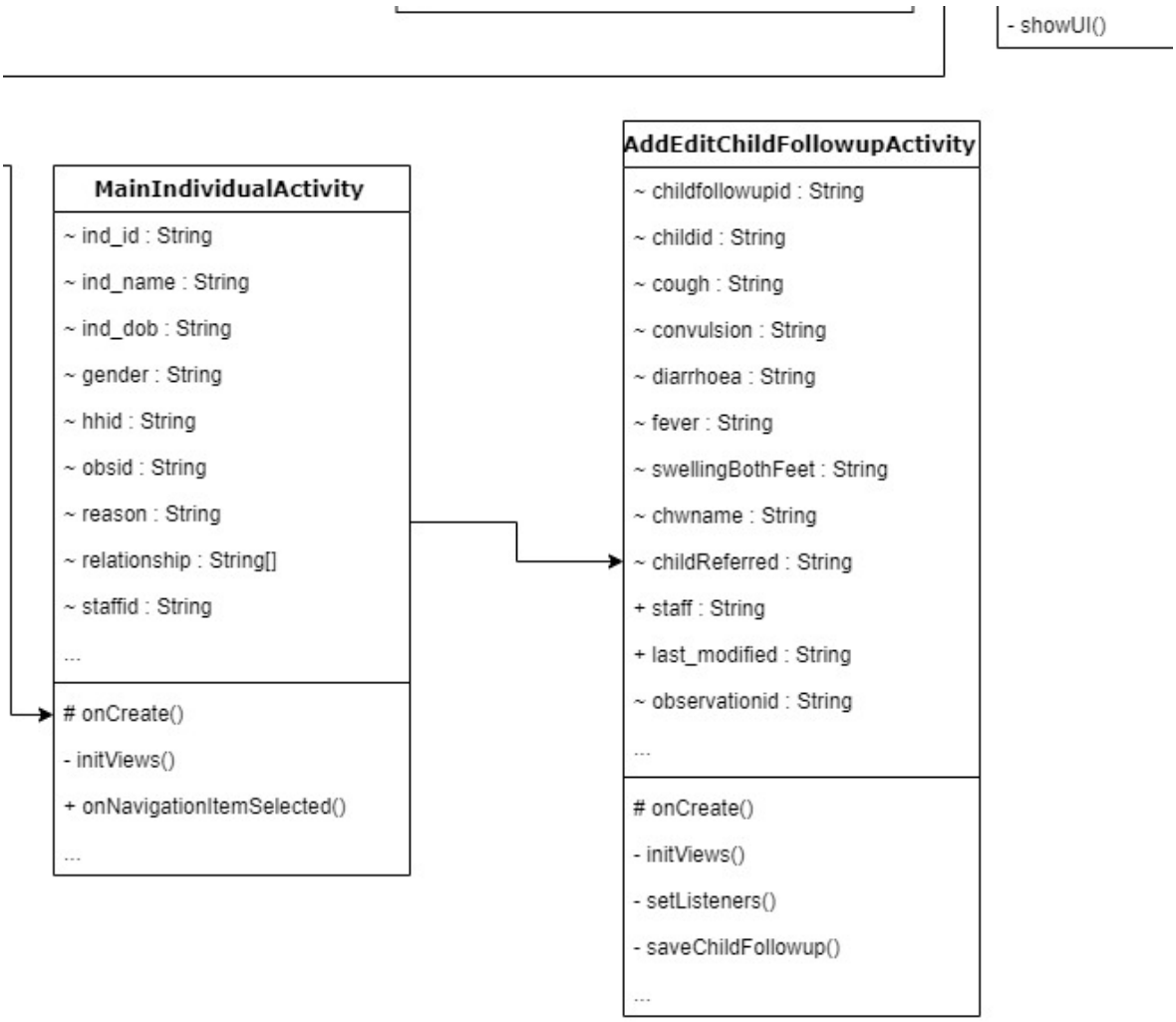


Figure 11 Child Followup Activity

This activity class is called from a respondent's context. It is therefore linked to an individual who is also linked to a household. This class can be invoked only once at every field visit.

Referral Activity

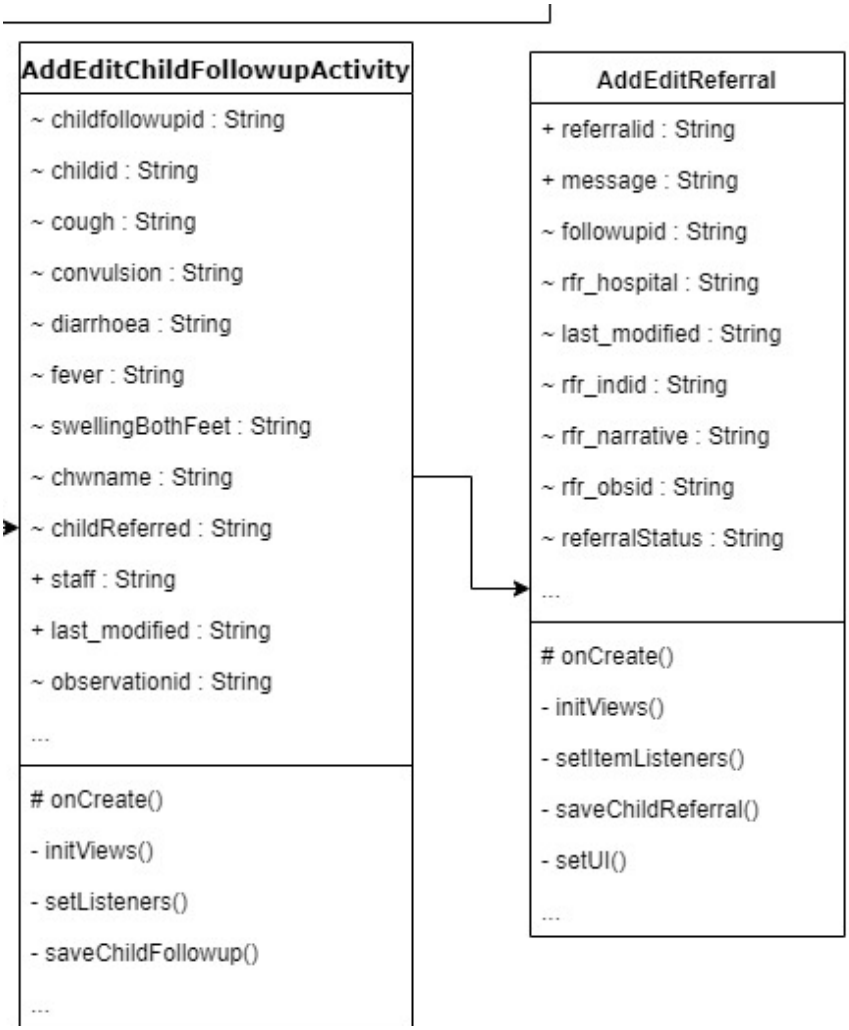


Figure 12 Referral Activity

This class is only invoked when necessary. This is particularly when there are danger signs in a child, that this class is activated.

Process Design

Login and Authentication Process

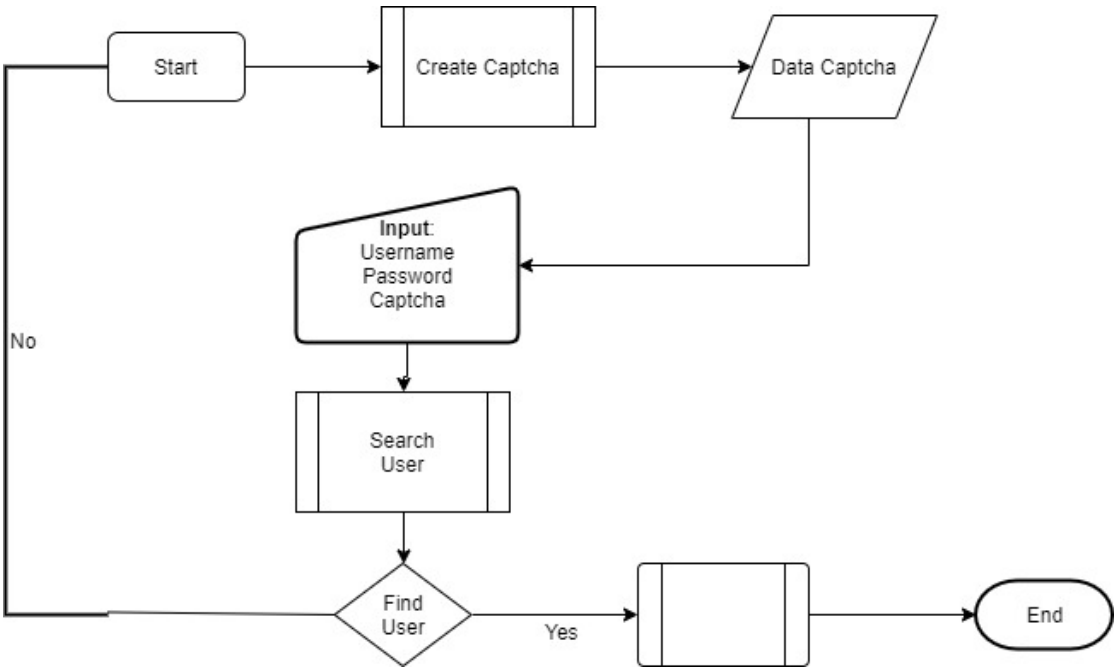


Figure 13 User Login Flow Chart

Database Design

There is a server database created in MSSQL that holds the data being collected by different CHWs. This is the same database accessed from the different Health facilities to access any referrals sent to them. There is an admin who does database administration thus determining who accesses what information and to what level i.e. can they edit or just read data from the database. Security was also key in determining the online database and ensure security and privacy of patients' information.

The database consists of the following tables;

DATABASE TABLE	**DESCRIPTION**
Staff	Contains information on different users and their roles
Room master	This is a system table determining the version of the application being used
Household	This is a table that holds information of all the households in the enumeration area i.e. households of interest.
Household Observation	This table holds information on visits made to a household, the CHW who visited and the date when the visit was made.
Individual	This table holds information about all the individuals registered through the CHW system, whether present or absent at times.
Individual status	This table holds information about individuals in every visit made to the household.
Child follow-up	This table holds information about the health status of the members being followed up by the CHWs.
Referral	Holds information about all the referrals made by the different CHWs. It also indicates whether a referral has been honored or not.
Sync Conversion	Holds information about data types and their conversion.
Sync Delete	This is a system table that holds information about on deletions made in the database.
Sync Log	System table logging database information.
Sync Result	A table holding data on records uploaded or not uploaded.
Sync Tables	This table holds information about tables whose data is uploaded and downloaded.

Figure 14 Summary of tables in the CHW Database

The table above is a summary of the tables in the CHW Mobile database both in the android application and also in the online MS SQL server where all the data is posted.

