



**CHALMERS**  
UNIVERSITY OF TECHNOLOGY



## **E-health to reduce maternal mortality in rural Ghana**

A case study of rural communities needs and design of a cloud based mHealth prototype

Master's thesis in Biomedical Engineering

**PEDRO PAGALDAY OLIVARES**

---

Department of Signals and Systems  
CHALMERS UNIVERSITY OF TECHNOLOGY  
Gothenburg, Sweden 2016

## Acknowledgments

First, give thanks to my Examiner and supervisor Bengt Arne Sjöviqst and supervisors Ruben Buendia and Ants Silbeberg for the support to make this thesis real. Of course, to my support in Ghana from UNiTED staff and the Adjordor family for taking care of me on a daily basis. This thesis, was possible due to all the previous researchers at UNiTED that with their previous work settled the background for this research.

This project would have not been possible without the support of the Ghana Health Service, especially Kpando, South Tongu and South Adfajato Health Directorates, that supported me and give me freedom to research in the area. To all the health workers that have participated in the research, thank you for your patient and all the laughs that we had during the interviews and the simulations. Finally, never forget the support of my family, I know it has been difficult for them to have me far away.

## Abstract

**Introduction:** 830 women died each day in 2015 due to pregnancy related complications, especially in developing countries like Ghana. Rural areas show the lowest number of deliveries attended by a Skilled Birth Attendant. Maternal health faces various challenges. An eHealth solution can contribute to reducing these challenges. The aims of this master thesis were to study the potential and requirements of eHealth solutions to improve maternal health and develop a prototype of a cloud based mHealth solution to satisfy local needs, especially in remote peninsulas and islands of the Lake Volta. The study was carried out in cooperation with the local health directorate of Kpando Municipality, one of the administrative areas in Volta Region.

**Methods:** Maternal health challenges were identified through semi-structured interviews, focus group discussions with local stakeholders and review of local research. Thus, Use Cases of different pregnancies in the area were developed. The Three Delays Model for healthcare utilization and Drury's 5 C's eHealth model for developing countries were used to analyze the data and identify eHealth challenges and potential. Based on the results, a prototype of a cloud based mHealth solution was developed using Android Studio. Each feature of the application has been tested through simulations in real environment to identify trouble shooting and re-design the prototype.

**Results:** Socio economic, geographical situation and quality of care directly influence the health care outcomes in maternal health. This influence results in a delay seeking care, accessing to health facilities and receiving adequate care. A mHealth prototype to be used in Android devices have been designed to reduce the delay in receiving adequate care. The prototype provides protocol driven guidance, a decision support system to identify high risk pregnancies and a monitoring system to visualize patient vitals and detect risk patterns. The prototype is adapted to local practices. The cloud based design allows to work under no network conditions. The solution brings health care to the doorstep of the poorest people and facilitate data collection and exchange between facilities.

**Conclusion:** The prototype designed shows great potential to improve maternal health care in remote areas and among poorest communities. The challenges, facts and methodology presented in this research can be used as background guidelines for other eHealth solutions to improve maternal health in Ghana. If taken with caution, the conclusion of this thesis can be extrapolated to other rural areas and remote communities of Africa.

# Table of Contents

Acknowledgments.....	1
Abstract .....	2
List of Tables.....	6
List of Figures .....	8
1 Introduction .....	11
2 Background.....	12
2.1 The national health care system .....	13
2.2 Health Care in Kpando.....	13
2.3 Skilled-care attendance and MMR.....	16
2.3.1 Maternal Health at National Level .....	16
2.3.2 Maternal Health in Kpando .....	17
2.4 EHealth in Ghana.....	17
3 Literature Review .....	18
3.1 Methodology.....	18
3.2 The Three Delay Model in Maternal Health Care .....	19
3.3 EHealth potential to reduce delays in Maternal Health Care .....	19
3.3.1 EHealth to reduce the delay in decision to seek care .....	20
3.3.2 EHealth to reduce the delay in reaching the facility .....	20
3.3.3 EHealth to reduce the delay in receiving adequate care .....	21
3.4 Model for eHealth in Developing Countries.....	21
4 Methods.....	23
4.1 Part 1: Potential and Requirements of eHealth to improve MHC .....	23
4.1.1 Selection criteria.....	23
4.1.2 Literature review .....	24
4.1.3 Semi-structured interviews.....	24

4.1.4	Focus Group Discussion.....	25
4.1.5	Use Cases.....	25
4.1.6	ICT infrastructure assessment.....	25
4.1.7	Data Analysis .....	25
4.1.8	Solution .....	26
4.2	Part 2: Design, Development and Testing of the Prototype .....	26
4.2.1	Selection Criteria .....	26
4.2.2	Agile Software Development .....	27
4.2.3	Focus Group .....	28
4.2.4	Simulations.....	28
5	Results Part 1: Potential and Requirements of eHealth to improve MHC.....	28
5.1	Use Cases.....	28
5.1.1	Pregnancy in Kpando Islands.....	28
5.1.2	Use Cases Agbenoxoe .....	32
5.1.3	Use Case South Tongu.....	37
5.2	Challenges in maternal health.....	41
5.3	Stakeholders Opinion .....	42
5.4	EHealth Challenges.....	42
5.4.1	Context .....	42
5.4.2	Community .....	43
5.4.3	Capacity .....	43
5.4.4	Connectivity.....	46
5.4.5	Content.....	50
5.5	Solution Proposal .....	50
6	Results Part 2: Design, Development and Testing of the Prototype.....	51
6.1	Define features of the prototype according to user opinion .....	51
6.2	Prototype Architecture .....	53
6.3	Collect Patient History.....	55

6.3.1	Usability Test .....	58
6.4	Educational Services and Protocol Driven Guidance .....	60
6.4.1	Protocol Driven Guidance .....	60
6.4.2	Education Services.....	62
6.4.3	Usability Test .....	65
6.5	Pregnancy Monitoring System .....	66
6.5.1	Do examinations.....	70
6.5.2	Decision Support System.....	71
6.5.3	Monitoring Interface .....	73
6.5.4	View Patient Records .....	73
6.5.5	Usability Test .....	75
6.6	FireBase Cloud Service .....	77
6.6.1	Test Results .....	78
6.7	Technical Limitations and Solutions Proposed.....	79
6.7.1	Prototype Architecture Limitations.....	79
6.7.2	Security Limitations.....	81
6.8	Budget .....	83
6.9	Discussion.....	84
7	Conclusions .....	86
8	Limitations of the research .....	86
9	Future Work .....	86
	References.....	88

## List of Tables

Table 1: Type of facility and owner .....	14
Table 2: Laboratory Services offered per facility .....	16
Table 3: Participants included in this and previous research in the area .....	24
Table 4: Summary of women living in the Islands.....	29
Table 5: Health Worker Profile.....	32
Table 6: Patient Profile Teenager .....	32
Table 7: Use Case - Adolescent High Risk Pregnancy .....	33
Table 8: Patient Profile Typical Pregnancy Agbenoxoe.....	34
Table 9: 1 <sup>st</sup> Trimester Typical Pregnancy Agbenoxoe .....	34
Table 10: 2nd Trimester – Typical Pregnancy Agbenoxoe .....	35
Table 11: 3rd Trimester- Typical Pregnancy Agbenoxoe.....	36
Table 12:Patient Characteristics South Tongu .....	38
Table 13: 1st Trimester - Use Case South Tongu .....	38
Table 14: 2nd Trimester Use Case South Tongu .....	39
Table 15:3rd Trimester Use Case South Tongu .....	40
Table 16:Work Routines according to WHO guidelines.....	45
Table 17:Health Centers and CHP Compounds outside Kpando Network Coverage.....	47
Table 18: Network Coverage in Kpando.....	48
Table 19: Resume of Network Quality by operator .....	48
Table 20: Network Coverage in the Islands.....	49
Table 21: Factors to consider a High Risk Pregnancy .....	67
Table 22: Causes of Maternal Deaths in Ghana .....	67
Table 23: Summary of Typical Danger Signs during pregnancy and labor.....	68
Table 24: Anemia and (Pre) Eclampsia: Symptoms, Risk factors, Potential Complications and Parameters to Monitor .....	70
Table 25: Classification Criteria to detect danger signs and Risk Factors .....	72

Table 26: Logic to Detect Signs of Eclampsia .....	72
Table 27: Logic to detect signs of Anemia.....	73
Table 28: Equipment available in the facilities .....	76
Table 29: Medical Equipment Budget .....	84



## List of Figures

Figure 1: Ghana and Research Area .....	12
Figure 2: Map of Kpando Municipality with facilities.....	14
Figure 3: Number of Outpatients per facility .....	15
Figure 4: Three Delays Model (TDM) .....	19
Figure 5: Ways eHealth solutions can help solving MHC challenges according to TDM model .	20
Figure 6: The 5Cs Model.....	22
Figure 7: Three Delay Model (TDM).....	25
Figure 8: Stages of Design and Development Process .....	27
Figure 9: Use Case Islands 1st and 2nd Trimester.....	29
Figure 10: Use Case Islands - 3rd Trimester .....	30
Figure 11: Use Cases- Child Birth .....	31
Figure 12: Use Case Multiparity .....	37
Figure 13:TDM Data Analysis .....	41
Figure 14:Pyramid of priorities according to local Stakeholders .....	42
Figure 15:Vodafone Network Coverage in Kpando.....	47
Figure 16:MTN Network Coverage in Kpando .....	48
Figure 17: Network map in Kpando Municipality .....	49
Figure 18: Solution Proposal .....	50
Figure 19: Importance of app features according to users.....	53
Figure 20: Main Activities Diagram .....	54
Figure 21: 1st ANC Work Routine.....	54
Figure 22: Home Visits Routine .....	54
Figure 23: General Information Interface .....	55
Figure 24: Personal History Interface.....	55
Figure 25: Major Risk Factors Interface .....	56
Figure 26: Menstrual History Interface .....	56

Figure 27: Obstetric History Interface.....	56
Figure 28: Breastfeeding History.....	57
Figure 29: Medical and Surgical History Interface .....	57
Figure 30: Family, Drug and Contraceptive History Interface.....	57
Figure 31: History of Sexually Transmitted Infections Interface.....	58
Figure 32: Protocol Driven Guidance for Anemia .....	60
Figure 33: Protocol Driven Guidance for Anemia and Abdominal Pain.....	61
Figure 34: Protocol Driven Guidance Pre-eclampsia.....	61
Figure 35: Protocol Driven Guidance Excessive Vomiting.....	62
Figure 36: Danger Sign 1 - Headache .....	63
Figure 37: Danger Sign 3 - Anemia .....	63
Figure 38: Danger Sign 3 - Bleeding .....	63
Figure 39: Danger Sign 4 - Abdominal Pain.....	64
Figure 40: Danger Sign 5 - Swellings .....	64
Figure 41: Danger Sign 6- Excessive Vomitting .....	64
Figure 42: Education about Nutrition .....	65
Figure 43: Pregnancy Monitoring System Diagram .....	69
Figure 44: Add New Patient .....	70
Figure 45: List of Patients.....	70
Figure 46: Capture Results of Examinations .....	71
Figure 47: High Risk Pregnancy Dialog .....	72
Figure 48: Mild Pre-Eclampsia Dialog.....	72
Figure 49: Severe Eclampsia Dialog.....	72
Figure 50: Anemia Dialog .....	73
Figure 51: Monitoring System Interface .....	73
Figure 52: View Patient Record General Information .....	74
Figure 53: Blood Pressure Graph .....	74
Figure 54: Weight Graph.....	74

Figure 55: Fundal Height Graph .....	75
Figure 56: Hemoglobin levels Graph .....	75
Figure 57: Pulse Graph .....	75
Figure 58: Danger Signs.....	75
Figure 59: Firebase Cloud Service .....	78
Figure 60: Solution Architecture .....	80
Figure 61: Network Architecture Proposal.....	81

# 1 Introduction

EHealth has the potential to enhance healthcare systems capacity in developing countries [1]. Due to the incomplete Millennium Development Goal (MDG) 5 with the aim of reducing maternal mortality by three-quarters in 2015 there is the need to investigate new solutions to reduce mother and child mortality. EHealth solutions are new healthcare delivery models capable of making qualified healthcare accessible to underserved areas, such as remote and rural areas as well as areas lacking on site medical expertise [2]. In addition, eHealth solutions also reduce costs for delivery, maintenance and support. This makes them a viable and affordable way to improve maternal care in developing countries [3].

Maternal death is defined by the World Health Organization (WHO) as “death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes”. It is estimated that 99% of maternal deaths occurred in developing countries of Sub-Saharan Africa and South Asia. [4]

In Ghana, despite great efforts and improvements made to reduce maternal deaths, maternal mortality and morbidity are higher than acceptable and one of the biggest burden of the country [5]. Limited number of health workers, equipment, transportation and ambulance service, inadequate data sets on maternal healthcare, lack of structure and regulation in maternal programs and reduce number of limited number of maternal health services at district level are among the biggest challenges that Ghana is facing to improve maternal health [6].

Maternal deaths are preventable with accessible and quality care before and during pregnancy, childbirth, and the postnatal period [7]. One third of maternal deaths in Ghana occur due to conditions which are directly related with inadequate care during pregnancy [7, 8]. Even though maternal health services are in place, educational, geographic, economic and socio-cultural barriers make that the attendance to these service, especially in rural areas, remains low [9]. Therefore, management and early detection of pregnancy related complications is almost impossible [7].

The aim of this master thesis is to investigate the pre-requisites and develop an eHealth solution with the potential to improve maternal care in remote communities of Kpando, Ghana. Improving early detection and referral of possible and actual complications during pregnancy. Besides Kpando Municipality, research has also been done in South Tongu and South Adfajato, Municipalities. It will demonstrate how an eHealth solution can improve maternal health services, especially to those living in rural areas. This thesis is divided into two parts, the first one includes the results of the investigation of technical implementation-prerequisites, as well as investigation of medical and healthcare implementation prerequisites. In order to obtain this data, studies on site and technical studies has been carried out for three months in the study areas in Ghana. Based on this requirements, a draft of the proposed solution has been included. The second part, involves the development of a prototype of the solution. The prototype has been developed to be used in Android devices and each feature has been tested and re-design according to local requirements. The thesis counts with the collaboration of UNiTED, a Ghanaian based Ngo, and Chalmers University of Technology.

The document starts with background information about Ghana, the healthcare system, the maternal health situation and eHealth strategy in Ghana. Then, the results are presented. An analysis of the challenges in maternal health in remote communities is presented through Use Cases that represent typical pregnancies in these areas. Then, all the background information is

structured to analyze eHealth implementation challenges. In the second part, an mHealth solution demonstrator is developed. The demonstrator has been evaluated through simulations in real environment. The demonstrator and the results of the solution are presented.

## 2 Background

A maternal death is defined by the World Health Organization (WHO) as: “death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes” [4]. In 2015, each day 830 mothers died worldwide from largely preventable causes like eclampsia, obstructed labor and complications of abortion [4].

In the year 2000 world leaders adopted the United Nations Millennium Declaration. Eight time-bound targets were set with the deadline in 2015. Millennium Development Goals (MDGs) aimed to reduce extreme poverty and promote peace, human rights and security. MDG 5 focused on reducing the maternal mortality ratio (MMR) between 1990 and 2015, from 400 to 100, defined as number of maternal deaths per 100,000 live births [10]. As MDG5 was not met, continued action is needed. To build on the MDGs and achieve what they did not, 17 Sustainable Development Goals (SDGs) and 169 targets were announced in the draft 2030 agenda. Maternal health falls under goal 3, target 3.1 and 3.7. The goal is “to reduce MMR to less than 70 per 100,000 live births” and “ensure universal access to sexual and reproductive health care services, including family planning, information and education, and the integration of reproductive health into national strategies and programs”. [11]

Ghana is one of the countries that have adopted the draft 2030 agenda. This West African country with a population of 27 million estimated in 2015 is divided into ten administrative regions, 138 districts and 58 councils [12]. The research area, Kpando Municipality, is located in the Volta Region. Kpando lies east of Lake Volta, the world’s largest man made reservoir by surface and the fourth largest by water volume. Almost 30 % of the land of the Kpando Municipality is submerged by the lake, resulting in many remote communities – peninsulas – on the lakeside [13]. Census conducted on seven of the islands situated close to Kpando, confirmed 1,092 inhabitants [14]. The research area can be seen in Figure 1



Health care in Ghana is decentralized. Ghana Health Service (GHS) is responsible for implementation of policies. Strategies and interventions in maternal health are based on the Safe Motherhood Initiative (SMI), a worldwide effort that was launched in 1987. This Initiative consists of five pillars; Antenatal Care (ANC), delivery care, Postnatal Care (PNC), Emergency Obstetric Care (EmOC) and family planning. The aim of interventions is to increase the number of deliveries supervised by Skilled Birth Attendants (SBA), decrease the number of unsupervised deliveries, increase the number of Antenatal Care (ANC) attendants and increase the number Postnatal Care (PNC) attendants [6].

Figure 1: Ghana and Research Area

## *2.1 The national health care system*

Ghana Health Service (GHS) is the agency responsible for the implementation of policies. It is an autonomous and executive agency under the control of the Minister of Health. The aim of the Ghana Health Care System is to maintain and improve the health outcomes of people living in Ghana. GHS is structured into five different levels: national, regional, district, sub-district and community level. [15]

Currently the GHS is struggling to bridge the inequity gap between urban and rural areas, the northern and southern sectors of the country and between the rich and the poor. Another problem is the lack of skilled personnel across the country. The Minister of Health is exploring new ways of delivering the service, looking for ways to improve the outcome of investments made on the sector. This result in new policies such as the close-to-client policy, free maternal care, review of the premium payment systems and the introduction of incentive for health workers to work in deprived areas. [16]

There are different divisions that take care of different aspects of health care services. The division in charge of improving clinical care is the institutional care division. The clinical engineering department at the health administration and support services division is in charge of procurement, distribution, installation and maintenance of medical equipment. [15]

The Family Health division is formed by three departments, the Reproductive and Child Health (RCH) department, the Nutrition department and the Health Promotion department. The coordination of all reproductive and child health activities at the national level is done by the RCH. It cooperates with the regional Health directorates, which cooperate with the district health directorates. Districts report to the regions, and regions to the national level. The main goal of the RCH is to improve health and quality of life for children and people in the reproductive age. Maternal health services fall under this division. [17]

## *2.2 Health Care in Kpando*

Ghana Health Service sets standards for care by creating protocols and providing training for health workers and community members. The directorate also reinforces rules, regulations and protocols, and assesses the quality of care. Health care services in the Kpando Municipality are managed by the Municipal Health Management Team (MHMT), with the Municipal Director of Health Services being the head of the team.

The provision of health care is provided by a total of eighteen (18) health care facilities, which are structured into the municipal level, the sub-municipal level and the community level. Health care at the community level is provided by Community Health Planning Services (CHPS), which are complemented by outreach services organized by the sub-municipal level. Services at the community level focus on health promotion, disease prevention and to some extent curative services. Health care services at the sub-municipal level is provided by the ten Health Centers (HC), which provide curative services on minor ailments, health promotion and disease prevention. At the municipal level two hospitals provide health care services. Table 2 shows the available types of facilities, their names, locations and the owner. Picture 2 shows the map of the Kpando Municipality and the available health care facilities.

