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# A Mobile health application for patient monitoring in maternal healthcare

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*Faculty of Information Technology (FIT)*  
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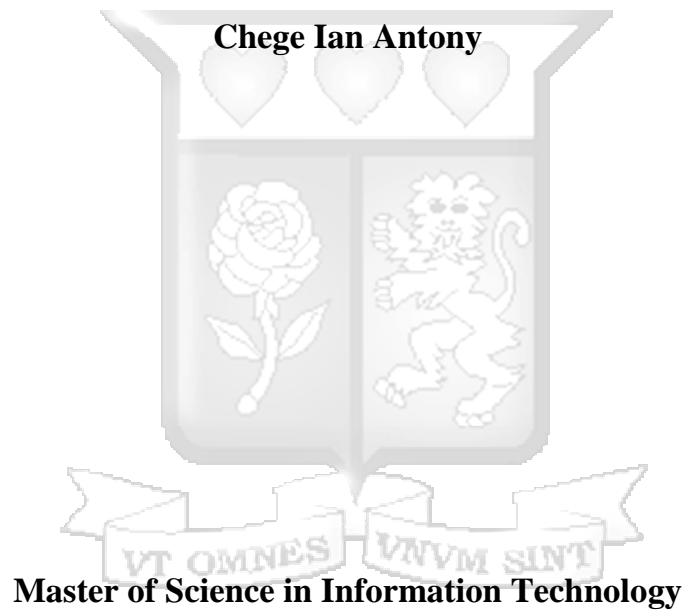
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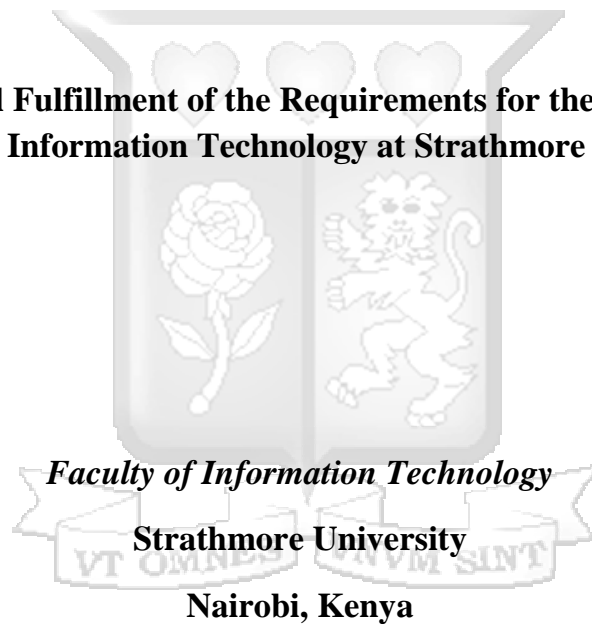
# **A Mobile Health Application for Patient Monitoring in Maternal Healthcare**



# **A Mobile Health Application for Patient Monitoring in Maternal Healthcare**

**Chege Ian Antony**

**Submitted in Partial Fulfillment of the Requirements for the Degree of Master of  
Science in Information Technology at Strathmore University**



**June, 2019**

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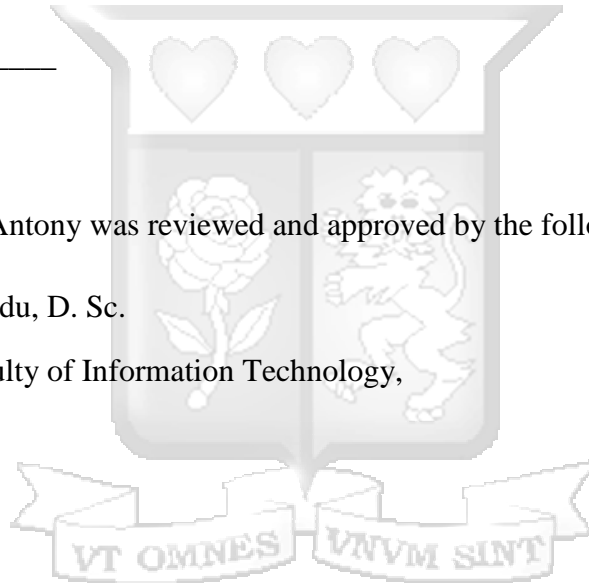
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## ABSTRACT

With the recent global uptake of mobile devices and mobile connectivity services, a new avenue for the dispatch of health information services to patients by health facilities has emerged. Mobile health applications complementing patient monitoring systems have enabled access to health care services by patients whereby medical practitioners are able to monitor their patients remotely and therefore provide healthcare information either in real time or intermittently through the use of mobile devices. Of particular importance is the field of maternal health care, which has received a major boost by virtue of mobile penetration. This has brought about uptake of patient services and the receptiveness towards mobile capabilities for the patients to their respective health facilities. In Kenya, a majority of the number of women do not receive the recommended four or more required antenatal care visits. A contributing factor towards these low figures is that a number of these women live in abject poverty. In order to combat these low figures, monitoring of patients by doctors and community health workers through use of mobile applications will go a long way in increasing health care services to expectant mothers. This application area focuses on a mobile health application for gathering of patient data and dissemination of stage-based maternal health information to the patients' mobile devices. The application also provides timely antenatal care tips as well as allowing the user to set reminders on upcoming appointments and expected antenatal care visits. The application also allows for two-way interactive text messaging between the expectant mother and the health worker. Testing and implementation of the application yielded 60% acceptability and user satisfaction from the respondents, with users determining the accuracy and responsiveness of the application at 62%. From the testing results provided by the respondents, the application can be deemed as usable and viable for implementation. In conclusion, the application was deemed acceptable by the respondents, who found the two-way interactive messaging functionality unique.

**Keywords: mobile devices, mobile health, maternal health care, patient monitoring.**

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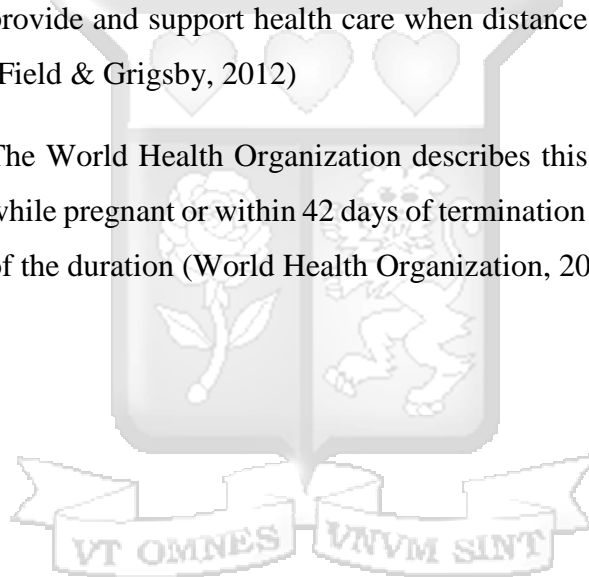


## ABBREVIATIONS

<b>API</b>	-	Application Programming Interface
<b>ECG</b>	-	Electrocardiogram
<b>HIV/AIDS</b>	-	Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome
<b>LMIC</b>	-	Low and Middle Income Countries
<b>MDG</b>	-	Millennial Development Goals
<b>MEOWS</b>	-	Modified Early Obstetric Warning Scores
<b>mHealth</b>	-	Mobile Health
<b>MMR</b>	-	Maternal Mortality Ratio
<b>M-Pesa</b>	-	A mobile money transfer service provided by Safaricom and Vodafone
<b>KEMRI</b>	-	Kenya Medical Research Institute
<b>SMS</b>	-	Short Messaging Service
<b>TextIT</b>	-	Texting to Improve Testing mobile application developed by KEMRI
<b>USSD</b>	-	Unstructured Supplementary Service Data
<b>UNICEF</b>	-	United Nations Children's Fund
<b>WHO</b>	-	World Health Organization

## DEFINITION OF TERMS

- Mobile health** Mobile health is defined as the use of mobile devices and other wireless technology in the provision of health services and management of patient information (Källander , et al., 2013)
- Antenatal Care** Method of preventive health care with the goal of providing regular checkups that allows doctors or midwives to treat and prevent potential health problems through the course of a woman’s pregnancy (World Health Organization, 2015)
- Patient Monitoring** The use of electronic information and communication technologies to provide and support health care when distance separates the participants (Field & Grigsby, 2012)
- Maternal Mortality** The World Health Organization describes this as the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration (World Health Organization, 2015)



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Last but not least, I would also like to appreciate the efforts of my fellow researchers for their endless support throughout the time period of this work.



## DEDICATION

I dedicate this dissertation to my family members for their endless guidance and support towards my undertaking of this work. I would not have come this far without their input and support, and for that I am truly grateful.



# CHAPTER 1

## INTRODUCTION

### 1.1 Background of the Study

Patient monitoring is defined as the use of information technology to provide healthcare services at a distance (Sebastian, Neethu, Yedu , Anand, & Jayashree, 2012). It involves the passive collection of physiological and contextual data of patients in their own environment, using medical services, software and optionally environment sensors. As a result, this data is retransmitted back to the remote care provider, either in real-time or intermittently, for the providers review and intervention via mobile devices (Simons, Egami, & Perry, 2006). To enable patient monitoring, mobile devices are often used as an intermediary tool. This is realized by the ubiquity of mobile devices in the African context that has led to a resultant increase in the use of mobile applications to develop solutions in order to solve various challenges. A contributing factor to this is that over 60% of Africa now has mobile coverage (Aker & Mbiti, 2010). As a result, the healthcare industry has benefitted tremendously due to mobile penetration. Medical services have been efficiently increased through use of mobile applications to cater to remote patients through healthcare provision (Asongu, 2015).

In healthcare, one sector that requires consistent patient monitoring is maternal health. With lack of continuous and consistent monitoring, chances of maternal health deterioration are more likely, and thus ultimately leading to maternal morbidity or mortality. As pointed out by (Fotso , Ezeh, Madise, Ziraba, & Ogollah, 2009), maternal mortality and morbidity relate to death or illness occurring during pregnancy or childbirth, or within two months of birth or termination of pregnancy. In 2005, it was estimated that over half a million women die each year of complications during pregnancy or childbirth. These complications include severe bleeding, infection, hypertensive disorders and obstructed labor. Other causes include malaria, diabetes, hepatitis and anemia which are explained to be aggravated by pregnancy. Most of the women facing maternal morbidity and mortality are located in low and middle-income developing countries where access to healthcare poses a significant challenge. In 2010, the World Health Organization estimated the number at 900 maternal deaths per 100,000 livebirths (World Health Organization, 2010). A decade later in 2015, this still posed significant challenges as well as an unfinished agenda for the

Millennial Development Goals (MDG) of the World Health Organization (WHO) set for the year 2015 (World Health Organization, 2015). Major contributors to these disparities in the Kenyan context are associated with the ratio of health workers to patients as well as the ratio of patients to hospital beds (Kumar, Parton, & Kirigia, 2016).

According to the Kenya Health Demographic Survey (Timæus & Momodou , 2014), outline that 58% of Kenyan women make the required four or more antenatal care visits during their pregnancy. With the implementation of remote patient monitoring and mobile health applications, this figure would be significantly increased in order to realize the set Millennial Development Goals.

## **1.2 Problem Statement**

A World Health Organization report on “strategies towards ending maternal mortality” (World Health Organization, 2015), outlines that worldwide Maternal Mortality Ratio (MMR) decreased by 44% from 1990 to 2015. However, the global target of a 75% reduction was not reached. A majority of countries that fell short of attaining the target are in Sub-Saharan Africa and Asia. The ultimate goal for vision 2030 is that no country should have a ratio higher than 140 deaths per 100,000 live births.

In Kenya, the MMR ratio is estimated at 362 per 100,000 live births by the Kenya Demographic Health Survey. Organisation’s such as WHO and UNICEF determine that these figures highlight insufficient progress towards ending maternal mortality and morbidity. In 2010, approximately 47% of women in Kenya had received the recommended four or more required antenatal care visits. This was as a result of lack of access to healthcare resources and the fact that a number of these women live in abject poverty, thus equating to a number of them preferring home deliveries as opposed to incurring costs associated with modern health facilities (World Health Organization, 2015). As a result, the government of Kenya undertook an initiative to combat the decreasing rates of maternal morbidity and mortality in the country with the introduction of a free maternal services policy in all public health care facilities. The effects of this policy were far reaching to the effect that some health facilities, such as the Kenyatta National Hospital, were experiencing 100 percent increase in the number of pregnant women seeking maternal health services (Bourbonnais, 2013). The initiative had brought with it an inherent disadvantage by the fact that the ratio of doctors and

nurses to patients had been exceeded and this brought a resultant decline in the provision of health services due to the high number of patients.

This work proposes the implementation of a mobile health application for monitoring of expectant women in low resource settings and rural areas, through delivery of stage-based health tips, two-way interaction, and follow ups. The user is expected to provide parameters related to their bio-data such as height, weight, Body Mass Index and whether or not they are currently going through any chronic illnesses. The user also provides their perceived symptoms and in turn is provided with information related to remedy of their symptoms and whether that symptom is related to their trimester period.

### **1.3 Research Objectives**

- i. To identify maternal health data required for patient monitoring.
- ii. To identify the challenges posed by patient monitoring systems in maternal health.
- iii. To review the existing architecture, models and frameworks in patient monitoring for maternal health.
- iv. To develop a mobile application for monitoring of expectant mothers.
- v. To test the mobile application.

### **1.4 Research Questions**

- i. What maternal health data is required for effective patient monitoring?
- ii. What are the challenges posed by patient monitoring systems in maternal health?
- iii. What are the existing architectures, models and frameworks in patient monitoring?
- iv. How can a mobile application solve these challenges?
- v. How can the mobile application be tested to see its effectiveness in maternal healthcare?

### **1.5 Justification**

The proposed mobile application seeks to address the maternal health challenges faced by developing countries in Sub-Saharan Africa, and more specifically in Kenya, by facilitating monitoring of expectant mothers through gathering of patient data and dissemination of stage-based health information to the expectant mothers. By doing so, it will lead to improved treatment

understanding, increase in medication compliance and the health practitioners are also able to interact with their patients, as well as offer clinical advice. Expectant mothers will also receive antenatal care tips and reminders.

### **1.6 Scope of the study**

The scope of the proposed mobile application will be limited to gathering of patients' data and provision of stage-based maternal care information to expectant women. The system will be used by expectant mothers, who are required to either perform self-registration or get registered by a health official. These women will then receive stage-based updates and notifications, based on the provided information, on their mobile devices concerning antenatal care and upcoming clinical appointments.

### **1.7 Limitations**

A majority of the target population is in the Low and Middle Income bracket and thus will limit the implementation of sensors and other Near Field Communication devices used for gathering of patient vital signs. The main avenue for data collection will be from the patient's mobile device, this bringing about language barrier limitations for implementation of two-way interaction. The accuracy of the patient's location is outside the scope of this work as a majority of the target users do not use internet enabled mobile devices. The proposed mobile application will be developed using the android platform and thus will disregard other application development platforms. These may be avenues for future implementations of this dissertation.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

A number of mobile health applications have been developed towards bringing change in healthcare provision, and specifically in relation to maternal healthcare. This section aims at reviewing the current literature available in the context of mobile health and patient monitoring systems, hence building on their advantages. Different application contexts including Short Messaging Services, mobile applications and mobile payment services are currently being used to administer and facilitate healthcare services to patients.

#### 2.2 Maternal Monitoring

In the context of this study, monitoring refers to capability and use of technology to provide continuous follow up of a patient's health status. A variety of maternal health vital signs are required to be monitored in order to ensure a progressive pregnancy period. However, in as much as all the data is relevant for sufficient monitoring, (Loerup, et al., 2016) point out that key vital signs used to assess the clinical status of women throughout the pregnancy include:

- i. Heart Rate
- ii. Blood pressure
- iii. Respiratory rate
- iv. Oxygen Saturations
- v. Temperature

Supplementary data to this would include the patient's age, weight, height, Body Mass Index (BMI) and gestation age. The perceived normal ranges of these vital signs, as the authors' state, underpin the Modified Early Obstetric Warning Scores (MEOWS), developed to assist in early recognition of deterioration. Using these vital signs to detect physiological deterioration is complicated by the normal dynamic changes in maternal vital signs throughout the pregnancy. In

the case of the MEOWS, they define the thresholds that determine whether the woman requires review (Loerup, et al., 2016).

### ***2.2.1 Antenatal Care Data***

While majority of severe obstetric complications cannot be predicted, many can be prevented and more can be treated with the right administration of antenatal care (Ali & Kuroiwa, 2007). Regular antenatal care is important in identifying and preventing adverse outcomes when it is sought early in the pregnancy and administered up until the delivery. Antenatal care from a skilled provider is important to monitor pregnancy and reduce the risk of morbidity for mother and baby during pregnancy and delivery. Quality of antenatal care can be monitored through the content of services received and the kind of information mothers are given during their visit (Timæus & Momodou , 2014).