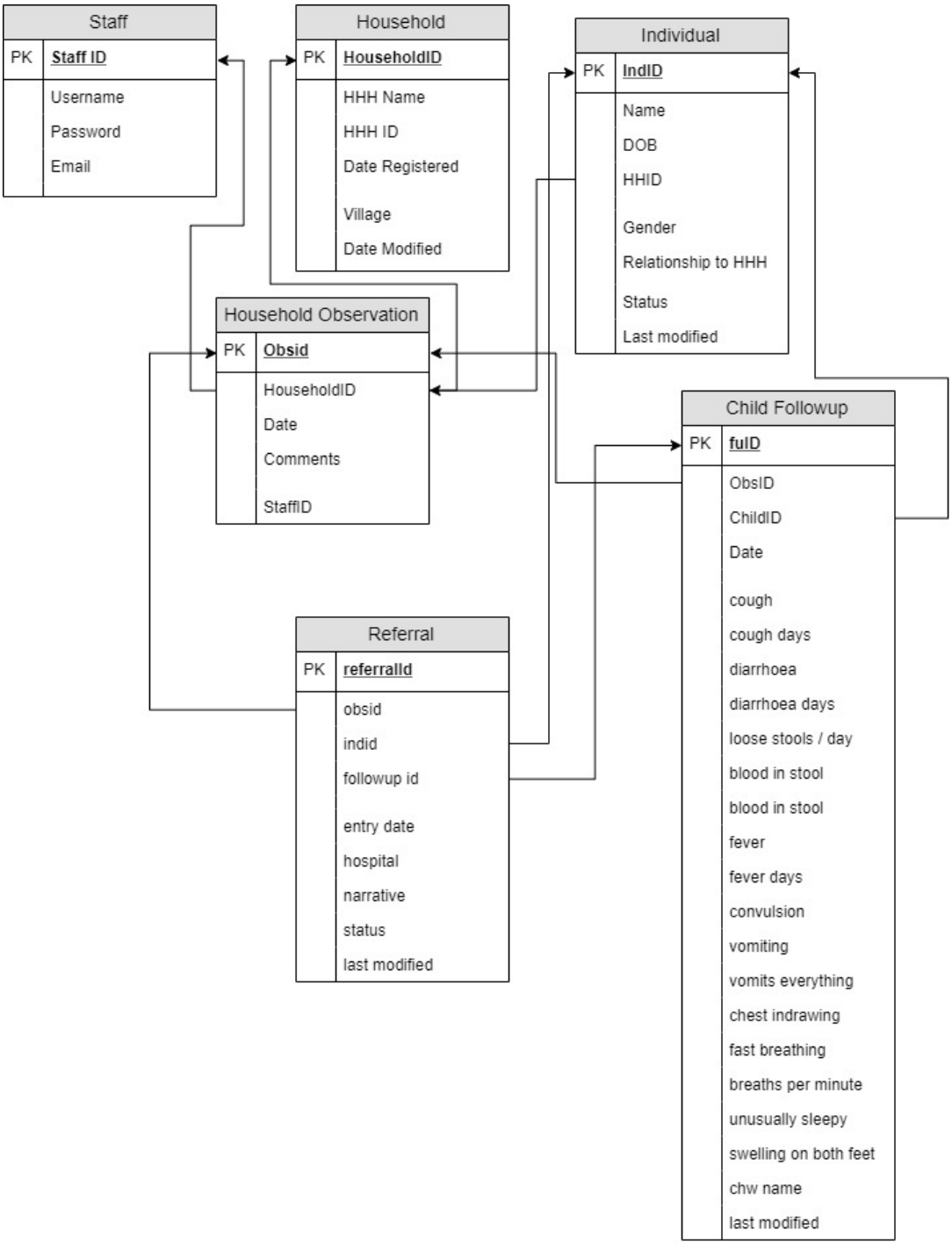


Figure 15 Tables in MS SQL Server Database

Some of the requirements the CHWs had were that the system should be portable, not connected to the internet continuously as that would make cost of running it expensive, the system should be able to register households, visits to the households, filling of follow-up data for the respondents as well as processing of referrals in cases when they are required. The above system was developed with this in mind. They also wanted the system not to be complicated when someone is using it but rather should be easy to use.

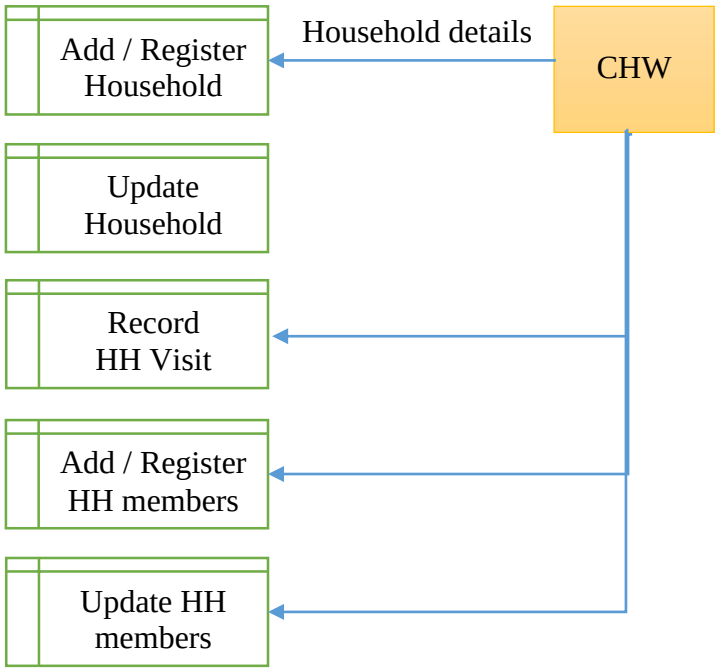


Figure 16 Architectural Design

The above is the constituent modules of the data system that was developed to help CHWs use smart phones to go about their day to day work routines. The application helps in collecting household data (household registration), filling of referral forms for patients needing specialized care (referral processing). Data collected by a CHW is first saved locally in a phones local storage then later transmitted to a central server which is accessible to health facility/clinic personnel in charge of monitoring and evaluation. There is a function (service) that exposes data in the remote

storage and which is invoked by the CHW mobile application on which households to follow up or whether filled referrals were completed.

3.5. System Implementation

Development Overview

The CHW Mobile app and the Health facility website were designed based on the requirements stated in 3.4. A number of libraries were used in designing the CHW Mobile application, CHW database and improvement of user experience. Also worth to note is that since the system was composed of a number of sub-systems (CHW android application, website, local and online database), quite a number of tools were used and are explained below.

Tools (Choice of tools)

The tools and platform to be used were determined at this stage. It was decided that the following tools would be used for developing this system;

- Android IDE was used in developing the CHW Mobile application. Java language was used in defining the classes. XML was used in defining the user interface components e.g. buttons for login, button for saving. XML was also used for defining other user interface components e.g. edit text for capturing user inputs, text views for displaying information to the users, in this case information that
- SQLite is the local database that holds data before it is uploaded to the MS SQL server.
- PHP language was used in developing the web service (scripts) that would access the online database. It was also used in developing the health facility website that an admin logs into to monitor data coming in. through it the admin can also do administration of the website e.g. registering new staff, assigning roles to them. through this website different health facility persons can login using
- MSSQL is the server database where all data collected by the CHWs are collated. The health facility website also visualizes data from the MSSQL database.

Android IDE was used in the development of the CHW Mobile app. Java was the language that was used in the development of the android application and hence the use of android integrated environment as the editor.

PHP was used in the development of the web service. A number of scripts were created to help in fetching and posting of data. Data was saved in an online mysql database, that is the same place where it was being fetched.

SQLite is the database that is being used for local storage. Data captured by the CHW mobile application is saved locally in CHW SQLite database. Every end of the day or after a number of days is uploaded and downloaded to the online CHW MySQL database.

MySQL was used as the online data storage. This online database is accessed by the CHW mobile app using scripts and Uris in form of web services. Any application can access this data as long as it understands JSON format. This is one of the strengths of web services as they can be accessed by different application developed with different languages. Other services used to access the database are xampp web service host.

This was also combined with other libraries to make the application perform optimally.
Net-beans IDE (8.0.2) and Sublime Text 3 Editors.

Below are some screen shots of the platform tools that were used;

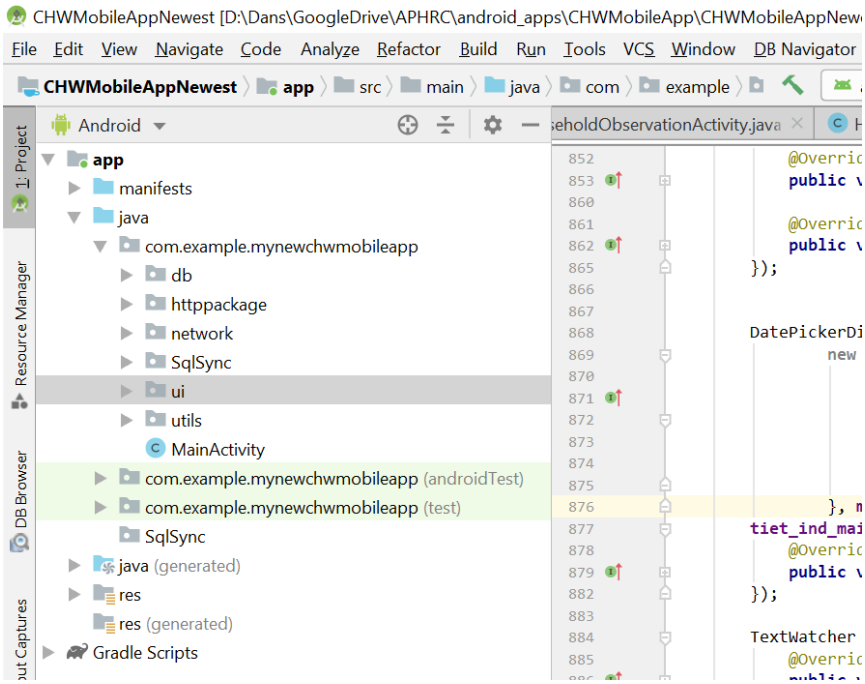


Figure 17 Overview of the Project in Android Studio

The above diagram shows the IDE that was used in developing the CHW Mobile application.

```
<?xml version="1.0" encoding="utf-8"?>
<manifest xmlns:android="http://schemas.android.com/apk/res/android"
    package="com.example.mynewchwmobileapp">

    <uses-permission android:name="android.permission.INTERNET" />
    <uses-permission android:name="android.permission.ACCESS_NETWORK_STATE"

    <application
        android:allowBackup="true"
        android:icon="@mipmap/health_aspects_round"
        android:label="CHW Mobile App"
        android:roundIcon="@mipmap/ic_launcher_round"
        android:supportsRtl="true"
        android:theme="@style/AppTheme">
        <activity
            android:name=".ui.activities.ViewIncompleteReferrals"
            android:label="ViewIncompleteReferrals"
            android:parentActivityName=".ui.activities.ListHouseholds"
            android:theme="@style/AppTheme.NoActionBar">
            <meta-data
                android:name="android.support.PARENT_ACTIVITY"
                android:value="com.example.mynewchwmobileapp.ui.activities.
```

Figure 18 Overview of the AndroidManifest.xml file

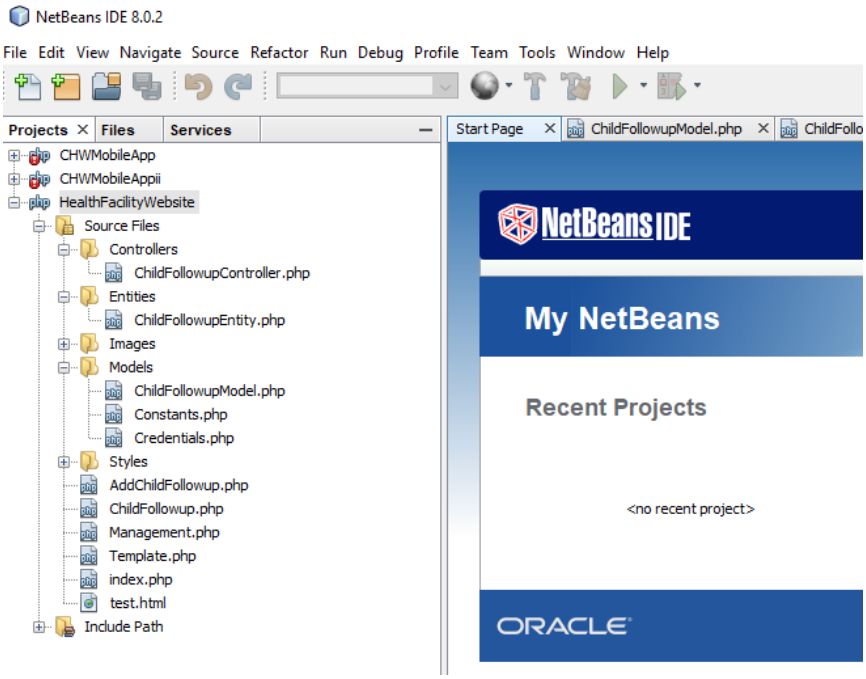


Figure 19 NetBeans IDE

Net beans was used to develop the web service side. Specifically, slim-PHP framework was used. Both the Health facility component as well as CHW Mobile App web service were developed using PHP and editors being net beans and sublime text 3.