Type of facility	Name of facility	Location	Owned by
Hospital	Margret Marquart Catholic Hospital St. Patrick	Kpando Konda KpandoTsakpui	CHAG Private
Health Center	Agbenoxoe Gadza Kpando Kudzra Torkor	Agbenoxoe Gadza Kpando Kudzra Torkor	Government
CHPS	Dafor Fesi / Bame Gbefi Market Avetikope Kpando Senior High School Bishop Herman College	Dafor Fesi / Bame Gbefi Gabi Avetikope (Torkor) Aziavi Aloyi	Government
RCH	Sovie	Sovie	Government
Maternity home	Matty's Maternity Wisdom's Maternity Home	Kpando Gabi Torkor	Both private
Clinic	Senam Clinic	Aziavi	Private

Table 1: Type of facility and owner

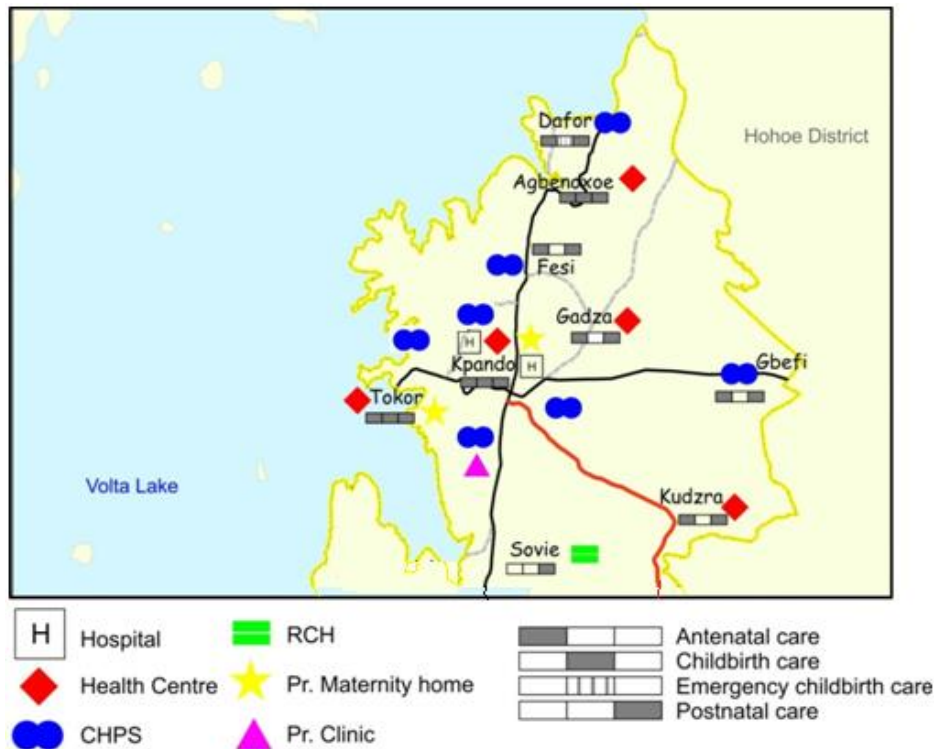


Figure 2: Map of Kpando Municipality with facilities

The number of outpatients that were seen in 2014 is 194,924, while this was 180,444 in 2013 and 168,400 in 2012. The increase in patients was 7.2 % between 2012 and 2013, and 8.0 % between 2013 and 2014. It is expected that this trend of increase in outpatient department (OPD) visits will continue, as more and more people are signing up for the National Health Insurance Scheme (NHIS), which increases (financial) access to health care facilities and lead to patients visiting a hospital at an earlier time in case of disease.

Figure 3 shows the number of outpatients per facility in 2012, 2013 and 2014. Two of the facilities, the market and Avetikope CHPS, do not reflect as they were not yet implemented. Kpasec and Bishop Herman College CHPS were only implemented in 2014, hence no data were available for 2012 and 2013. There is an increase in outpatient departments in all facilities, except Senam Clinic and Dafor CHPS. The reason for decrease in OPD visits at Dafor CHPS is unknown, but there is a significant increase of patients at Agbenoxoe Health Center, which is not far from Dafor. This health center was not easily accessible until 2014 due to the high water level in Lake Volta – a lagoon has to be crossed from Dafor to Agbenoxoe. The water level was extremely low in 2014, which might have given more patients the opportunity to attend the health center, where more OPD services are available. Decrease at Senam Clinic can be attributed to the fact that this facility is not accredited by the NHIS. As more patients have signed up for NHIS, they might prefer free health care services over paid private health care. Next to that a new CHPS facility opened at Kpando Senior High School which is in the same area. Therefore, patients can now choose between the two facilities. Most patients attend one of the three biggest facilities, Margret Marquart Catholic Hospital (missionary), St. Patrick (private) or Kpando Health Center.

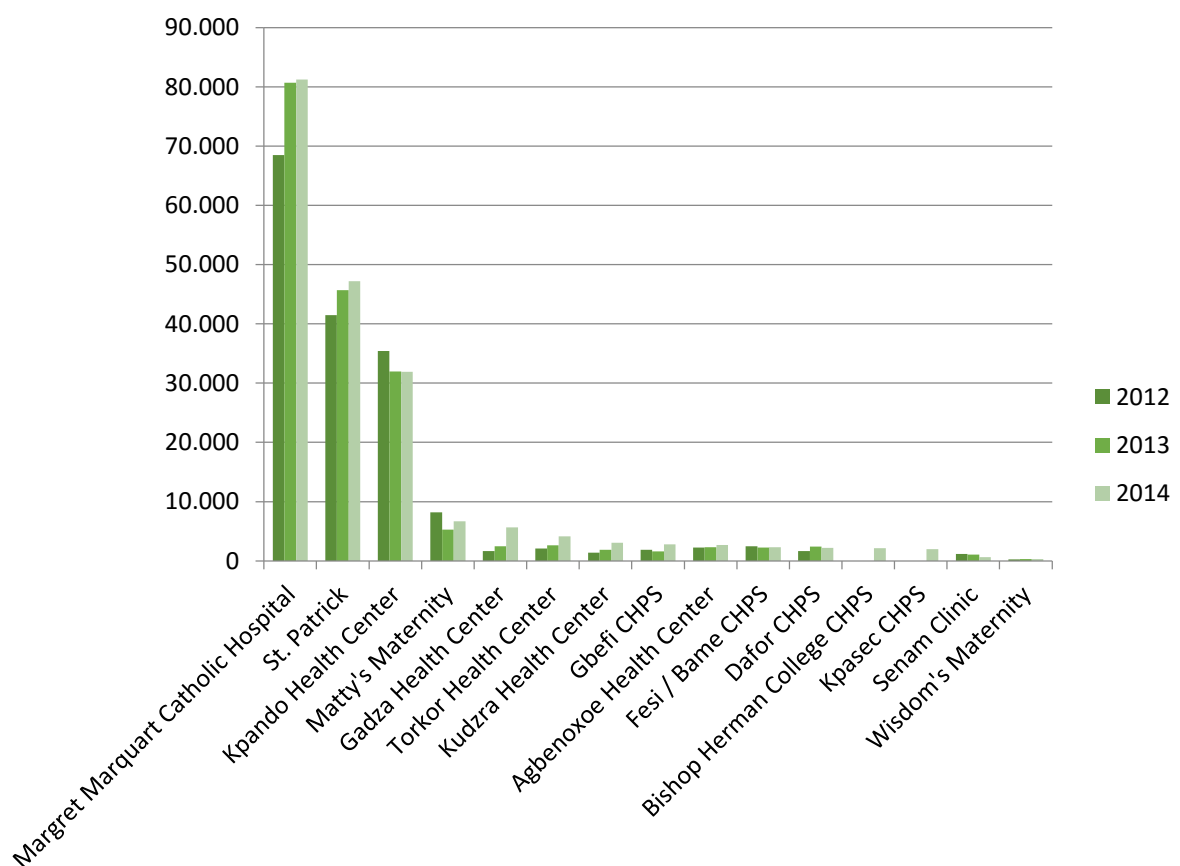


Figure 3: Number of Outpatients per facility



Laboratory services in the Kpando Municipality are provided at three different laboratories. Table 2 shows the provided services per facility type. Health care facilities do have access to rapid tests for malaria and HIV/AIDS, if available. Not provided in Kpando are the following services: microbiology and hormonal research. Patients are referred to Ho, the regional capital, for these services. This is over an hour by private car and can take up to three hours by public transport. The time and costs included form a burden for many patients. Lack of financial resources often results in the decision to discontinue care [18].

Type of facility	Provided laboratory services
CHAG Hospital	Clinical pathology: hematology, histopathology, cytology, routine pathology
Private Hospital	Clinical pathology: hematology, histopathology, cytology, routine pathology
Kpando Health Center	Clinical pathology: hematology, histopathology, cytology, routine pathology
Health Centers	Not provided, except at Kpando Health Center (see above)
CHPS	Not provided
RCH	Not provided
Maternity home	Not provided

Table 2: Laboratory Services offered per facility

## 2.3 Skilled-care attendance and MMR

### 2.3.1 Maternal Health at National Level

Women and children are the most vulnerable population group and account for 77.7% of the Ghanaian population in 2010 census. Morbidity and mortality among this group account for major proportion of all the other ill-health and death in Ghana. Maternal, neonatal and nutritional diseases are the biggest burden of Ghana, accounting for 3000 years of life lost due to premature mortality (YLL) and years of healthy life lost due to disability (YLD) [5]. Most of these deaths are preventable. Whilst women are important contributors to the development of the nation, children are the nation's most important resource. Their needs are therefore a national priority and through different measures the Ghanaian government try to improve maternal healthcare [17]:

- Free maternal health services through the National Health Insurance Scheme (NHIS). However, the National Health Insurance is not always able to pay the hospitals falling under the scheme, so it is common for patients to pay for the services.
- The government is promoting direct midwife training. Opening midwifery schools in different location. However, the lack of midwives is still a problem
- High Impact Rapid Delivery (HIRD) approach; through which staff assists health providers and their managers to improve the coverage, quality, reliability, and patient-centeredness of health services for pregnant woman and children under five years of age.
- Ghana Vitamin A Supplementation Trial Survival Program, Prevention of Maternal Mortality Program (PMMP), and Safe Motherhood initiative (SMI).

- Other projects include: Making Pregnancy Safer Initiative, Prevention and Management of Safe Abortion Program, Maternal and Neonatal Health Program, RollBack Malaria Program, Intermittent Preventive Treatment (IPT),

### 2.3.2 Maternal Health in Kpando

The MMR in Ghana reduced from 590 in 1995 to 380 in 2013. However, the MDG target to reduce MMR to 185 in 2015 has not been achieved [6]. More than 80% of the maternal deaths occur in the communities or within 24 hours of admission to a health facility [8]. 80 % of these maternal deaths can be appointed to five treatable and preventable complications; hemorrhage, sepsis, eclampsia, obstructed labor and complications of abortion [19]. The MMR of non-institutional deaths that occur outside the facilities remains unknown. These deaths are not recorded; it is assumed that counting these deaths MMR would be higher.

Deliveries with skilled health personnel are increasing in Ghana but there is a big disparity between urban and rural areas. For instance, the Greater Accra Region around the capital of Ghana records 92% while the Volta Region has one of the lowest of the country with less than 50%. Equally worrying is that the rate keeps decreasing. On the other hand, the Contraceptive Prevalent Rate (CPR) that is defined as “proportion of women of reproductive age who are using (or whose partner is using) a contraceptive method at a given point in time” is the highest in the country with 32% in the Volta Region. ANC, which is the care provided before childbirth, is used for early detection and referral of pregnancy related complications. Women attending ANC at least one visit was 90.9% in the country, however in the Volta Region this number is below the average with 70% in 2010 [6, 19].

The MMR in Kpando was 623 in 2010 and reduced to 161 in 2013. However, there was an increase from 2013 to 205 in 2014, mainly caused by cardiac failure, hemorrhagic shock, respiratory failure and acute chest syndrome. The proportion of births attended by skilled personnel was increasing steadily from 70% in 2010, reaching a peak value of 87% in 2013. In 2014 there has been a decrease of 13% and an increase in deliveries attended by Traditional Birth Attendants (TBAs). The health directorate attributes this to the lack of midwives in most facilities. ANC Attendance has shown an increase compared to 2013. However, only 30% of registrants attended the four visits as recommended by WHO. Most women, especially in rural areas, register for ANC services during the 2<sup>nd</sup> or 3<sup>rd</sup> trimester of pregnancy. Nevertheless, there has been an increase of registrants in the 3<sup>rd</sup> trimester of pregnancy compared to 2013 [13].

## 2.4 EHealth in Ghana

Maternal healthcare in Ghana faces various challenges, some of the biggest are: limited number of health workers, equipment, transportation and ambulance services, inadequate data sets on maternal healthcare, lack of structure and regulation in maternal programs and limited number of health services at district [6]. Nevertheless, Ghana has a high quality of care where it is available, a national health insurance system and well recognized facilities for medical education and accreditation [20]. However, the government struggle to extend these services to rural areas, even with the introduction of Community based Health Planning and Services (CHPS) initiative two decades ago. The program coverage is affected by several problems, such as logistic problems, supervisory lapses and resource shortages. The Ministry of Health is exploring new ways to improve the outcome of investments made in the health sector and reduce the

inequity between rural and urban areas. New policies such as free maternal health care, or incentives for health workers to work in remote areas, have been included [21].

As part of the exploration to optimize resources, in 2003, the country started to consider ICTs as a way of improving healthcare [22]. EHealth has the potential to enhance healthcare systems' capacity in developing countries [23]. EHealth solutions are new healthcare delivery models capable of making qualified healthcare accessible to underserved areas, such as remote areas as well as areas lacking on site medical expertise [23, 1]. In addition, eHealth solutions also reduce costs for health service delivery, maintenance and support. This makes them a viable and affordable way to improve health care in rural Ghana [24, 2].

In 2010 The Ghana National eHealth Strategy was published with the goal to: "Harness the potential of Information and Communication Technology to improve the health status of people living in Ghana". The report identifies eHealth as a solution to the large inequalities to access to healthcare among regions, weak referral and poor emergency systems, the increase of non-communicable diseases and the lack of medical personnel. Among the challenges identified are the lack of ICT infrastructure in most facilities, low IT literacy and lack of funding for ICT infrastructure. Due to increased cost in providing eHealth solutions, the local counterparts cannot afford them [25].

### 3 Literature Review

In this chapter a literature review that support the use of eHealth applications in developing countries is presented, the aim is to analyze the challenges and opportunities that eHealth solutions offer in low and middle income countries, evaluating the decision making process, implementation and effectiveness of eHealth projects in developing countries to improve maternal health, especially in the African region.

The literature review consists of an evaluation of the characteristics and challenges of maternal healthcare in Africa, introducing the Three Delay Model (TDM) by Thaddeus and Maine [26]. The framework is used to classify eHealth projects and their approach to solve maternal health issues. Then, a review of eHealth projects to evaluate their impact to reduce the three delays is presented. Finally, the 5Cs model to implement eHealth in developing countries [27] is used to analyze the impact of mhealth solutions used to improve maternal health in developing countries.

#### 3.1 Methodology

The literature was reviewed with the main purpose of identifying theoretical discussions and recommendations of the use and implementation of eHealth in developing countries, identify mHealth projects in developing countries and publications regarding the impact assessment of mHealth solutions. Keywords used for the research were: eHealth in developing countries, maternal health, mHealth in maternal and child health, eHealth frameworks, impact assessment of ICT projects and healthcare in Africa.

The materials included in the review included research papers, peer reviewed and grey literature, whitepapers, news articles and websites. Preference has been given to literature review focusing on mHealth programs in developing countries with a special focus on maternal and child health. Projects identified in other literature reviews in [28, 3] has been included when relevant.

### 3.2 The Three Delay Model in Maternal Health Care

The paper published in 1994 by Thaddeus and Maine [26], presents a framework widely used to review the factors contributing to maternal mortality in developing countries. It develops and explains a three delay model in seeking, reaching and accessing adequate maternal care. Evaluating the factors that influence healthcare utilization and the outcome of care as shown in Figure 4-

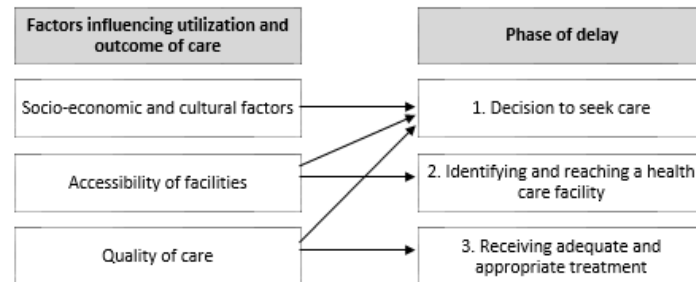


Figure 4: Three Delays Model (TDM)

Prompt, adequate treatment after the onset of obstetric complications will most likely result in a satisfactory outcome, preventing maternal death, while a delay might have the adverse effect. For example, when a woman has an obstetric emergency, the delay in seeking health care, can result in death.

The first delay is the decision to seek care. In developing countries, the decision is influenced by socio-economic and cultural factors such as economic level and traditional beliefs. Other factors that delay the decision are the accessibility to health facilities and the perceived quality of care by patients. The second delay is the time that takes to identify and reach a health care facility. Geographical barriers and lack of knowledge of health care services offered are the influencing factors. The third delay is the time it takes to receive adequate and appropriate treatment. In the developing world, health workers are not well trained and medical staff is scarce in rural areas, even though a woman with an obstetric complication reach a facility on time, the complication might not be detected or medical staff will not be available to treat an emergency.

The TDM will be used to classify the results of the research and analyze the maternal health care situation in our study area.

### 3.3 EHealth potential to reduce delays in Maternal Health Care

Nowadays, with the increased adoption of mobile devices in developing countries there has been an increased in reliance on mobile networks for daily communications [29]. Thus, countries have started with the implementation of programs relying on mobile communications for healthcare activities [3]. In this section, we analyze different eHealth solutions that aim to reduce the three delays in maternal health care utilization. In Figure 5 the different eHealth solutions to reduce the delays are presented.

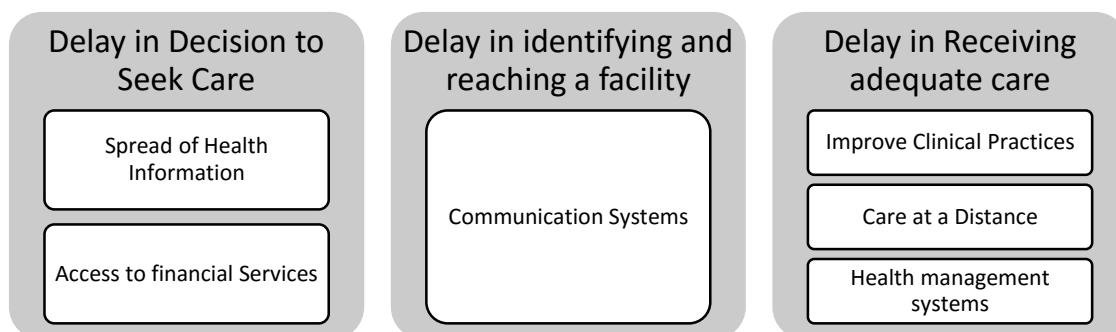


Figure 5: Ways eHealth solutions can help solving MHC challenges according to TDM model

### 3.3.1 EHealth to reduce the delay in decision to seek care

As shown in Figure 5, there are two kinds of eHealth solutions that aim to reduce the first delay. Through the spread of health messages through mobile phones and offering financial services to reduce the economic barriers that keep women from accessing maternal health care, taking advantage of the mobile phone penetration in developing countries.

The spread of health information through mobile phones is a common solution. Mainly through SMS and voice messages [30, 31, 32]. Other alternatives use hotlines and call centers [32, 33]. The aim of this solutions is to bridge the gap between communities, health facilities and information services. Due to low mobile phone penetrations in rural areas, some solution relies on the use of community volunteers to provide access to mobile phones.

The aim of these projects is to bridge the gap between communities and health facilities and information services, providing timely and reliable health information to pregnant women and caregivers. The services provided are personalized advice and reminders and the use of a hotline to pregnant women and health workers that offer protocol-based health information, advice and referral when needed to health facilities. It is believed that these solutions will lead to increase awareness about maternal health interventions, increase uptake of maternal health practices and as a result, a reduction in maternal and child mortality. A study of one of this project showed that these interventions did not increase knowledge among pregnant women [34]. However, it increased skilled birth attendance [31].

Another innovative intervention is to provide financial services through mobile phone for pregnant women, allowing them to save and access to financial services for maternal health. However, no quantitative data has been found on the impact of these solution, only studies that outline the potentials of fusion financial mobile services with healthcare. [35]

Among the lessons learned of these technologies, we can outline three of them: partnership to scale up and implement the projects, human centered designed techniques to tailor projects to local needs and capacity building through training and education to increase capacity and knowledge about services provided. [35, 31]

### 3.3.2 EHealth to reduce the delay in reaching the facility

How eHealth can reduce geographical barriers and reduce the delay in reaching the facilities has been found controversial in the literature. All these solutions are based in improvement of communication systems, especially in case of obstetric emergencies, providing mobile equipment to TBAs and midwives in isolated areas and connecting them with the emergency

services. However, the time it takes a woman to get to a facility requires of emergency systems, available transportation and good road infrastructure. [36, 34]

Several communication systems were implemented in different African countries, and all of them noted a reduction in maternal deaths and increased in skilled birth attendance, however, these were only achievable with the combination of faster transport. For instance, in hard to reach areas that cannot be accessible by vehicles, a communication system could help to identify emergency situations, but if the infrastructure is not in place and these areas do not have better transport access and human resources there is very few evidence that these solutions will be effective. [37]

### 3.3.3 EHealth to reduce the delay in receiving adequate care

There are two main kind of solutions that can reduce the third delay. Solutions that facilitate clinical practices and solutions that facilitate care at a distance. Typical solutions that facilitate clinical practice are electronic medical record systems and communication systems for managing digital medical images. EHealth solutions that facilitate care at a distance are typically telemedicine solutions, monitoring systems and communication systems between clinicians. [38]

Medical record systems are not widely used in developing countries, only large hospitals use systems such as OpenMRS, Baobab Health or ZEPRS antenatal system [3]. These systems have the potential to detect medical errors, improve referrals and coordination between facilities and departments. There is empirical evidence that decision support systems improve the clinician's performance in 57% of the systems evaluated in REF however, the impact on patient outcomes is smaller, only 30%. In addition, it increases preventive care services. [39, 40]

Telehealth solutions and monitoring systems that store digital forms of patient information and is analyzed remotely by better trained medical staff improves diagnostic accuracy, increase satisfaction with services, reduce waiting times and improve the referral management [41, 42]. Live Telemedicine solutions are cost saving services that provide care as good as in the conventional way [43]. Monitoring systems can track patients through the system and show great potential for the management of chronic diseases, the hypothesis is that these systems would have positive outcomes in the treatment of high risk pregnancies [44].