The World Health Organization recommends that women have at least four antenatal care visits during each pregnancy in which a complete antenatal care package can be delivered appropriately. According to this recommendation, a woman with an uncomplicated pregnancy is expected to make antenatal care visits; once in each of the first and second trimesters, and twice in the third trimester. The current antenatal care package includes: health education and counselling on pregnancy and emergency preparedness, nutrition, hygiene, birth plan, postpartum care, breast feeding, sexually-transmitted infection prevention and family planning. It also involves antenatal examinations, inter-current disease treatment, voluntary counselling and testing for HIV, prevention of mother to child transmission of HIV, periodic de-worming, nutrition supplementation and tetanus immunizations. During these visits, detection of health problems associated with the pregnancy is much more likely, and therefore intervention planning is much easier (World Health Organization, 2015).

### ***2.2.2 Expected Date of Delivery***

An obstetrician is tasked with calculating the expected date of delivery and gestational age, which is sometimes done in a very traditional kind of way. The gestational period usually varies between 38 to 42 weeks (Valente, Braga, Machado, Santos, & Abelha, 2013). The most common reasons for complications and deaths during the period of pregnancy include maternal sepsis, maternal bleeding, abortion complications, high blood pressure in pregnancy, gestational diabetes and

weight gain during period of pregnancy. Among these complications, abnormalities in Blood Pressure (BP), Blood Glucose Levels and Weight Gain are considered the most dangerous and preventable complications. Some women develop high blood pressure while they are pregnant called gestational hypertension. High blood pressure can harm the mother's kidneys and other organs, and it can cause low birth weight and early delivery (Lakshmi, Indumathi, & Ravi, 2016). The authors go on to state that an important point to factor in here is that medically assisted pregnancies require different kinds of calculations and need to be analyzed differently. These calculations prove crucial to pregnant women and any mistake may cause serious consequences. However, gestational age calculated from the pregnant medical history or by physical examination is not usually considered because of its low accuracy and difficulty to apply to clinical practice. Current methods to deduce the gestational period entail the last menstrual period. Despite its use in clinical practice, (Valente, Braga, Machado, Santos, & Abelha, 2013) argue that it is not a reliable method due to the existence of irregular menstrual cycles or abandonment of contraceptives.

The prediction of gestational age and expected date of delivery using inaccurate methods implies inefficient patient management by the health professional (Valente, Braga, Machado, Santos, & Abelha, 2013). This in turn leads to event mismanagement such as in the case of the expectant mother's dislocation before her actual date of birth and increased costs by both the patient and the health facility. On the other hand, access to the expectant mother's medical history and other personal data is not available ubiquitously and is usually handwritten.

It is crucial that health professionals find new strategies towards the improvement of healthcare delivery towards patients. In the context of maternal health and obstetrics, health professionals deal with different pregnancy related cases on a daily basis. The authors (Valente, Braga, Machado, Santos, & Abelha, 2013) advocate for strict monitoring such that patient information can be consulted anytime and anywhere.

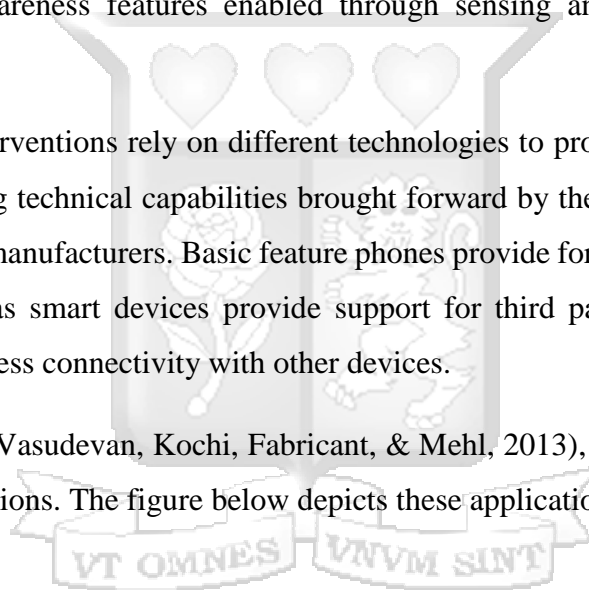
### **2.3 Mhealth and Technology behind Mobile Health Applications**

Mobile health, also referred to as m-health, is an emerging field that has been on the rise due to mobile penetration. As a result, researchers have tapped into this area and increasingly begun to use mobile phones as platforms for delivery of health interventions (Klasnja & Wanda , 2012). The reason these mobile devices offer an attractive package for the delivery of health services is due to:

- i. Widespread adoption of phones with increasingly powerful capabilities.
- ii. People's tendency to carry their phones everywhere.
- iii. People's attachment to their phones.
- iv. Context awareness features enabled through sensing and phone based personal information.

Different health care interventions rely on different technologies to provide health care services. This is due to the varying technical capabilities brought forward by the different mobile devices available from different manufacturers. Basic feature phones provide for text messaging and voice capabilities only, whereas smart devices provide support for third party applications, internet access, sensing and wireless connectivity with other devices.

According to (Labrique, Vasudevan, Kochi, Fabricant, & Mehl, 2013), there are twelve common mhealth and ICT applications. The figure below depicts these applications.



1	Client education & behaviour change communication (BCC)	7	Provider-to-provider communication User groups, consultation
2	Sensors & point-of-care diagnostics	8	Provider workplanning & scheduling
3	Registries / vital events tracking	9	Provider training & education
4	Data collection and reporting	10	Human resource management
5	Electronic health records	11	Supply chain management
6	Electronic decision support Information, protocols, algorithms, checklists	12	Financial transactions & incentives

Figure 2-1 Common mhealth and ICT applications

In order to make mhealth possible, mobile devices require various mobile application functions so as to provide health care services. Table 2.1 below depicts the mentioned common mhealth and ICT applications and mobile phone functions used to administer the resultant services.

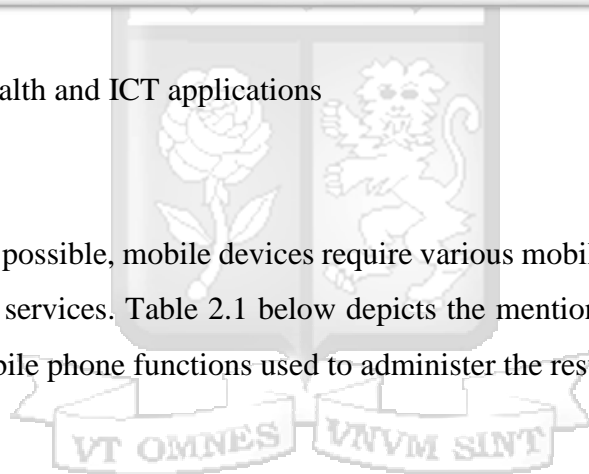


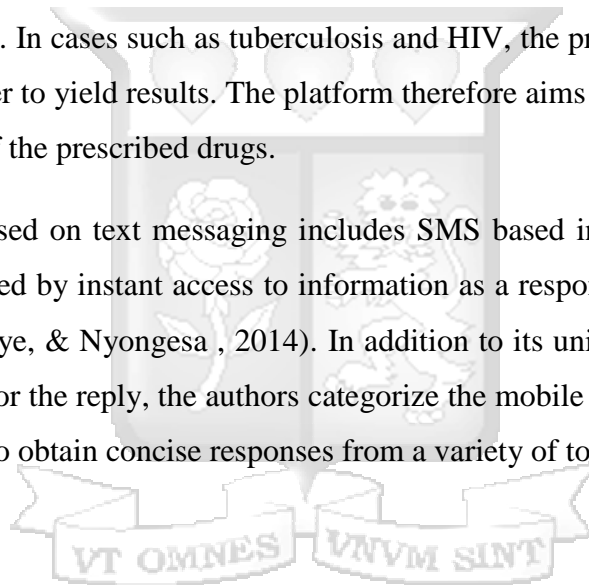
Table 2-1 Mobile phone functions used in common mhealth and ICT applications

COMMON MHEALTH AND ICT APPLICATION	MOBILE PHONE FUNCTIONS
Client education and Behavior change Communication (BCC)	<ul style="list-style-type: none"> <li>• Short Message Service</li> <li>• Multimedia Messaging Service</li> <li>• Interactive Voice Response</li> <li>• Video Clips</li> <li>• Images</li> </ul>
Sensors and point of care diagnostics	<ul style="list-style-type: none"> <li>• Mobile phone camera</li> <li>• Tethered accessory devices</li> <li>• Built in accelerometer</li> </ul>
Registries and vital event tracking	<ul style="list-style-type: none"> <li>• SMS</li> <li>• Voice communication</li> <li>• Digital forms</li> </ul>
Data collection and reporting	<ul style="list-style-type: none"> <li>• SMS</li> <li>• Digital forms</li> <li>• Voice Communication</li> </ul>
Electronic Health Records	<ul style="list-style-type: none"> <li>• Digital forms</li> <li>• Mobile web</li> </ul>
Electronic Decision Support	<ul style="list-style-type: none"> <li>• Mobile web</li> <li>• Stored information</li> <li>• Interactive voice response</li> </ul>
Provider training and education	<ul style="list-style-type: none"> <li>• SMS</li> <li>• MMS</li> <li>• IVR</li> <li>• Voice communication</li> <li>• Audio or video clip images</li> </ul>
Financial transactions and incentives	<ul style="list-style-type: none"> <li>• Mobile money transfer and banking services</li> <li>• Transfer of airtime minutes</li> </ul>

### ***2.3.1 Text Messaging***

Text messaging is a service that enables the composition and sending of electronic messages, which are 160 characters long, from one mobile device to virtually any other device in the world. Whereas text messaging users vary by age, country and culture, its receptive use in both developed and developing nations is as a result of its availability and cost effectiveness. SMS communication is used for information access and retrieval in health care related applications. It has enabled minimization of patient visits to physicians and improved consultancy services and patient appointment reminders. For example, in South Africa, Project Masiluleke uses text messaging to increase testing rates of tuberculosis and HIV, as well as provide counselling to patients (Cole-Lewis & Kershaw, 2010). In cases such as tuberculosis and HIV, the prescribed drugs need to be taken consistently in order to yield results. The platform therefore aims to ensure that the patients adhere to the timetable of the prescribed drugs.

A different technique based on text messaging includes SMS based information retrieval. This technology is characterized by instant access to information as a response mode to SMS queries (Adesina, Agbele, Abidoeye, & Nyongesa, 2014). In addition to its uniqueness as a result of the restricted size available for the reply, the authors categorize the mobile retrieval search system as a system enabling users to obtain concise responses from a variety of topics.



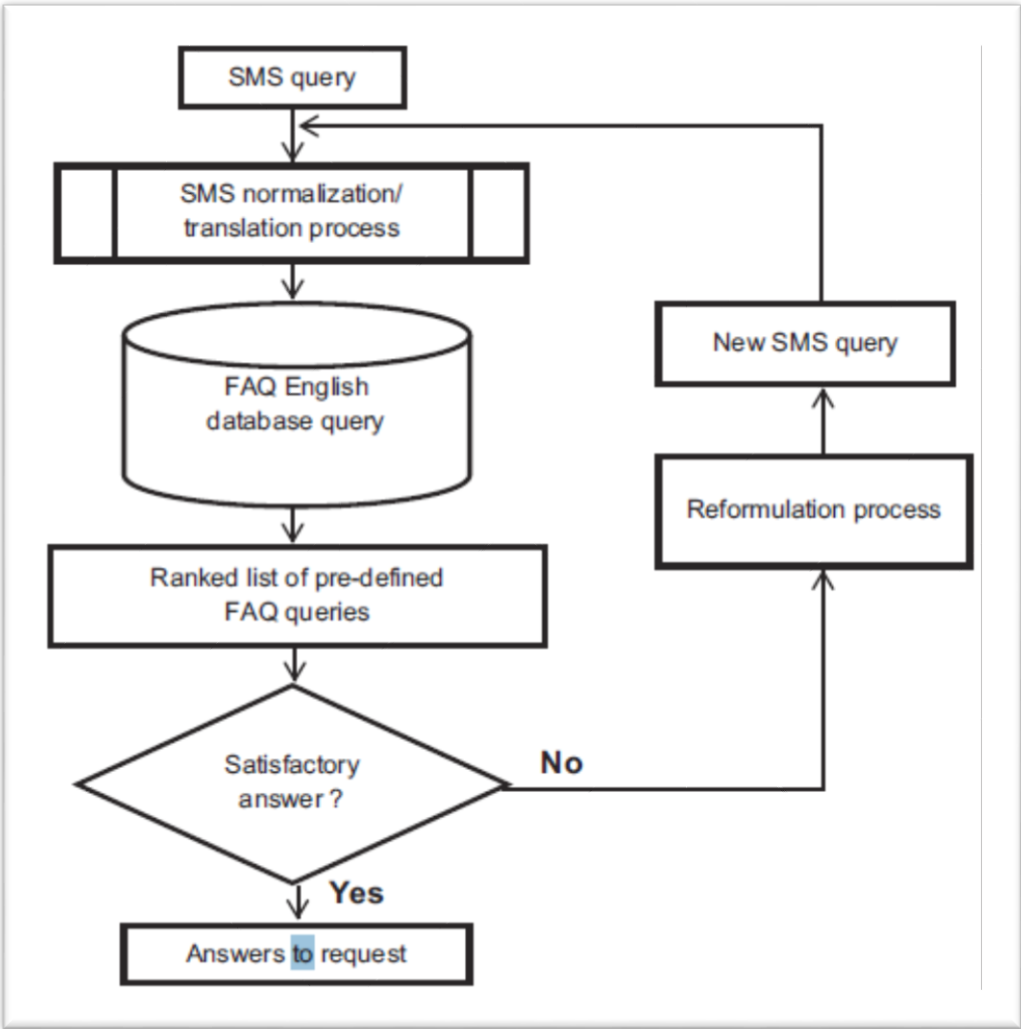


Figure 2-2 Flowchart of SMS based retrieval System

Challenges associated with the above system, as the authors (Adesina, Agbele, Abidoeye, & Nyongesa , 2014) highlight, are that the users were impatient and could not source results from the preliminary download pages. However, the widespread use of the Short Message Service makes it the most universally appropriate and accessible method of delivering health interventions to patients. Research implemented in the area of text messaged based health care intervention, according to (Househ, 2014), found evidence that the impact of SMS based healthcare on activities such as appointment reminders, was better as opposed to traditional based methods including postal and phone call reminders.

### 2.3.2 Cameras

Cameras have become a standard feature on all but the basic mobile phones. Their constant availability makes them a useful tool for collecting health related data. According to (Klasnja & Wanda , 2012), health interventions have used cameras in three primary ways:

- i. An alternative method of journaling health related behaviors such as food consumption.
- ii. As a method of providing health care providers with additional information about a certain condition.
- iii. As a way to document circumstances relevant to the self-management process.

Phone cameras can be and are a valuable tool for the effortless collection of health related data. However, photos cannot be automatically processed as easily as texts can. An example would be a case whereby the goal is to support learning through active engagement of a user's data. Figure 2.3 below depicts a model implementing use of digital cameras for data capturing, information analysis and extraction by use of MATLAB tools, and data sending via the internet.

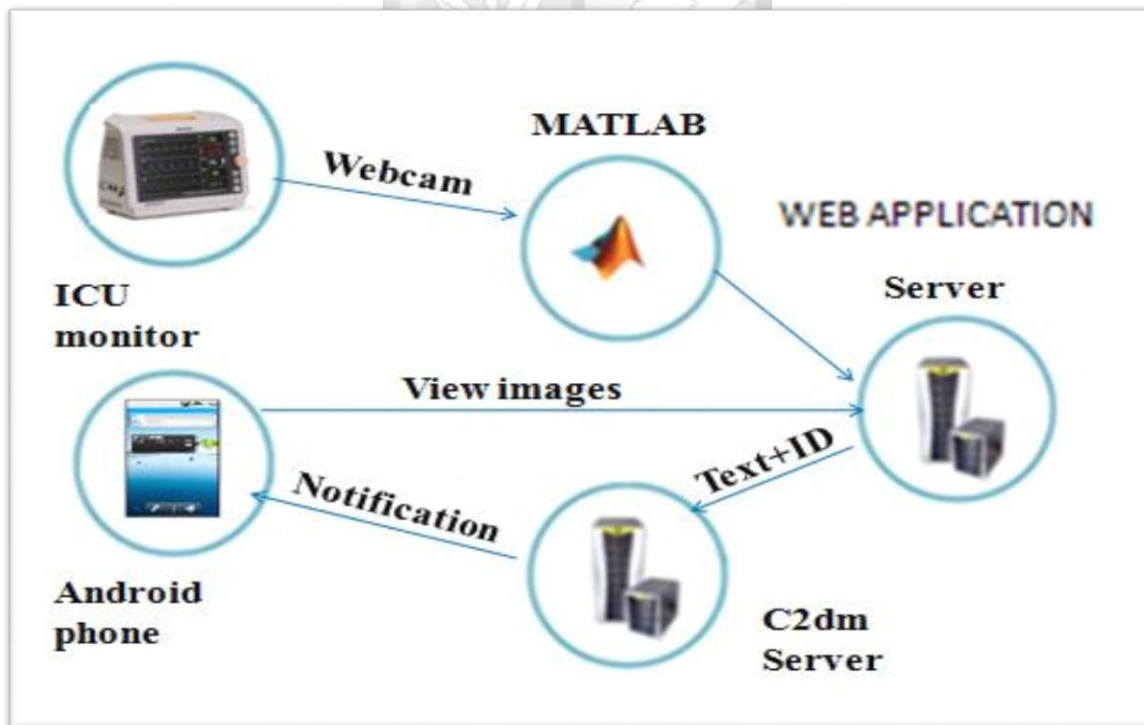


Figure 2-3 Remote Patient Monitoring System implementing a webcam application

### ***2.3.3 Native Applications***

All major Smartphone brands provide programmers with an Application Programming Interface (API) that can be used to build customized and special purpose applications. The APIs provide access to interface controls and the phones hardware features such as the camera and the accelerometer, as well as other data and applications on the phone. These capabilities have been leveraged by different companies and researchers to build different types of health applications (Klasnja & Wanda , 2012).