This step entailed defining classes and their properties that would make up the system:

1. Model - classes,
2. Data access objects (DAOs), coming up with use cases for the project as well as the designs.
3. Addition of necessary libraries
    a. Room libraries – abstraction of SQLite database
    b. Retrofit – for serialization of objects on the networks
    c. OkHttp libraries
4. Views - User interface definition.
5. Model View layer – classes involved in holding data for the user interface
6. Repository – responsible for holding data from both the local database as well as the data from the internet (MySQL database)
7. Adding of security module (login access and registration of users)

8. Synchronization module.
9. The online module for access by the Health Facility personnel.

All components of the system responsible for business logic, rules and processing were defined. These items ranged from user interface files, controllers, classes, and libraries needed.

Classes (Java Files)

This step involved defining all the objects (classes, interfaces), fields that were needed in capturing data from the households, neonates, children and their mothers. Other fields and constants that were used in running the algorithm were also defined.

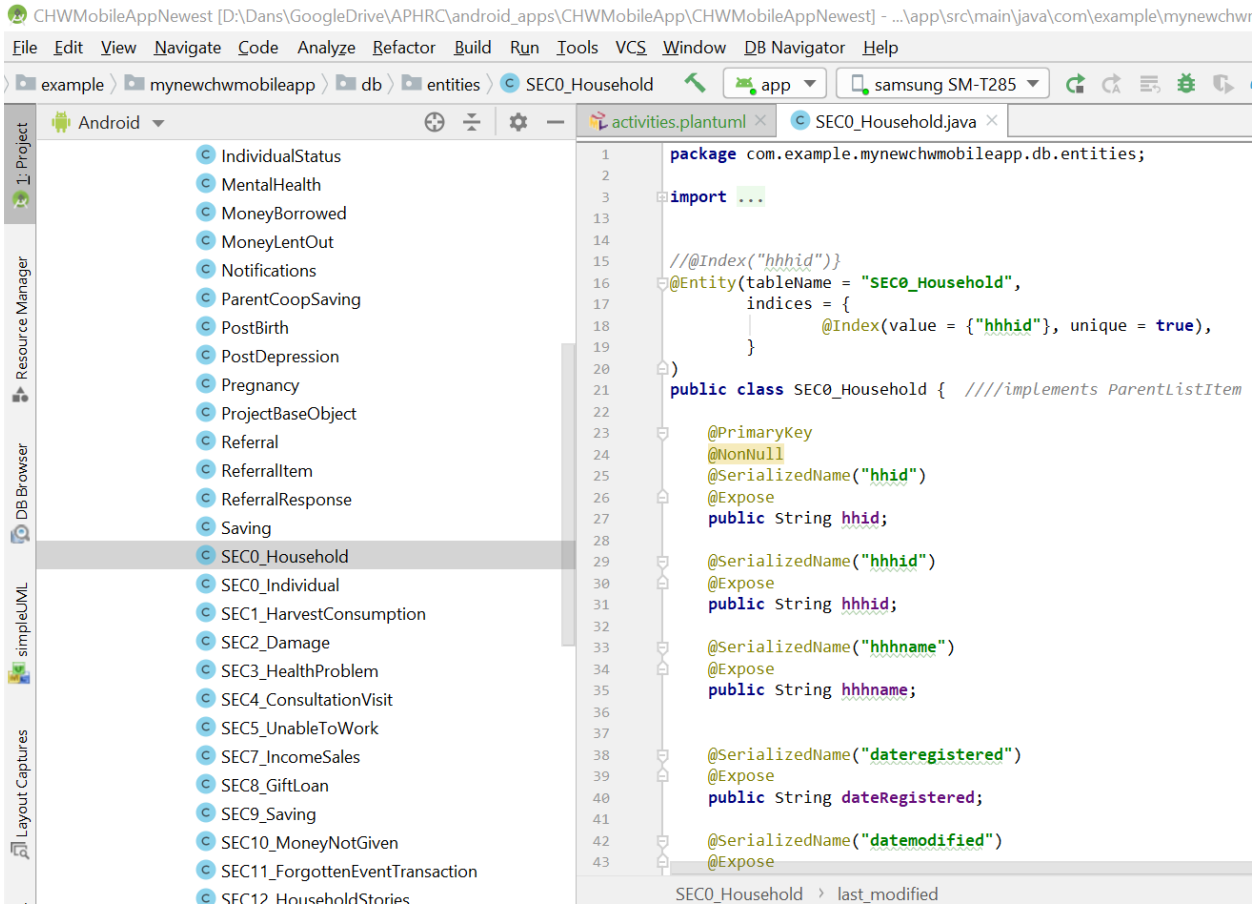


Figure 20 Java Classes

A number of activity files were also added to the application and linked to the models and activities through which a user interacts with. Below is a snapshot of the layout files that were defined in XML.

XML files

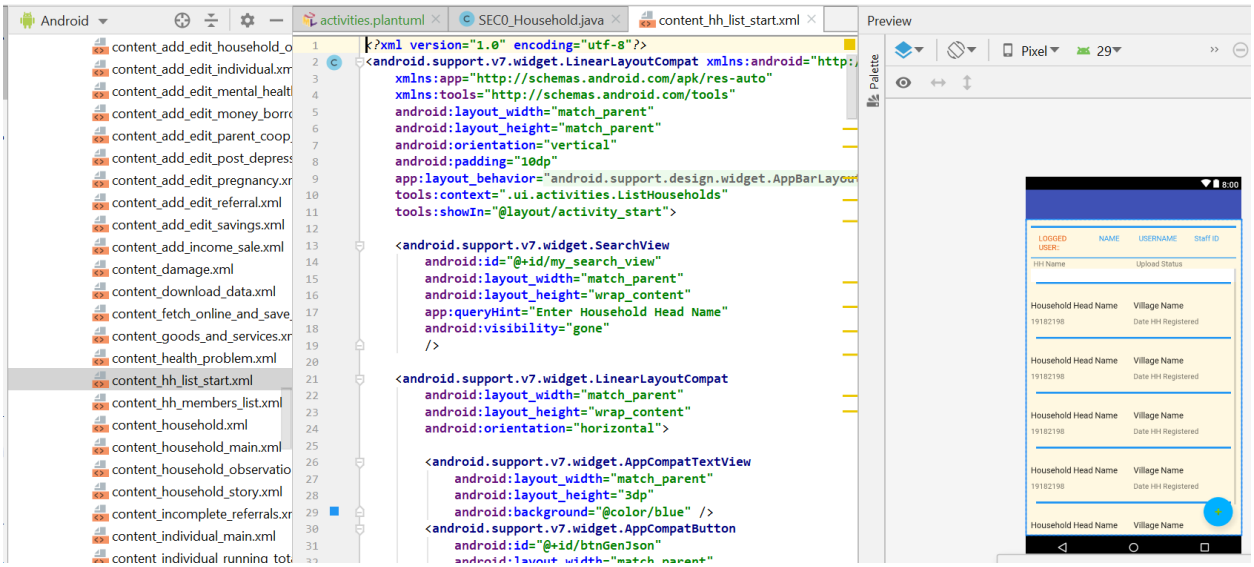


Figure 21 XML Files

Definition of the business logic (algorithm) through which data is run against was developed. The data collected using the above fields was run through this algorithm to determine if there is any urgency in handling a case or if a case has any special characteristic.

The breakdown of the components is as follows:

1. User Interface components
2. View Models
3. Live Data libraries
4. Repository
5. Room Database
6. Remote database and associated retrofit library
7. Web service functions
8. Health facility website

Each class only keeps a reference of the class or classes directly below it and together they form a logical model containing primary keys, foreign keys and their attributes.

An external model was developed to show potential users of the system who are CHEWs, CHW and Sub-County Focal Persons and on the other end health facility personnel. This was to ensure that there was a common understanding amongst the CHWs, patients, facility owners and the government.

Through the analysis done at the previous stage, it was noted that there are quite a number of needs that had to be addressed with a view to make smooth the CHW work. The application has an algorithm that processes danger signs, processes referrals and determines if a case has completed a referral where it is needed.

View Model Layer

Its role is to provide data to the user interface and also key survive configuration changes. In a layman's term, a view-model is designed to hold and manage UI-related data in a life-cycle conscious way. It gives the ability to separate UI implementation from application data ("ViewModels : A Simple Example – Android Developers – Medium," n.d.). Instances of a view model survive configuration changes, such as screen rotation. An activity is usually a poor choice to manage app data. It is the intermediary between the repository layer and the user interface. It is also used for sharing data between fragments and is part of the lifecycle library. It fetches data from the repository which as stated abstracts access to multiple data sources or multiple back-ends (data storage systems).

Local Storage System and Repository

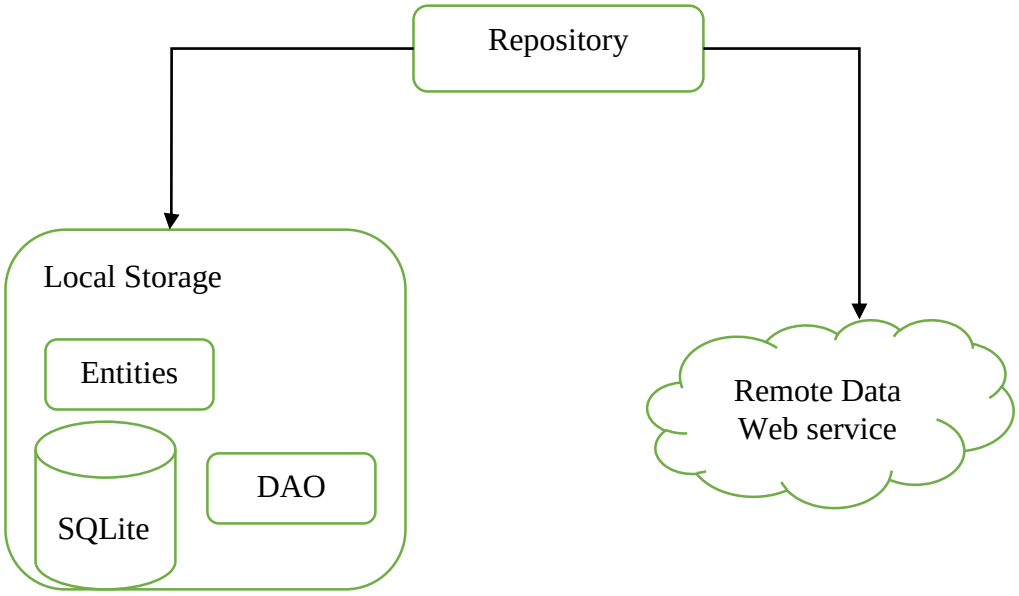


Figure 22 Data and Data Access Classes

Locally data is stored in SQLite database which supports the usual SQL select statements and relational database model. Since from time to time there is need to collate the data in the online database and the local database, the need to develop a repository which is essentially a class that abstracts access to multiple data sources (it collates data from the online storage with the data stored locally).