Another kind of solutions that indirectly influence the quality of care received are health management tools, systems that will facilitate and improve health management among authorities. However, the outcomes of these systems in patient care has not been measured, they have been mainly focused on measure efficiency and costs. These systems could be a solution to improve the logistics and allocate resources in those areas where are more needed. [38]

The lack of available data regarding the maternal health situation in remote areas could be improved with the use of these systems. All the data gathered through effective data collection tools in health facilities can be used to research new effective solutions to improve maternal health care. [24]

## 3.4 Model for eHealth in Developing Countries

EHealth has been in practice for many years now. However, very few sustained eHealth projects of demonstrated success and sustainability exist. According to the ITU, thousands of pilot sites, trials, tests, etc. have been implemented since 1960 to 2000 in developing countries, but less

than 10% survived beyond the initial funding, 45% of the projects failed after one year, and 45% failed after 3 years. [23]

The data can be discouraging when it comes to invest in eHealth in developing countries. However, there is evidence in the literature about how eHealth can address health concerns and may lead to cost savings, especially in the developed world [45, 46, 47]. Even in the developed world several years are needed to show positive annual socioeconomic return (SER). The US health system spends around 3% (approx. 200 million dollars) on eHealth solutions per year, in systems that spend that amount of money, perhaps there is room for saving through greater efficiencies, but this is not the case of developing countries, where their annual budget for health is around 10-35 million dollars [48].

The WHO's Report on Macroeconomics and Health stated that countries need 34 million dollars per capita to provide basic health care [49]. When we introduce another system like eHealth, developing countries have to save money from somewhere else, like sanitation or rural clinics. Developing countries do not have room to invest public money in eHealth. Therefore, the eHealth solutions to be implemented must be aligned with the needs of the health system and culture appropriate. This is an extremely complex goal that can only be achieved through an appropriate eHealth strategy, that justifies the expenditure and ensure a wise investment of scarce resources [48].

eHealth can be considered a complex system. Human beings, economies, culture, health systems and ICT infrastructure are complex settings, all these settings will affect the implementation of eHealth in developing countries [50]. Therefore, an analysis techniques used for decision making in complex and dynamic areas is needed. In Figure 6, the 5Cs model by Drury [27] is presented. It analyzed eHealth as a combination of different interrelated parts that need to be understood for successful implementation of eHealth in developing countries.

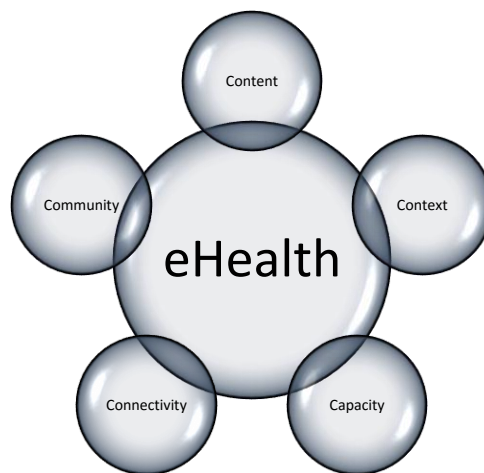


Figure 6: The 5Cs Model

- **Context:** Solutions need to be adapted to a context of poverty, with very limited resources. User needs and knowledge must be understood, especially for facility based health workers. Country strategies should be taken into account, and eHealth solutions should be aligned with these strategies, providing a long term focus [27]. Solutions are more effective when designed for those who deeply understand the setting [48].

- **Content:** Major effects of poverty are limited access to healthcare and delay in treatments. Content has to be created to improve access to knowledge to health workers and other users. In addition, protocol compliance and reduce delays in the TDM model need to be considered when designing the content.
- **Community:** Traditional beliefs and community organization need to be understood. In developing countries, especially in Africa, isolated communities have a different decision making process to attend healthcare. This decision making process needs to be understood and changed. The role of different community members need to be understood, these members could jeopardize eHealth implementation.
- **Capacity:** Medical staff is scarce in developing countries. There is a continuous human migration from rural to urban areas. High skilled medical staff use to leave their home countries looking for better opportunities. Hence, health workers in rural areas has limited knowledge. Medical staff is not the only shortage of human resources. Same situation applies for eHealth professionals or technical support for equipment.
- **Connectivity:** In rural areas, there are no wired networks that provide access to Internet. The local infrastructure for connectivity is limited. Mobile networks are very common in developing countries and expected to continue growing in the next years. EHealth solutions can help creating new infrastructure. However, for projects with low resources, solutions need to be tailored to local connectivity.

## 4 Methods

The methods section is divided in two parts:

- Part 1: Corresponds with the work done during the 1<sup>st</sup> semester, where the potential and requirements to implement an eHealth solution are identified. This part finishes with the proposal of a solution.
- Part 2: Design, development and testing of the prototype of the solution proposed.

### 4.1 Part 1: Potential and Requirements of eHealth to improve MHC

The current MHC situation in Kpando, Ghana, especially remote in selected communities, and the potential for an e-health solution to decrease delay in maternal healthcare were analyzed using triangulated research methods and sources. Use cases analyzed perspectives of various stakeholders in MCH on factors that influence delay during pregnancy and assess the potential of eHealth solutions. Methods used for data collection: literature review, semi structured interview, focus group discussion and ICT infrastructure assessment

#### 4.1.1 Selection criteria

Communities were selected upon availability of care. Islands and peninsulas in Lake Volta were selected as remote communities where no qualified MHC is available. One remote community i.e. Agbenoxoe, with a unique type of care was selected too. This care consists of ANC, delivery care, PNC and outreach MHC. Health care providers in this HC work close together with the TBAs in the communities. This exceptional cooperation will provide valuable information that is different from other remote communities.



Semi-structured interviews were conducted with maternal health workers. Two health facilities were selected through purposive sampling as they were selected as the first point of care for selected communities. Through convenience sampling facilities that are involved in the health care provision to our study areas were included to identify delays in seeking and receiving maternal care. Facilities that were willing to collaborate were interviewed.

#### 4.1.2 Literature review

Scientific articles, data provided by the local health authorities and national reports were reviewed to gain understanding of the current maternal health care situation in Kpando. Research outcomes on delay in MHC were included [51, 52, 53, 18, 14, 54, 55, 56]. Seven recently conducted research in the area are provided in Table 1. The stakeholders in maternal health included in this research are shown in Table 1, each research identified barriers that contribute to the delayed in seeking and receiving maternal health care.

Stakeholders interviews	MHC in Kpando [51] (2013)	Influence of HIV testing on ANC attendance (2013)	ANC utilization [18] (2014)	Delay in EmOC [52](2014)	TBA influence in decision making (2014)	Maternal health on the islands of Kpando [14] (2015)	Stimulating skilled care attendance in Kpando [54] (2015)	eHealth to reduce maternal mortality (2015)
Pregnant women / mothers	20	18	14	21	22	60	11	-
Family members	-	-	3 husbands	-	-	-	4 (husbands), 5 (parents), 1 grandmother, 1 cousin	-
TBAs	13	-	-	7	6	6	2	-
Maternal health workers	26	5	10	6	3	3	12	20
GHS Directorate	1	-	1	1	-	1	1	2
NHIS Office	-	-	1	-	-	-	-	-
Additional Focus Group Discussion	-	-	-	1 with TBAs, 1 with mothers	1 with TBAs, 1 with mothers	1 with various stakeholders	1 with mothers, 1 with husbands, 1 with various stakeholders	1 with various stakeholders

Table 3: Participants included in this and previous research in the area

Local and national reports on maternal health provided quantitative information on skilled care attendance and maternal mortality. This information was used to design semi-structured interviews and a focus group discussion. In addition, literature review on eHealth solutions in developing countries was conducted. The main focus was on eHealth solutions that decrease the delay in maternal health care [57, 58, 32, 33, 37, 30, 59, 31, 39, 36]. Other articles included were reviews and studies of clinical outcomes of eHealth solutions [42, 41, 40, 38, 60, 44].

#### 4.1.3 Semi-structured interviews

Semi-structured interviews [61] with health care providers at various levels in the Kpando Municipality were conducted in order to identify the maternal health care needs at the levels of the facilities, but also to identify work routines in ANC, delivery care and PNC. Through these interviews perspectives of maternal health workers on barriers and facilitators for pregnant women to access MHC were gathered. Finally, the possibility and willingness to use eHealth solutions in their job was discussed with these health workers.

#### 4.1.4 Focus Group Discussion

A focus group discussion [61] was organized in order to discuss different solutions to facilitate access to MHC to women living on the islands around Kpando. The aim of this group discussion was to elaborate with various stakeholders in MHC on the main pregnancy related challenges on these islands. The challenges and their respective solutions were discussed and prioritized.

#### 4.1.5 Use Cases

In the Use Cases [62], occurrences during pregnancy were mapped through the pregnancy timeline. The previously described methods gathered perspectives of various stakeholders in maternal health care. Causes of each of the occurrences were identified through the methods described above. The outcomes were organized according to the TDM. This resulted in a list of factors contributing to delay in maternal health care in remote areas.

#### 4.1.6 ICT infrastructure assessment

In order to quantitatively analyze the telecommunication infrastructure naturalistic observations [63] of the equipment in the healthcare facilities was done. Focus was on mobile phone penetration among patients and ICT infrastructure in the facilities. Moreover, a network coverage test for the two biggest telecommunication operators in the area was done. The android application OpenSignal was used for this purpose, testing network coverage in selected healthcare facilities and islands. Four different measurements were taken at different geographical locations at three minutes' intervals. The average of four measurements was considered as parameter.

#### 4.1.7 Data Analysis

Two Theoretical Frameworks were used. The Three Delays Model (TDM) by Thaddeus and Maine [26] is a leading framework to assess issues in maternal health care systems. Prompt, adequate treatment after the onset of obstetric complications will most likely result in a satisfactory outcome, preventing maternal death, while a delay might have the adverse effect. Delays are not caused by one single factor, but by various interrelated factors. These factors are categorized in three groups. Three Delay Model (TDM) presents TDM and the factors that influence delay.

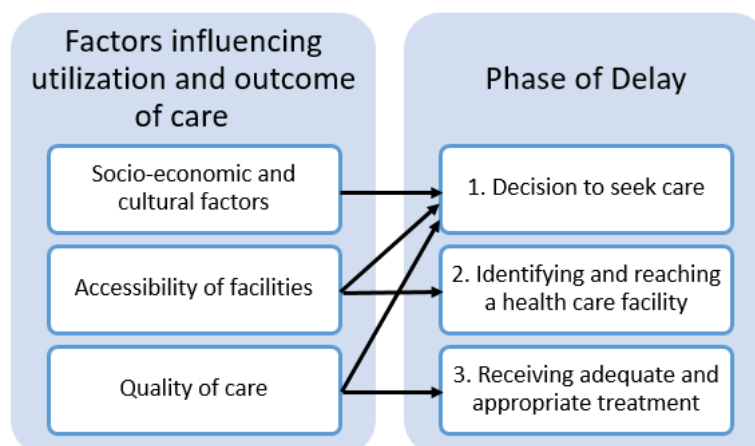


Figure 7: Three Delay Model (TDM)

The conceptual framework was used to structure research activities, outcomes and recommendations. While the application of TDM provided factors that delay maternal health care, a framework to analyze the potential and requirements of eHealth solutions was also needed. The 5C framework by Drury [27], shown in Figure 3: The 5Cs Model, was used to identify challenges and evaluate the context to assess in which delay phase an eHealth solution will have the biggest impact. The five Cs stand for context, content, connectivity, capacity and community. Information on the context connectivity, capacity and community was collected and analyzed during this research. The content will structure implementation research on the proposed solution.

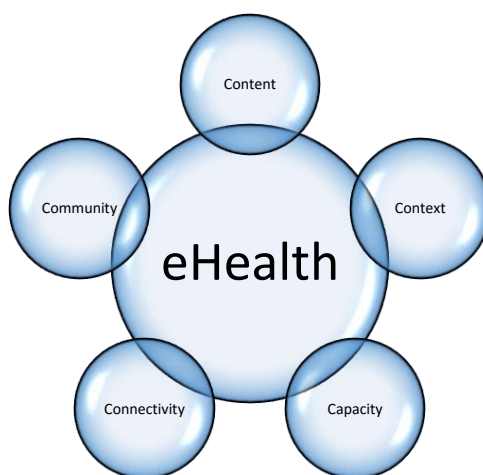


Figure 3: The 5Cs Model

#### 4.1.8 Solution

All gathered data led to the proposal of an eHealth solution. This strategic proposal should have the biggest impact on decreasing the delays in maternal health care. It should improve the health status of mothers living in remote areas through prioritization of the main challenges of the healthcare system and challenges of mothers to access health care. The prioritization is done based on the importance that each participant of the study gave to the main challenges.

### 4.2 Part 2: Design, Development and Testing of the Prototype

With the results obtained in part one, a prototype of the solution proposed have been developed and tested in different facilities. The aim was to design a solution appropriate for the setting.

#### 4.2.1 Selection Criteria

##### 4.2.1.1 Mobile Platform and Device

The selection criteria for the software platform was to choose the platform with most users in the area. Android is the main platform in Ghana, especially in Kpando. iPhone can only be bought in the capital, Accra, and the price of them makes them very unaffordable for most of the population. Another key factor, is that most health workers are already used to Android since they already own android devices.

The device chosen for testing the App, is the tablet DroiPad 7 from TECHNO. Tablets have been used over mobile phones due to their biggest screen, so health workers can visualize the information better. The tablet selected has a 7" screen. TECHNO have been selected as the provider because they are one of the main providers of mobile phones and tablets across the country. They have offices in almost all the cities in the country, the company is Ghanaian, offer mobile devices at low prices and adapted to local conditions. In case that repayment is needed, they have affordable technical support across the country, better than the big international mobile providers such as Samsung, Huawei, etc.

The software is Open Source, and the repository can be downloaded at GitHub. Open Source was selected in order to make the prototype accessible to a bigger audience and offer the possibility to other developers around the world to collaborate with the project.

#### 4.2.1.2 Facilities selected for Simulation

The facilities selected are those that work with patients in the most remote and isolated areas. In Kpando Municipality, the facility selected have been Agbenoxoe, due to the especial care provided and the remote communities that they served. Simulations were also done in 4 facilities in South Adfajato province. The facilities selected were those close to the Togolese border, where the communities are remote and hard to access.

#### 4.2.2 Agile Software Development

The design and development of the prototype will follow a cyclic cycle of three stages as can be seen in **¡Error! No se encuentra el origen de la referencia.:**

1. **Define / Update Requirements:** The first stage is to define the features (backlogs) of what is possible and feasible to achieve. This list of backlogs has been consulted with the stakeholders and which backlogs are more useful for them.
2. **Development:** The second stage is to program the features. Each problem encountered during the development is written down, and also the solution to avoid same problems in other stages. Each feature has been developed in short deadlines. Only when a feature is complete, and complete it means fully functional, we will move to the next stage.
3. **Feedback and Retrospective:** When a backlog is complete, it was shown to the stakeholders and feedback was gathered. Then, the backlog will be re-design with problems encountered and when finished, we will move to the next backlog.

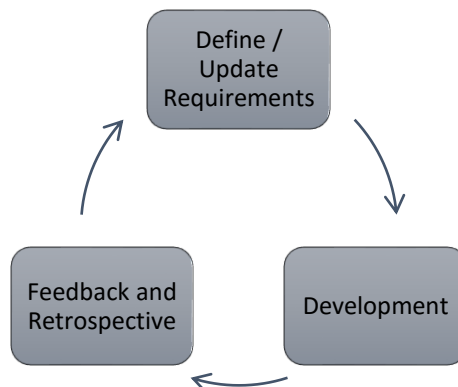


Figure 8: Stages of Design and Development Process

### 4.2.3 Focus Group

A focus group discussion with 60 participants was held at Ve Golokoati Assembly. The features of the mobile application and how the simulations were going to be was explained to the participants. Each participant, received a booklet with visual information about the features and a schedule for the simulations. During the discussion, the participants shared their doubts and concerns about the project. Finally, the participants were asked to sort out the features in order of importance in order to evaluate which features were most important and schedule the development task.

### 4.2.4 Simulations

A total of four sessions of simulations were carried out at eight different facilities, and a total of eighteen health workers tried the application. The users that tried the application were CHNs and Midwives. Each simulation lasted between 45-60 minutes. The first simulations consisted on testing the interfaces for gathering patient history and register them on the service, during the second one, protocol driven guidance and educational services included on the app were tested, in the third one, the interfaces for examinations in home visits, and finally, in the fourth one, the decision support system, monitoring system and connection with cloud service were tested.

The process of each of this test was the same, one or two users tried the application at the same time. First, the project goals and how the prototype worked was presented to the health workers. Afterwards, health workers tried the app with either a patient that was at that moment in the facility or between them, simulating that one of them was a pregnant woman. During this process, notes of observations of how the app was used were taken. During all the process, health workers were free to ask question and suggestions about the app functionality. This feedback, was gathered to re-design the app afterwards. Finally, during a semi structured interview of 10-20 minutes' duration, the satisfaction of the patients with the app, their opinion about the impact on the app in their work and in the health status of the patients was gathered. The semi structured interview consisted of three fixed questions, depending on their answers more questions were asked.

## 5 Results Part 1: Potential and Requirements of eHealth to improve MHC

### 5.1 Use Cases

The aim of the Use Cases is to identify the challenges in maternal health care in our research areas. Five different use cases will be presented:

- Typical pregnancy in Kpando Islands
- Pregnancies in Agbenoxoe communities:
  - Teenage Pregnancy
  - Normal Pregnancy
  - Multiparity
- Typical pregnancy in South Tongu

#### 5.1.1 Pregnancy in Kpando Islands

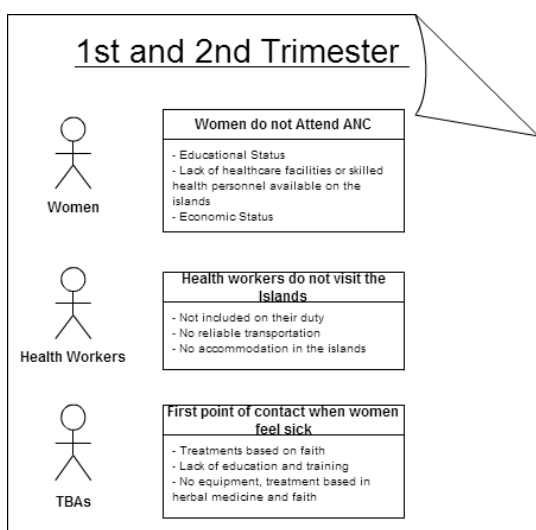
Table 4 presents the profile of the average woman living in the Islands. All the indicators provided are average taken from the research done by UNiTED in Kpando Islands [14].

SUMMARY TABLE OF WOMEN LIVING ON THE ISLANDS			
Age	27 years		
Nº of pregnancies	4.2		
% of lost pregnancies	8%		
Deliveries	3.94		
Nº of children	3.79		
Age at first Pregnancy	18		
Distance to Health Care Facility	Average of 30 minutes by motorboat and average cost of 20 GH Cedi = 5 Euros = 50 SEK		
Place of delivery	Percentage	Reasons	
	Hospital	35%	<ul style="list-style-type: none"> <li>• Family took them there</li> <li>• Sick during pregnancy</li> <li>• Difficulties during delivery</li> <li>• Too many previous pregnancies</li> </ul>
	TBA	60%	<ul style="list-style-type: none"> <li>• No reason</li> <li>• Family Recommendation</li> <li>• No time to go to the facility</li> <li>• Hospital error on date of delivery</li> <li>• No money</li> </ul>
	Alone	5%	<ul style="list-style-type: none"> <li>• No reason</li> </ul>
National Health Insurance	Yes	65	
	No	35	

Table 4: Summary of women living in the Islands

Based on the previous data we can see the characteristics of the average patient from Kpando Islands. However, we observed that many women said that they had NHIS only when they had the card even though the insurance was expired.