Such applications include journaling applications that enable users to log and chart data about their diet, exercise as well as blood glucose levels. Patient terminals for tele monitoring of various conditions such as hypertension and chronic heart failure, applications that receive data from pedometers, blood pressure monitors and other devices.

### ***2.3.4 Automatic Sensing***

A variety of smart mobile phones are able to connect to sensing devices over Bluetooth or through Near Field Communication technology. In this way, (Klasnja & Wanda , 2012) state that mobile phones can connect to digital scales and sensors such as electrocardiograms (ECG), pedometers and gym equipment. Mobile phones connected to automatic sensors are therefore able to act as receivers and data stores for the collection of relevant health data. Figure 2.4 outlines various automatic sensing devices.



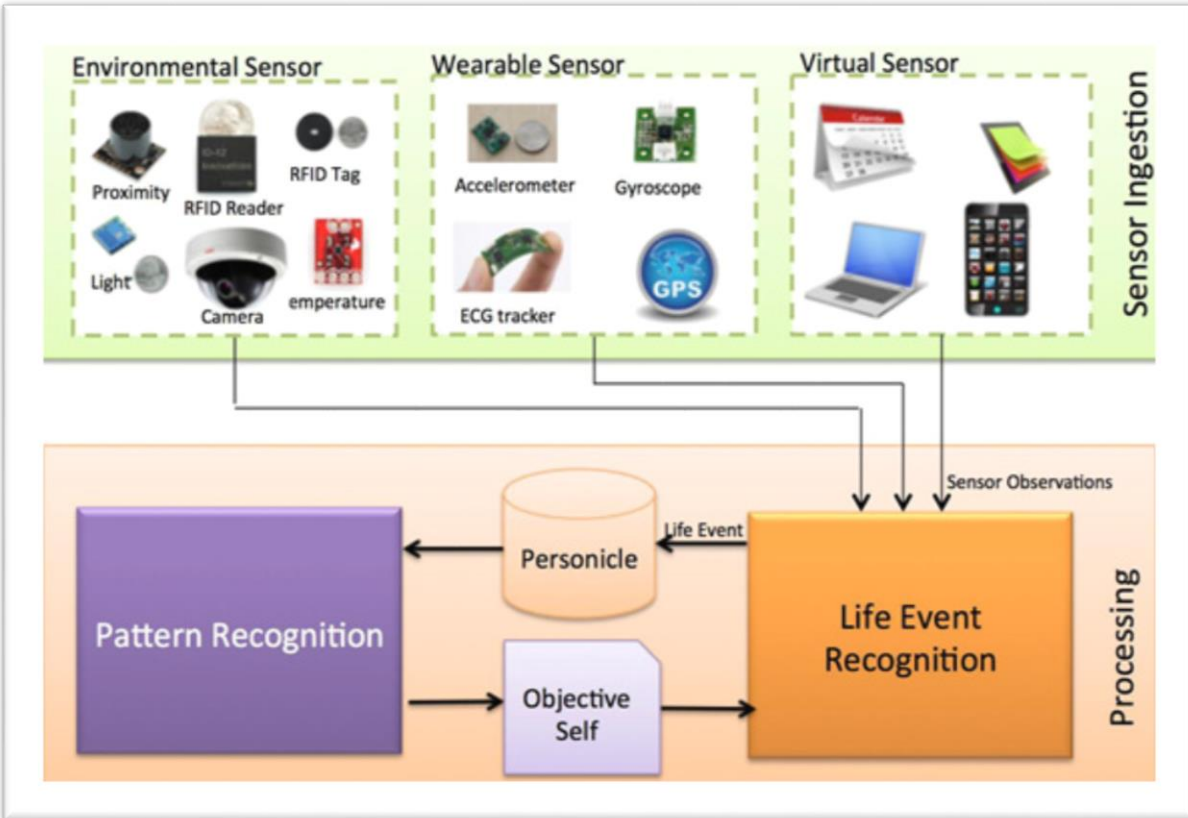


Figure 2-4 Automatic sensing applications

## 2.4 Mobile Based Remote Patient Monitoring Systems

With telemedicine, patients in underserved areas can now receive services that they may not have received without the need to travel great distances and overcoming other transport barriers (Sebastian, Neethu, Yedu , Anand, & Jayashree, 2012). For instance, implementation of a remote patient monitoring system for management of hypertension in diabetic patients, using a mobile based application, was proposed by (Logan, et al., 2007). The model intended to address the rising concern over the poor level of blood pressure control among hypertensive patients. This came about as a result of a wide assortment of health care aids designed for home use being available, and challenges associated with internet usage among elderly citizens, as well as the lack of direct communication between patients and their physicians.

Figure 2.5 below gives an architectural overview of the model. The authors describe it as having four main components; the patient's components, a data repository and decision support system, as well as the physician alerting and reporting component.

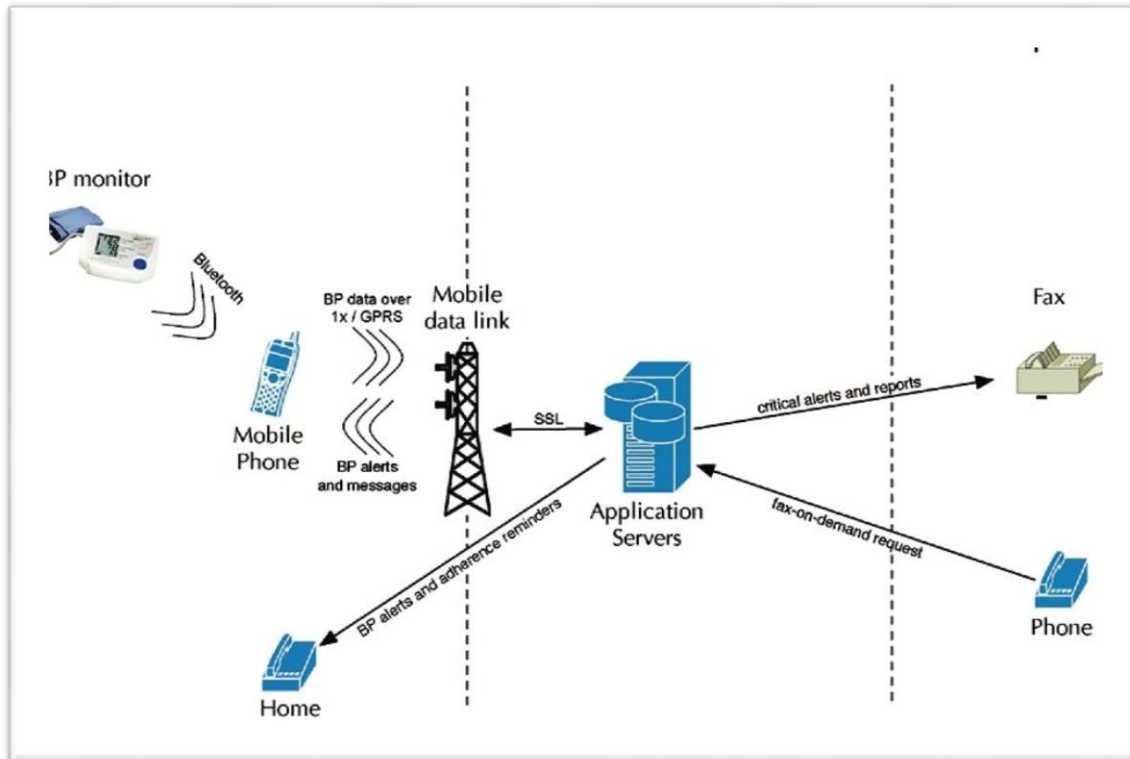


Figure 2-5 Mobile phone based remote blood pressure monitoring system

A similar example would be a remote patient monitoring system for monitoring patients' cardiology (Sebastian, Neethu, Yedu, Anand, & Jayashree, 2012). The system introduced an ECG measurement, analysis and transmission system, incorporating a mobile device as a base station. A small sized mobile ECG recording device is used to send data wirelessly to the mobile phone. The received data is then analyzed and if any abnormalities are found, the relevant data is captured and sent to the server for further analysis by the medical personnel. Figure 2.6 gives an overview of how the model works.

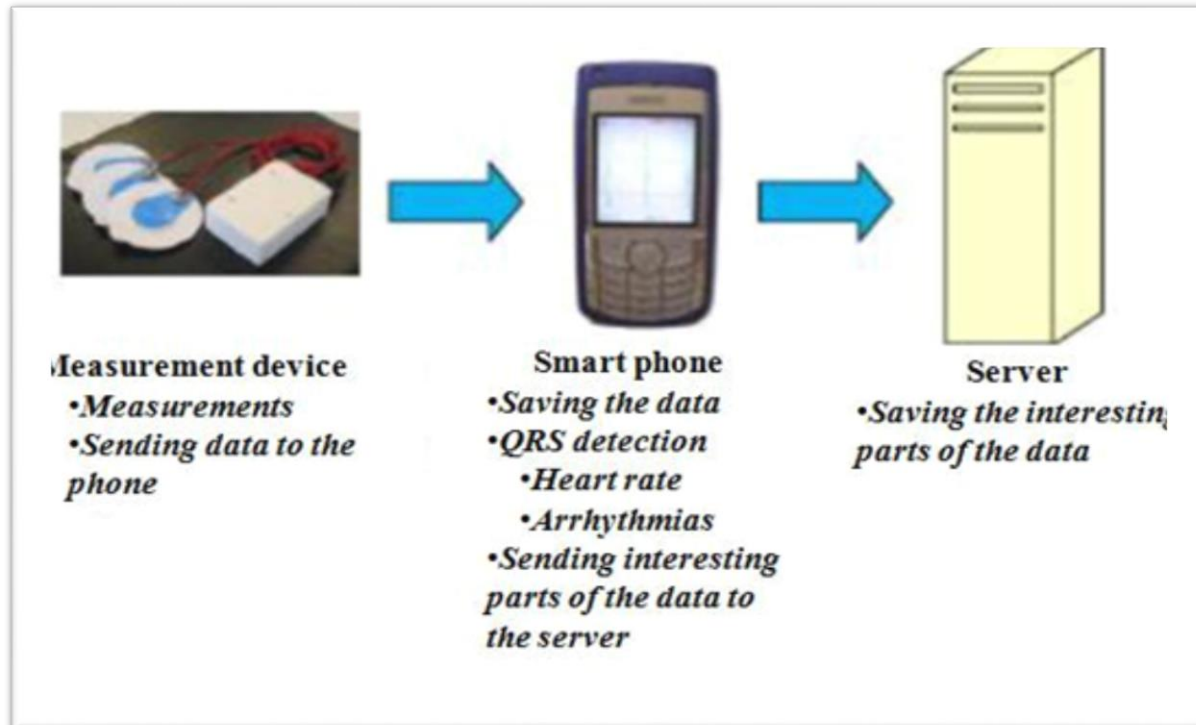


Figure 2-6 Remote patient monitoring system to monitor patient ECG

A critical point brought forward by (Sebastian, Neethu, Yedu , Anand, & Jayashree, 2012), is that most of these systems use a GSM module to generate an SMS to the doctor, but do not convey actual readings of the patient during the critical condition.

#### ***2.4.1 Challenges of Remote Patient Monitoring Systems***

While most authors agree that remote patient monitoring through the implementation of mhealth has the potential to improve health care in low resource settings, (Chib, Velthoven, & Car, 2015) states that it has not translated into a large scale investment. A contributing factor to this is that most health workers use mobile devices informally to support health care delivery to patients. This presents a variety of challenges and consequences. A recent study conducted in the United States on public health communication and alert fatigue, focused on identifying the most effective methods to share public health messages between public health agencies and providers. The study found that although sharing messages through SMS was effective in communicating between public health agencies and providers, frequent information delivery through numerous

communication channels had a negative impact on healthcare providers to recall the information sent to them. The study recommends re-examining the frequency of SMS messages sent out in order to improve the recall of information by public health providers during emergencies. The examples of the use of SMS in health provide a high-level overview of how SMS messages have been used in healthcare.

## **2.5 Mhealth Applications in Maternal Health Care**

### ***2.5.1 Texting to Improve Testing (TextIT)***

Some organizations have taken up the initiative of coming up with solutions to the maternal health dilemma. These include organizations such as the Kenya Medical Research Institute (KEMRI), which is the national body responsible for carrying out health research in Kenya. In order to solve the challenges associated with maternal healthcare, particularly in relation to expectant women living with HIV/AIDS, an application was developed for the sole purpose of interacting with these women. A mobile text message based service application known as Texting to Improve Testing (TextIT) was developed in order to aid in provision of interactive two way text messaging for expectant HIV positive women, through the use of pre-programmed texts so as to encourage them to attend postpartum clinics and also have their infants tested for HIV/AIDS. According to (Odeny, et al., 2014), HIV positive pregnant women, who were at least 18 years old and enrolled in the prevention of mother to child transmission of HIV programme, were randomized to either receive text messages or usual care. The women received up to eight text messages before delivery depending on gestational age and six messages postpartum.

The maternal baseline characteristics of this initiative, according to (Odeny, et al., 2014), are provided in figure 2.7 below.

maternal baseline characteristics.

Characteristics	SMS group (n = 195) n (%)
Maternal age	
18–24	60 (30.8)
25–34	111 (56.9)
35+	24 (12.3)
Gestational age at enrolment – median weeks (IQR)	34 (32–36)
Shared phone	51 (26.2)
Employed	35 (17.9)
Education	
None	3 (1.5)
Primary	115 (59.0)
Secondary	64 (32.8)
Post-secondary	13 (6.7)
Ethnicity	
Luo	188 (96.4)
Other	7 (3.6)
Married or with regular live-in partner (versus no partner)	169 (86.7)
First pregnancy	27 (13.8)

VT OMNES VNVM SINT

Figure 2-7 TextIT maternal baseline characteristics

**2.5.2 Changamka Micro Health**

In 2008, Changamka Micro Health Limited undertook an initiative to aid in the improvement of access to quality and affordable healthcare. This entailed the introduction of a medical smartcard, which incorporates mobile technology to enable users to save money over an extended period of time in order to gain access to primary health care services. The clients save for health care expenses using the medical smartcard combined with mobile money transfer services such as M-PESA and make payments at designated providers for goods and services at pre-contracted prices (Haas & Center , 2011).

However, according to (Bastelaer, Woodman, Chatterji, & Long, 2015), most users discontinued the cards use after only one transaction. Another factor the authors note is that an estimated six percent of the total number of women who acquired the card used it to pay for delivery and slightly less than 1% used it for its original intent and purpose; which was to pay for antenatal care and delivery services. Key respondents note that a lack of understanding of the cards workings and how to use it was the main factor attributing to their discontinued use of it. Similarly, card users were found to be of higher educational and economic status than non-card users.

### ***2.5.3 mHealth for midwives***

A number of expectant mothers preference lies towards assistance from midwives as opposed to seeking health care from modern health facilities, in the provision of prenatal, antenatal and postnatal care. Mhealth aids in the provision of creative solutions to the challenges faced by midwives in caring for women.

An example of this application entailed the provision of midwives with mobile applications in the remote Aceh province of Indonesia (Chib & Chen, 2011). The midwifery-focused pilot program was launched to find out how mobile technologies would serve as a supporting device to midwives and expectant women after the 2004 Tsunami. The devices allow midwives to remotely access clinical data, collect patient information and critical health indicators as well as track patients and actively participate in information provision.

Another application being utilized by midwives and nurses is the Mobile Technology for Community Health (MoTeCH), which is being used in Ghana. The system, according to (Speciale & Freytsis, 2013), is used to strengthen the maternal health system and educate mothers and families. Each woman's data is entered into mobile devices during prenatal visits by nurses and midwives and thus creating a mobile electronic health record. In provision of feedback, women are sent educational text messages and pre-recorded voice messages in the local dialect that can be retrieved by the women at their convenience.