Through this screen a user is able to edit an existing child record or add a new child for a household.

3.6. Testing

Testing for the components of this project were done at different levels as indicated below with collaboration with other software developers, the research team, quality assurance team from APHRC as well as Community Health Workers based in Baba Dogo community unit in Ruaraka Sub County.

At a high level two types of testing were done;

1. Client-side testing – testing on the client side was primarily done using tablets. It entailed creating a dummy household, adding members to the household, doing different follow-up and

invoking a referral for one of the members. The following screen shows the sequence of events that were used to test the CHW mobile application;

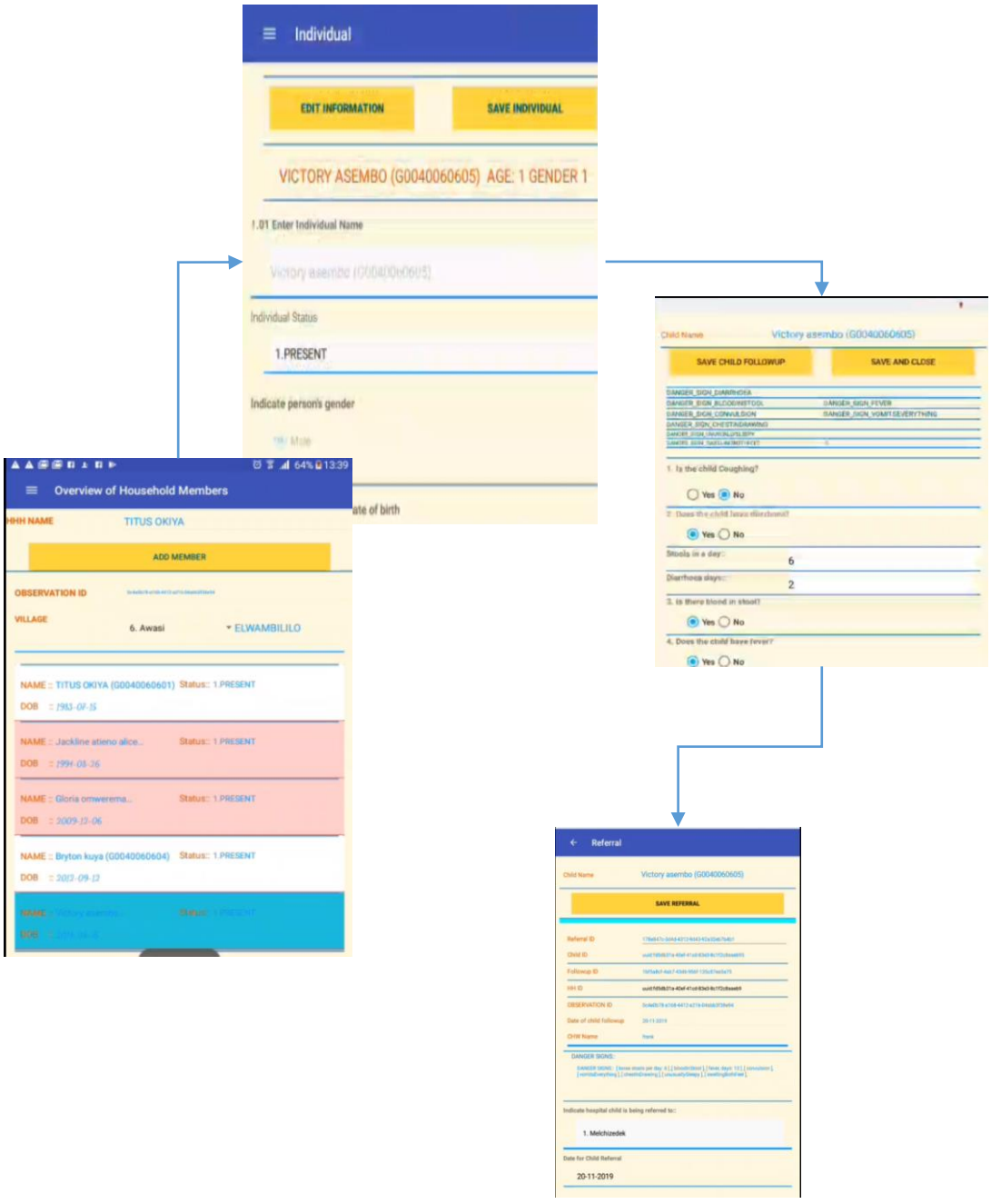
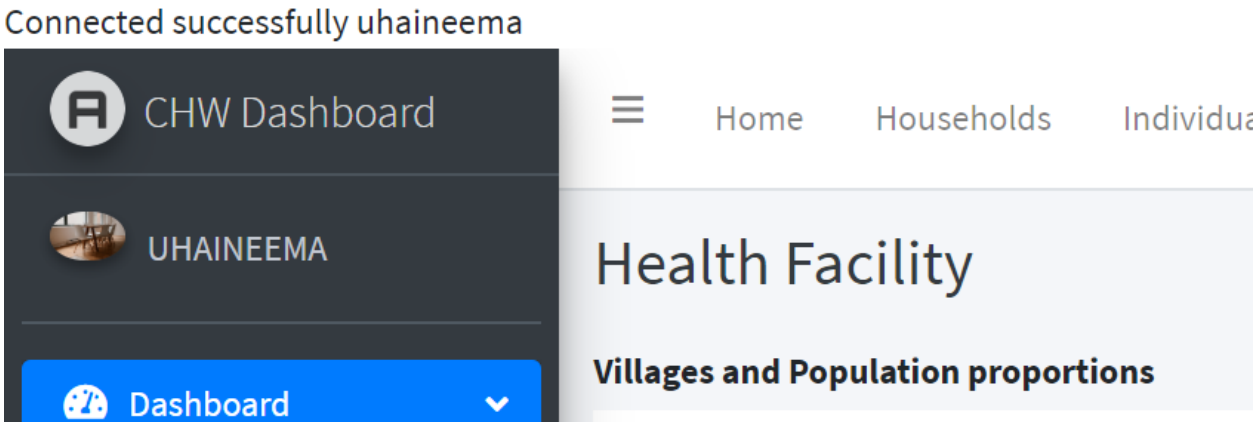


Figure 23 Sequence for doing a Followup

The above picture depicts what usually happens when a user is authenticated by a system and thus allowed to access the information there-in.

2. Server-side testing – this was done on different web browsers and pinging the server.



the above screen shows authentication of uhaineema user to access information drawn from the server.

Types of Testing done on CHW Mobile System were, flaw testing, data flow testing, data set testing, unit (component) testing, system testing, integration testing, white box testing, regression testing, automation testing, user acceptance testing, performance testing. To successfully test the website a dummy hospital profile was created and used in accessing the data therein.

a. Unit test / Component testing / functionality testing

Every building block of the application was tested to verify that it was doing what it was meant to do. The module for registering household successfully captured household information and was saving accordingly. Whenever a CHW visits a household s/he has to record that visit. In the application it is called observation. The module for registering visits was also tested for correct functionality. Module for registering different members of the household was also tested to ensure that it captured data for an individual and the data was being saved successfully. The other modules that were also tested are; child follow-up module, referral module and module for uploading and downloading data.

Objectives of CHW Mobile App component testing

- We verified the input and output behavior of the system. Input included what the user was feeding into the system and output as the information or processed data from the system. This

step helped in knowing what information needed to be captured by the system and hence add properties or remove already existing properties.

- We also verified usability of the following components; households list, observation, member registration, child follow-up module as well as referral registration module.
- The other aspect that was looked out is whether it was comprehensible to use the software. Was it difficult to know what a component was supposed to do?
- The other testing that was done on the system was the different states that a component was going through.

b. Integration test

After testing the different units/components separately, it was now time to integrate them into a single unit in a process known as System Integration. Then the single whole unit had to be tested to verify that the different units were working together as should be in a process known as integration testing. This was to ensure that the CHW Mobile application worked well. This included checking whether the different modules linked well on some variables e.g. Individuals belonged to a specific household, and that all the sections had a link to the visit module.

Objectives of integration testing

- To ensure that the whole system functioned as expected after combining the different components.

c. System test

At this level the CHW Mobile application was tested to try break the system. It was meant to see if there is any error that would cause the system stop functioning.

Objectives of system testing

- Smooth functioning of the CHW Mobile system which is a combination the Mobile app and the health Facility website.

d. User Acceptance Testing (UAT)

It is validating a product in a real setting by the intended audience, it is done by another person on someone's work for the purpose of accepting it (Otaduy & Diaz, 2017; Pandit & Tahiliani, 2015; Watkins & Watkins, 2009). User Acceptance Testing is usually done to help develop confidence of the user in the developed software product (Leung & Wong, 1997; Pandit & Tahiliani, 2015). This is the point at which the client/user validates the solution to find out whether it satisfied their business needs. Issues identified at this stage are rectified accordingly before a certificate of acceptance is handed to the software development team.

Objectives of user acceptance testing

- Validate that the system fulfills the system requirements specifications.
- The system has fulfilled the system requirement statement.
- Whether it varies from what is defined in the contract.

Importance of Testing

Testing a software helps assess the quality of the product developed (Lewis, 2008). It also helps ensure that the needs of the client are satisfied. This also helps in reducing bottlenecks and handover times.

The following section discusses the testing that was selected for the development of CHW Mobile App, Web service and Health facility website. Agile UAT was chosen as it enabled exhaustive generation of all possible / scenarios that could come up in the field and help the product in handling them. This was enabled by the great collaboration between the software developer, fellow software developers, two research officers of APHRC and Community Health Volunteers (CHVs) from Baba Dogo, Ruaraka Sub County of Nairobi. The next step that was taken was evaluation to see if the acceptance criteria was fulfilled or not, through which decision tables were developed. The following are the different types of testing that were conducted on the system (CHW Mobile Application, Web service and Health Facility website);

- Usability
- Linking was okay
- Simulated environmental dependencies (databases, file systems, networks, queues)

- Different components run successfully in isolation, in case of failure it was obvious where to look for the problem.
- Tests were running on the different machines.
- Clearly reveals its intention i.e. someone else can look at the code and tell what it does without being given an explanation.
- Navigation evaluation (around the system)
- Interaction with the user (that a user was able to know where they were in the system)
- Application performance (load time, application startup time, low processor performance, low RAM performance)
- Consistency in behavior (across all test scenarios,)
- Strengths and weaknesses
- Engagement to users' interests
- Graphical content evaluation
- Evaluation of user experience

Each unit was developed and tested for its functionality a process known as Agile Unit Testing. In summary this step involved programming and writing of code for the different functions that the CHW mobile application will have. Testing started to be done early and often in the SDLC a process known as "continuous testing", to ensure that quality of the product was maintained in every step of the delivery cycle.

3.7. Integration

This stage involved bringing together the different components / functions / modules of the system to make a whole. The entire system was then tested for any faults or failures, which is after having tested the different components separately and establishing that they were fault proof on their own.