Based on the information gathered through interviews with women, TBAs and midwives of the different healthcare facilities a use case has been developed where the challenges faced for the stakeholders involved can be seen. Each event is presented in a box, and the reasons for it to happen are included in the same box, we call this reasons Stress Factors.



Each event is presented in a box, and the reasons for it to happen are included in the same box, we call this reasons Stress Factors.

Figure 9 shows typical occurrences for the first two trimesters of pregnancy. Woman do not usually attend ANC. Health workers do not visit the islands, government does not know exactly which Islands fall under its jurisdiction so community visits are not implemented. TBAs are usually the first point of contact with these communities. However, the care they provide is based in faith and herbal medicines

Figure 9: Use Case Islands 1st and 2nd Trimester

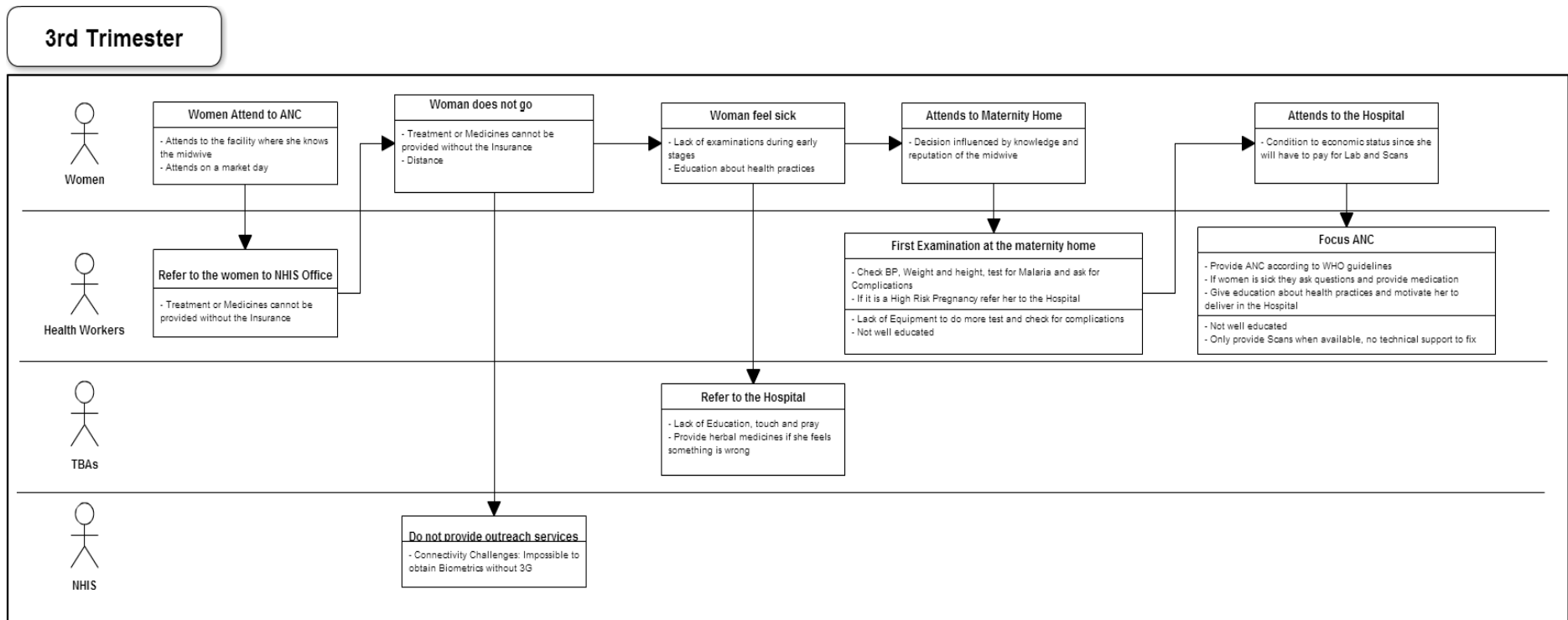


Figure 10: Use Case Islands - 3rd Trimester

During the third trimester, most women usually decide to attend ANC, the first step for any pregnant woman is to sign up to the NHIS, which is free for pregnant women. To do that, woman need to travel to Kpando. The NHIS does not offer outreach services, the new system is based on biometrics and require good connectivity that cannot be found in the communities or islands. Then, when women feel sick, usually with dizziness or vomits, they first visit the TBAs since they are close to the communities and travel to the mainland is expensive. TBAs touch the belly and pray to detect abnormalities, TBAs usually refer women to the hospital, but if she cannot attend, TBAs offer them herbal medicines. One of the market days' women attend ANC at the Maternity Home in Torkor, the closest point of care. The lack of equipment does not allow to make examinations, women are only asked how they feel and Blood Pressure is checked. In the Hospital, the care provided is supposed to follow WHO guidelines, however, that is not always true due to lack of equipment. Treatments and diagnosed are done based on symptoms and not in evidences.

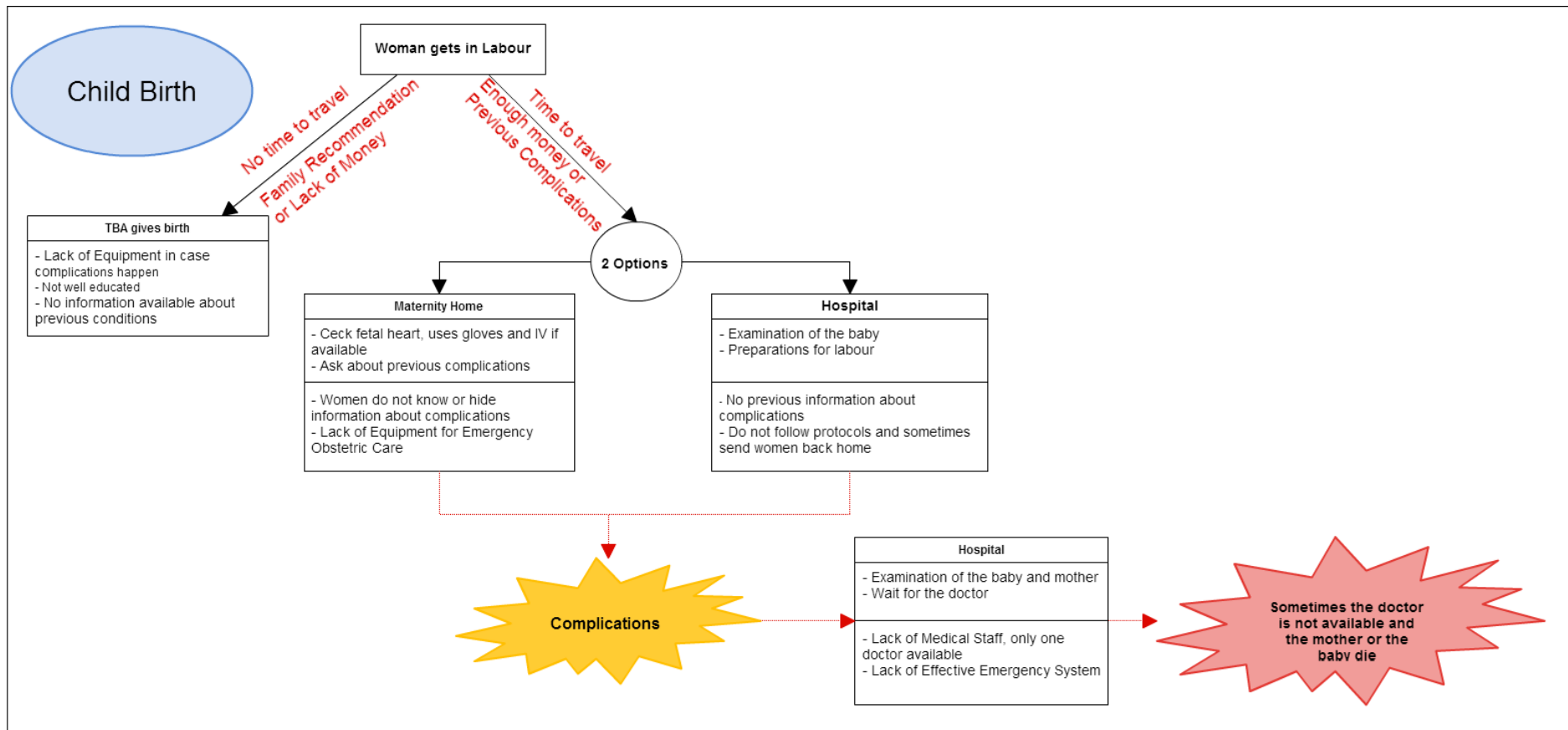


Figure 11: Use Cases- Child Birth

When women get in labor, there are two options. The first one is to give birth with a TBA, especially if it's late at night and they do not have money or available transportation to the mainland. The second one is to go to a healthcare facility. There are two facilities available to give birth, the Maternity Home in Torkor and the Hospitals. In both of them the process is the same, they do preparations for giving birth and in case some complication arise they have to wait for the doctor to come. However, the doctor is not available and mother or baby die while waiting.



### 5.1.2 Use Cases Agbenoxoe

This document shows how a typical pregnancy is for a woman living in the communities close to Agbenoxoe. Agbenoxoe has a maternity clinic where a midwife works 24 hours and a Community Health Nurse (CHN) that do home visits every day. In this section, the challenges that women face during pregnancy on these communities are presented along with the challenges that the CHN face during her job.

The use case presented have been developed with the collaboration of the CHN, what challenges does she found to do her job and the different kind of patients that she has to deal with. The decision of focusing on this community have been taken due to the implementation of daily community visits and that the clinic works with deprived areas where women have a difficult access to quality health care. In Table 5 the profile of the CHN is included.

SUMMARY TABLE OF HEALTH WORKER PROFILE	
Age	25 years old
Profession	Community Health Nurse
Education	2 years of nursing school
Place of Work	Agbenoxoe
Other factors:	<ul style="list-style-type: none"> <li>• Highly Motivated and Enthusiastic</li> <li>• Do Home visits every morning 6AM to pregnant women in the communities</li> <li>• Works at the Maternity Clinic from 8 AM – 4 PM</li> <li>• Low IT literacy</li> </ul>

Table 5: Health Worker Profile

#### 5.1.2.1 Teenage Pregnancy

The first typical pregnancy is an adolescent pregnancy, single and with very low economic resources. It is considered a High Risk Pregnancy and is very important that the woman go through an appropriate ANC to avoid complications during childbirth. In Table 6 patient profile can be seen. The information is provided by the CHN, who explained the typical characteristics among teenagers in the area.

Patient Profile	
Age	16 years old
Nº of pregnancies	1
Type of pregnancy	High Risk
Marital Status	Single
Income level	Very Low
Deliveries	0
National Health Insurance	No

Table 6: Patient Profile Teenager

The Use Case is presented on a table, the columns represent the timeline of pregnancy and the events that occur. In the rows, the role and stress factors of each stakeholder involved is presented.

Chain of Care	0-12 Weeks	12-24 Weeks	24-40 Weeks
<b>Pregnant Women</b>	Women does not realize she is pregnant, only goes for a checkup if she feels sick or vomiting.	<ul style="list-style-type: none"> <li>The CHN visits her again and does a pregnancy test</li> <li>She receives education about diet and pregnancy related complications</li> <li>The CHN motivates her to attend to ANC to the facility but first she has to sign up for the NHIS <ul style="list-style-type: none"> <li>She cannot afford to go to the NHIS.</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>The CHN keeps on visiting her regularly but the situation hasn't change for her.</li> <li>She is afraid to go to the Hospital to deliver because the health workers attitude towards her due to her age and marital status. In addition, she cannot afford it so she decide to deliver with a TBA</li> </ul>
<b>Stress Factor</b>	<ul style="list-style-type: none"> <li>Lack of education about pregnancy symptoms.</li> <li>They do not see pregnancy as a health risk</li> </ul>	<ul style="list-style-type: none"> <li>Lack of economic support from partner or Husband</li> <li>NHIS office is very far away, going to the city will take her all the day and she cannot afford it</li> </ul>	<ul style="list-style-type: none"> <li>Behavior of Health Workers</li> <li>Geographical and Economical Barriers <ul style="list-style-type: none"> <li>Marital Status</li> <li>Traditional beliefs</li> </ul> </li> </ul>
<b>CHN – Agbenoxoe</b>	<ul style="list-style-type: none"> <li>Home visits with Pregnancy Tests to check on women that could be pregnant.</li> <li>If the woman is pregnant register the woman of on her list and ask her to go to first ANC to the Health Center</li> <li>Once per month visit other communities to provide information about their health facility and the services they can offer</li> </ul>	<ul style="list-style-type: none"> <li>Identify that the woman is pregnant and make a pregnancy test</li> <li>Motivate her to go to the NHIS because without it, she will have to pay for the medicines</li> <li>Extra official: Even though they cannot treat High Risk pregnancies she tries to help this woman at least to motivate them to attend ANC at Agbenoxoe, she does not want to leave a woman without care.</li> <li>Extra official: Sometimes she gives them money to go to the NHIS .</li> </ul>	<ul style="list-style-type: none"> <li>Even though the CHN kept visiting the woman and giving her advice she could not do anything else to motivate the woman to have a Skilled Attended Delivery or to go to ANC</li> <li>If some complications happen to this woman they just know due to rumors across town, however, when they are able to reach there is usually too late.</li> </ul>
<b>Stress Factor</b>	Even though she does home visits it is very difficult to convince women to attend during the first trimester.	<ul style="list-style-type: none"> <li>Regulations that she cannot treat high Risk pregnancy</li> <li>Lack of equipment to provide a better care for this women <ul style="list-style-type: none"> <li>Cost of NHIS</li> </ul> </li> </ul>	
<b>Hospital-Midwife</b>		In the Hospital there is no information system to alert about High Risk pregnancies so they do not know what is going on	Women that do not attend to ANC and goes to the deliver to the Hospital show low Hemoglobin levels and abdominal pain which can lead to complications during birth.
<b>Stress Factors</b>		No community outreach programs to treat High Risk pregnancies	
<b>NHIS</b>	They do community outreach programs to register patient from rural communities into the NHIS.		
<b>Stress Factor</b>	<ul style="list-style-type: none"> <li>They use Biometric Data to register patients into the insurance scheme (Fingerprints and picture) <ul style="list-style-type: none"> <li>Due to lack of connectivity they cannot travel with the equipment to the facilities.</li> </ul> </li> </ul>		

Table 7: Use Case - Adolescent High Risk Pregnancy

### 5.1.2.2 Typical Pregnancy Agbenoxoe

The next use case represents a normal pregnancy for women living in communities close by to Agbenoxoe, her characteristics can be seen at Table 8.

PATIENT PROFILE	
Age	24 years old
Nº of pregnancies	3
Type of pregnancy	Normal
Marital Status	Married
Income level	Medium
Deliveries	3
National Health Insurance	Yes

Table 8: Patient Profile Typical Pregnancy Agbenoxoe

In the next tables, the use case for a typical pregnancy in this communities can be seen

Chain of Care	1st Trimester
Patient	
Pregnant Women	<ul style="list-style-type: none"> <li>• During the First Trimester most women do not know if they are pregnant or not, they do not attend to the facilities at least they are feeling bad vomiting with pregnancy symptoms.</li> <li>• When the CHN visits her they know they are pregnant, however, until the second trimester she will not attend to ANC.</li> </ul>
Stress Factors	<ul style="list-style-type: none"> <li>• Lack of knowledge when they are pregnant</li> <li>• Do not see pregnancy as something that could cause them health complications</li> </ul>
Agbenoxoe Health Center	
CHN	<ul style="list-style-type: none"> <li>• Home visits with Pregnancy Tests to check on women that could be pregnant.</li> <li>• If the woman is pregnant register the woman of on her list and ask her to go to first ANC to the Health Center</li> <li>• Once per month visit other communities to provide information about their health facility and the services they can offer</li> </ul>
Stress Factors	<ul style="list-style-type: none"> <li>• Even though she does home visits it is very difficult to convince women to attend during the first trimester.</li> </ul>
NHIS	
Staff	<ul style="list-style-type: none"> <li>• The woman is registered at the free NHIS for pregnant women from previous pregnancy and the insurance still covers her.</li> </ul>
Stress Factors	

Table 9: 1<sup>st</sup> Trimester Typical Pregnancy Agbenoxoe

Chain of Care	2nd Trimester	
Patient		
Pregnant Women	<ul style="list-style-type: none"> <li>• Woman decides to attend to first ANC visit, usually on market days.</li> </ul>	<ul style="list-style-type: none"> <li>• Woman attends to ANC to the Hospital</li> <li>• She has to live very early to the Hospital, walk for one hour until the main road or take a motorbike, in the main road she waits for a car to take her to Kpando</li> <li>• The journey is long and expensive</li> <li>• When she arrives to the Hospital she has to wait for hours because is busy and the Midwives are busy</li> <li>• She will have to pay 25 GH Cedis for the Ultrasound</li> <li>• It is very difficult for her to get back to her community before it gets dark, somebody will have to wait for her at the main road to take her back to the community</li> </ul>
Stress Factors	<ul style="list-style-type: none"> <li>• The decision is influenced by her knowledge about previous pregnancy and the information received at the home visits</li> </ul>	<ul style="list-style-type: none"> <li>• Geographical and Economic Barrier</li> <li>• Organizational structure of the Hospitals and load of work on big facilities</li> </ul>
Health Center		
CHN and Midwife	<ul style="list-style-type: none"> <li>• First ANC visit routine: <ul style="list-style-type: none"> <li>○ Pregnancy Test</li> <li>○ HIV Test</li> <li>○ Malaria test</li> <li>○ Syphilis Test</li> <li>○ Fetal Doppler</li> <li>○ Hand in Maternity Card and record medical, obstetric and breastfeeding history.</li> <li>○ Medication given to all the woman: Folic acid, Fersolate and multi-vitamin</li> <li>○ Information about health diet, personal hygiene and danger signs</li> </ul> </li> <li>• At this stage of pregnancy women has to be referred to the Hospital for Ultrasound and Lab</li> </ul>	<ul style="list-style-type: none"> <li>• The CHN will visit the woman in their home every week: <ul style="list-style-type: none"> <li>○ Make sure she is attending the schedule appointments</li> <li>○ Make sure she is taking the medication and provide them with more if needed</li> <li>○ Check woman diet and provide more information</li> <li>○ Check if there is any need to refer them again</li> </ul> </li> </ul>
Stress Factors	<ul style="list-style-type: none"> <li>• Lack of Equipment: Lack of Ultrasound and Lab to perform a complete examination</li> <li>• When they record history about previous pregnancies women hide important information such as previous complications during pregnancy.</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of equipment and the need of referral to do better examinations is affecting them.</li> <li>• Some women leave the community and is impossible to track them</li> </ul>
Hospital		
Midwife		<ul style="list-style-type: none"> <li>• Midwives do not prioritize patients depending on where they come from, first come first served policy</li> <li>• Check maternal book to view previous examinations</li> <li>• Major risks and STIs are mapped</li> <li>• Check BP, Weight, Height, Pulse and Temperature</li> <li>• Abdominal/obstetric and pelvic examination</li> <li>• Blood test to determine Hemoglobin levels and antibody screening</li> <li>• Ultrasound</li> <li>• Medication given to all the woman: Folic acid, Fersolate and multi-vitamin</li> </ul>
Stress Factors		<ul style="list-style-type: none"> <li>• Midwives do not like patients changing between facilities</li> <li>• Their Attitude towards patients influence ANC attendance on the facilities, so some women do not go back</li> </ul>

Chain of Care		3rd Trimester	
<b>Patient</b>			
Pregnant Women	<ul style="list-style-type: none"> <li>• Woman attends to ANC at Agbenoxoe</li> </ul>		<ul style="list-style-type: none"> <li>• The woman feels she is in labour and goes to the facility</li> </ul>
Stress Factors	<ul style="list-style-type: none"> <li>• The Distance to her place is an advantage</li> </ul>		
<b>Agbenoxoe Health Center</b>			
CHN and Midwife	<ul style="list-style-type: none"> <li>• ANC visit routine: <ul style="list-style-type: none"> <li>○ Check BP, Weight, Height, Pulse and Temperature</li> <li>○ Measure Fetal height</li> <li>○ Provide Routine Medication</li> <li>○ Convince woman to deliver at the facility</li> </ul> </li> </ul>		<ul style="list-style-type: none"> <li>• The Midwife will do the routine preparations and deliver the baby</li> <li>• The Midwife is available 24 hours</li> <li>• In case of complication the woman will be referred to the Hospital, however, ambulance service is not always available</li> <li>• Due to hide of information about previous complications to the health workers some complications can happen again such as hemorrhage.</li> </ul>
Stress Factors			<ul style="list-style-type: none"> <li>• Lack of effective emergency services in case of complications</li> <li>• Lack of information about previous pregnancy complications</li> <li>• Some Women hide information about previous complications</li> <li>• Lack of Equipment in case the woman is weak and needs blood</li> </ul>
<b>Hospital</b>			
Midwife	In the Hospital they lose track of the pregnancy and they do not know if the woman is attending again ANC		
Stress Factors	Lack of effective exchange of information		

Table 11: 3rd Trimester- Typical Pregnancy Agbenoxoe

### 5.1.2.3 Multiparity Pregnancy

The third Use case from Agbenoxoe is about a high risk pregnancy that ended up in dead. It shows how difficult it is to convince women to attend ANC. The case is shown in the next diagram.