#### **2.5.4 Text4Baby**

Text4baby uses new technology to deliver health messages and engage pregnant women and new mothers in healthy behaviors (Parker, Dmitrieva, Frolov, & Gazmararian, 2012). The authors describe the need for a carefully conducted evaluation in women, infants, and children clinic population in the United States and its proposed adaptation for use among early users of Text4baby in Russia.

Text4baby (T4B) started as a U.S. mobile health information text messaging service that sends free text messages to women who are pregnant or have children younger than 1 year old, providing them with information and reminders to improve their health and the health of their babies. Women sign up for the service by sending a text message with their child's expected birth date and they receive three messages a week offering evidence-based information relevant to the stage of pregnancy they are in. T4B U.S. is a program of the National Healthy Mothers, Healthy Babies Coalition supported by a public-private partnership. The T4B U.S. project launched in February 2010 and currently has approximately 240,000 enrollees. Furthermore, the authors (Parker, Dmitrieva, Frolov, & Gazmararian, 2012) describe it as a new opportunity for the advancement of client-doctor relationships, with women more actively participating in active conversations with their doctors. The text messages are used as a vehicle for the provision of evidence based information and education to the pregnant women.

Although Text4Baby was messages were designed for all literacy levels, a study conducted by (Gazmararian, Yang, Elon, Graham, & Parker, 2012) outlines concerns of literacy levels affecting the ability of the target women in enrolling for and receiving these messages.

## 2.6 Conceptual Framework

As depicted from the reviewed literature, interventions for expectant mothers often fail as they don't focus on changing care seeking behavior. Improved implementation of low cost tools in order to provide and build better awareness and prompt healthy behaviors need to be taken into consideration.

Access to medical care can benefit tremendously from health financing applications, such as Changamka micro health, which aid in decreasing the overall costs associated with related health care services and management of some chronic diseases. However, user training and access to information was the major reason for users discontinued use of the service.

Mobile health platforms incorporating the use of mobile devices and internet services are improving the capacity for service delivery to patients. Also, by use of intermediaries such as health workers, the improvement is viewed to be much more efficient and the data collected to be more accurate. To complement this, the reviewed existing works are seen to improve coordination of care to patients. This is seen through the implementation of rapid data exchange, via mobile devices, among midwives, community health workers, patients and hospitals.

The proposed application seeks to incorporate features of client education and behavior change communication through the implementation of stage-based health care tips and antenatal reminders as reviewed from existing applications. The application also includes a two-way interactive text messaging feature which would aid the expectant mother in seeking further attention from the health worker. Existing applications outlined in the literature review provide maternal health care tips as well as interactive communication. However, a number of applications such as TextIT, allow for one-way interaction from the health worker to the expectant mother. This application incorporates the use of two-way interactive text messaging as a low cost tool to aid in the implementation of monitoring expectant mothers located in low resource settings.

This conceptual framework aims to justify the different literature reviewed and correlate it with the defined research questions and objectives. The figure outlines two actors of the system, entailing the health worker and the expectant mother. The health worker facilitates collection and review of patient data by use of a mobile device as opposed to implementation of paper-based

systems. The expectant mother performs registration and passes queries to the database regarding antenatal care. The collected patient information is then uploaded and stored onto a secure database. The patient is then able to receive reminder notifications on upcoming clinical appointments and stage-based follow up advice.

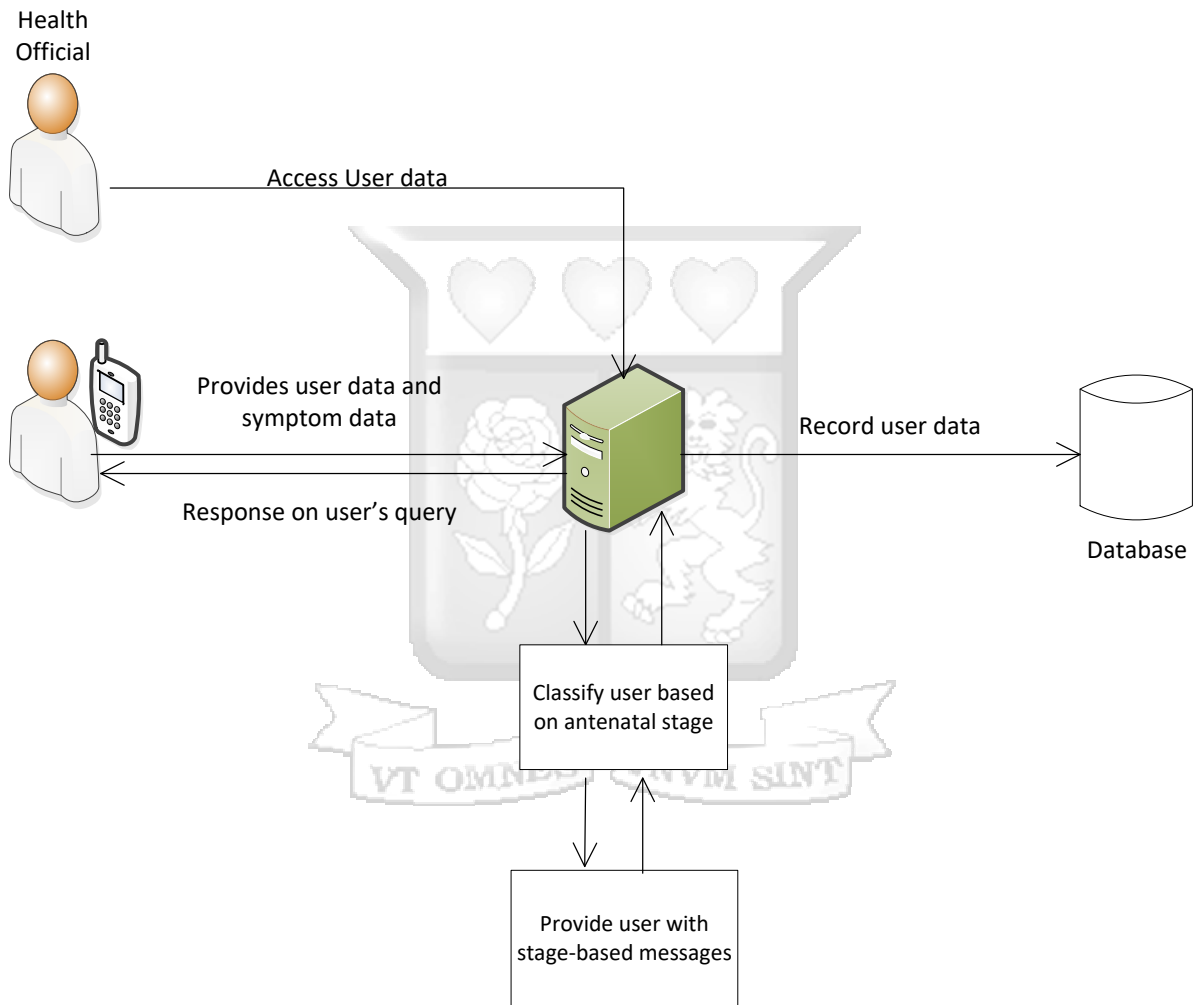


Figure 2-8 Conceptual Framework for patient monitoring application in maternal health care

## **CHAPTER 3**

### **RESEARCH METHODOLOGY**

#### **3.1 Introduction**

The proposed system is a mobile application that will provide patient monitoring capabilities in the field of maternal health. This section seeks to provide an in depth representation of the different methodologies that the researcher intends to use so as to provide a working concept of the proposed mobile application.

#### **3.2 Research Design**

Research design is defined as the systematic arrangement of conditions for the collection and analysis of data in order to relate relevance to the research purpose (Kothari, 2004). With this in mind, the researcher intends to collect data, analyze it and interpret results using the software engineering model for mobile applications development (SEMMA) methodology. The SEMMA model applies ideas from agile development initiatives such as adaptability, iterations, and making heavy use of prototyping and testing as early as possible in the process. The use of prototypes will be primarily helpful in eliciting requirements and will enable the researcher to gain a common understanding with the stakeholders early in the project.

This research will implement use of quantitative data collection methods to gather information from a sample population, thus assisting the user to answer the research questions stipulated in chapter one. Two types of questionnaires will be issued to the users. The first questionnaire will be used to gather information from the sample population relating to mobile application usage and challenges relating to patient monitoring, whereas the second questionnaire will be used to test the mobile application.

#### **3.3 Location of the Study**

The chosen location for this study will be Nairobi region. The study will be conducted under the Kenya Medical Research Institute's Centre for Public Health Research programme. The institute conducts research initiatives related to public health as well as undertaking health clinic initiatives that will provide an avenue for the collection of data to be used in this research.

### 3.4 Target Population

The target population for this study consists of expectant women, doctors and community health workers. The target population age for the expectant women is between 18 and 45 year olds.

### 3.5 Sampling Procedures and Sample Size

Sampling is the process by which a relatively small number of objects, individuals or events is selected and analyzed so as to find out something about the entire population from which it was selected (Kothari, 2004). The researcher intends to use random sampling technique as this will enable generalization of a large population with a confidence interval that can be determined statistically.

From the 100 patients who visited the Centre for Public Health Research, a sample size has been calculated using confidence level and confidence interval to have the population well represented. Confidence interval refers to the margin of error in the survey. In this case, we have used a confidence interval of 7 this means that I can be sure that if I asked the same questions to the entire population  $\pm 7\%$  will pick that answer.

Confidence level refers to how sure you can be while doing the survey. The researcher has used the confidence level of 95% that showed that we are certain to be within the given confidence interval.

The sample size chosen to test the mobile application was 35 expectant mothers. The above data has been calculated using an online sample size calculator that based its formula from (Naing, Winn, & Rusli, 2006).

The formula used is as below:

$$Ss = \frac{z^2 * (p) * (1 - p)}{c^2}$$

Where:

Z = Z value (e.g. 1.96 for 95 % confidence level)

P = percentage picking a choice expressed as decimal (.5 used for sample size needed)

C = confidence interval, expressed as decimal (e.g., .04  $\pm 4$ )

Table 3-1 Sample Size Population

<b>Population Category</b>	<b>Target Population</b>	<b>Sample Size 50%</b>	<b>Percentage</b>
Expectant Mothers	50	25	77
Community Health Workers	10	5	19
Doctors and Clinical Staff	10	5	4
<b>Totals</b>	70	35	100

### **3.6 Research Instruments and Testing Tools**

#### **3.6.1 Questionnaires**

Questionnaires will be used as the main data gathering tool to undertake this research. This will include two distinct questionnaires; a pre-test and a post-test questionnaire. The pre-test will be used to gather general information about the participants regarding their smartphone experience and their maternal health experience. The post questionnaire will be used to gather information regarding the users' experience with the application. The post-test questionnaire provides the researcher with actionable guidelines on the user's acceptability and use of the system.

#### **3.6.2 Questionnaire Design**

The questionnaires will be designed in a simple and non- biased way. To accomplish this, different design scales will be used on both questionnaires.

- a) Dichotomous Scale: The questionnaires will have two possible responses; yes or no, true or false, agree or disagree. This will enable analysis of each question on its own.
- b) Likert Scale: This will enable the users to give varying points of view based on a specific order.

### ***3.6.3 Face to face interviews***

Structured and unstructured face to face interviews will be conducted to assess patients and caregivers needs and expectations of the mobile application.

### ***3.6.4 Observation***

Observation of patients will allow the researcher to capture their routines and thus give an understanding of the patients' perspectives.

### ***3.6.5 Clinical documents study***

In order to streamline design specifications and functionalities, maternal care documents will be reviewed by the researcher. These include admission registers, antenatal/postnatal care booklets, clinic follow up registers and documents relevant to pregnancy.

### ***3.6.6 Data Processing and Analysis***

Data gathered from the filled questionnaires will need to be statistically analyzed for interpretation and presented in graphical format using statistical software and applications such as Microsoft excel.

## **3.7 System Design**

System design emphasizes the development of a conceptual solution (Larman, 2012). The proposed system architecture will enable the researcher to describe and represent the system in an organized way. To attain this, the researcher will use an Object Oriented Programming approach to develop the proposed solution.

To represent the system, the researcher will use the Unified Modelling Language (UML), which is a visual language for specifying, constructing and documenting the artefacts of a system (Larman, 2012). It will represent all the actions and users in the system in a more comprehensive way. The following diagrams will be used to represent the system: Use Case Diagram, Design Class Diagram, System Sequence Diagram and Sequence Diagram. The Entity Relationship Diagram is not part of UML as it only represents the relationship of the tables created in the database.

### ***3.7.1 Use Case Diagram***

Implementation of use case diagrams will aid in identification and partitioning of the system's functionalities. It will enable the researcher to categorize the system into use cases and actors,

where actors are the users of the mobile application. Use case representation will be in the form of text that describes the set of actions that a particular user is effecting on the system.

### ***3.7.2 Design Class Diagram***

The researcher will use design class diagrams to represent all the classes used in the system. Class representation will be based on attributes and methods.

### ***3.7.3 System Sequence Diagram***

The System Sequence Diagram will enable use case break down and summarization. This includes the order of events generated by an external actor, the actions, and how the actions interact.

### ***3.7.4 Sequence Diagram***

The sequence diagram shows object interaction in an orderly manner. This will enable the researcher to display how the system works based on a timely manner.

### ***3.7.5 System Architecture***

The system architecture will enable the researcher to categorize the system into different components and show their relationship to each other. The main users of the mobile application will be expectant women who access the system using their mobile devices. The backend of the system will be represented by how the medical practitioner accesses the same system via their device.

### ***3.7.6 Entity Relationship Diagram***

The Entity Relationship Diagram will enable the researcher to graphically represent different objects of the system with real life relationships, such as people objects and places.

## **3.8 System Implementation**

The tools required by the researcher for implementation of both the front end and the back end of the mobile application are as stated below.

The hardware requirements will be as follows:

Pentium (R) Dual –Core CPU processor at 2GHz or faster, with a minimum of 1GB disk space availability for installation and a minimum of 512MB memory.

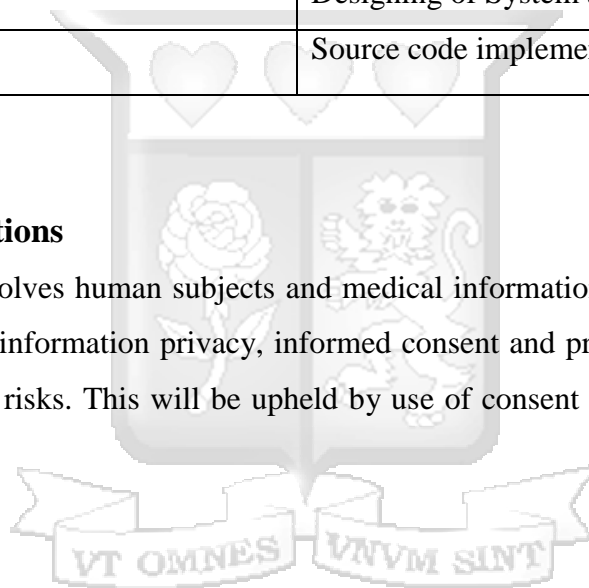
The system's front end and back end will be developed using PHP-MySQL. Table 3.2 below represents the application software that the researcher intends to use.

Table 3-2 Software Tools

Software	Purpose
MySQL	Database
XAMPP Server	Web Server
Visual Paradigm	Designing of UML diagrams
Ms Visio 2010	Designing of System architecture
Android Studio	Source code implementation

### 3.9 Ethical Considerations

Given that this study involves human subjects and medical information, medical ethics requires the researcher to uphold information privacy, informed consent and protection against physical, social and psychological risks. This will be upheld by use of consent letters and confidentiality from the researcher.



## CHAPTER 4

### SYSTEM ANALYSIS AND DESIGN

#### 4.1 Introduction

This chapter aims to fulfill the fourth research objective of developing a mobile application to address the challenges identified in the literature review. This will consist of design and modeling of the maternal health application and screen shots of the application prototype. The mobile application will be developed to enable continuous interaction with the health practitioner and the expectant mother. It intends to increase the number of expectant women receiving antenatal care and thus decrease the MMR ratio in the country.

#### 4.2 System Architecture

The health practitioner will be able to access the backend of the web application through an internet enabled device of different screen ratios, such as laptops, desktops, mobile phones or tablets. The expectant mothers will require an internet connection in order to access the system, upon which they can pass and read data from the database. All data read and written by the user will pass through the web server and saved on the database. Expectant women having mobile devices without internet connectivity will receive antenatal care messages by use of text messages.