3.8. Deployment of the system

The developed system is ready and has already been installed in the phones of some stakeholders i.e. Research Officers and CHWs.

4. CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter is the heart of the entire project as it includes the analysis of what was done and the steps taken to achieve the results. The results are organized according to specific objectives.

4.0. Tests and Results

The first objective was to identify existing methods through which CHWs register households, record household information for existing ones, do follow-ups, identify danger signs and process referrals in areas assigned to them. This objective was met as methods they use were identified and found out that, they use Ministry of health registers provided by the government for their daily work. The work performed by a CHW is not limited to what has been mentioned, sometimes they are engaged in activities initiated by different players in the community and includes, community mobilization, sensitizing the community on different programmes by the Government or Non-governmental organizations, participating in community outreach programmes. They use MOH513 to register new households and information from them and includes number of household members, household composition in terms of gender, age and general characteristics. This book for registering households is used only twice a year. They also use MOH514 books for frequent household visitation where they record different findings they get in the households like household individuals illnesses, new visitors in the household, aging people in need of healthcare. Additional information collected weekly includes; information about newly pregnant women, elderly people in need of healthcare and follow up, children under the age of 5 years, and child morbidity (diseases among young children). Whenever they encounter children that are sick, it is up to them to determine whether they need to be referred to a health facility or can be treated at home using readily available medication that they are allowed to dispense. For cases that need referral, they use MOH100 register. For cases that have danger signs and cannot be managed at home, the referral process is invoked.

The second objective was about building the application that mitigates weaknesses of existing manual process of household registration, follow-up of household individuals', danger sign identification and processing of referrals. Architectural designs were drawn that represented the entire CHW system. There was back and forth between the researcher and stakeholders of the

system in the course of development of the solution. Through this feedback, improvement was suggested and the system improved. It was composed of different components which were then integrated to form the bigger whole. The design was then used to build the proposed system. The system was tested by different stakeholders who included Research officers and other software developers. User acceptance and functionality testing was also done. This was done to ensure that the system was user friendly while functionality testing was to ensure that the system did what it was meant to do. The application is now fully developed and works as expected. It was confirmed that the system helps circumvent the challenge of requiring even a new CHW handle any case in the field. All they are required to do is capture data for a case, then the system helps in determining if the case has any danger signs and thus needs to be referred. The system also helps in processing referrals if a case is complicated and requires professional medical attention or services at a health facility. The system also gives information on steps to take based on the sickness signs identified in a case. Below are test results of the application and evidence of what was arrived at through this whole process;

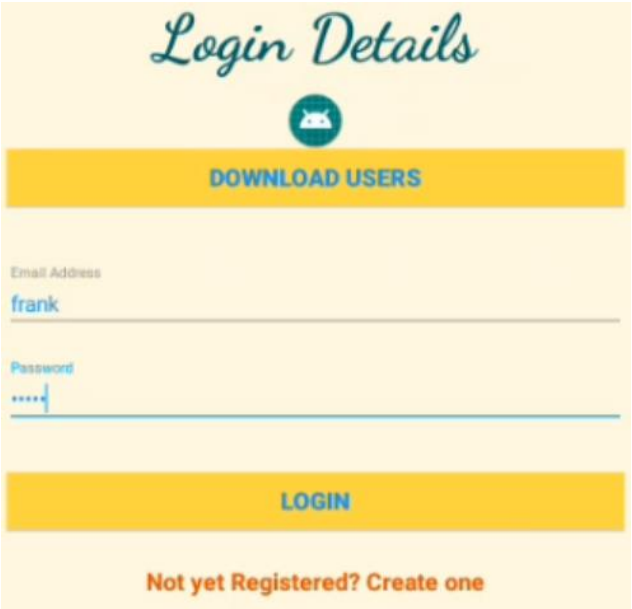


Figure 24 Login Screen

Through the above screen users were authenticated to use the functionalities of the system if the administrator had already registered them into the system. The same screen also barred users that did not have credentials from accessing the system.

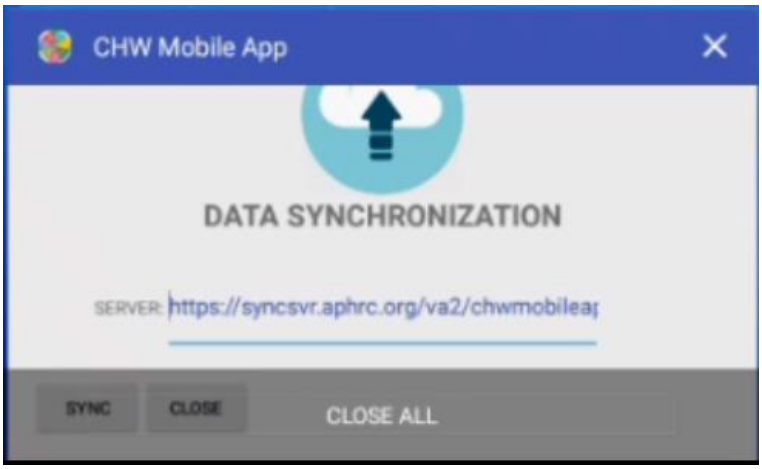


Figure 25 Data Synchronization Screen

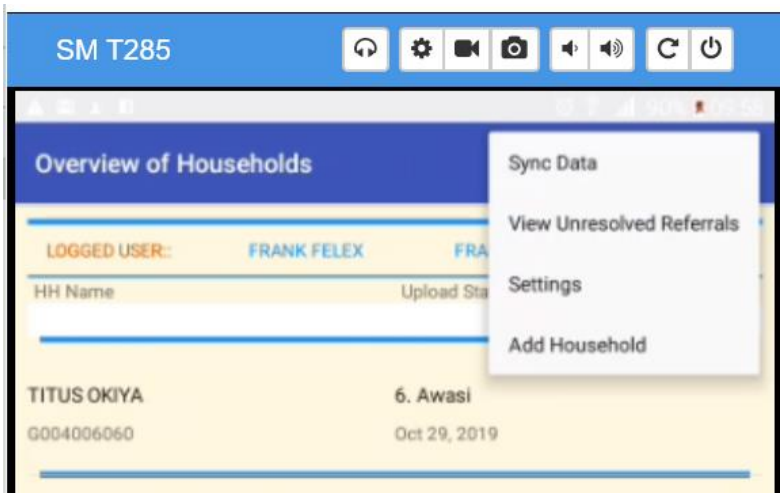


Figure 26 Households List

Through the above two screens users were able to access synchronization functionality for uploading and downloading of data as required.

Figure 27 Allocated Households

The users were also allowed to access only households allocated to them or households they themselves registered. Through this same screen a user was allowed to register new households and consequently access them for further data capture.

Figure 28 Household observations

The screen above had been developed to help users register visits to households. It was tested and confirmed that it allowed for the said functionality. A user could not be able to create / record two visits for the same household on the same day which was one of the desired functionalities of the screen.

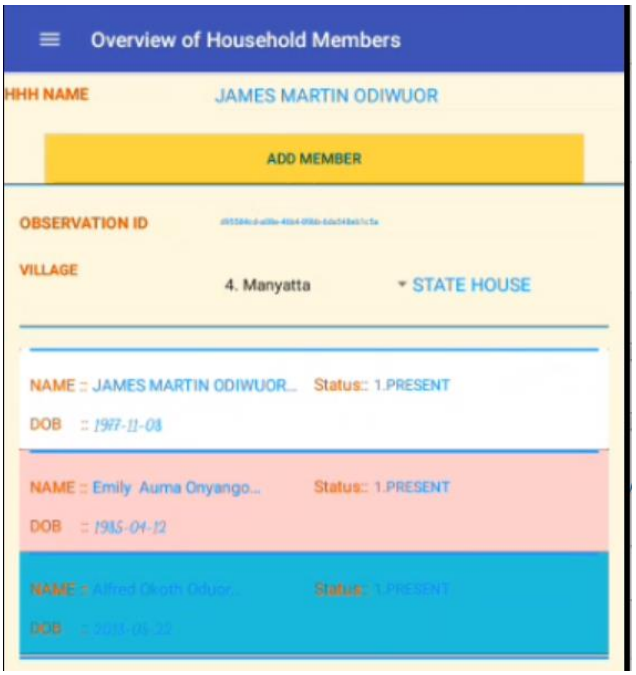


Figure 29 Household Screen

This screen enabled a user to view members of a household. They were also allowed to register new members and view them for further action e.g. recording extra information not captured or editing of information in the system.

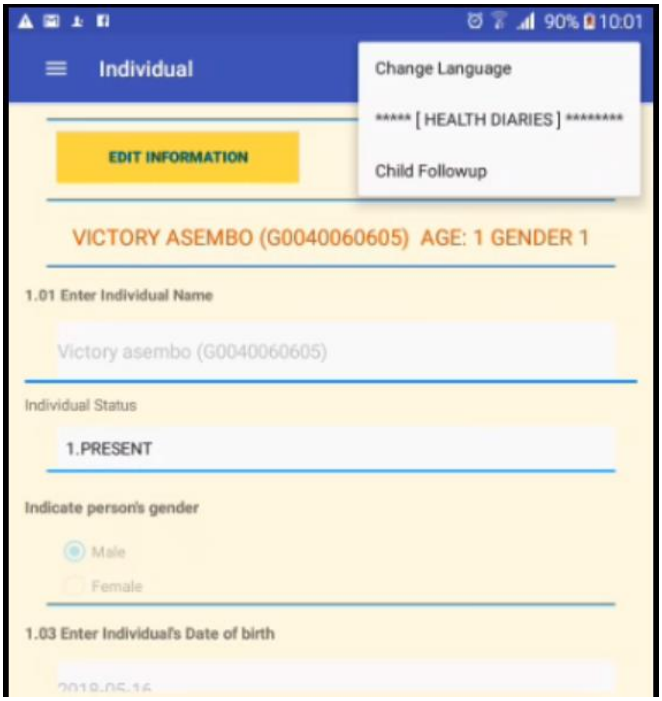


Figure 30 Individual Screen

Users were also able to collect health information specifically for children by invoking Child Follow-up functionality on the top right hand corner. By selecting the functionality, they were able to launch a follow-up form and

hence capture health indicators for the person.

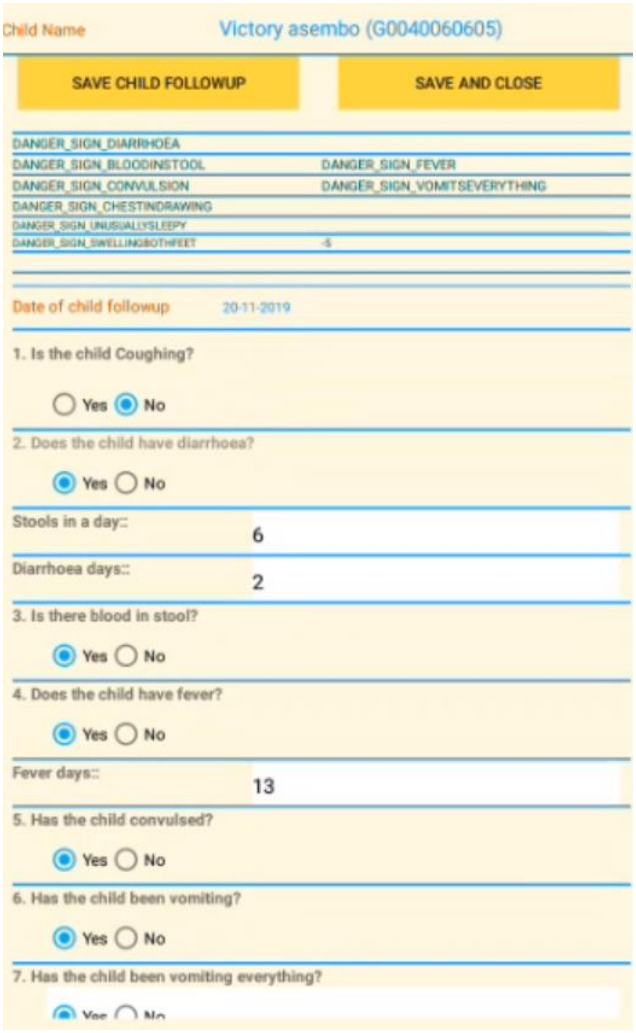


Figure 31 Child Follow-up Screen

The screen enabled capture of information about a child as anticipated, through the same screen danger or sickness signs were evaluating. In cases that had danger signs the screen provided a functionality for referral and therefore confirming that it worked as expected.