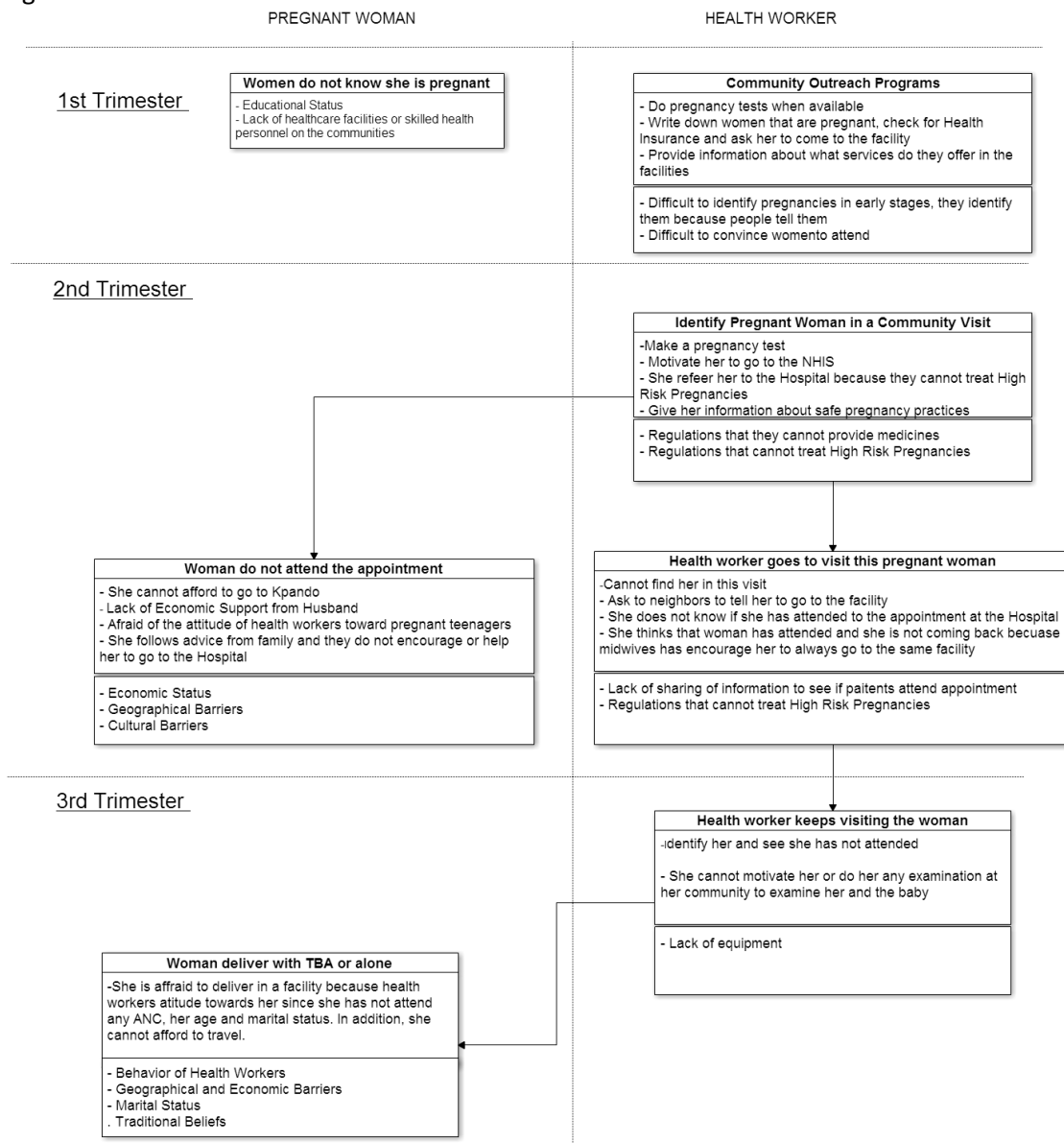


Figure 12: Use Case Multiparity

### 5.1.3 Use Case South Tongu

The use case has been developed with the information gathered during two visits to Sogakope, in the first visit some facilities and communities were visited and in the second one, the District Hospital. Midwives working in the facility were interviewed. The patient characteristics have been gathered using the Ghana Health Service Report in South Tongu [64]. There are some differences in the Chain of Care in South Tongu compared to Kpando, while in Kpando CHN make routine community visits as their duty in Sogakope there are CHN living within the communities and are the first point of care for the deprived communities. The rest of the healthcare structure is the same.

Age	27
Number of childs	3
Number of pregnancy	4
Occupation	Farming
Marital Status	Married
NHIS	Yes
Distance to District Hospital	Average 20 minutes by taxi

Table 12: Patient Characteristics South Tongu

The next Use Case represents a typical pregnancy for woman living in South Tongu

Chain of Care	1st Trimester
Patient	
Pregnant Women	<ul style="list-style-type: none"> <li>• During the First Trimester most women do not know if they are pregnant or not, they do not attend to the facilities at least they are feeling bad vomiting with pregnancy symptoms.</li> <li>• When she feels that she could be pregnant go to the CHN, however, until the second trimester she will not attend to ANC.</li> </ul>
Stress Factors	<ul style="list-style-type: none"> <li>• Lack of knowledge when they are pregnant</li> <li>• Do not see pregnancy as something that could cause them health complications</li> </ul>
CHN living within the communities	
CHN	<ul style="list-style-type: none"> <li>• The CHN lives within the communities</li> <li>• She does basic ANC and Child Welfare Clinics</li> <li>• When she knows a woman is pregnant she goes and visit her and refer them to the Hospital or a Health Center for ANC.</li> </ul>
Stress Factors	<ul style="list-style-type: none"> <li>• Women complain that they do not have money to attend to the Hospital.</li> </ul>
District Hospital Sogakope	
Staff	<ul style="list-style-type: none"> <li>• The woman is registered at the free NHIS for pregnant women from previous pregnancy and the insurance still covers her.</li> </ul>
Stress Factors	

Table 13: 1st Trimester - Use Case South Tongu

Chain of Care	2nd Trimester	
Patient		
Pregnant Women	<ul style="list-style-type: none"> <li>• Woman decides to attend to ANC at the District Hospital</li> </ul>	<ul style="list-style-type: none"> <li>• Woman goes back to her community</li> </ul>
Stress Factors	<ul style="list-style-type: none"> <li>• She attends when she has money to go</li> </ul>	
CHN living within the communities		
CHN		<ul style="list-style-type: none"> <li>• She will visit the woman that she knows are pregnant</li> <li>• Will check on the Maternal Health Book if they have attended to the facilities</li> <li>• They have a special referral system for alerts that she will call to the Hospital to inform that she is referring a patient</li> </ul>
Stress Factors		<ul style="list-style-type: none"> <li>• She has to pay from her own money the phone calls to advice that she is referring patients, most of the time she has no credit to do it, or she does not receive any confirmation from Hospitals or Health Centers</li> </ul>
District Hospital Sogakope		
Staff	<ul style="list-style-type: none"> <li>• First come first served, only if they come with the husband they are given priority</li> <li>• Focus ANC: the same midwife will attend the same woman through all the pregnancy</li> <li>• 1<sup>st</sup> visit Routine: <ul style="list-style-type: none"> <li>○ Major risks and STIs are mapped</li> <li>○ Check BP, Weight, Height, Pulse and Temperature</li> <li>○ Abdominal/obstetric and pelvic examination</li> <li>○ Blood test to determine Hemoglobin levels and antibody screening</li> <li>○ Sickling cell</li> <li>○ HIV Test</li> <li>○ Ultrasound when available (now is broken)</li> <li>○ Medication given to all the woman: Folic acid, Fersolate and multi-vitamin</li> <li>○ Medication for worms provided to all the woman during 2<sup>nd</sup> and 3<sup>rd</sup> trimester</li> <li>○ History (Some women will hide relevant factors, some of them do not know complications about previous pregnancies or other have new partners and do not want to share this information)</li> </ul> </li> <li>• If the woman is pregnant more than 16 weeks: Self Autoxine Parameter</li> <li>• No individual delivery plans, only if the woman needs a cesarean section.</li> <li>• A visit takes between 15-45 minutes</li> <li>• The same midwife that does the examination records the information in the Maternal Health Books</li> </ul>	
Stress Factors	<ul style="list-style-type: none"> <li>• Lack of Equipment, especially when late reimbursements from NHIS.</li> <li>• Some woman disappear after one visit and they do not have any way to track them</li> </ul>	

Table 14: 2nd Trimester Use Case South Tongu



Chain of Care	3rd Trimester	
<b>Patient</b>		
Pregnant Women	<ul style="list-style-type: none"> <li>• Woman goes to 2<sup>nd</sup> ANC visit</li> </ul>	<ul style="list-style-type: none"> <li>• Woman feels that she is in labor but decide not to go to the facility to deliver due to lack of money and traditional beliefs.</li> </ul>
Stress Factors	<ul style="list-style-type: none"> <li>• She attends when she has money to go</li> </ul>	<ul style="list-style-type: none"> <li>• Cultural Barriers: <ul style="list-style-type: none"> <li>○ Some believe that if they have to buy something for the baby before it is born the baby will die.</li> <li>○ Some women do not come to the Hospital because they do not have clean clothes for the baby and they are ashamed</li> </ul> </li> </ul>
<b>Hospital, Health Centers and CHP Zones</b>		
Staff	<ul style="list-style-type: none"> <li>• 2<sup>nd</sup> visit: <ul style="list-style-type: none"> <li>○ Monitor Fetal Height</li> <li>○ Monitor Maternal Condition</li> <li>○ If the woman complains then she receives treatment</li> <li>○ Woman receives information about delivery and motivate them to deliver in a facility.</li> </ul> </li> </ul>	
Stress Factors	<ul style="list-style-type: none"> <li>• Only some Health Centers and CHP Zones do deliveries</li> <li>• CHP Zones: One compound was visit were they do deliveries on a dentist char, they do not have water or electricity, it lacks of hygiene and it lacks of gloves and other equipment needed for sanitation to ensure safety of the health worker.</li> <li>• Health Centers: Are better equipped, they have a small maternity ward and water and power.</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of money to fight traditional beliefs, Hospital staff believe that if the facilities could provide free clean clothes for the baby once he is born, most women will come to deliver at the facility.</li> <li>• Maternal Death Case: 4 registered maternal deaths in the first half of 2015 in the district. Some of them are not registered, for instance, one woman was referred to the Hospital with severe hemorrhage after labor from one of the communities, in the Hospital they couldn't stop the hemorrhage so the woman was taken back to her community. The woman died in the community with a kidney failure, this dead was not recorded as a maternal death.</li> </ul>

Table 15:3rd Trimester Use Case South Tongu

## 5.2 Challenges in maternal health

In this section, the challenges in maternal health identified in the use cases are analyzed according to the TDM model. The challenges are divided into two categories, supply side (challenges affecting health workers) and demand side (pregnant women).

Figure 13 summarizes the factors that influence delay in maternal health care. Factors are divided over three categories: socio-economic/cultural factors, accessibility of care and quality of care. In addition all factors influencing care are separated into those on the demand side, the patient, and those on the supply side, the health care provider. This separation was made as factors on the demand side are personal factors that can often not be solved with an eHealth solution. However, the factors on the supply side, offer valuable information that can be included in an eHealth solution. An eHealth solution cannot decrease stigma, or improve road infrastructure. However, a well-designed solution can be used to improve quality of care.

On the demand side, education, low women empowerment, traditional beliefs and economic status are the factors that delay the decision to seek care [54]. Poor road infrastructure and geographical situation of communities affects directly the three delays. And the last factor influencing the first and third delay are the previous negative experiences with care [18]. On the other hand, cultural and socio-economic factors also affect the supply side. Staff attitude due to social stigma towards teenage and unmarried pregnancies influence patients' decision to seek care. Competitiveness between facilities influence the decision of patients to decide where to attend. Accessibility of care is mainly influenced by lack of equipment and human resources [51, 52]. Effective emergency systems are not in place. Errors in record keeping and referral systems are another influential factor for first and second delay. Quality of care is affected by staff attitude, lack of access to current knowledge and well trained medical staff. Poor referral systems, also delay the time in receiving adequate care, forcing patients to travel back and forth until they receive adequate care.

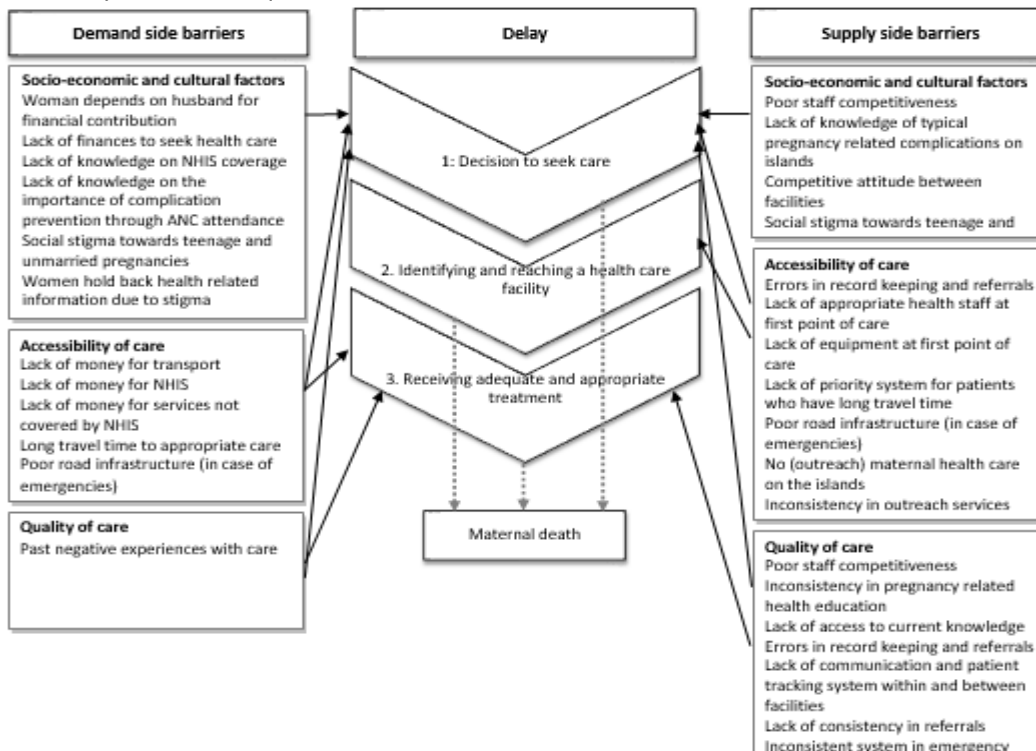


Figure 13: TDM Data Analysis

### 5.3 Stakeholders Opinion

Before considering eHealth solutions, different stakeholders were interviewed to prioritize the challenges in maternal health identified. The aim of this interviews was to prioritize the challenges and include stakeholders in the decision making process.

Figure 14 represents the importance of maternal health care barriers according to the stakeholders in health care. The barriers have been prioritized according to stakeholders' opinion. The main barrier according to them right now is the educational and cultural barrier that keeps women away from facilities due to their lack of health knowledge and the influence of traditional beliefs. In level two, economical and geographical are presented together, as due to distance and cost for transportation women do not access maternal health services. The third level was very close to the previous one in order of priority, the lack of equipment and personnel in the rural facilities makes that women living in deprived communities have to spend more money in order to access appropriate maternal health care. Errors in referrals are also related to the lack of equipment but according to health workers it is in one of the lowest levels of the pyramid. And finally, stakeholders thought that the behavior of health workers has the lowest impact when compared to the other barriers.

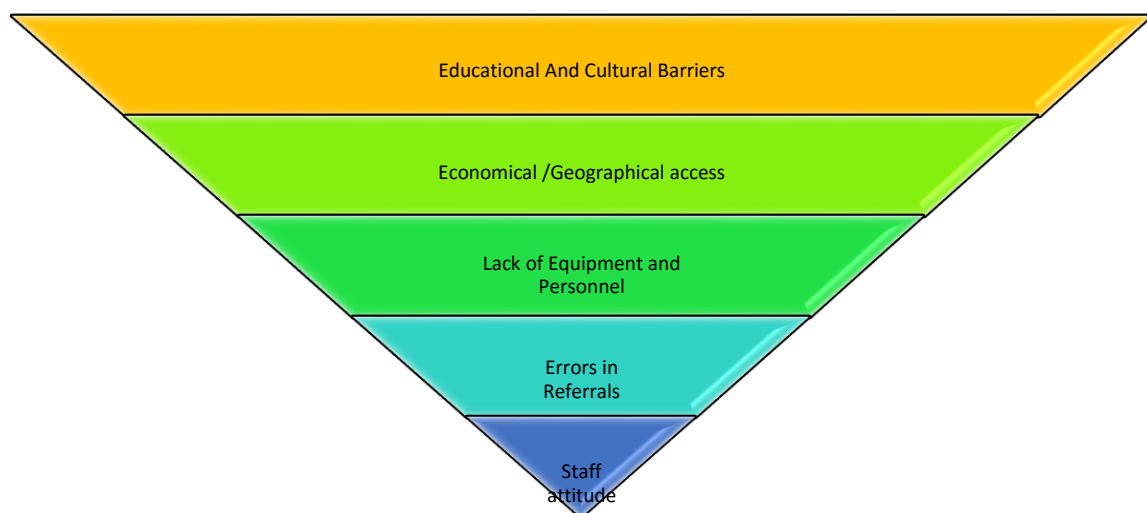


Figure 14:Pyramid of priorities according to local Stakeholders

### 5.4 EHealth Challenges

Once the barriers are prioritized, the challenges for eHealth implementation are identified, following the 5Cs model by Drury [27]. In this section, all the challenges identified are presented.

#### 5.4.1 Context

In the research areas there is a context of poverty. It presents the next challenges:

- Lack of Human resources. Only one doctor available in the municipality, and the number of midwives, especially in rural areas is reduced. Retired midwives have to go back to work when needed.
- Infrastructure:
  - Shortage of electricity

- No IT equipment available in the facilities. Only one system in place in Hospitals to connect with NHIS.
- Difficult access to current and reliable knowledge by health workers.
- Hard environmental conditions, especially humidity, dust and heat.
- The presence of difference stakeholders providing health services across different areas creates a fragmented health service. Therefore, can be difficult to coordinate and align information systems.
- Lack of funding for eHealth projects; main funding is going to drugs, vaccines and medical supplies to fight communicable disease. Hence, e-health solutions have two options, be funded through either donor support or internally generated funds, which keep on creating fragmented health services.
- Need to adapt to country strategies for future scaling of services.

#### 5.4.2 Community

Understand community needs and characteristics is key. Rural communities in our research areas have the next characteristics:

- Mainly rural populations with strong traditional beliefs. Herbal Medicines are common and cultural beliefs affect the family attitude toward healthcare services.
- Low woman empowerment makes that decision making process to access healthcare services relies on family members.
- Low education about pregnancy complications and health practices in rural areas.
- Where to seek care is influenced by personal relations. TBAs are respected and have an important role in healthcare in rural areas.
- There is a stigma between social classes, especially among single mothers and teenage pregnancies. For that reasons women hide important information to health workers.
- There is a competition among facilities that motivate patients to only attend their facility and not going to other facilities. These competition is because facilities with more patients receive more money from the government.

According to this characteristics, the next challenges can be identified:

- There is the need to adapt solutions to local communities
- Identify health workers needs and motivation
- Do not leave aside well respected members in the community that can jeopardize the project. Such as TBAs, community leaders and church representatives.

These challenges outline the importance of collaborating with local partners and inclusion of stakeholders through the design and implementation process.