Figure 4.1 gives an illustration of the proposed system's architecture

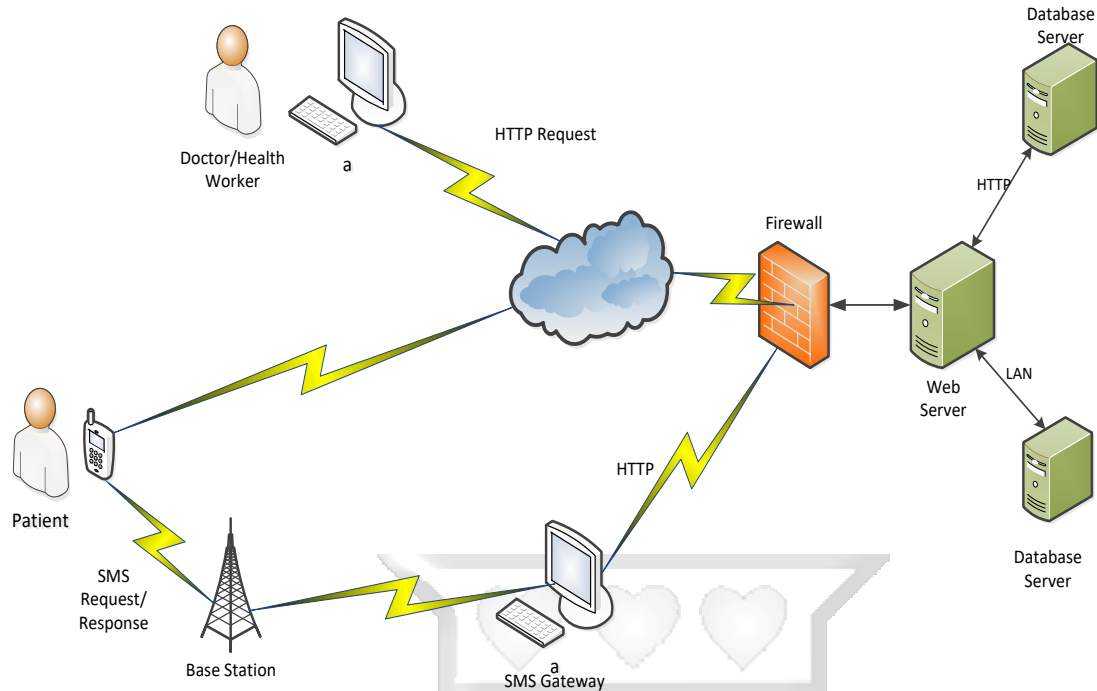


Figure 4-1 System Architecture

### 4.3 Context Diagram

The context diagram below depicts the basic level interpretation of the flow of information between the application and its users. The main users of the device include the Health Worker and the expectant mother. The expectant mother provides registration details to the system, where by the system verifies the details and notifies the Health Worker. The health worker is then able to view the submitted details of the user inclusive of symptoms they are experiencing and provide their professional opinion.

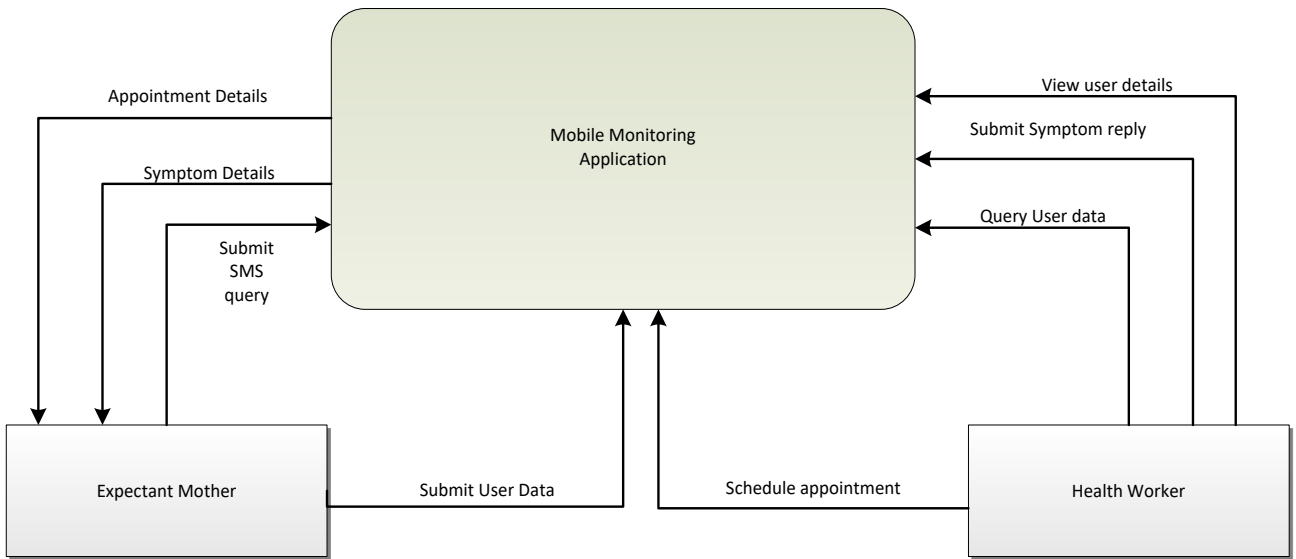


Figure 4-2 Context Diagram

#### 4.4 Use Case Diagram

The use case diagram describes how the main users of the application interact with the system. The system users include the expectant mother and a health official. Table 4.1 below gives the description of actors in relation to the functions of the application available to them. The use case diagram is presented in figure 4.3 below.

Table 4-1 Use Case Description

<b>Actor</b>	<b>Use Case</b>	<b>Description</b>
User / Expectant Mother	Register	A potential user is required to register in order to use the application by providing relevant details as required.
	Receive Notifications	A registered user is able to receive user specific notifications based on the provided registration information.
	Request Appointment	A registered user can request an appointment or receive an appointment request from the health official based on the symptoms provided by the user
	SMS Request	A registered user is able to submit an SMS request with queries or symptoms experienced
Health Official	View Profile	The health official is able to view the patient's details and provide feedback as necessary
	Request Appointment	The health official upon viewing the user's profile is able to schedule an appointment for the user based on the profile viewed
	Manage Users	The health official can add a new user as well as view all the registered users' profiles

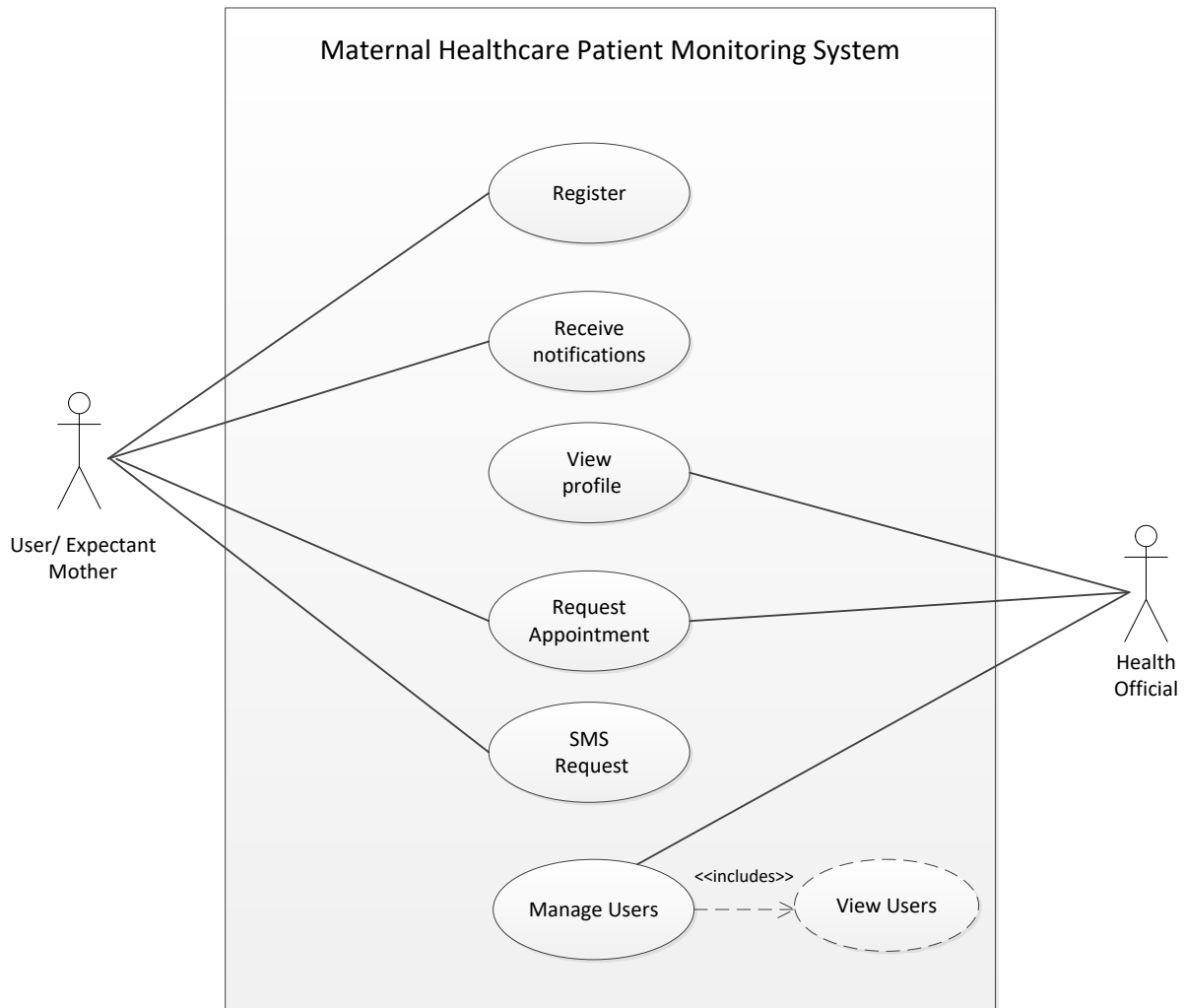
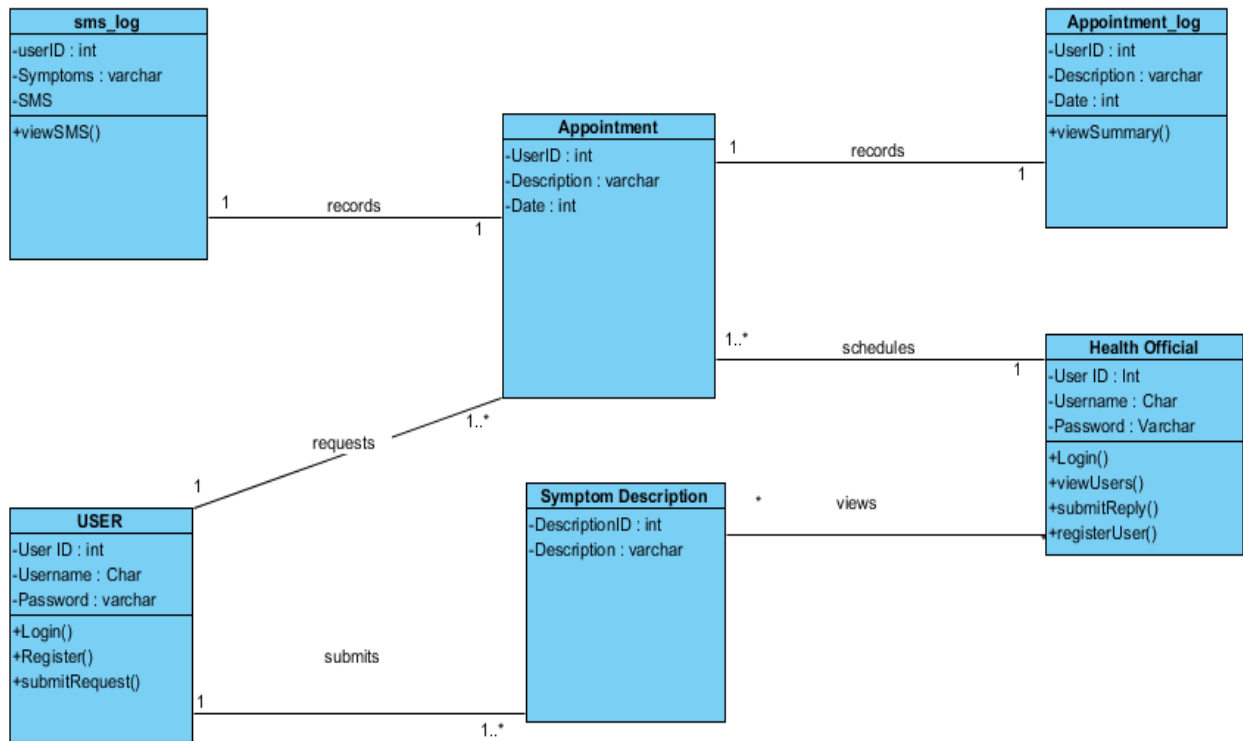


Figure 4-3 Use Case Diagram

#### 4.5 Design Class Diagram

Figure 4.4 below is the design class diagram which depicts the interaction between the various classes in the system and the associated attributes of each class. A class defines the methods and variables it contains. In this case, the class enables creation of real world objects, which are of value to the system.

The classes contain information for both the front end and back end of the system. Expansion or modification of the design class diagrams will enable identification of system actors by future developers and ease of attribute addition for an improved system.



VT OMNES VIVVM SINT

Figure 4-4 Design Class Diagram

#### 4.6 Sequence Diagram

The sequence diagram below depicts the interaction relationship between the actors of this system, as well as the objects and components associated with it. Figure 4.5 illustrates the sequence of the expectant user requesting a consult after providing details of the symptoms they have.

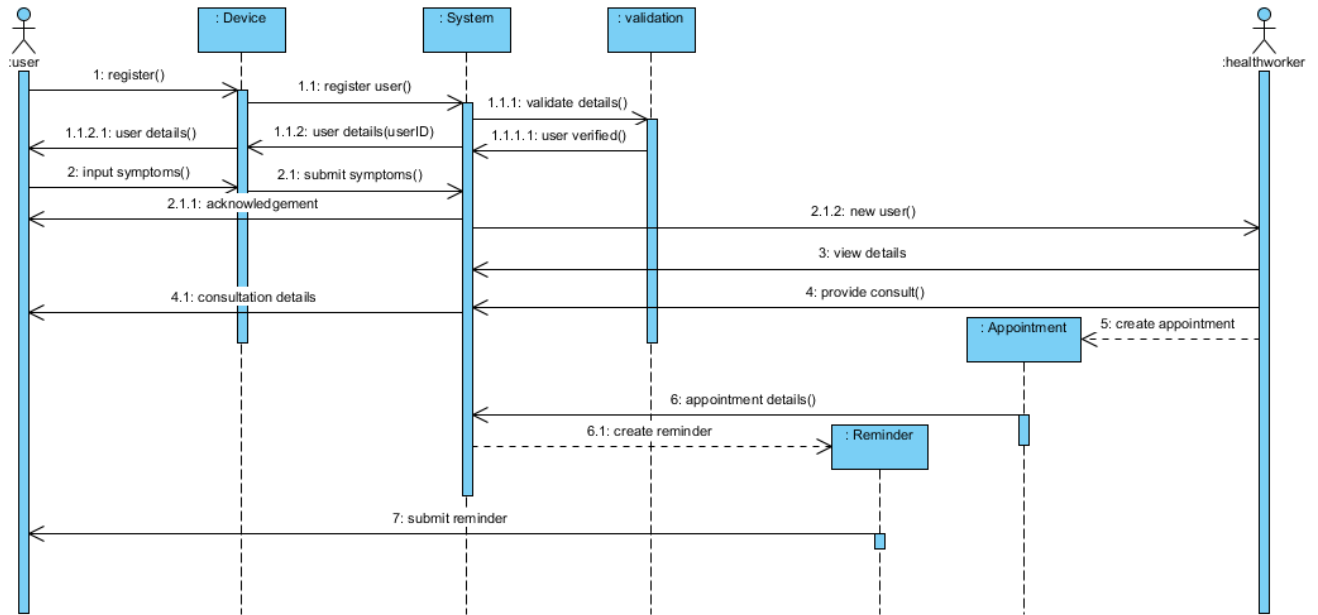


Figure 4-5 Sequence Diagram



## **CHAPTER 5**

### **SYSTEM IMPLEMENTATION AND TESTING**

#### **5.1 Introduction**

In this section, an analysis of the collected is represented in the form of tables, charts and graphs with brief but detailed explanations of what the data represents. The calculated sample size for this research is 70 participants and therefore, 70 questionnaires were handed out to random respondents in the identified target population.

#### **5.2 My Health Application**

The developed system called My Health Application enables user registration via mobile, where the user can then access maternal health information as well as interface with a designated health official. The health official has access to a backend system whereby he can view the registered users, as well as the symptoms exhibited and respond to queries posted by the user.

##### ***5.2.1 User Registration Module***

Once the application is installed on the user's device, the mother can the sign into the application using a created username and password. The registered user is then able to access the homepage of the My Health Application, illustrated in Figure 5.1 below, which contains Menu items from which the user can select a required service. A registration form is then presented for the user to fill out details pertaining to their pregnancy. The details include the user's name, age, location, phase of pregnancy. Figure 5.1 and 5.2 below depicts the login and registration pages respectively.