Figure 32 Screen to Invoke referral Form

Figure 33 Referral Screen

Through the above screen users were able to refer a child to any health facility provided in the system.

A web application was also developed that helps link a health facility with community health workers in their catchment area. Whenever a referral for a case is invoked the concerned person at the health facility is able to view all the referrals sent to that particular health facility. As long as the referred child or person hasn't been brought to the health facility completing the referral, the referral remains as incomplete. The CHW who referred a case can then go back to the community and follow up with the case to find out the reason(s) why they didn't honor the referral. Through this step the third objective was met which was about developing a web system that enhances the link between the health facility and the CHW. In essence this provided a communication channel between a health facility and CHWs linked to it.

Below are the results for the website;

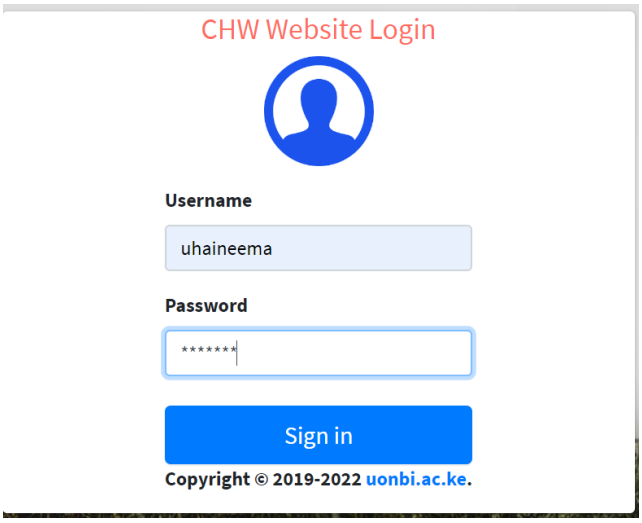


Figure 34 Website Login Screen

The above Health facility website login screen allowed users that had been allowed by the administrator to access information based on their roles.

Successful login took users to either health facility dashboard or a general dashboard where they could view information as required.

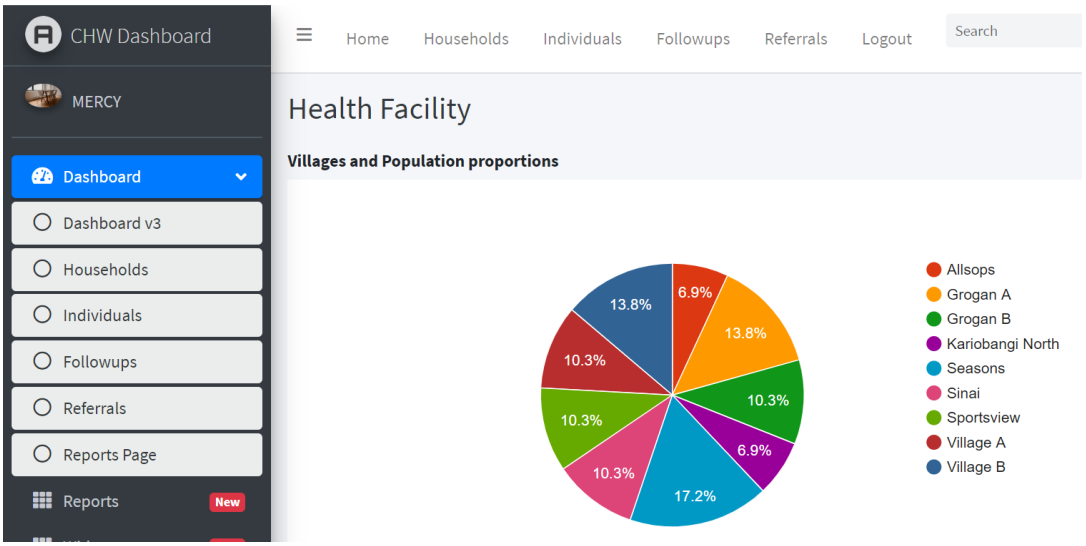


Figure 35 Website Dashboard

The last and not least objective was achieved as quite a bit of testing of the CHW Mobile application was done by a team of software developers, research officers, CHWs and also

Community Health Assistants. The Web Interface (application) was also tested to ensure that persons from different health facilities would not access information not sent to their facility. The server was also checked to ensure that data sent to it was being received as expected.

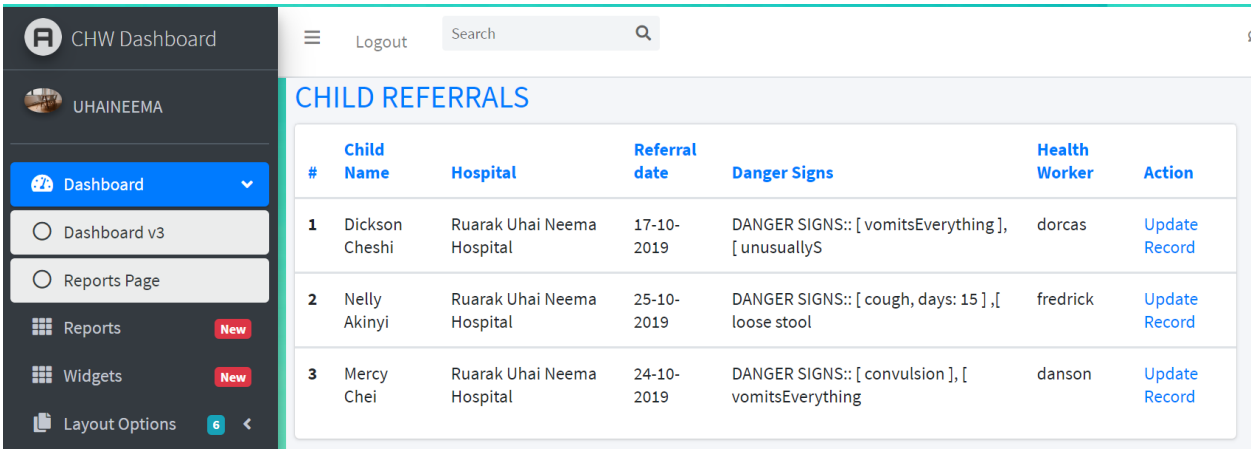


Figure 36 Website landing Page

The screen above shows the referrals that were sent to this health facility. Through this a CHA is able to track children that have been brought to this health facility or the ones that are yet to honor the referral.

Testing Results

We now discuss the results of our evaluation of the CHW Mobile application and the Health facility website. We also report the users' experiences using the CHW Mobile application and the CHAs experience using the Health facility website.

CHW Mobile application

Usability experiences

Part of time was used downloading the android package (apk) file shared through email and an alternative shared on a website. It took such a short time to set up the CHW mobile application in users' smart phones. Some of the comments received from users is that of making the application less complex. Navigating around it might be challenging to new users, however with time this challenge is alleviated.

Experimental results

Installation was successful in phones that were of android version 5 and above and not the ones with lower versions. Based on these results the development of the CHW Mobile Application was successful.

CHW Health facility website

Usability experiences

Since this is web based, there was no client-side setup, all a person needed to do is open any web browser like google chrome or Mozilla Firefox, and use provided credentials to access resources in the website. Access to the website resources was only granted to people with credentials. The output given by the website was human readable and no effort was required from the users to interpret the results.

Experimental results

Based on the above findings, development of the health facility website was successful as it fulfilled the requirements gathered from users of the system i.e. CHAs. CHAs were able to login into the website using provided credentials and only view cases referred to health facilities attached to them. The administrator also tested the website by login into the website and was able to access all areas they are allowed to. An administrator was able to handle user management as expected.

4.1. Discussions

The development and use of mHealth solutions helps healthcare providers in giving healthcare and help in providing health care services, especially in low resource settings. MHealth is able to provide advantages of convenience and efficiency compared with other technologies. As the adage goes, “prevention is better than cure”. MHealth is able to improve literacy of CHWs, better degree of access to healthcare services, extend outreach and engagement at the community, as well as in the provision of information. Other areas that mHealth can really help in are, call centers dealing with health, telephone services, identifying the right medicine, reminding patients about appointments and treatment compliance, keeping of patient records, helping in decision making through data entered in them and also in data collection.

As a highlight, there are a number of issues and qualities that were brought out regarding mHealth solutions. There is need to develop systems that embody the following very important qualities; prompt use of information entered in making decisions, a system that can help in creating linkages with health facility data and also systems that are error free. Such systems would help in making appropriate and correct conclusions based on data that is being fed into them.

Providing linkages with the health facilities means that patients can be able to communicate with health professionals when there is need. Thus, mHealth solutions that will provide that link between patients and healthcare providers/professionals will be very beneficial.

In the course of study, a number of limitations were also identified that are potential barriers to mHealth, namely, data security and privacy issues, issues with funding of such projects, power supply in the different communities or areas in the country, smart phone penetration among the communities of interest. Another issue that cuts across mobile technology is its reliability.

4.2. Conclusion

Findings from the project showed that CHWs rarely use the data they collect to make decisions. They rely on their own expertise in the case of experienced CHWs, while this proves to be a daunting task for new CHWs. It was found that the use of mobile technology and mHealth would help in the improvement of health systems and by extension health care service provision.

It is considered that the main objective of this project, which was to develop a CHW mobile Application that would help CHVs better perform their day to day work was technically accomplished.

Through optimization of mHealth capabilities, better solutions can be developed which would eventually help in achieving the three main desirable qualities of mHealth solutions which include, promptness in capturing data, correctness through the process and utilizing this data in a timely manner to help in making informed decisions.

Through this work it was also found that there are different mHealth solutions that have been developed with the intention of solving a single challenge that was being experienced in the industry. It is possible to combine the strength of these solutions to make a more powerful system rather than having multiple solutions in the Health sector.

4.3. Recommendations

The introduction of the CHW mobile application as a day-to-day tool for CHWs was necessary and would greatly help in their daily work. It will help the CHWs in their work in quite a number of ways. One they will no longer be required to carry around the bulky MOH513, MOH514 and MOH100 as the system allows them to register households, do follow-ups on the different types of cases as well as invoke the referral process. They don't have to register households twice a year as they can always register new households whenever they come across one which could be as a result of migration. It would be quite easy to access such households.

Secondly, they will promptly use the information they collect from households to make informed decision regarding cases they encounter in the households. New CHWs will also find the system helpful as they will not be required to have mastered the different danger signs and actions that should be taken in case a child or mother has certain danger signs. The system will automatically process every case accordingly, based on the data entered for each mother or child.

With the presence of danger signs that can only be addressed at the health facility, the system automatically invokes a referral process that can be recorded and sent to the health facility.