#### 5.4.3 Capacity

Through the research process, mobile phone penetration and IT literacy have been quantitatively analyzed. Work routines and medicine practices have been identified and observed, the results are the next ones:

- **Mobile Phone Penetration:**
  - Low in Rural Areas. Most of the patients asked did not have a mobile phone.
  - 80% of Health Workers interviewed owned a Smartphone
- **IT Literacy among health workers:**

- 50% know how to use a computer
- 90% states that they would feel comfortable using IT equipment to do their job
- All of them see ICT solutions as an improvement to their job
- **Infrastructure and Human Resources:**
  - All facilities have access to power supply. However, black outs are scheduled and common. 12 hours of power off for every 24 hours of power.
  - No IT equipment available in any facility. Only a computer in the Hospitals to be used for the NHIS.
  - Funding for ICT infrastructure, installation of management information systems and training of ICT professionals is not available in a structured and coordinated manner.
  - Government is willing to connect the regional hospitals and selected district hospitals with optic fiber, in order to improve the Telemedicine network of the country.
  - There is an ICT infrastructure for the National Health Insurance Authority (NHIA). Accredited healthcare providers operate a common ICT platform with common protocols for patient's authentication and claims management, although it does not support any shared service.
  - Two applications for health management information systems (at primary level, the District Health Information Management System is primarily used). In some pilot projects they have been trying to acquire the information at the community level through Personal Digital Assistants (PDAs).
- **Organizational Issues**
  - Continuous rotation of health personnel among facilities
  - Communication flow between facilities is poor.
  - Poor referral system. Most health workers do not know the referral system to use.
  - Emergency systems are not in place. Ambulance service requires patients to pay for fuel.
  - Data are not organized, everybody keeps its information in different formats and different places which makes the access to this data very complicated.
  - No policies available to electronic data interchanges and patient identifiable information in the health sector.
  - Patients have to pay for examinations like ultrasounds that should be included in the NHIS.
  - In market days, there are a lot of women in the facilities, when other days is completely empty.
  - Patients with emergencies have to wait long times until they are attended because caregiver is classifying the patient's files.
- **Work Routines**
  - Health workers stated that they provide Focus ANC, however, according to the information gathered about work routines, it can be seen that not all the recommendations are followed as can be seen in the **¡Error! No se encuentra el origen de la referencia.**

1 <sup>st</sup> Visit Recommendations	Done?	2 <sup>nd</sup> Visit Recommendation	Done?	3 <sup>rd</sup> Visit Recommendation	Done?	4 <sup>th</sup> Visit Recommendation	Done?
Basic examinations : pulse rate, blood pressure, respiration rate, temperature, pallor, etc.	Yes	Address complaints and concerns	Yes	Attention to signs of multiple pregnancy	Yes	Abdominal Examination	Yes
Determine gestational age	Yes	Check for pre-eclampsia	No	Review birth preparedness and readiness plan	No plans available	Individualized birth plan	No
Provide nutritional advice and routine iron and folate supplementation	No advice, Yes supplementation	Review and modify individualized care plan	No	Test for protein in the urine	No	Advice on signs of normal labor and pregnancy related emergencies	Sometimes
Provide HIV counseling	No	Give Advice on social or financial support	Sometimes	Decide on the need for referral	Yes		
Advice on malaria prevention	No			Advice on Family Planning	Sometimes		
Check Urine for sugar	No			Breastfeeding Advice	Sometimes		
Advise to save money	Sometimes						
Provide specific answers to woman questions	Sometimes						

Table 16: Work Routines according to WHO guidelines

- Community visits are done every two weeks, these community visits are conditioned to the amount of patients in the facilities. They are done before 8 AM and the aim is to provide education and information about health services offer. When available, pregnancy tests and other basic tests are done.
- Child Welfare clinics are also done in the communities every two weeks, they give vaccinations and check health status of children under five years old.
- **Wrong Medicine Practices**
  - Lack of privacy in examinations.
  - No follow up in examinations when a complication is seen
  - Patients that come with emergencies at night are not treated until the morning
  - No complete physical examination is done to the patients in any of the ANC visits.
  - No information about prevention is given to patients.

- When they see a small complication they immediately refer, no preventive treatment or examination is done to patients.
- Do not follow protocol guidelines. For instance, when fundal height has not change in a month, it means that the baby could not be growing and needs a scan. However, no further examination is done. Some midwives just fake the result.
- Patients has to pay for ultrasounds
- Lack of knowledge to treat some complications.
- Wrong blood pressure measurements
- Wrong practices during delivery:
  - Wash the baby just after childbirth
  - Do not check fetal heartbeat
  - Lack of communication between midwife and patient
  - No appropriate treatment to prevent bleeding

According to these characteristics the next challenges are identified:

- Low Mobile Phone Penetration in Rural Areas
- Power Conditions
- Rotation of Staff
- Need of training and technical support
- Change incorrect medicine practices
- No Data available about typical pregnancy complications in rural areas

#### 5.4.4 Connectivity

Using OpenSignal application, the network coverage at each facility has been measured, three speed test were performed at each facility and the result is the average of the three of them. Two networks operators have been tested (Vodafone and MTN) using a Samsung Galaxy S5. The network in Kpando has been measured in different locations, the network in Sovie has not been measured since they do not provide ANC services. We have tested the 6 facilities that works with the most rural areas in the municipality. The reasons for selecting these facilities are:

- Torkor Health Center: Is a strategic point for women living in the islands to stop looking for healthcare. The provide community outreach programs to the communities in Torkor but not to the islands.
- Fesi/Bame CHP Compound: Is a 15 min tax ride from Kpando which is relatively close to the big facilities. However, in their community outreach programs they work with communities that is impossible to access by car, only by motorbike or walking. For a pregnant woman to reach this facility will take her between 1 and 2 hours by foot.
- Agbenoxoe Maternity Clinic: Is the only rural facility that has a midwife 24 hours, they provide community outreach programs every morning through community health nurses to very deprived communities. It is a key point because women from Dafor and other communities that are very hard to reach can deliver and have Antenatal and Postnatal care on this facility.
- Dafor CHP Compound: Is one of the most deprived communities in Kpando municipality, they do community outreach programs and for women living in those communities is hard and expensive to reach the Hospitals, that is why the Agbenoxoe Maternity Clinic was build.

Table 17 show the results for the facilities outside Kpando:

Name of Facility	MTN		Vodafone		Time Without Connection	Web Quality		Video Quality	
	Down	Up	Down	Up		MTN	Vodafone	MTN	Vodafone
Torkor Health Center	3G: 1208 Kbps	3G: 397 Kbps	2G: 521 Kbps	2G: 408 Kbps	0%	Very Good	Good	Good	Poor
Gbefi	n/a	n/a	2G: 289 kbps	2G: 421 kbps	30%	n/a	Good	n/a	Very Poor
Dafor CHP Compound	2G: 68 kbps	2G: 320 kbps	2G: 179.69 kbps	2G: 468.75 kbps	28.90%	Very Poor	Good	n/a	Very Poor
Kudzra Health Center	3G: 1128 kbps	3G: 412 kbps	2G: 514 kbps	2G: 235 kbps	n/a	Very Good	Good	Good	Poor
Agbenoxo Health Center	No Network in the facility, the nurses find spots with network to receive calls but no data available on the facility, it is possible to find places with data network close by to the facility with Vodafone, with a rate of 152 kbps Download and 75 Kbps Upload.								
Fesi /Bame	n/a	n/a	2G: 1280 kbps	2G: 447 kbps	0%	n/a	Very Good	n/a	Good

Table 17: Health Centers and CHP Compounds outside Kpando Network Coverage

The Network Coverage in Kpando has been measured at different points during three days with OpenSignal, the time spent on each network type has been measured

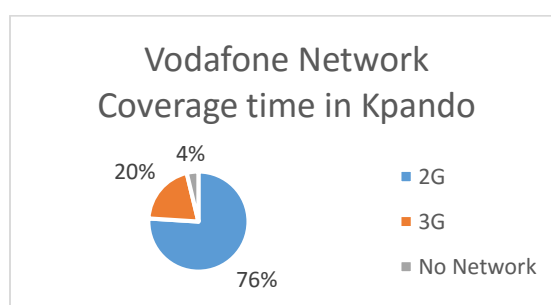


Figure 15: Vodafone Network Coverage in Kpando



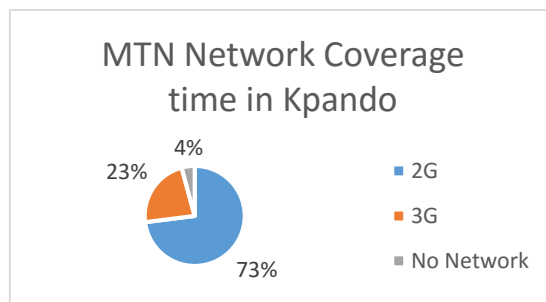


Figure 16: MTN Network Coverage in Kpando

In order to quantitatively analyze the network 4 Test Speeds have been taken for 3G and 2G for both networks and the results can be seen in the next table:

Vodafone					MTN				
2G		3G		Time Without Signal	2G		3G		Time Without Signal
Down	Up	Down	Up		Down	Up	Down	Up	
833 kbps	685 kbps	3209 kbps	2152 kbps	3.75%	703 kbps	152 kbps	1120 kbps	275 kbps	4.26 %

Table 18: Network Coverage in Kpando

With these numbers we can achieve the next Web and Video Quality:

Vodafone				MTN			
Web Quality		Video Quality		Web Quality		Video Quality	
2G	3G	2G	3G	2G	3G	2G	3G
Good	Very Good	Poor	Good	Good	Very Good	Poor	Good

Table 19: Resume of Network Quality by operator

To sum up, with this speed and network coverage allows browsing. Hence, a cloud service could be implemented to download and upload patient information and offer other services with reliability.

### Network Coverage in the Islands

During a one-day trip, 5 islands of the Lake Volta were covered, the network coverage was measured using the same guidelines as we used for measure the network at the facilities, once again, only Vodafone and MTN Operators were checked, since Tigo has no network coverage on the area. The results can be seen on Table 20.

It can be seen how the network coverage at the islands is fairly poor, and some operators does not have network. Islands that are closer to Torkor have a better network connectivity with Vodafone, but those far away from the mainland have better connectivity with MTN since the signal comes from the other side of the island.

Name of Island	MTN		Vodafone		Time Without Connection	Web Quality		Video Quality	
	Down	Up	Down	Up		MTN	Vodafone	MTN	Vodafone
<b>Kporve</b>	2G: 898 Kbps	2G: 148 Kbps	2G: 75.54Kbps	2G: 15.21Kbps	7.5%	Very Good	Very Poor	Good	n/a
<b>Biobio</b>	992 Kbps	210 Kbps	2G: 109 kbps	2G: 414 kbps	n/a	Very Good	Poor	Good	Very Poor
<b>Adzbo</b>	n/a	n/a	2G: 171 kbps	2G: 500 kbps	n/a	n/a	Good	n/a	Very Poor
<b>Dzidorkpo</b>	n/a	n/a	2G: 640 kbps	2G: 429 kbps	n/a	n/a	Good	n/a	Very Poor
<b>Gabikpo</b>	n/a	n/a	2G: 226 kbps	2G: 375 kbps	n/a	n/a	Good	n/a	Very Poor

Table 20: Network Coverage in the Islands

As a summary of all the measures, we can see the whole map of the network at Kpando Municipality in Figure 17.

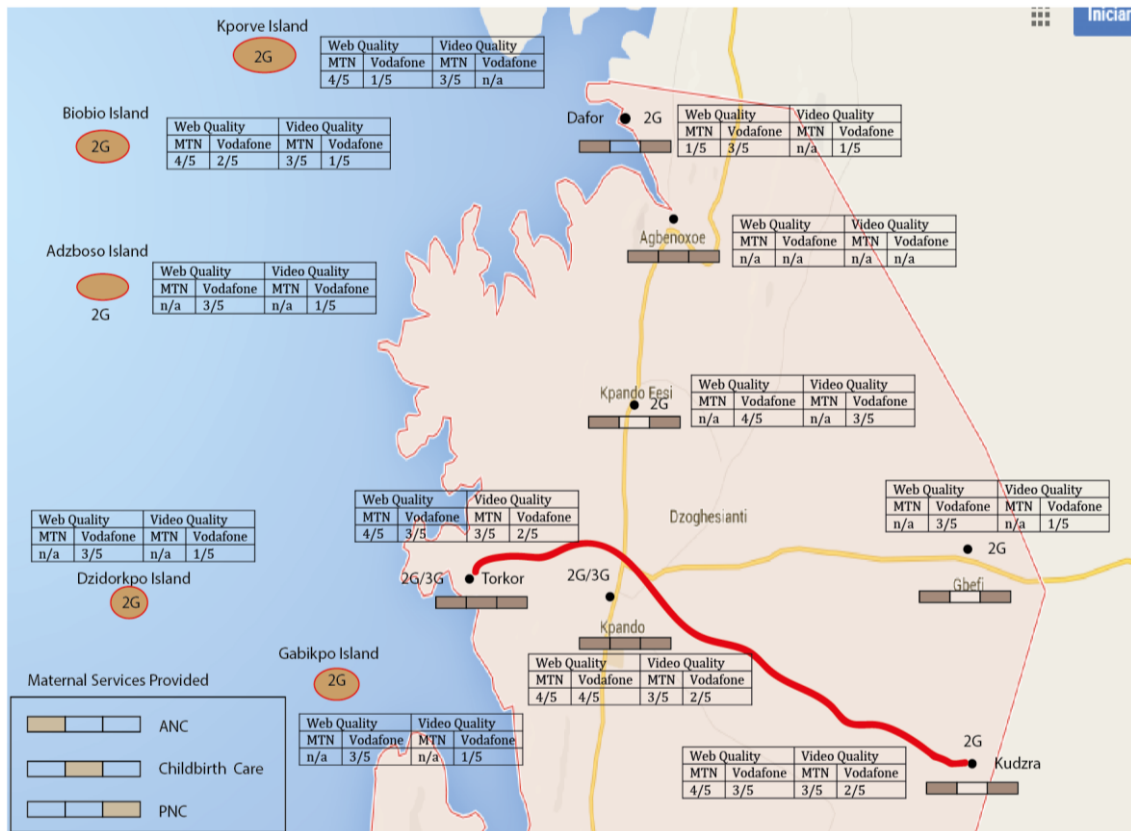


Figure 17: Network map in Kpando Municipality

### 5.4.5 Content

In order to design the content of the solution, the next considerations need to be taken into account, which are the typical characteristics of our study areas:

- Some health workers do not follow medical protocols
- Access to experts and current and reliable knowledge is limited.
- Paper forms are not filled correctly
- Poor referral system
- Patients hide sensitive information to health workers
- Patient information is not treated properly
- Symptoms of pregnancy related complications are not treated on time
- Strength Focus ANC

### 5.5 Solution Proposal

Based on all the previous results, a solution is proposed in Figure 18. This solution is a first draft and aim to be implement in Kpando Municipality. In the next sections, all the details of the design and the decision making process will be explained. The solution is planned to have the biggest impact according to the context in these areas.

The solution proposed is a mHealth solution to be used in Android mobile phones or tablets by front line health workers (CHNs in CHPS zones). The solution is Cloud based and uses the available mobile communications network in the facilities. It is focused on providing a pregnancy monitoring system, bridging the distance between facilities and communities.

The solution is included in work routines, to be used in facilities and community visits. We aim to equip CHNs with a mobile phone or tablet and equipment needed to monitor pregnancies. Decision support systems and data gathering services are included. That will help develop birth plans based on real evidences to increase skilled birth attendance.

The application will allow information sharing among facilities, track patients and improve collaboration among professionals. Health Administrators will be provided with data summaries, indirectly improving emergency systems. System should work offline and asynchronously will send the information to the server whenever connection is available. Cloud services are accessible in Ghana and allow remote maintenance of the network.

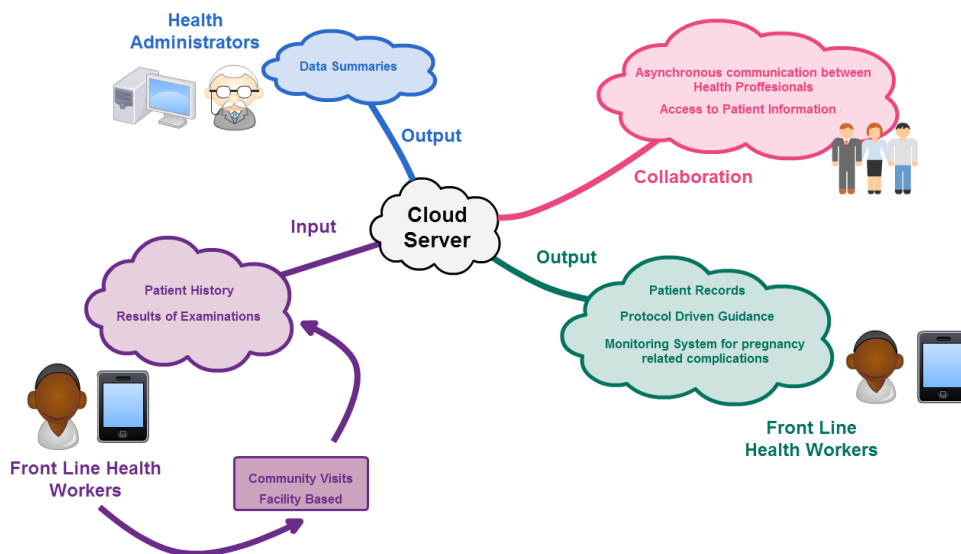


Figure 18: Solution Proposal

## 6 Results Part 2: Design, Development and Testing of the Prototype

### 6.1 Define features of the prototype according to user opinion

With the solution proposal presented in the previous section, a focus group discussion took place to prioritize and define the features requirements of the prototype. The aim of this discussion was to analyze which features add the biggest value to the application. These features, will be developed and tested first. On the other hand, it will also identify the features that add less value to the application and will be less used. In order to do that, a meeting at Ve Golokoati Assembly with representatives of all the facilities of South Adfajato municipality took place.

One booklet with specifications and drawing of the different features was handed in to all the participants, each feature was explained with drawings and using local references to explain complex features in a simple manner. In addition, a schedule for the simulations was introduced in the booklets. Contact Information was available, and the participants were encouraged to contact us at any time to clarify any doubt they had or suggest new ideas for the application.

The features presented and the visual help used to explain them were the next ones:

#### **FEATURE 1: COLLECT PATIENT HISTORY**

✓	PREVIOUS COMPLICATIONS
✗	STIs
✓	PATIENT INFORMATION

Questionnaire / Checklist for ANC Screening

#### **FEATURE 2: INCLUDE RESULTS OF EXAMINATIONS**



Use of Portable Equipment

To be used in Community Visits or Facility Based

#### **FEATURE 3: EDUCATIONAL SERVICES**



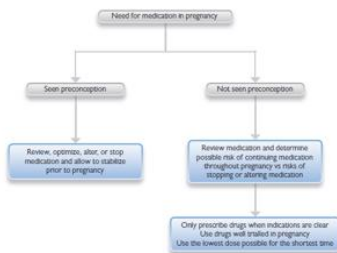
Show educational images or videos about pregnancy related issues

#### **FEATURE 4: MEDICAL RECORDS**



Patient History  
 Information about previous pregnancies  
 Information about previous examinations  
 Lab Results

**FEATURE 5: PROTOCOL DRIVEN GUIDANCE**



Guidance of what to do in every situation

**FEATURE 6: PREGNANCY MONITORING SYSTEM**



See status of pregnancies in your catchment area

Identify women at risk

Track patients that do not attend ANC

**FEATURE 7: COLLABORATION WITH OTHER PROFESSIONALS**



Get Help from other professionals

Doctors and Midwives remotely can access patient records to review them

**FEATURE 8: DATA SUMMARIES FOR HEALTH MANAGERS**



Provide Data summaries to health managers in an electronic form

When the features were explained, a lot of questions arise regarding them, especially how they were going to change their working routines. Hence, we prioritized answering this questions

before going on with the activities. However, the activity to prioritize each feature could not be done due to lack of time. Therefore, this activity was done on each facility individually. The activity consists that each health worker sorts the features out in order of importance, the criteria they have to follow is to give the highest priority to those features that they think will be more useful on their daily routines and which ones will have the highest impact on patients' health. The results can be seen sorted in Figure 19:

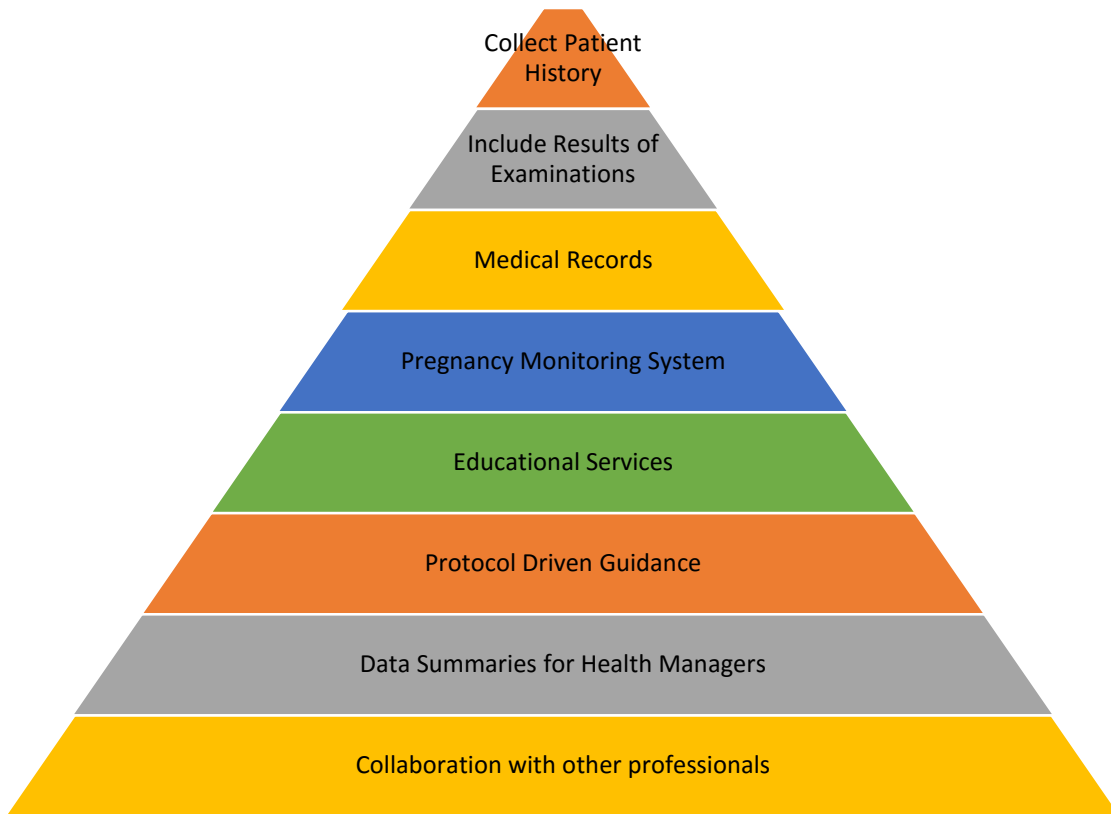


Figure 19: Importance of app features according to users

With that information, the last two features were rejected for the prototype and can be included in later stages. The classification of the features was almost unanimous, only two users classified them as not the less important. Therefore, the focus has been on design, develop and test the first six features on the app in three simulation sessions. The medical records feature has not been included completely due to complexity. However, patient information of previous examinations can be seen in the application.