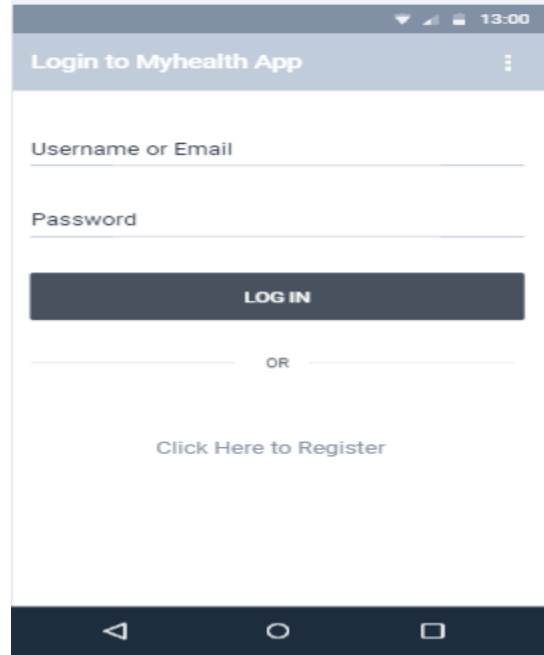


Figure 5-1 Login Page

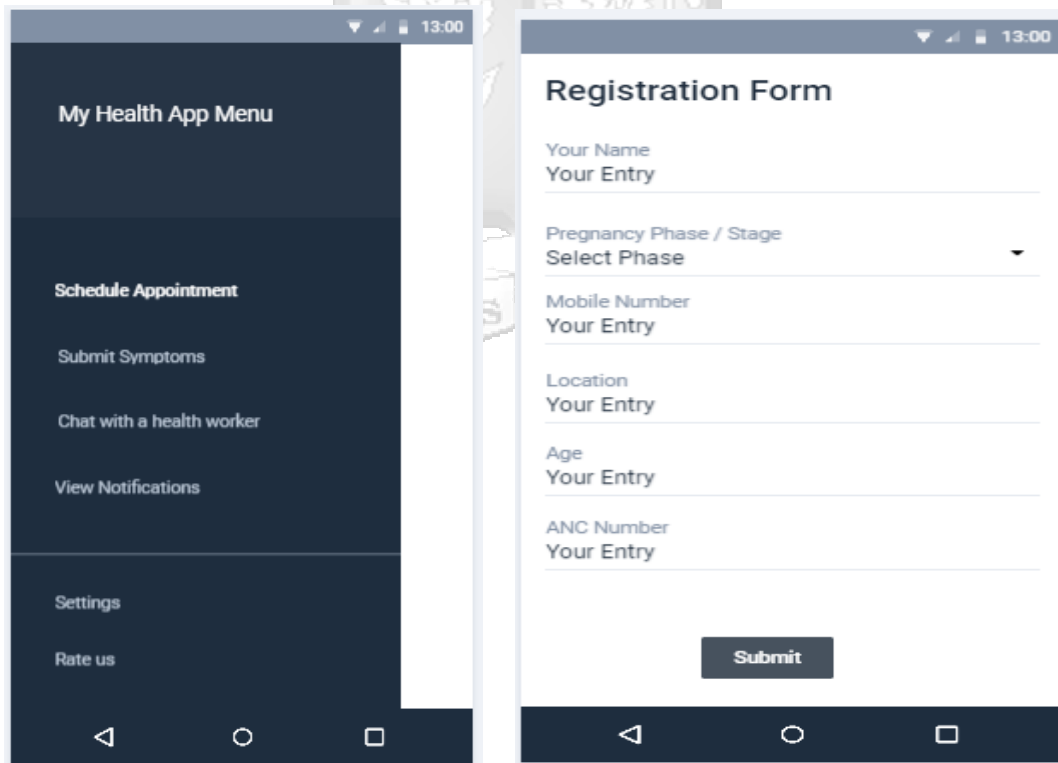


Figure 5-2 Application Registration Page

Upon registration, the user then receives a notification on the mobile via SMS informing them of their registration status. Figure 5.3 below depicts this.

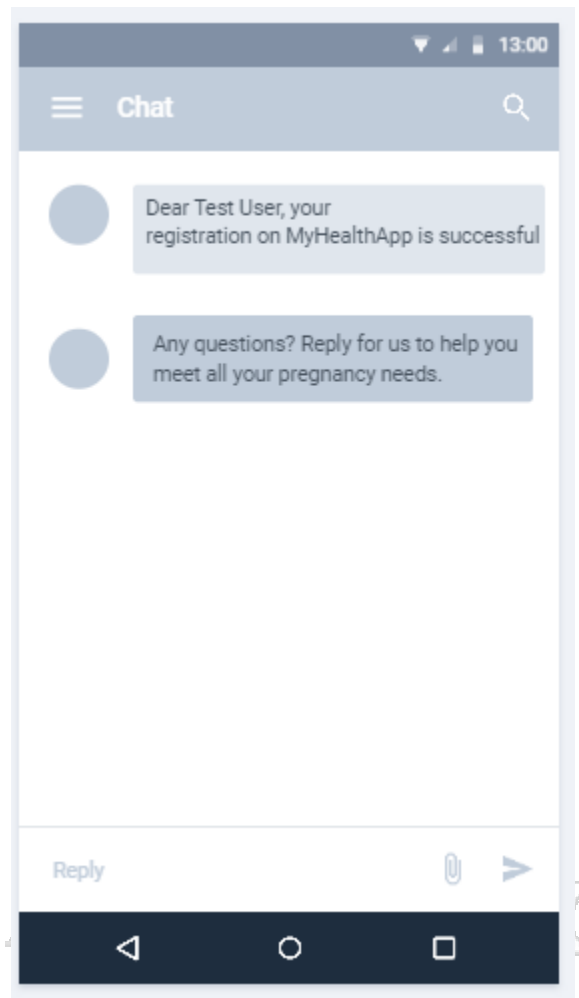


Figure 5-3Successful Registration Notification

### ***5.2.2 User Symptoms Module***

Upon successful registration, the user can then submit any symptoms that they are experiencing for further action by the health official. If the symptoms are consistent with the pregnancy period, then the health official can only provide advice, if the symptoms are not consistent with the pregnancy phase, then immediate action is required to be taken by the health official. If the perceived symptoms are not available, the user is able to submit additional symptoms.

Figure 5.4 below depicts the symptoms page of the My Health Application.

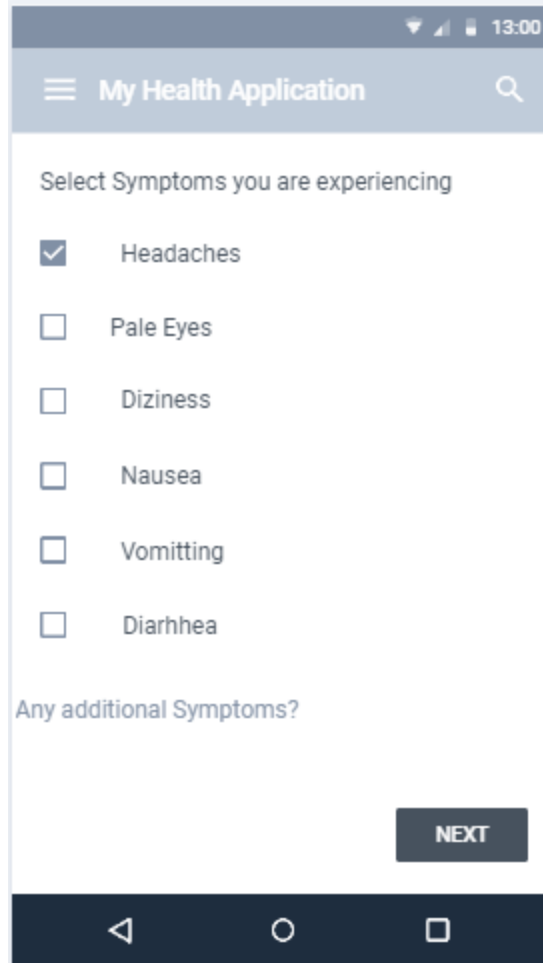


Figure 5-4 Submit Symptoms Page



### ***5.2.3 Schedule Appointment Module***

A user is able to schedule an appointment with the health official using the My Health mobile application. If successful, the user receives an appointment notification with the details of the appointment via text or via the mobile application.

Figure 5.5 below gives a representation of the schedule appointment page of the application.

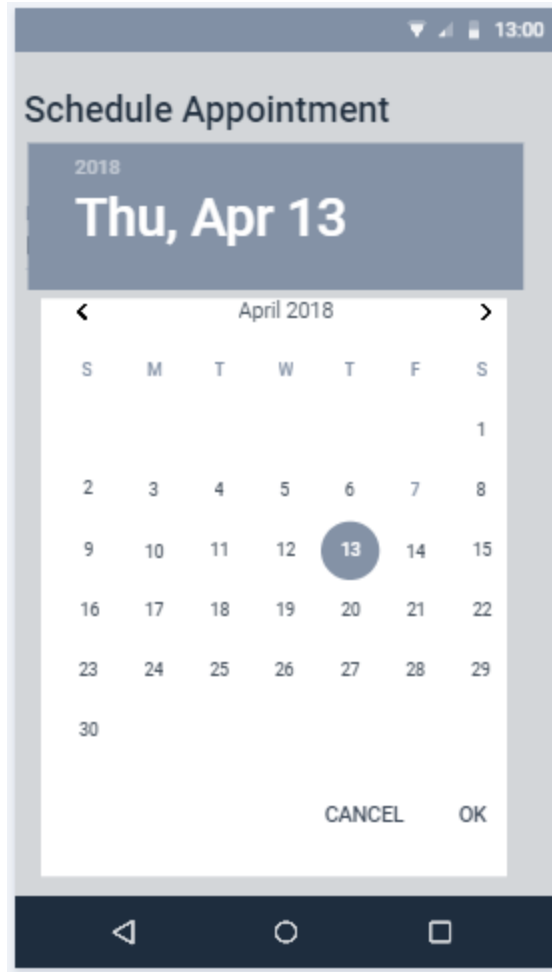


Figure 5-5 Schedule Appointment Page

The user then receives periodical updates regarding their next appointment as well as their next antenatal care visit with the health official. Figure 5.6 below shows the notification received by the user.

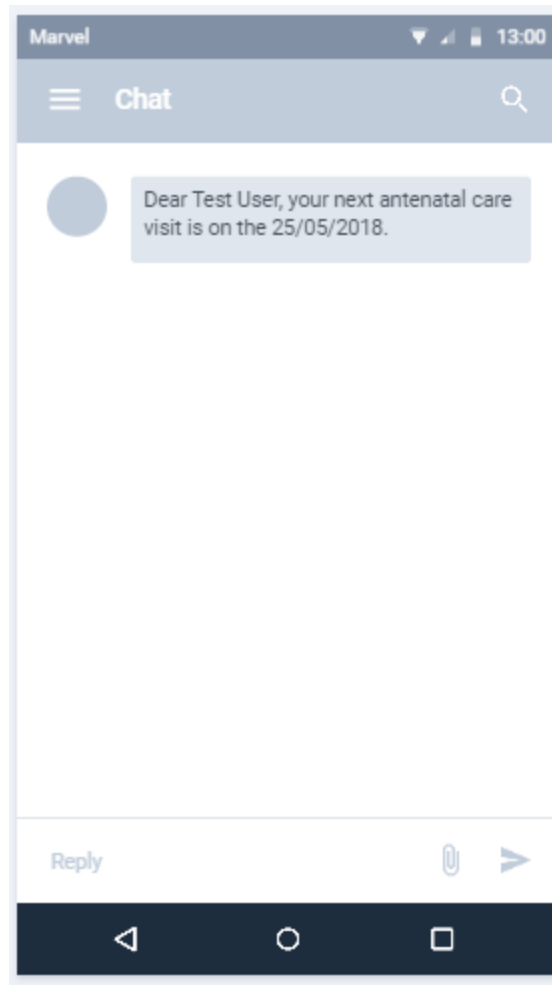


Figure 5-6 Appointment Notification

#### **5.2.4 SMS Chat Module**

The application contains an SMS chat module that enables two-way interaction between the user and the health official. The user can submit any queries they may have to the health official and the health official is notified and prompted to provide a response. Figure 5.7 below depicts the chat module of the application.

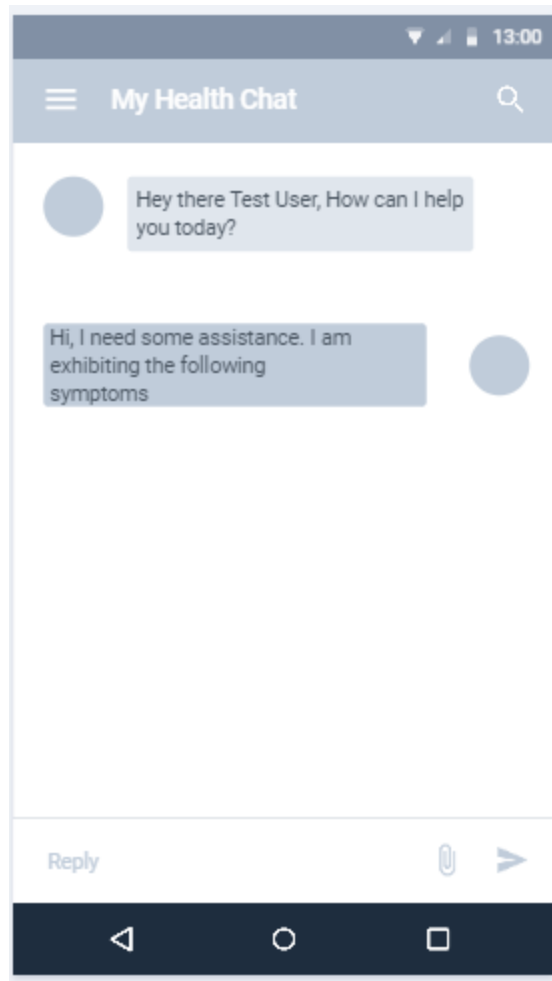


Figure 5-7 SMS chat module

### ***5.2.5 My Health Application Back End***

This module acts as the interface where the health official or the administrator can view details and symptoms submitted by the user. The health official is then able to respond to user queries and confirm appointments made by the user.

Figure 5.8 illustrates the back end of the application with some of the symptoms submitted by users of the application.

Sign up Log Out

Filter by :

Symptoms	Address	Symptom Date
Head ache,pale eyes alot of sleep,heavy breathing ,Weak joints and dizziness	Kipleno ,Tanzania	2013-07-03 15:59:57
Weak joints,head ache,Morning Sickness	Rongai way,Kenya	2013-07-03 15:59:57
Heavy breathing,stomach ache,head ache	Ngara Road,Nairobi Ken	2013-07-03 15:59:57
Head ache,pale eyes alot of sleep,heavy breathing and dizziness	Limury Road,Nairobi Kei	2013-07-03 15:59:57
Weak joints,head ache,Morning Sickness	Turkana,Kenya	2013-07-03 15:59:57

Figure 5-8 Application Backend

The administrative end of the mobile application also allows the health official to view registered users. The health official is then able to manage appointment dates for the users as well as view submitted symptoms. Figure 5.9 illustrates the registered users of the application.

GET MOTHERS Sign up

Filter by :

Patient No	Surname	Other Names	Address
1	Euvin	Muema	Mutomo, Kenya
2	Milka Ndinda	Kisulu	Kibwezi,kenya
3	Veronica	Juma	Mutomo, Kenya
4	Florence	Kasivi Kathoka	Kitui Kenya
5	Margret	Mueni Nicodemus	Kyatune, Kenya
6	Brigid Kasungwa	Mutisya	Kitoo, Kenya
7	Francisca	Kiboi	Mutomo, Kenya
8	Catherine	Kyalo	Ndili, Kenya
9	Felistus	Munyao	Kitoo, Kenya
10	Joyce Katuku	Munyao	Kitoo, Kenya
11	Munyiva Githome	Mbithuka	Katwala, Kenya
12	Maria	Kasanga	Kenze, Kenya
13	Lucia	Kisovi	Ilaani, Kenya
14	Mary David	Savi	Kisasi, Kenya
15	Rose Ndava	Kathenge	Uae, Kenya
16	Pauline Kasumuni	Kyenze	Mwangala, Kenya
17	Nancy	Makundi	Mwangala, Kenya
18	Faith	Nancy	Mwangeni, Kenya
19	Kambua Munyasya	Kathale	Mwangeni, Kenya
20	Rhoda	Benard	Kyoani, Kenya
21	Zipporah	Kyengo	Athi, Kenya
22	Juliana Kangalu	Mwangangi	Kamutei, Kenya
23	Joyce Nzembi	Mbuvi	Mallii, Kenya

Figure 5-9 Registered Users

## 5.3 System Testing

### 5.3.1 Respondents' Demographics

Testing of the application will be centered upon evaluating the applications effectiveness, efficiency as well as user acceptance. The data below shows information related to the randomly selected participants.