Through literature review it was noted that the success of mHealth is related to accessibility, low cost of mobile devices and technology as a whole, as well as users' acceptance of the technology. More research and adoption of mHealth should be conducted with an aim of enhancing healthcare deliver, utilization and also in the provision of information around healthcare. There is also need to collaborate with the government and research bodies in order to tap into the advantages brought by mHealth.

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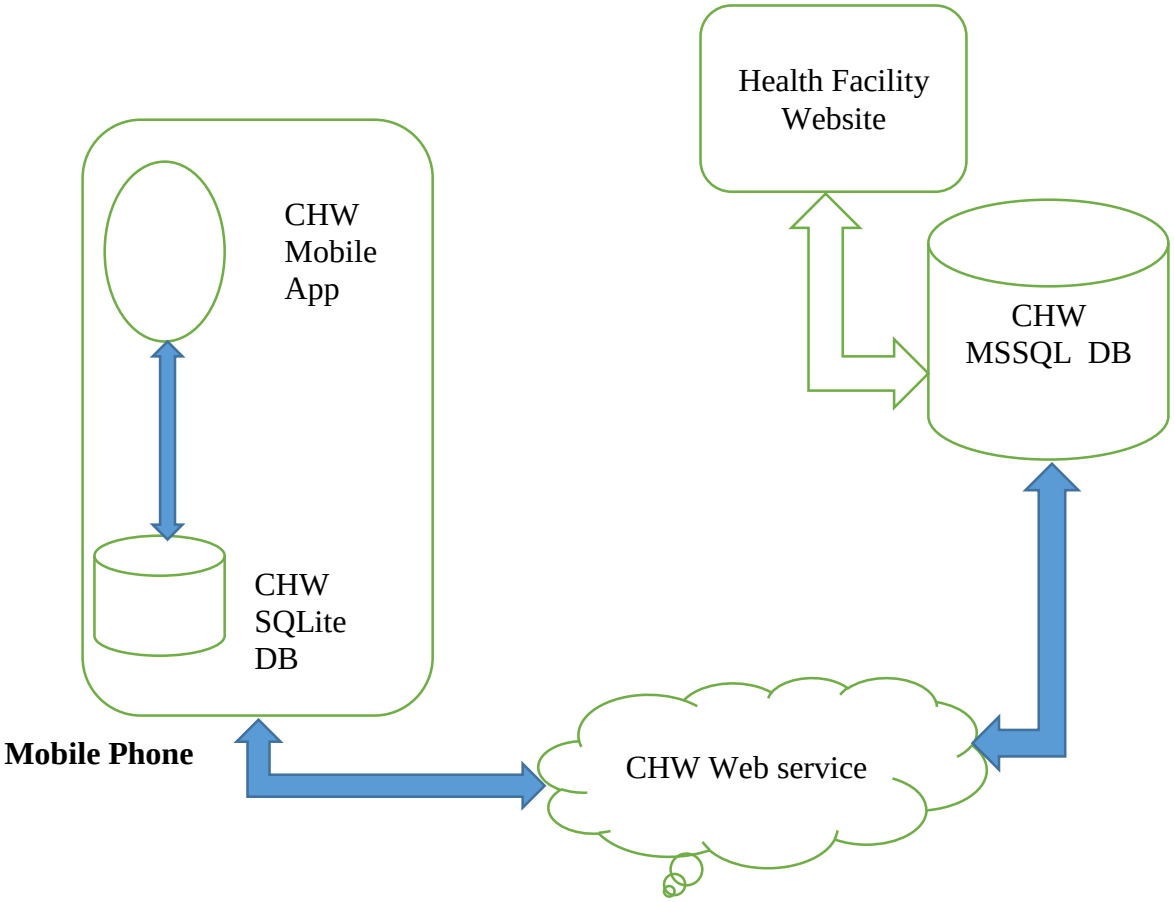
6. APPENDICES

6.0. CHW Mobile System Components



6.1. Sick Child Recording Form (SCRF)

Question	Answer
B3. SICK CHILD RECORDING FORM	
START TIME:	

Question	Answer
B3.1. Child's **First** Name	
B3.2. Child's surname **(Family name)**	
(ii) Childs **Date** of Birth	
B3.3. (i) Age in **Years** (Please check card)	
B3.4. (ii) Age in **Months** (Please check card)	
B3.5. **Gender**	1 MALE 2 FEMALE
B3.6 **Caregiver's** Name	
B3.7 **Relationship** with child	1 Father 2 Mother 96 Other
B3.7 Other (**Specify** Relationship with child)	
B3.8 Name of **Community Unit**	
B3.9 Name of **Link Facility**	
B3.11 **Caregivers Phone** number e.g. 0722xxxxxx 998 - Don't know/ Don't have	
END TIME:	
ASK AND LOOK	
START TIME:	
INSTRUCTIONS: CHW seek or systematically ask for the general danger signs	
1. **Cough**	
Days cough lasted	
2. **Diarrhea** *Three or more loose stools in 24 hrs.*	
How long has the diarrhea lasted?	
3. If Diarrhea **Blood in stool**	

Question	Answer
4. **Fever** (*reported or now*)	
5. If Yes Fever, Started **how many days ago**	
5. ii Vomiting	
5. iii Vomits everything	
6. **Convulsions**	
7. Difficulty **drinking** or **feeding**	
8. i. If Yes, **not able** to drink anything	
8. ii. If Yes, **not able** to feed on anything	
9. **Chest in-drawing** (For all Children)	
10 i. Did CHW **count** number of breadths?	1 Yes 2 No
10. If **Cough**, count breaths in 1 minute: **Breaths per minute (bpm)** ***Age 2 months up to 12 months : 50 bpm or more*** ***Age 12 months up to 5 years : 40 bpm or more***	
12. Unusually **Sleepy** or **unconscious**?	
13. For child 6 months up to 5 years, **MUAC strap color**	
14. Swelling of **both feet**	
There being no illness the CHW proceeded to;	1 Child treated 2 Child not treated 3 Caregiver advised 4 Caregiver not advised
COUGH danger sign	
COUGH < 14 days refer	
DIARRHOEA danger sign	
BLOOD IN STOOL danger sign	
FEVER danger sign	

Question	Answer
FEVER < 7 days refer	
CONVULSIONS danger sign	
DIFFICULTY IN FEEDING danger sign	
CHEST INDRAWING danger sign	
VOMITS EVERYTHING danger sign	
RED on **MUAC** danger sign	
SWELLING ON BOTH FEET danger sign	
COUGH danger sign (Number of breadths)	
Please Refer Urgently to Health Facility *Explain why child needs to go to health facility. Give first dose of treatment.*	1 Yes 2 No
ASSIST REFERAL TO HEALTH FACILITY	
Tick treatments given and other actions	
Diarrhea	
If child can drink, **Begin giving ORS solution** right away.	1 Yes, given 2 No, not given
If **Fever and Convulsions** or **Unusually sleepy** or Unconscious or Not able to eat or drink anything , Vomits everything	
Give rectal articulate suppository (100 mg) *Age 2 months up to 3 years - 1 suppository* *Age 3 years up to 5 years - 2 suppositories*	1 Yes, given 2 No, not given
If **Fever and danger sign** other than the three above.	
Give first dose of oral antimalarial AL. (100 mg) *Age 2 months up to 3 years - 1 tablet* *Age 3 years up to 5 years - 2 tablets*	1 Yes, given 2 No, not given
If **Chest in drawing or fast breathing**	

Question	Answer
If child can drink, **Give first dose of oral antibiotic.** (amoxicillin tablet 250 mg) *Age 2 months up to 12 months - 1 tablet* *Age 12 months up to 5 years - 2 tablets*	1 Yes, given 2 No, not given
For any sick child who **can drink**, advice to **give fluids** and continue **breastfeeding**.	1 Yes, given 2 No, not given
Advice to keep the **child warm**, if child is **not hot with fever**	1 Yes, given 2 No, not given
Write a **referral note**	1 Yes, given 2 No, not given
Arrange transportation, and help solve other **difficulties in referral**	1 Yes, given 2 No, not given
Follow up the child on return at least once a **week** until child is well.	1 Yes, given 2 No, not given
DIARRHOEA Sickness no danger sign	
FEVER Sick no danger sign	
FAST BREATHING sickness sign	
YELLOW on **MUAC** sickness sign	
If No Danger sign, treat the child and give advice to caregiver	1 Yes 2 No
If NO DANGER Sign, TREAT at Home and ADVICE on Home Care	
if **Diarrhea** *less than 14 days AND no blood in stool*	
Give ORS. Help caregiver give child ORS solution in front of you until child is no longer thirsty.	1 Yes, given 2 No, not given

Question	Answer
Give caregiver 4 ORS packets to take home. Advice to give as much as child wants, but **at least** 1/2 cup ORS solution after each loose stool.	1 Yes, given 2 No, not given
Give zinc supplement. Give 1 dose daily for 10 days; *Age 2 months up to 6 months - 1/2 tablet (total 5 tabs)* *Age 6 months up to 5 years - 1 tablet (total 10 tabs)* Help caregiver to give first dose now.	1 Yes, given 2 No, not given
Fever *(less than 7 days) in a malaria area*	
Did you do an RDT	1 Yes 2 No
Do a Rapid Diagnostic Test (RDT).	1 Positive 2 Negative
If RDT is positive, give oral antimalarial AL (Artemethelumefantrine).	1 Age 2 months up to 5 months - 1/2 tablet (total 3 tabs) 2 Age 5 months up to 3 years - up to 1 tablet (total 6 tabs) 3 Age 3 years up to 5 years - up to 2 tablets (total 12 tabs) 4 didn't give oral anti-malaria 5 didn't help give 6 didn't give that advice
Help caregiver give first dose now.	1 Yes 2 No
Advice to give second dose after 8 hours. And to give dose twice daily for two more days.	1 Yes 2 No
Fever give paracetamol every 6 hours for 3 days.	1 Yes 2 No

Question	Answer
Yellow on MUAC straps	
Counsel caregiver on feeding	1 Yes 2 No
Referred the child to a supplementary feeding programme, if available.	1 Yes 2 No
Evaluators Comments *Why are the results the way they are?*	
For **ALL children treated at home, advice on home care**	
Advice caregiver to give more fluids and continue feeding	1 Yes, given 2 No, not given
Advice on when to return. Go to nearest health facility immediately or if not possible return if child - cannot feed or drink - becomes sicker - has blood in stool	1 Yes, given 2 No, not given
Advice caregiver on the use of bed nets (ITN)	1 Yes, given 2 No, not given
Follow-up child in 3 days (Schedule appointment in item 6 below)	1 Yes, given 2 No, not given
CHECK VACCINES, DEWORMING AND VITAMIN STATUS	
Advise caregiver if needed; WHEN and WHERE to get the next dose	
Child referred based on other issues	1 Yes 2 No
Please specify the condition(s) why child referred	

Question	Answer
END TIME:	
RECORD ANY GENERAL COMMENTS ABOUT THE INTERVIEW/RESPONDENT	
8.0. END OF INTERVIEW	

6.2. Project Schedule

Table 1 Project Activities

Activity	**Predecessor**	**Time Estimates (x1)**	**Time Estimates (x2)**	**Expected time**
1. Proposal Development	-			3 month
2. Proposal Correction and submission to Graduate School	1			
3. Defense at UoN (M1)	2			1 week
4. Requirements gathering (Data collection)	4			4 week
5. Requirements Analysis	5			1 week
6. System Design and development	6			2 month
7. Code & Unit Test	7			1 month
8. Write User's Manual	8			3 weeks
9. Write final report	9			Continuous
10. Final Documentation and Report	10			3 weeks