## 6.2 Prototype Architecture

In Android, and Activity is an application component, it provides a user interface where users can do operations on it. The prototype architecture is divided in different activities that offer different functionalities as can be seen in Figure 20.:

- Login Activity: This activity is the first screen of the application. Currently, the user logs in with administrative privileges.
- Main Menu Activity: In the main menu, the user can decide the actions to do next. Go to the Patient Directory, access to guidance for what to do on different situations or access to education services for pregnant woman.

- The Patient Directory Menu offer the possibility of adding new patients to the database, collect patient History, capture patient vitals (where the decision support system is included), view patient records, the pregnancy monitoring system and do examinations (capture patient vitals and danger signs).
- The activity “What to do when”, offers protocol driven guidance for different pregnancy related complications.
- The activity “Education Services”, offers education services about danger signs during pregnancy and nutrition. This activity can access to the protocol driven guidance.

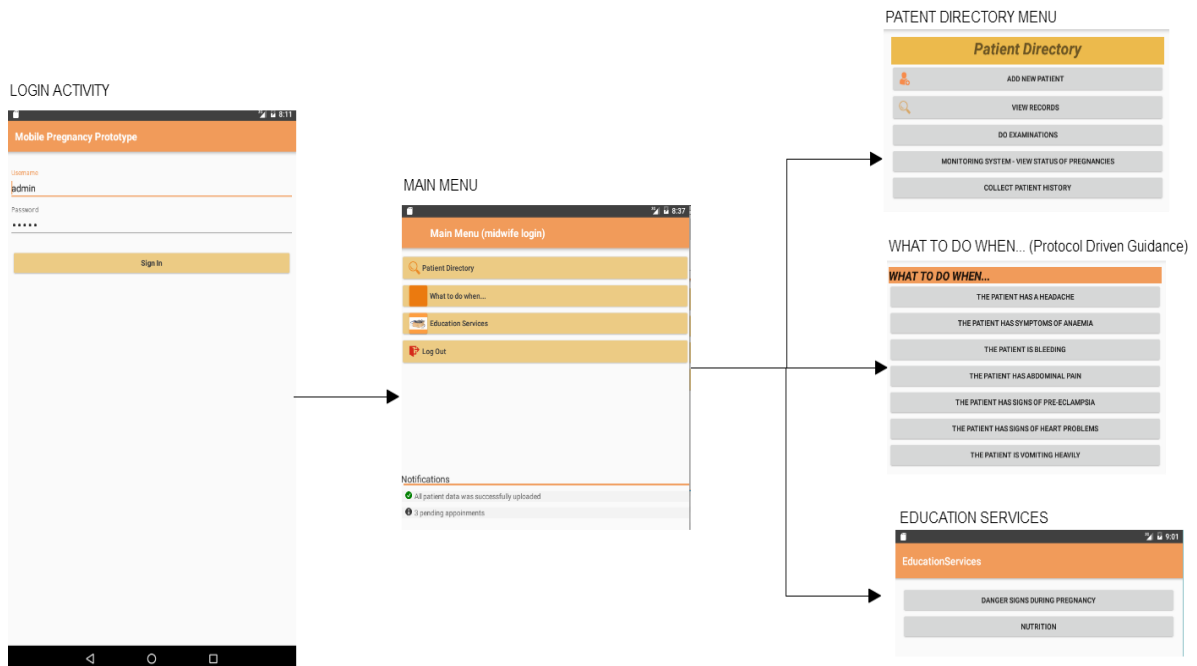


Figure 20: Main Activities Diagram

The prototype follows this architecture in order to have simple functionalities that are adapted to the local work routines. The prototype will not introduce any change in the work routines, currently the prototype is only designed for the 1st ANC visits and do examinations on patients on home visits. The routine remains the same as established by Ghana Health Service as can be seen in the next Figure:

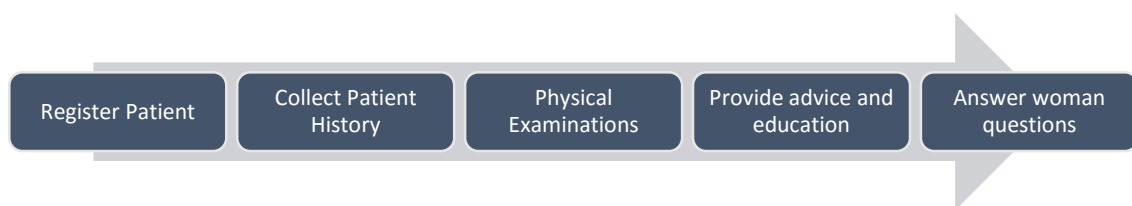


Figure 21: 1st ANC Work Routine

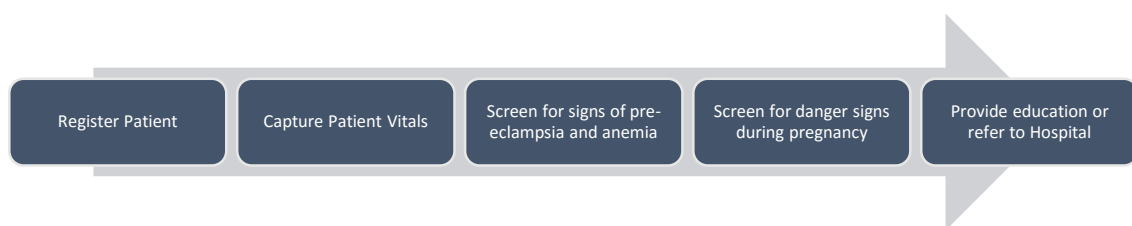


Figure 22: Home Visits Routine

In the next sections, each activity is explained in detail. The activities have changed after each simulation; all the process is explained in the next sections.

### 6.3 Collect Patient History

When a patient attends for the first time to an ANC appointment, the first thing done is to collect her previous history. Currently, this information is collected in the maternal health records. One of the considerations taken into account is to create an application adapted to local work routines. Hence, the first version of the feature consisted on an electronic form of the maternal health records used to collect patient history. It includes one Interface where health workers can scroll through different sections, always following the same format as in the maternal health books:

- General Information Interface:** In this section, information about the facility, the date of the visit and the name of the Midwife or Community Health Nurse that attends the patient is registered. Each patient should be attended by the same health worker during all the pregnancy.

Figure 23: General Information Interface

- Personal History Interface:** In this Section, the patient information is collected, all the personal data is gathered, such as name, age, address, educational status, street name or landmark, location, telephone number, occupation and marital Status. The same information about the father is also gathered.

Figure 24: Personal History Interface





**Major Risk Factors**

Grand multiparity

Previous C/S

Previous PPH

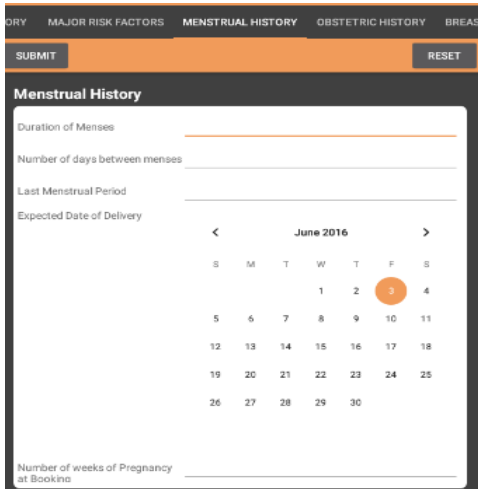
Myomectomy

Sickle Cell Disease

Other (Specify) \_\_\_\_\_

Figure 25: Major Risk Factors Interface

- Major Risk Factors Interface:** In this section, with a checklist, users can gather information about the risk factors of the patient. The risk factors are: Grand multiparity, Previous C/S, Previous Post-Partum Hemorrhage (PPH), Myomectomy and Sickle Cell Disease. However, if the patient has other major risk factors they can be included in the field *Other*.



**Menstrual History**

Duration of Menses \_\_\_\_\_

Number of days between menses \_\_\_\_\_

Last Menstrual Period \_\_\_\_\_

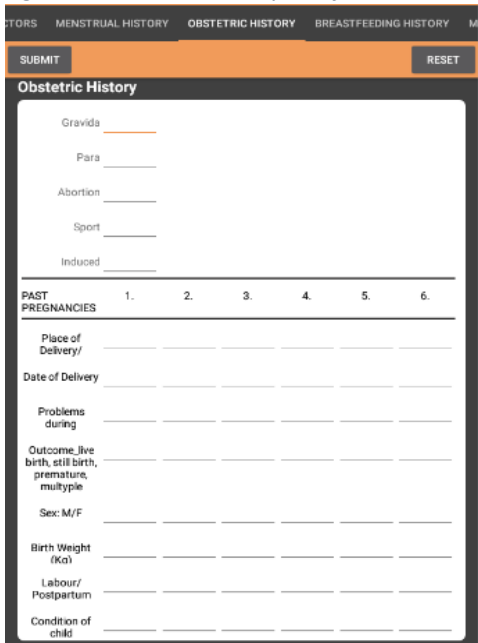
Expected Date of Delivery

June 2016						
S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

Number of weeks of Pregnancy at Booking \_\_\_\_\_

Figure 26: Menstrual History Interface

- Menstrual History Interface:** In this section, the menstrual history of the patient is gathered. The Expected Date of Delivery needs to be calculated by the health worker, and the number of weeks of pregnancy at the first visit.



**Obstetric History**

Gravida \_\_\_\_\_

Para \_\_\_\_\_

Abortion \_\_\_\_\_

Spont \_\_\_\_\_

Induced \_\_\_\_\_

PAST PREGNANCIES	1.	2.	3.	4.	5.	6.
Place of Delivery/	_____	_____	_____	_____	_____	_____
Date of Delivery	_____	_____	_____	_____	_____	_____
Problems during	_____	_____	_____	_____	_____	_____
Outcome live birth, still birth, premature, multiple	_____	_____	_____	_____	_____	_____
Sex: M/F	_____	_____	_____	_____	_____	_____
Birth Weight (Kg)	_____	_____	_____	_____	_____	_____
Labour/ Postpartum	_____	_____	_____	_____	_____	_____
Condition of child	_____	_____	_____	_____	_____	_____

Figure 27: Obstetric History Interface

- Obstetric History Interface:** Another important factor, is to gather previous obstetric history. This interface, allows the user to record the history of up to six previous pregnancies, and record any previous complication that the woman had.

- Breastfeeding History Interface:** In this section, the user collects the breastfeeding history of the patient. If the patient breastfed the last child, the duration is collected.

Figure 28: Breastfeeding History

- Medical and Surgical History Interface:** In this interface, the user goes through a checklist to collect a complete medical and surgical history of the patient. Besides the checklist, the user can also enter, other history facts and previous operations that the patient had.

Figure 29: Medical and Surgical History Interface

- Family, Drug and Contraceptive History Interface:** In this interface, family history about previous disease that are genetically transmitted are collected. Then, if the patient has any drug abuse is also collected. Finally, previous contraceptives taken are also recorded.

Figure 30: Family, Drug and Contraceptive History Interface

- **History of Sexually Transmitted Infections Interface:** The last interface to collect patient history, is to record if the patient had any history of STIs.

Figure 31: History of Sexually Transmitted Infections Interface

### 6.3.1 Usability Test

The feature was simulated in 5 health care facilities, health workers filled the information asking to pregnant women when they were available, and when not, they used a colleague to collect their information simulating a pregnant woman. The simulation lead to different conclusions, we were able to identify what kind of difficulties health workers have when introducing the information into the application, detect trouble shooting, design failures, gather feedback about future features and observe how the app fits the work ecosystem.

#### 6.3.1.1 User Interfaces and tablet

Among the different user’s profiles that tested the application, most of them were able to introduce the information correctly without big issues. The user profile was Community Health Nurses between 25-40 years old. The problems observed are:

- **Problems introducing information:** One user, had problems finding the spacebar in the tablet. The keyboard type used was simple for most of the users. However, one user in particular had problems finding it. After a few tries, the user identified the spacebar and worked with it without problems.
- **Menstrual History Interface:**
  - Two users did not know how to calculate the duration of menses and had to ask to their colleagues.
  - Calculation of the expected date of delivery is only possible if the patient is able to give the last day when she saw the menses.
- **General Information Interface:** Most of the user did not find useful the first Interface “General Information” where information about the facility and name of midwife is collected.
  - **Solution:** Most of them suggested that this information should be automatically detected by the application itself when they user logs in.
- **Personal History Interface:** The fields Address and House Number, are most of the times unknown, patients do not know their house number or even the street. However, users where explained that the field *Landmark*, can also be used for that.
  - **Solution:** Address will be easily filled by CHNs at community visits, and when patients come to the facilities, the will write in this field the family house (e.g. Address: Gyan Family House), which is the common way to know where somebody lives in the communities.

- **Medical and Surgical History Interface:** Nurses stated that HIV status of the patient must be confidential. Not all of them are allowed to know this information about the patient. Therefore, this information should only be available to nurses that has been trained to treat patients with HIV.
  - *Solution:* Different user credentials to introduce or to view HIV status of the patients. This feature should be added to the final solution; the prototype does not implement it right now.
- **Bugs Detected:**
  - **Bug 1 – Session Expired:** When the user is having a long conversation with the patient, the tablet goes to sleep. When that happens, the application logged out and information was lost. Some users needed a few trials to unlock the tablet.
    - *Solution:* The tablet was reset for not sleeping and log out while the session is open. The bug was fixed.
  - **Bug 2 – Fatal error when orientation of the tablet changes:** This activity was first designed using a Viewpager, this allowed users to scroll between the different sections easily. However, since the interface was designed for a smaller screen, when the user changed the orientation of the screen the app stopped.
    - *Solution:* The interfaces were re-designed for a tablet of 7” and for both orientations, the same as where the prototype is tested. The bug was fixed.

### 6.3.1.2 Users Opinion and Suggestions

#### Observations about general usability

Users used the tablet properly, they usually placed the tablet on the table and use it as if it was a book where they record the information. The tablet size, seemed appropriate to be used within the facilities and in community visits. The main users that tried this feature were young nurses, however, two elderly users test it, the time it took them to type the information was longer than those younger users. These users said that the problem they had is typing in the information. However, they showed enthusiasm to keep trying it.

As conclusion, this features did not need major changes, the feature was re-design including a new activity to create a new patient directly to the database, and store the location and date of the visit automatically so users do not need to use the *General Information Interface*.

#### User satisfaction and feedback

All the user stated that the interfaces are simple to use, and they are already familiar with it since they are the same as the maternal health books. All of them show great satisfaction with the potential that the application could have. They did not suggest big changes. The changes needed are to adjust in the future user permissions to meet privacy policies regarding HIV status.

#### Suggestions

Most of the user suggestions were to include more information in the application that right now is not included. Users suggested new content for the future that has not been included in the prototype were:

- Include the forms when patient is receiving Malaria Treatment.
- Include section where results of physical examinations are introduced.
- Include a feature that allows health workers to see when patient have attended other facilities, in order to avoid scams with medications.

User's main concern was how the application will be used by users that are not good at typing, especially for elder health workers. One suggestion that was repeated several times, is to develop the application in a way that users that do not know how to type, can include the information with a pen and write it down in the tablet.

## 6.4 Educational Services and Protocol Driven Guidance

### 6.4.1 Protocol Driven Guidance

During the first part of the research, the need for strengthening protocols on how to treat patients under certain conditions was identified. Hence, the prototype includes an activity "What to do when" that gives protocol guidance to act under the next circumstances:

- When the patient has symptoms of Anemia
- When the patient is bleeding
- When the patient has abdominal pain
- When the patient has signs of pre-eclampsia
- When the patient is vomiting heavily

The protocol guidance can be accessed from the Main Menu, clicking on "What to do when", from the educational services, when danger signs are explained and from the decision support system that detects symptoms of Anemia and Eclampsia. The guidance for each of the symptoms are explained in the following sections.

#### 6.4.1.1 How to treat symptoms of Anemia

**What to do when the patient has symptoms of Anemia?**

1. Refer patient to Hospital to do Hemoglobin Test. And identify the cause of Anemia. If the test has been done check Hemoglobin levels results.
2. If its iron deficiency anemia, give the patient iron tablets. Alternatively, recommend the patient to eat food rich in iron. (See nutrition information)
3. If its vitamin B12 deficiency anemia, give to the patient Vitamin B12 supplements
4. If its Folate deficiency anemia, treat the patient give folic acid
5. Inform the patient about Anemia and possible risk for her health: A preterm or low-birth-weight baby, possible need of blood transfusion in case of bleeding during birth, Postpartum depression, A baby with anemia, A child with developmental delays and A baby with serious birth defect of the spine or brain

**Diet Information for Patient With Anemia**

	Iron Deficiency Anemia	Vitamin B12 Anemia	Folate Deficiency
<b>Foods Recommended</b>	- lean red meat, poultry, and fish - leafy dark green vegetables (spinach, broccoli and kale) - Iron enriched cereals and grains - Beans, lentils, and tofu - Eggs	Meat Eggs Dairy products	Leafy green vegetables Citrus fruits and juices Fortified breads and cereals Dried beans


When a patient show symptoms of Anemia, such as nausea or low hemoglobin levels, further actions is required. Health works can access to this information to see what to do. There are different protocols to follow depending on the kind of Anemia that the patient might have. The first action is to refer the patient to the hospital to identify the type of anemia she has. However, if the type of anemia is already identified, different supplements to treat the patient can be given. Then, information about the risk of anemia have to be given in any case, so the patients know what could happen. Finally, another source of Iron, Vitamin B12 and Folate to treat anemia can be found in local foods. A table with diet information with foods that can provide nutrients to the patient to treat each type of anemia is provided.