- Gender
- Age
- Occupation
- Level of Education
- Number of infants
- Monthly Income
- Mobile Provider
- Type of phone

The demographic information above will aid the researcher in identifying whether the proposed solutions addresses the challenges presented by current mobile health applications.

### 5.3.2 Respondents' Gender

Figure 5.10 below shows the distribution of respondents by gender. The findings indicate that of the 70 respondents, 21% were male whereas 79% were female. This figure composed of expectant mothers, doctors and community health workers, with the majority of the respondents being female respondents.

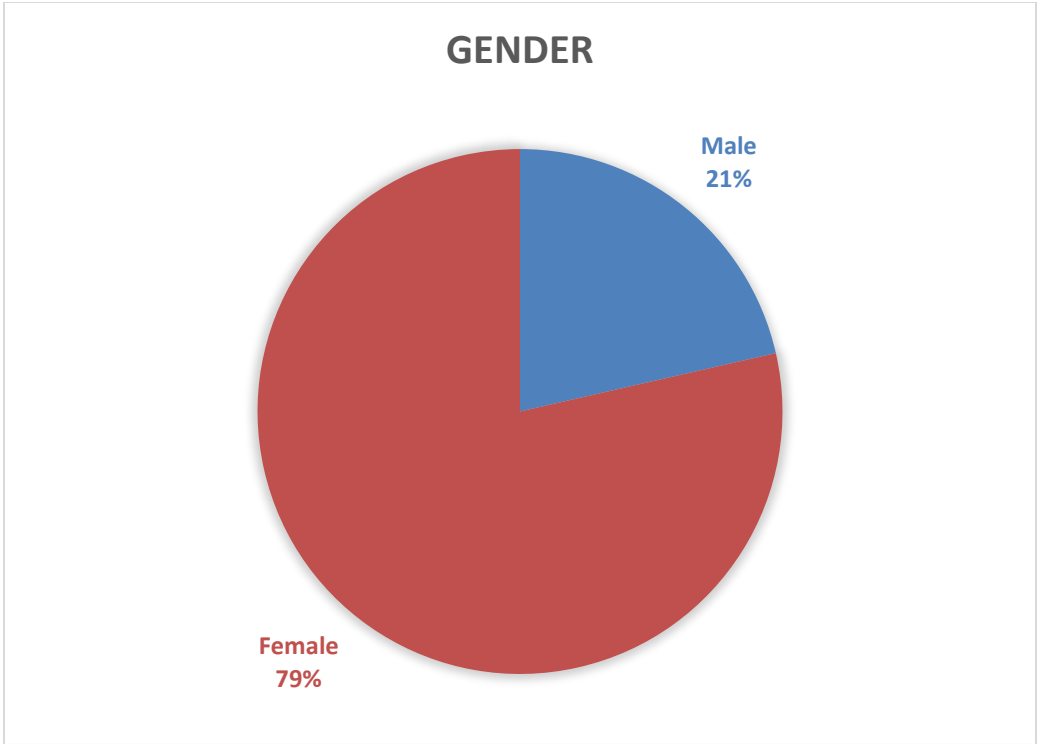


Figure 5-10 Respondents' Gender

**5.3.3 Respondents' Age**

Figure 5.11 represents the distribution of the respondents by age. The findings indicate that out of the 52 respondents, 58% of the respondents were between the age of 19 years and 29 years. 29% of the respondents were between the age of 30 and 39 years. 9% of the respondents were above the age of 40.

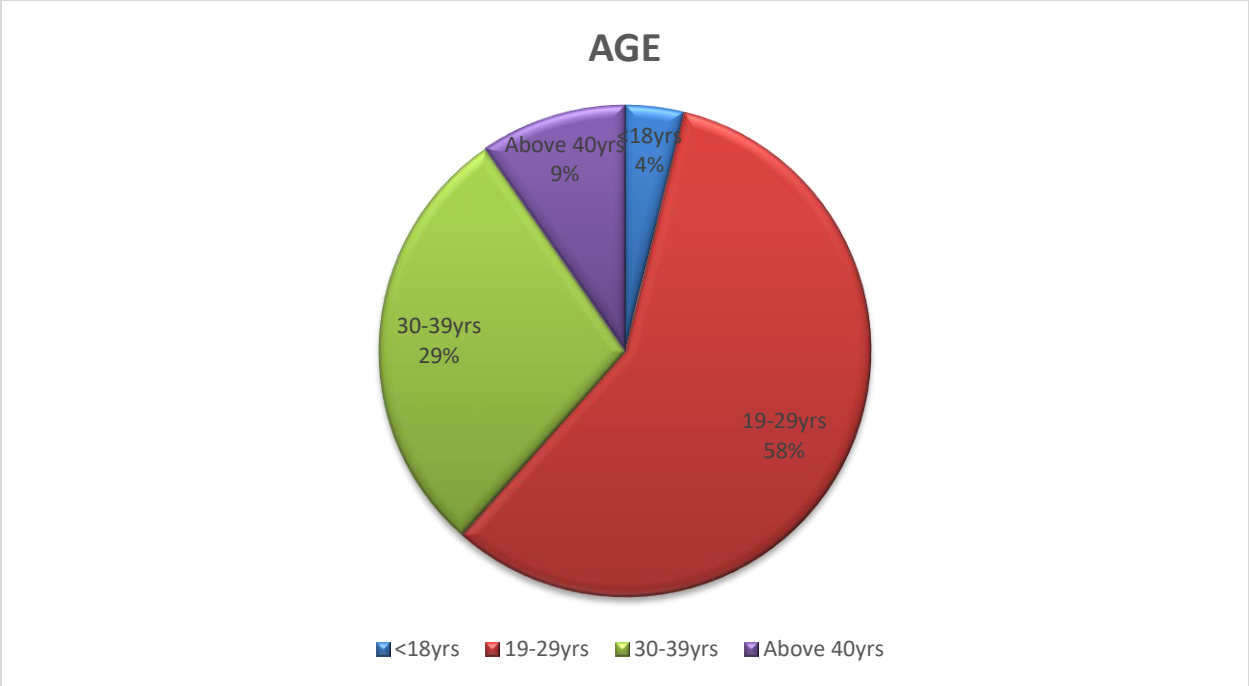


Figure 5-11 Respondents Age

**5.3.4 Respondents' Occupational status**

Figure 5.12 represents the respondents' distribution by occupational classification. The data shows that 32% of the respondents are unemployed, 26% are employed and 42% are self-employed.





Figure 5-12 Occupational Status

**5.3.5 Respondents' Level of Education**

The educational level of the respondents was classified into 3 main categories. These were divided into primary school education, tertiary education and secondary education. The findings in figure 5.13 indicate that 34% of the respondents have primary education whereas 58% of the respondents have secondary education, with the least number of respondents, 8% having tertiary education.

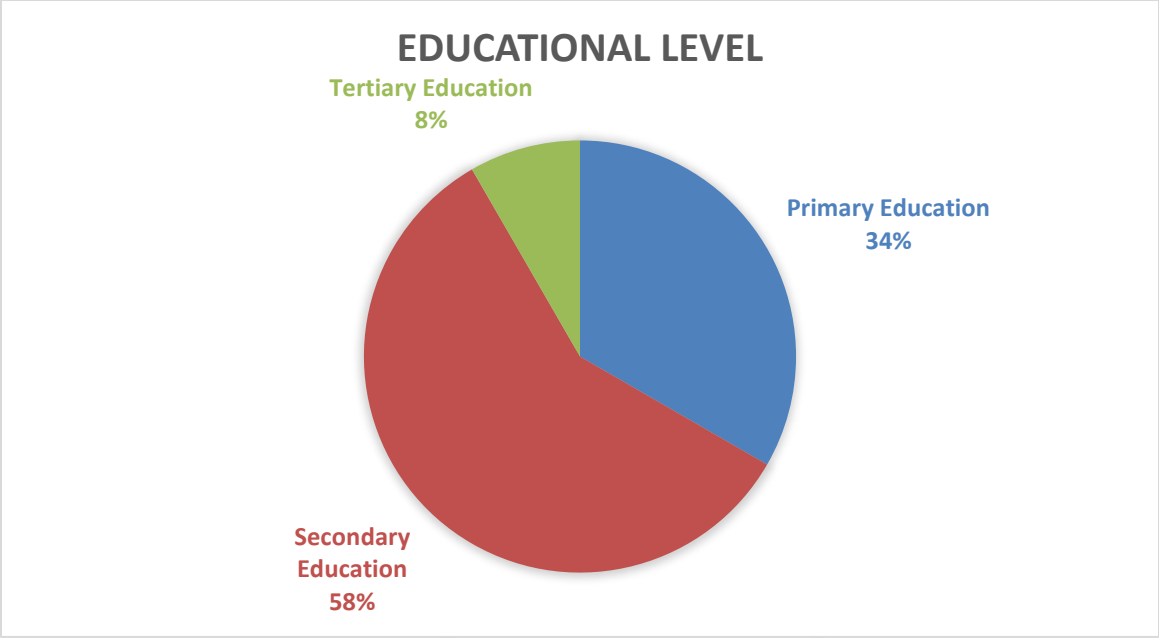
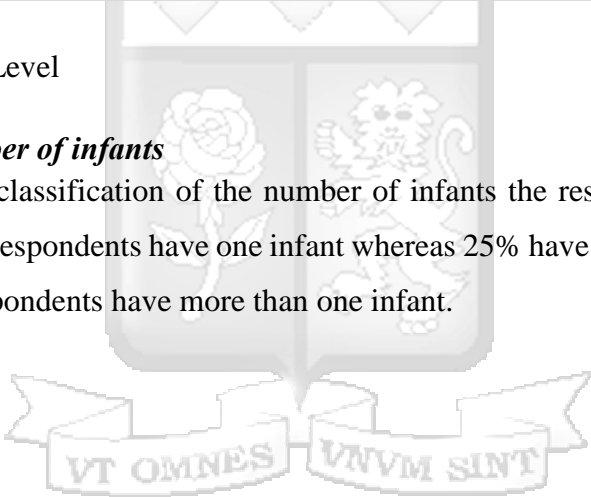


Figure 5-13 Educational Level

**5.3.6 Respondents' number of infants**

Figure 5.14 displays the classification of the number of infants the respondents have. The data indicates that 60% of the respondents have one infant whereas 25% have none or are about to have their first. 15% of the respondents have more than one infant.



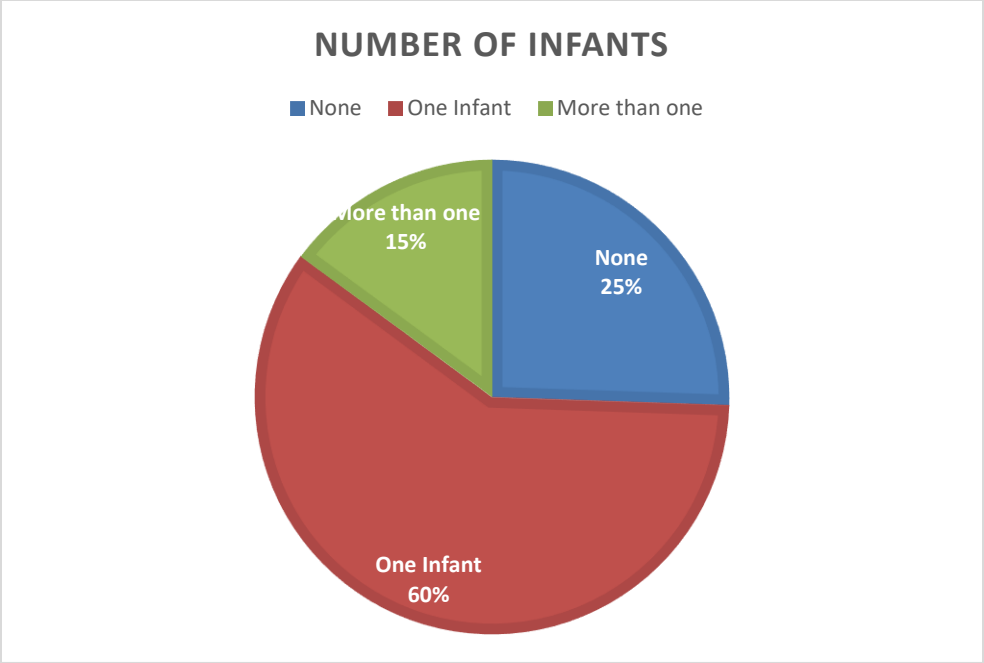


Figure 5-14 Number of Infants

**5.3.7 Respondents’ preferred mobile carrier provider**

Figure 5.15 displays the classification of respondents by their preferred network solutions provider. The data indicates that there are three dominant players within the telecommunication space preferred by the respondents. 73% of the respondents preferred Safaricom as their provider of cellular network coverage, whereas 23% of the respondents prefer and use Airtel as their provider of cellular network coverage.

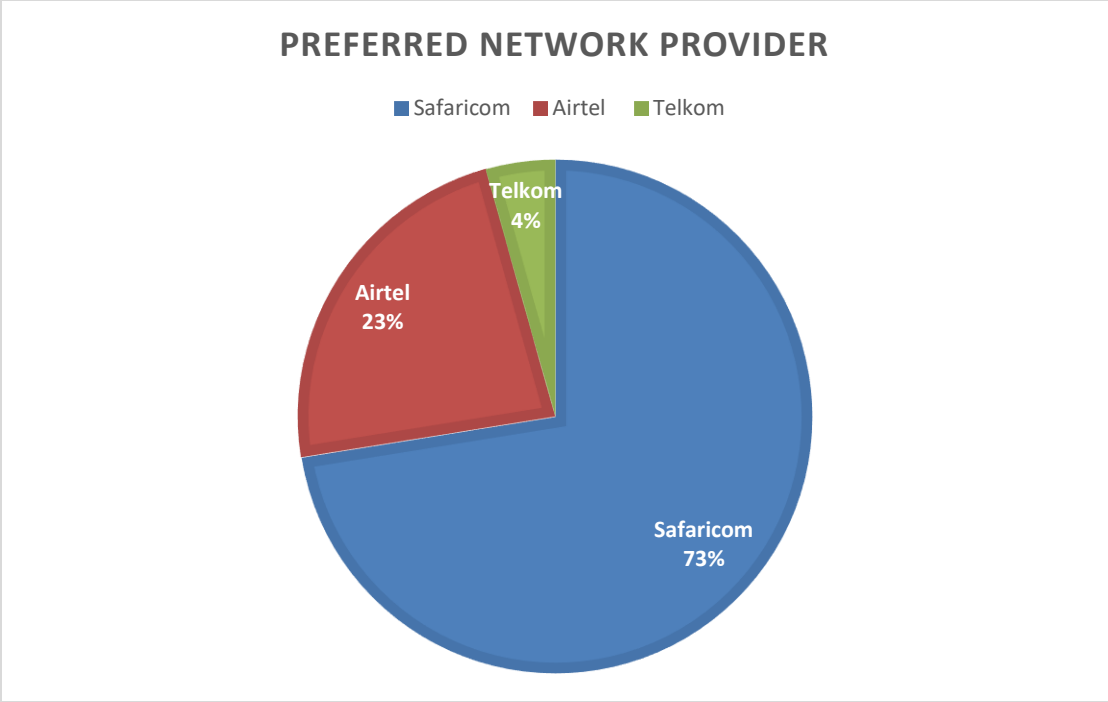


Figure 5-15 Preferred Network Provider

**5.3.8 Respondents' mobile device network (2G OR 3G)**

Figure 5.16 depicts the respondents' classification according to the network reception received by the phones they possess. The data indicates that a majority of the respondents at 62% are using a mobile device using the 2G spectrum, whereas 34% of the respondents use a 3G enabled device.