6.3. Sample Code

Sample code:

```
7. public class RegistrationActivity extends AppCompatActivity implements
   LoginActivity.OnLoginFormActivityListener, View.OnClickListener {

       private EditText et_rf_act_name, et_rf_email_address, et_rf_act_user_password,
   et_rf_act_school;
       private Button btn_rf_act_register;

       public RegistrationActivity() {
           // Required empty public constructor
       }

       @Override
       protected void onCreate(@Nullable Bundle savedInstanceState) {
           super.onCreate(savedInstanceState);
           setContentView(R.layout.activity_registration);

           et_rf_act_name = findViewById(R.id.et_rf_act_name);
           et_rf_email_address = findViewById(R.id.et_rf_email_address);
           et_rf_act_user_password = findViewById(R.id.et_rf_act_user_password);
           et_rf_act_school = findViewById(R.id.et_rf_act_school);
           btn_rf_act_register = findViewById(R.id.btn_rf_act_register);

           btn_rf_act_register.setOnClickListener(new View.OnClickListener() {
               @Override
               public void onClick(View v) {
                   userSignUp();
               } //
           });

           TextView tv_login_rf = findViewById(R.id.tv_login_rf);
           tv_login_rf.setOnClickListener(new View.OnClickListener() {
               @Override
               public void onClick(View v) {
                   Intent intent = new Intent(RegistrationActivity.this,
   LoginActivity.class);
                   startActivity(intent);
               }
           });

       }

8. public class LoginActivity extends AppCompatActivity {

       public static PrefConfig prefConfig;
       public static ApiInterface apiInterface;


       private TextView RegText;
       private EditText et_lf_emailaddress, et_lf_password;
       private Button btn_lf_sign_in;

       TextView tv_register_lf;

       OnLoginFormActivityListener loginFormActivityListener; //handler for the below
   interface
```

```
public interface OnLoginFormActivityListener {
    public void performRegister();

    public void performLogin(String name);
}

@Override
protected void onCreate(Bundle savedInstanceState) {
    super.onCreate(savedInstanceState);
    setContentView(R.layout.activity_login);
    // Set up the login form.
    et_lf_emailaddress = findViewById(R.id.et_lf_emailaddress);
    et_lf_password = findViewById(R.id.et_lf_password);
    btn_lf_sign_in = (Button) findViewById(R.id.btn_lf_sign_in);
```

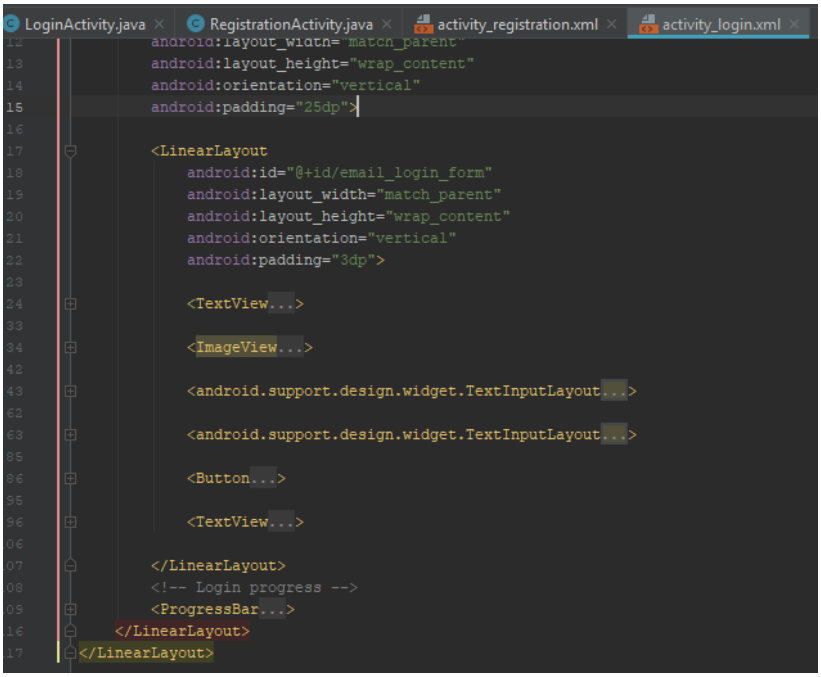
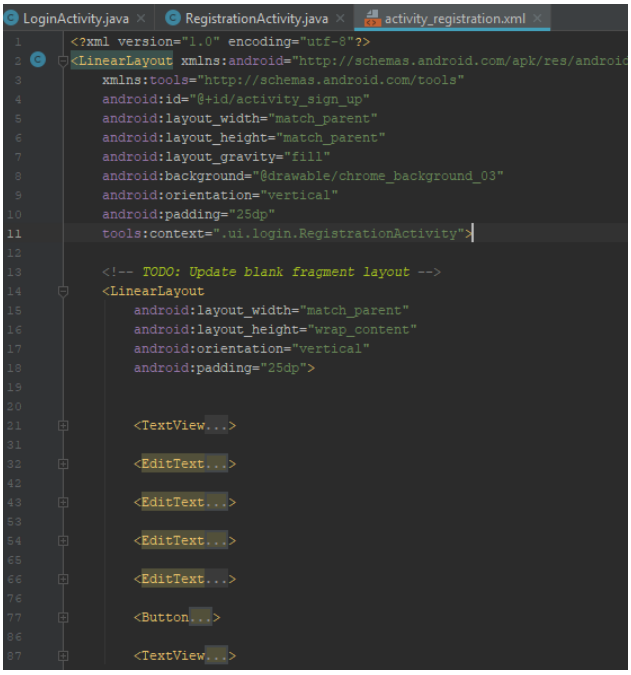


Figure 37 Registration and Login XML

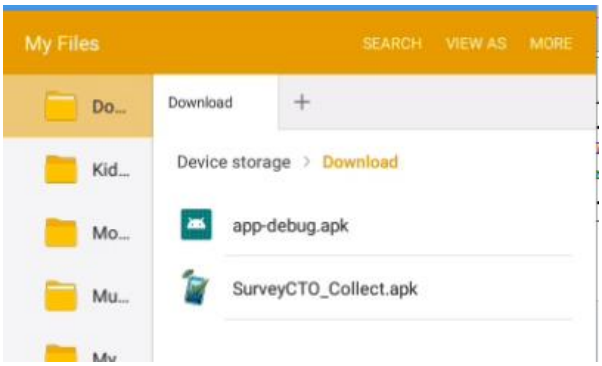


7. CHW Mobile App User's Manual

7.0. Installing the application

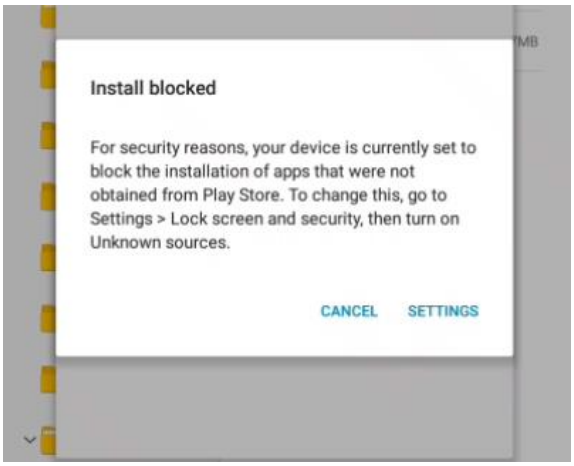
To install an android application, you must have an android package (apk) file. All one needs to do is download the file from the location given or playstore and install on an android phone or tablet.

Locate the installation file (apk) in your tablet / phone



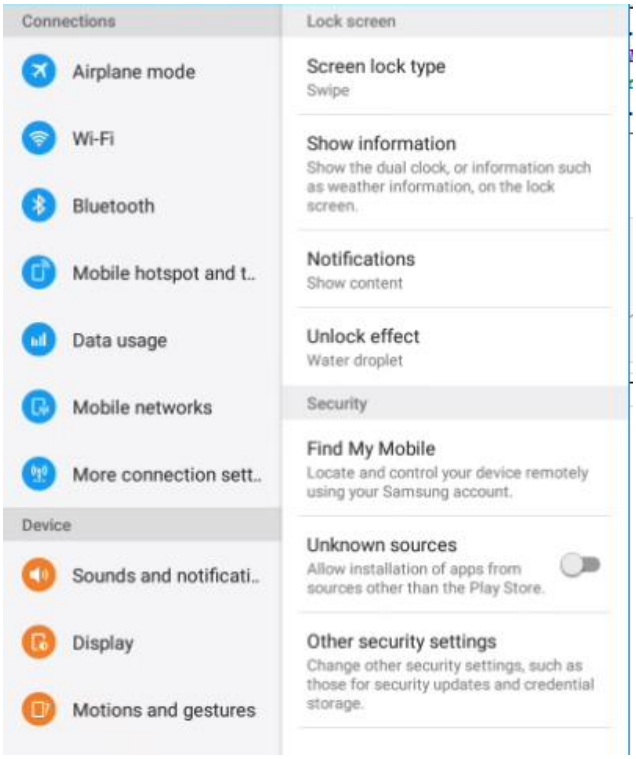
It is called app-debug.apk or as instructed.

Click on the item to install the application.

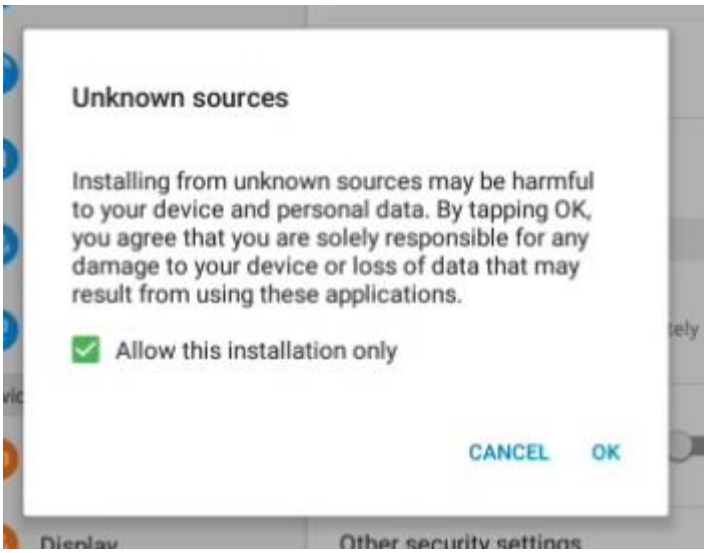


Click on settings in the above screen.

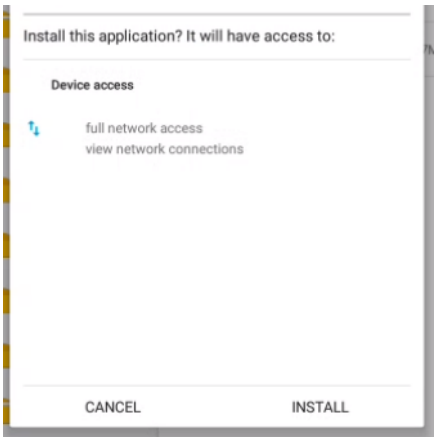
Allow unknown sources



Unknown sources option is on the right hand side options and switch it on, then click ok.



7.1. Install CHW Mobile application.



Once through just open and proceed on with Login as explain shortly after.

Log into the application

A user will have to use given credentials for them to be able to access the system and its functionalities.