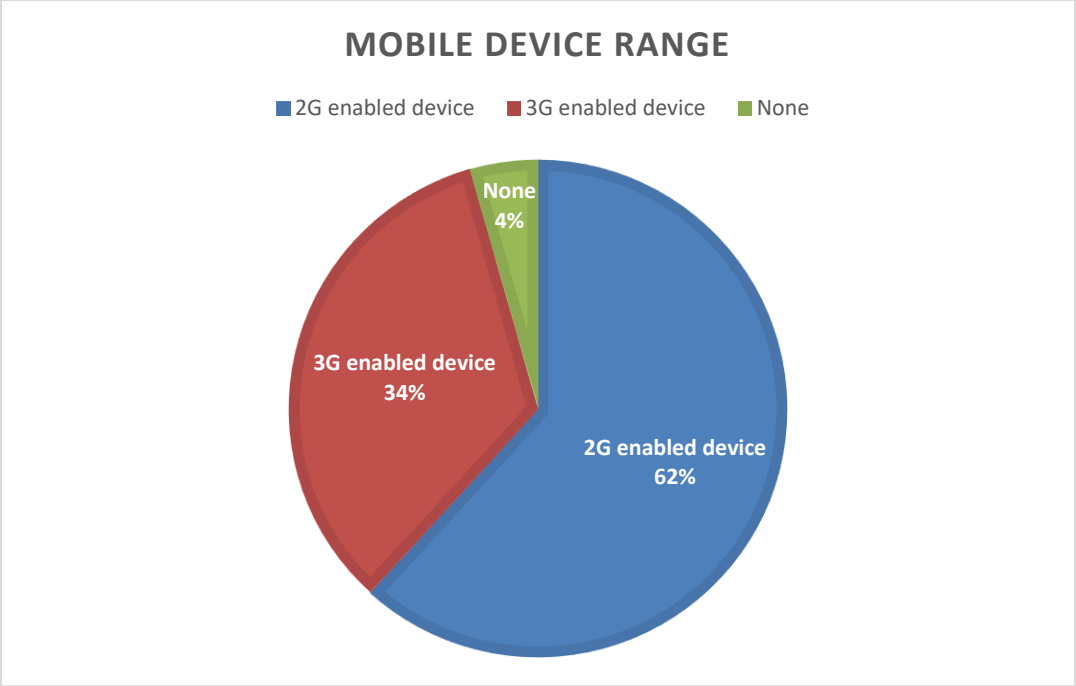


Figure 5-16 Mobile Device Range

**5.4 Application Testing Results**

Post testing of the application sought to determine the application’s user friendliness, responsiveness, functionality, acceptability and level of user satisfaction. The data obtained from the respondents is expressed in figure 5.17 below, which is represented in form of a scale. The scale is expressed by labels 1-5, with 1 representing the lowest and 5 representing the highest: 1-Poor, 2-Fair, 3-Good, 4-Very Good, 5-Excellent.

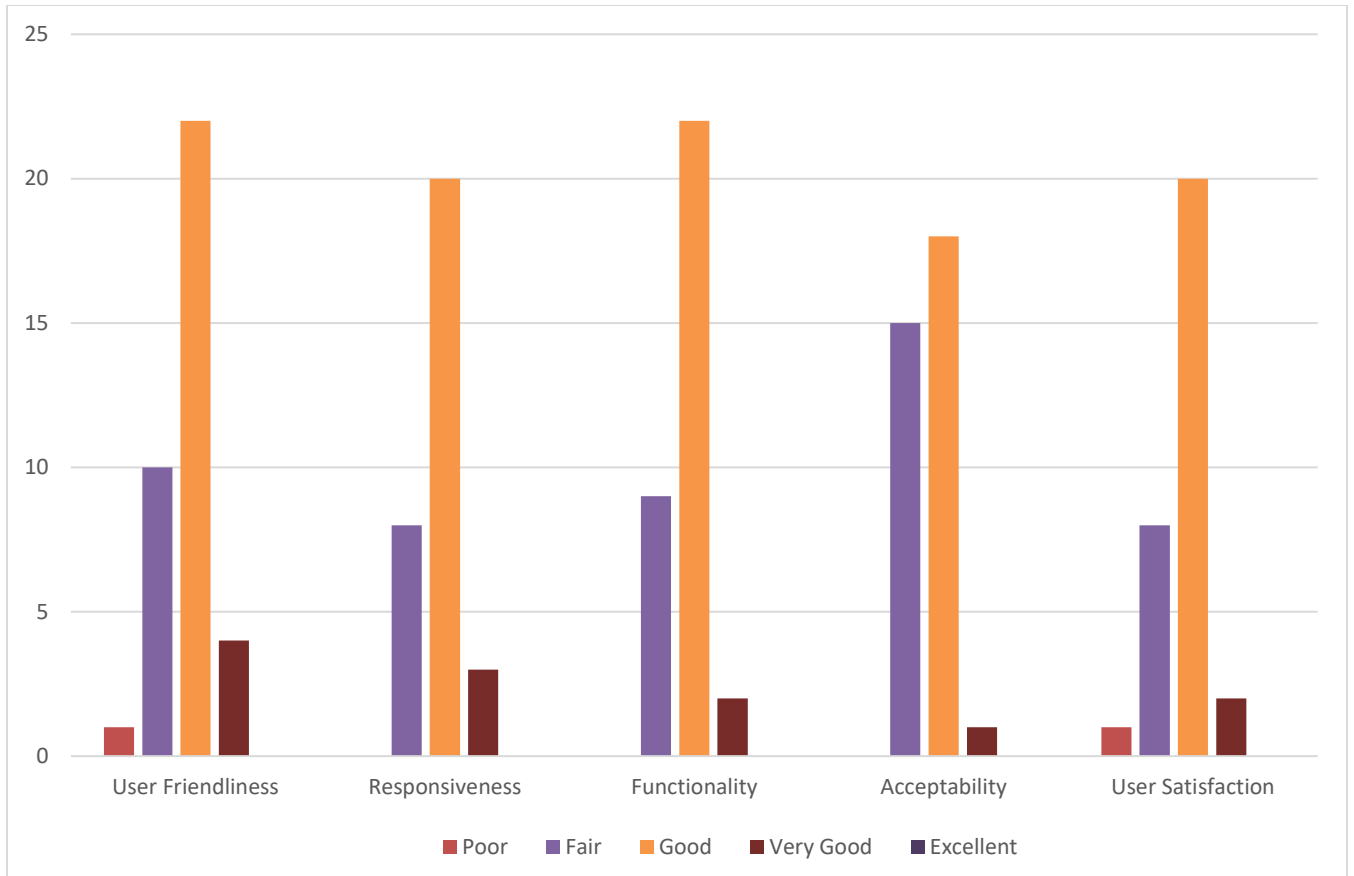
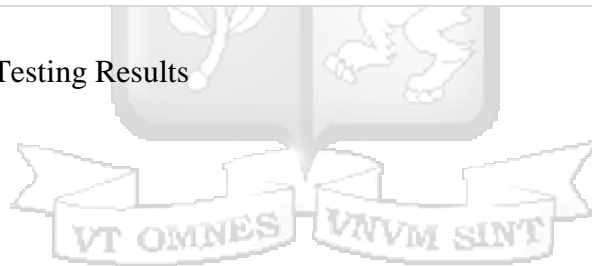


Figure 5-17 Application Testing Results



## **CHAPTER 6**

### **DISCUSSION OF KEY FINDINGS**

#### **6.1 Introduction**

This chapter focuses on the discussions of key findings made from the work in relation to the research objectives and research questions of the study. It seeks to focus on the aspects brought out in trying to reduce the Maternal Mortality Ratio by use of the proposed mobile application. By use of the literature review as well as the previous chapters outlined in this work, this section will aim to discuss the research questions by highlighting the key findings and results that emerged from the study.

#### **6.2 According to research objectives and research questions**

The first research question entails identifying critical maternal health data required for effective maternal monitoring. Antenatal care information as well as expected date of delivery were identified as some of the critical aspects required for effective maternal monitoring to take place. According to (Ali & Kuroiwa, 2007), with the right administration of antenatal care, a majority of the obstetric complications and challenges experienced by expectant women can be prevented with the identification of vital signs and their thresholds that assist in underpinning a Modified Early Obstetric Warning Score (MEOWS). These vital signs include blood pressure, heart rate, respiratory rate and gestational age of the expectant mother. Taking into consideration the dynamic changes that take place during pregnancy, implementation of MEOWS would aid in the identification of physical deterioration among expectant mothers. However, threshold identification of such vital signs would incorporate the use of body sensors, RFIDs, blood pressure monitors and other such devices. Implementation and use of this equipment in the Low Income areas would prove costly and difficult to maintain for the users as well as the health officials. Thus, implementation of a mobile based mHealth tool that reduces costs to both entities and increases outreach to the users is recommended.

The second research question focuses on challenges posed by current systems. One of the challenges identified related to informal use of mobile devices by community health workers, whereby the health workers administer patient monitoring through use of their personal mobile devices. However fruitful this technique, the authors (Chib, Velthoven, & Car, 2015) identified

that it carries with it considerable challenges in that administering of follow ups by the health worker to the patient is not only quite low, but also limited to emergency situations, dependent on the availability of the health official. Additionally, another challenge identified was based on illiteracy and language barrier, whereby use of applications that cater to maternal health were in the English language, and a majority of the target population, who are from low income areas, are quite illiterate. During the survey, one of the questions posed to the respondents was on their level of education. Most of the respondents were noted to have dropped out in primary or secondary level. Respondents from primary were at 38% whereas respondents having secondary education were at 58%. Implementation of an application that caters to low literacy levels proves to be one of the major challenging factors.

With the identified challenges and deficiencies in current systems, the proposed application also sought to integrate the advantages of current systems and improve on their limitations, by integrating two-way interaction between the Community Health Worker and the expectant mother through both an online platform as well as an SMS platform. The proposed application also sought to improve information dissemination and the relationship between Community Health Workers and expectant mothers. The literature review brought forward issues pertaining to the high ratio of Maternal Mortality and this was mainly brought about by financial hardship and a lack of knowledge.

Identified existing architectures relating to the third research question, consisted of Mobile Health applications and mobile remote patient monitoring applications. Increased use of mHealth applications is attributed to the growth and penetration of mobile devices. A majority of these applications implement the use of USSD, text messages and online applications. A different category of existing architectures reviewed included mobile remote patient monitoring systems, which incorporate use of sensors and RFIDs, that are used to capture data from the patient from a remote area, then the data is transmitted to the caregiver either in real-time or intermittently. A majority of these devices and applications require a consistent internet connection, and thus their implementation in low resource settings may prove difficult. From the survey, 62% of the respondents are viewed to have a mobile device that is 2G enabled whereas 34% of the respondents are viewed to have a mobile device that is 3G enabled. A significant number of the respondents would thus be unable to use a number of current market applications due to their lack of internet

connectivity, price of acquisition of the sensors and RFID devices. The implementation of a mobile application comprising of both internet enabled capabilities as well as and SMS platform improves client education as well as client behaviour, while addressing the need for use of cost effective tools in the rural settings.

Testing of the mobile application involved issuing the respondents with a questionnaire, consisting of a pre-test section and post-test section. The pre-test section focused on acquiring the respondents' demographics as well as their experience with mobile devices whereas the post-test section focused on realizing the respondents' experience with the My Health mobile application. A distribution of the questionnaires to both the Community Health Workers and the expectant mothers was done at the Kenya Medical Research Institute, Center for Public Health Research facilities.

### **6.3 Usability Test Results**

Usability of the application takes into consideration 5 key criteria for testing the proposed application. 60% of the respondents determined the system as user friendly, whereas 28% determined the application's user friendliness was moderate and 5% deemed the application as difficult to use. This data shows us that the overall user friendliness of the system is above average.

Testing results of the system responsiveness yielded 20% of the respondents determining the application as moderately responsive whereas 62% of the respondents determined the application's responsiveness as good.

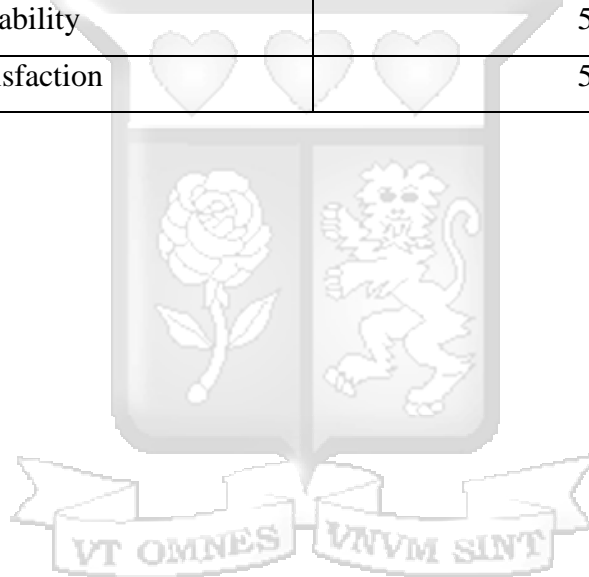
The application's functionality was deemed moderate by 24% of the respondents whereas 60% of the respondents determined that the application's functionality was good. None of the respondents determined the system's responsiveness to be poor.

The application's acceptability and user satisfaction were determined as moderate by 40% of the respondents whereas 50% of the respondents determined the application was good and fairly acceptable, with no respondents determining the systems acceptability as poor.

Table 6.1 below gives a summary of the application's testing results as determined by the 70 participants.

Table 6-1 Application Testing Results

<b>Metric</b>	<b>Respondents</b>
User friendliness	60%
Responsiveness	62%
Functionality	60%
Acceptability	50%
User Satisfaction	54%



## **CHAPTER 7**

### **CONCLUSION AND RECOMMENDATIONS**

#### **7.1 Conclusion**

The main objective of this study was to review existing systems used in the implementation of patient monitoring and thus identify a way of improving access of useful information by expectant mothers regarding antenatal care, through use of a mobile based application. The literature review aimed at pointing out existing systems and identifying their advantages as well as their drawbacks.

The researcher can conclude that the application would be a useful tool in monitoring of expectant mothers by providing antenatal care information as well as symptom related information. A majority of the respondents, 72%, concluded that they found the system a useful tool in improving knowledge sharing for expectant mothers.

However, a major challenge that is still to be addressed with regard to mHealth applications is the language barrier. A significant number of respondents found it quite difficult to use the application as well as fill out the questionnaire. The respondents requested implementation of an application that conveys maternal information in the local language.

Use of an application that incorporates two-way interaction via SMS between the expectant mother and the health official was well received, as a majority of the users did not have internet enabled mobile devices, thus cost reduction was a major factor that would influence continued use of the application.

Mobile health applications should be used to improve information sharing and dissemination between health officials and expectant mothers. With increased penetration of mobile devices and an increase in mobile infrastructure across the country, expectant mothers in Low Resource settings should receive mobile health services much more efficiently. This will go a long way in ensuring expectant mothers receive the required antenatal care visits and information, as well as access to health officials should they need further consultation, thus reducing the growing Maternal Mortality Ratio in the country.

## **7.2 Recommendations**

Based on the research findings, the researcher recommends the following actions to be taken:

- i. Setting up of baseline parameters that allow for measurement and collection of data from the expectant mothers via mobile based solutions. This would ultimately aid in collection of accurate data and allow for effective monitoring of the expectant mothers.
- ii. Involvement of health officials from the onset of the registration process, and especially Community Health Workers.
- iii. Continued use of the application in Low Income settings of the country, as this is where the highest rates of Maternal Mortality are recorded.
- iv. Development of the application for use by different operating systems such as IOS and Symbian which are also available in the Kenyan market.
- v. The application should be made open source to allow for a variety of programmers to improve on certain aspects of the system to suit a variety of countries and other setups.

## **7.3 Limitations of the study**

The study undertaken involved use of two sets of questionnaires; a pre-test and a post-test questionnaire, which were used to capture the users' perceptiveness towards such an application. The study was limited by time constraints during implementation of the data collection process, brought about by unavailability of the respondents as well as lack of response from the respondents. The study was also limited by literacy levels among the respondents, which hindered collection of survey data and a longer response time.

#### 7.4 Suggestions for future research

- i. Implementation of remote patient monitoring devices adaptive to low income settings as well as settings that have limited access to the internet.
- ii. Implementation of public private partnerships in order to allow private organizations to participate in reduction of maternal mortality in the country.
- iii. Implementation of expert knowledge and machine learning aspects to improve on usability of the application.
- iv. Implementation of a text translation feature to allow for better communication in areas with language barrier difficulties.
- v. Implementation of audio visual features in the application to aid in areas with low literacy levels.



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## APPENDICES

### Appendix 1: Mobile Testing Questionnaire

#### Section One: Demographics

1. Age: <18yrs  19-29yrs  30-39yrs  >40yrs
2. Gender: Male  Female
3. Occupation: Employed  Self-employed  Unemployed
4. Level of Education: Primary  Secondary  Tertiary
5. Monthly Income: <5000  5000-15,000  >15000
6. Mobile Provider: Safaricom  Airtel  Telkom
7. Mobile Device Range: 2G enabled  3G enabled  None
8. Number of Infants: None  One  More than one

#### Part B:

9. For how long have you owned a phone? \_\_\_\_\_
10. Which phone are you currently using? \_\_\_\_\_
- b. Is it a smartphone? Yes  No
11. Do you currently use any health based mobile application? Yes  No
12. How do you receive information pertaining to maternal health care?
- Health Worker
- Mobile Application
- Other
- If other, briefly explain \_\_\_\_\_

## Section Two: Feedback on use of the application

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Respondents Score	1	2	3	4	5
<b>User Satisfaction</b>					
I am able to get all the information required using the application					
I found using the application enjoyable					
<b>Perceived Usefulness</b>					
I believe access to the application will improve my access to maternal health information					
I would recommend the application to other maternal health users					
I intend to continue using the application for my maternal information needs					
Use of the application has greatly increased my maternal health knowledge					
<b>Perceived ease of use</b>					
I am able to easily use the application					
I find the application design and layout easy to understand and use					
I am able to navigate through the application with ease					
<b>Reliability</b>					
The information received from the application is both accurate and reliable to me					
The modules of the application are accessible whenever I require them					