Figure 32: Protocol Driven Guidance for Anemia

### 6.4.1.2 How to treat Bleeding and Abdominal Pain

**How to treat a patient when she is bleeding**

**1. WATCH FOR SIGNS OF SHOCK**  
 Sign 1: Very fast heart rate, more than 110 beats per minute  
 Sign 2: Pale, cold, damp, skin  
 Sign 3: Pale inner eyelids, mouth and palms  
 Sign 4: Fast breathing, more than 30 breaths a minute  
 Sign 5: Confusion or unconsciousness (fainting)

 **Take Woman to the Hospital!!**

**2. WHAT TO DO IN THE WAY TO THE HOSPITAL**  
 1. Send 2 family members with her to the hospital to give blood in case of need  
 2. If she is in shock, treat her for shock. In case you know how, start an intravenous drip (IV) or give rectal fluids

**3. HOW TO TREAT A WOMAN IN SHOCK**  
 1. Treat the Bleeding  
 2. Lay the patient down with the head to one side so she does not choke in case of vomit  
 3. Raise her legs. Cover the patient with a blanket or clothes and keep her calm  
 4. If the patient can drink, give her water or rehydration drink. Start rectal fluids otherwise or an Intravenous drip (IV)  
**If the patient is unconscious, do not give her anything by mouth until she has been awake for an hour (not even medicines)**

Bleeding and Abdominal Pain during the second and third trimester of pregnancy are very dangerous signs. The woman needs to be referred immediately to the Hospital for further care. However, the study areas of the research, are communities far away from hospitals. Therefore, when a patient shows any of this symptoms, there is the need to provide information to health workers of how to treat the patient in the way to the Hospital or until the emergency systems arrive. The application recommends to watch for signs or shock, give guidance on what to do in the way to the hospital, and provide guidance of how to treat woman that are in shock.


The protocol is the same for bleeding and abdominal pain, since severe abdominal pain usually comes together with bleeding.

Figure 33: Protocol Driven Guidance for Anemia and Abdominal Pain

### 6.4.1.3 What to do when a patient has signs of pre-eclampsia

**What to do when a patient shows signs of pre-eclampsia?**

**Signs**  
 1. High Blood Pressure (140/90 or greater)  
 2. Protein in the urine

 **IF THE PATIENT HAS THESE 2 SIGNS, SHE HAS ALREADY PRE-ECLAMPSIA. TAKE THE WOMAN DIRECTLY TO THE HOSPITAL**

When a patient has high blood pressure, it has to be monitored once a week to see if the pressure goes higher

**Severe Pre-eclampsia**  
 1. 160/110 blood pressure  
 2. Strong headaches  
 3. Vision changes  
 4. Severy abdominal pain. In the top of the belly or the right side under the ribs  
 5. Seizures  
 6. Swellings

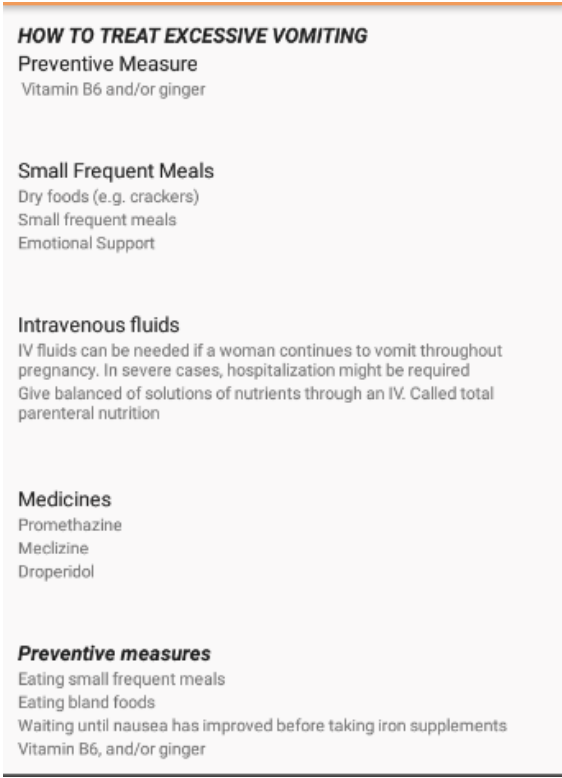
**WITH ANY OF THIS SIGNS AND HIGH BLOOD PRESSURE, TAKE HER TO THE HOSPITAL TO SAFE HER LIFE. GIVE MAGNESIUM SULFATE ON THE WAY, AND HAVE THE WOMAN LIE ON HER LEFT SIDE**

Eclampsia, is a very dangerous condition during pregnancy. When a patient shows signs of pre-eclampsia such us high blood pressure or protein in the urine, there two options depending on how high the levels are, that the patient has mild or sever eclampsia.

The symptoms for this conditions are presented in the screen. The patient must be taken to the hospital immediately to save her life and the baby. In case the patient does not have pre-eclampsia but just high blood pressure, it also states that the patient must be visited once a week to see if the pressure goes higher.

Figure 34: Protocol Driven Guidance Pre-eclampsia

## 6.4.1.4 How to treat excessive vomiting



**HOW TO TREAT EXCESSIVE VOMITING**

**Preventive Measure**  
Vitamin B6 and/or ginger

**Small Frequent Meals**  
Dry foods (e.g. crackers)  
Small frequent meals  
Emotional Support

**Intravenous fluids**  
IV fluids can be needed if a woman continues to vomit throughout pregnancy. In severe cases, hospitalization might be required  
Give balanced of solutions of nutrients through an IV. Called total parenteral nutrition

**Medicines**  
Promethazine  
Meclizine  
Droperidol

**Preventive measures**  
Eating small frequent meals  
Eating bland foods  
Waiting until nausea has improved before taking iron supplements  
Vitamin B6, and/or ginger

Morning nausea and vomiting can be normal during pregnancy. However, when the patient shows excessive vomiting, needs treatment. In this section, the health workers have recommendations of medicines and preventive measure of how to treat this condition.

In case the patient cannot hold any food, intravenous fluids are needed, or provide some medicines to stop vomiting.

Figure 35: Protocol Driven Guidance Excessive Vomiting

## 6.4.2 Education Services

During an ANC visit, a patient has to receive education about different topics, GHS hands out a book with health information to each patient so they can read and have more information about their pregnancies. This book includes information about nutrition, danger signs during pregnancy, birth preparedness, etc. However, this books often get lost, or patient do not know how to read properly. Therefore, health workers need to provide education about these topics on each ANC visit, although not always is done. Hence, an activity that provides education services have been included. This activity provides information to the health workers and they can explain it to the patients. In the prototype, only information about danger signs during pregnancy and nutrition have been included.

### 6.4.2.1 Danger Signs during Pregnancy

In this screen, the health worker can go through different slides explaining to the patient six different danger signs during pregnancy. This danger signs are right now drawn in the maternal health books. Including the same pictures in the prototype was a requirement given by health workers, the explicitly wanted the same pictures. In addition, information about this conditions are included. Due to some patients do not attend ANC until late stages in pregnancy, the education service is connected with the protocol guidance, in case the patient shows any of this danger signs during the visit, the treatment can start as soon as possible.



**Danger Sign 1: Headache**  
**WITH ANY OF THIS SIGNS ATTEND IMMEDIATELY TO THE HOSPITAL!**



Headaches are common during pregnancy, especially during the first trimester. If you are having headaches attend directly to the closest health facility

**1. Types of Headaches**

- Tension headaches: Squeezing pain on both sides of the head or the back of the neck
- Migraines: 1 out of 5 women have migraines during pregnancy. If migraines get worse during pregnancy that does not mean you have a higher risk of pregnancy complications

Figure 36: Danger Sign 1 - Headache

### Danger Sign 1: Headache

In this slide the health worker can explain to the patient the different types of headaches that she might have. Telling her that headaches can be normal during the first trimester, but when she has them she should attend to the hospital to identify the causes of the headache.

**Danger Sign 2: Anaemia**  
**WITH ANY OF THIS SIGNS ATTEND IMMEDIATELY TO THE HOSPITAL!**



**Types of Anaemia**

- Iron Deficiency Anaemia
- Folate-deficiency Anaemia
- Vitamin B12 deficiency

**Symptoms**

- Pale skin, lips, and nails
- Feeling tired or weak
- Dizziness
- Shortness of breath
- Rapid heartbeat
- Trouble concentrating

**Risk Factors**

- Multiple pregnancy
- Two pregnancies close together
- Vomit a lot because of morning sickness
- Pregnant teenager
- Don't eat enough foods that are rich in iron
- Had anaemia before she came pregnant

**HOW TO TREAT ANAEMIA**

Figure 37: Danger Sign 3 - Anemia

### Danger Sign 2: Anemia

Is important to give information to the patient about anemia. It is a very common condition among woman living in remote communities. With this slide, health workers can explain the types of anemia to women, the symptoms and the risk factors.

In case the patient has any of this symptoms, the health worker can click on the button *“How to treat Anaemia”* and she will access to the protocol guidance of how to treat cases of anemia.

**Danger Sign 3: Bleeding**  
**WITH ANY OF THIS SIGNS ATTEND IMMEDIATELY TO THE HOSPITAL!**



**Bleeding during the first trimester**

- Normal Bleeding: Light bleeding or spotting for a few days at the beginning of pregnancy with no cramps
- Dangerous Bleeding: When the bleeding is the same as in their period, that means miscarriage. This may not be dangerous, but watch for danger signs
- Danger signs: Fever, feeling faint, bad smell from the vagina

**Bleeding during the second half of pregnancy**

**- VERY DANGEROUS! The placenta could be in the wrong place or have detached from the womb. GET MEDICAL HELP IMMEDIATELY TO SAFE MOTHER AND BABY**

**HOW TO TREAT WOMAN IN THE WAY TO THE HOSPITAL**

Figure 38: Danger Sign 3 - Bleeding

### Danger Sign 3: Bleeding

Bleeding is a very important danger sign during pregnancy. The health worker can explain the patient what is normal bleeding during the first trimester, and how abnormal bleeding can mean miscarriage. The danger signs are also stated.

However, if the woman is bleeding during the second half of pregnancy it is very important to refer the woman fast to safe mother and baby. The health worker can click on the button *“How to treat woman in the way to the hospital”* to access the protocol driven guidance.



**Danger Sign 4: Abdominal Pain**  
**WITH ANY OF THIS SIGNS ATTEND IMMEDIATELY TO THE HOSPITAL!**



It may mean that the placenta has become separated from the wall of the womb  
 - Signs that the placenta is separated from the womb:  
 1. Starting contractions early  
 2. Back or abdominal pain that continues between contractions  
 3. Frequent contractions

**VERY DANGEROUS! GET MEDICAL HELP IMMEDIATELY TO SAVE MOTHER AND BABY! Watch for signs of shock and start IV if possible**


**HOW TO TREAT WOMAN IN THE WAY TO THE HOSPITAL**

### Danger Sign 4: Abdominal Pain

The fourth danger sign is abdominal pain, when the woman has it she has to attend immediately to the hospital. Clicking on the button “How to treat woman in the way to the hospital” the health worker can access to the protocol driven guidance for guidance.

Figure 39: Danger Sign 4 - Abdominal Pain

**Danger Sign 5: Swellings**  
**WITH ANY OF THIS SIGNS ATTEND IMMEDIATELY TO THE HOSPITAL!**



**Normal Signs**  
 - Puffy ankles are fet  
 - Edema in the hands, feet and ankles are common during warm weather

**Danger Signs**  
 - More swelling in one leg than the other  
 - Pain  
 - Persistent headache, along with vision changes could be signs of pre-eclampsia  
 - Chest paing or difficulty breathing could mean heart trouble

**VERY DANGEROUS!**

**HOW TO TREAT SIGNS OF PRE-ECLAMPSIA**


**HOW TO TREAT SIGNS OF HEART PROBLEMS**

### Danger Sign 5: Swellings

Even though swellings can be normal during pregnancy, it is very important to inform the patient about the danger signs that can mean that the patient has pre-eclampsia or heart problems. Clicking the button “How to treat signs of pre-eclampsia” the health worker can access to the protocol guidance on how to treat eclampsia. The protocol guidance on how to treat heart problems have not been included yet.

Figure 40: Danger Sign 5 - Swellings

**Danger Sign 6: Excessive Vomiting**  
**WITH ANY OF THIS SIGNS ATTEND IMMEDIATELY TO THE HOSPITAL!**



**Symptoms**  
 - Prolonged and sever vomiting  
 - Unable to eat and drink without vomiting  
 - Lost more than 5% of your pre-pregnancy weight  
 - Been dehydrated  
 - If the woman have fever and pain can be: gastric upset, urinary tract infection, thyroid disease or pre-existing diabetes

**Excessive Vomiting**

**If it is treated, it's very unlikely that it will harm the baby. Without treatment, there is a risk that the baby my be smaller than average**

**HOW TO TREAT EXCESSIVE VOMITING**

### Danger Sign 6: Excessive Vomiting

The last danger sign presented is Excessive Vomiting. The symptoms can be presented to the patient, and the protocol guidance can be accessed clicking on the button.

Figure 41: Danger Sign 6- Excessive Vomitting

## 6.4.2.2 Nutritional Advice



**Stay Healthy During Pregnancy - Nutrition**

You need to eat more during pregnancy, the unborn baby also needs the good food from your body to grow well. A pregnant woman requires more nutrients, especially in the second half of pregnancy.

There are three groups of food that you should combine every day to get the nutrients you need:

**Group 1: Proteins**

Protein from animal sources like meat, fish and eggs is very good.

Protein from plant sources such as beans and nuts

Recommended foods: Waakye, groundnut soup with omu tuo or whole grain porridge with koose



**Group 2: Fruits and Vegetables**



Dark green leafy vegetables, fresh fruits and iron rich foods help prevent anaemia

**Group 3: Foods rich in fiber**

Food rich in fiber prevent constipation. Such as brown rice, vegetables and fruits



Remember to drink 6-8 glasses of water or fruit drinks everyday

If the woman cannot afford to eat properly, ask for help to the neighbors and family

Appropriate information about nutrition is very important during pregnancy for woman to stay healthy. In our research area, is common to see patients with malnutrition, even though foods are abundant and accessible. Therefore, access to information about nutrition, and examples of local foods and fruits that can be taken are given in this section. In this section, the health worker is also advice than if the woman cannot afford to eat properly, the health worker should talk with neighbors and family so they can help her.

Figure 42: Education about Nutrition

## 6.4.3 Usability Test

In order to test this features, health workers were asked to review them, see if there were any information that was not true, or some protocols that should be changed. A total of 18 health workers reviewed the content of the education services and the protocol guidance, they provided the following feedback:

- No issues about the content of the application were found, health workers found it appropriate, adapted to local situation and useful for them and pregnant woman. They recommended to include more content like that for different situations, such as birth preparedness or complications during child birth.
- Some technical issues were found in the first trial with the color of the fonts and the background. After the first trial, the font size was increased and the background colors changed so the information can be visualized properly.
- All health workers accepted the feature the feature and show satisfaction with it.

## 6.5 Pregnancy Monitoring System

During the background research, it has not been possible to identify all the pregnancy related complications that are common in rural areas. However, the symptoms patients from these communities usually have during pregnancy and childbirth have been identified. These complications are not identified due to the fact that women are checked only for anemia. Even though they show symptoms of other complications such as high blood pressure, which could be a symptom of eclampsia only medication is provided and no more screenings are done. The audit of maternal deaths is also a problem; no information is available of the cause of complications that lead to death. Hence, for our research we need to assume that pregnancy related complications that are most common and have a high mortality and morbidity are the same as in a study presented in the Ghana Medical Journal that analyzed the causes of death among pregnant women in Korle.Bu Teaching Hospital [8].

One of the main problems encountered is that pregnancies are not monitored properly; most women do not attend enough ANC visits to be able to have a clear medical view of their pregnancy conditions. Due to the paper form records there is no previous pregnancy complications history, no appropriate screening of pregnant women that shows symptoms of complications, women get lost in the system. Therefore, when they go to deliver, they have complications, if these complications arise in a Hospital or a health care facility they can be treated, however, if these complications arise during childbirth with a TBA or at home they can be deadly due to the amount of time that takes to get to a healthcare facility. Almost 80% of maternal deaths occurs within the communities.

It is important to monitor pregnancy properly, especially those consider 'High Risk'. High Risk pregnancy is one in which some conditions put the mother and the fetus at higher risk of developing pregnancy related complications during or after the pregnancy and birth. The reasons to consider a high risk pregnancy are presented in Table 21.

The parameters to monitor that are relevant to the medical conditions in the area have been identified combining the results of our study with a retrospective study that analyzed the causes of maternal deaths in Ghana [8].

Based on a previous study that identified the most common causes of maternal deaths in Ghana (Table 22). The symptoms and risk factors that can lead to these causes have been analyzed. Some of these cases are obstetric emergencies that appear during labor and some cannot be predicted or prevented beforehand. Therefore, we will focus on the ones that with an appropriate antenatal screening can be identified earlier or identify women that are more likely to develop these complications based on their risk factors.

In the Use Cases, the typical symptoms of complications that pregnant women have in our study areas have been identified. Analyzing the symptoms of each mortality cause in Table 22, we can relate the danger signs with the possible cause of death. The results are shown in Table 23:

Some of the causes of deaths showed in Table 22 cannot be predicted (e.g. Hemorrhage). Many women do not have any risk factor and end up suffering of PPH. Abortions and Complications, Hypertensive disorders complications, Ectopic gestation and Anemia in pregnancy, could be prevented with adequate ANC screening. In Table 23, we can see how most of the symptoms showed can be related to pre-eclampsia and anemia. Hence, the focus of our monitoring system is to analyze those indicators that could lead us to identify pregnancy related complications on time and women that need a special care or have conditions that have not been treated.

<b>Maternal Factors</b>
Age: younger than 15 or older than 35
Weight: Less than 50 kg or Body Mass Index higher than 40
Height: Under 1.52 m
Previous History of Complications: Stillbirth, preterm labor, fetal loss, small-for-gestational age baby, large baby, pre-eclampsia, eclampsia.
More than 5 previous pregnancies
Bleeding during the third semester
Reproductive tract abnormalities
Uterine fibroids
Hypertension
Rh incompatibility
Gestational Diabetes
Sexual Transmitted Infections
Kidney infection
Fever
Acute surgical emergency: appendicitis, gallbladder disease, bowel obstruction
Post-term pregnancy
Pre-existing chronic illness: asthma, autoimmune disease, cancer, sickle cell anemia, tuberculosis, herpes, AIDS, heart disease, kidney disease, Crohn's disease, ulcerative colitis and diabetes.
<b>Fetal Factors</b>
Exposure to infection: herpes, viral hepatitis, mumps, rubella, varicella, syphilis, toxoplasmosis, and infections caused by coxsackievirus.
Exposure to damaging medications: phenytoin, folic acid antagonist, lithium streptomycin, tetracycline, thalidome, and warfarin
Exposure or abuse of addictive substances: cigarettes, alcohol and drugs.
<b>Other factors</b>
Serious health problems in mother or fetus identified during ANC examinations

Table 21: Factors to consider a High Risk Pregnancy

<b>Direct Obstetric Causes (79.5%)</b>	<b>Indirect Obstetric Causes (20.5 %)</b>
21.8 % Hemorrhage	9.2% Infections outside the genital tract
20.7% Abortion and Complications	2.8% Anemia in pregnancy
19.4% Hypertensive disorders complications	8.5% Other causes
8.7% Ectopic gestation	
4.3% Uterine Rupture	
4.6% Other causes	

Table 22: Causes of Maternal Deaths in Ghana

	Typical Symptoms	Comment
During Pregnancy	Abdominal Pain	Typical symptom of preeclampsia
	Nausea and Vomiting	Typical symptom of anemia
	Low Hemoglobin Levels	Anemia
	High Blood Pressure	Preeclampsia
During Labor	Bleeding	Post-Partum Hemorrhage that could be caused for Anemia, preeclampsia or Gestational Diabetes. Even though it could also happen without any of this conditions
	Placenta Complications	It caused a maternal death, the woman did not attend ANC and delivered at home. A possible cause is placental abruption. Which can be caused by preeclampsia.
	Kidney Failure	Kidney failure after a heavy hemorrhage can be a caused of untreated preeclampsia.
	Need of Caesarian delivery	

Table 23: Summary of Typical Danger Signs during pregnancy and labor

In Table 24, symptoms, risk factors, potential complications and the parameter to monitor are presented for both Anemia and (Pre) Eclampsia. Monitoring these parameters and with the design of a decision support system we will be able to identify high risk pregnancies, and early detection of symptoms that could be signs of Hypertensive disorders, (Pre)Eclampsia and Anemia.

How the pregnancy monitoring system works can be seen in **¡Error! No se encuentra el origen de la referencia..** The User register the patient and this information is stored in the local database. If the user is already registered this stage is not necessary. Then, the list of patients is displayed and the user can choose the patient to do examinations at. The user, introduces the values of the parameters to monitor and the danger signs, this information is analyzed by a decision support system that will detect possible symptoms of eclampsia and anemia, it will store the information in the data base, classifying the patients in high risk, medium risk and low risk pregnancies. The system will pop out alerts, at this stage the user can go directly to the Protocol Driven Guidance to receive information on what to do. Finally, the user can visualize this information at the monitoring system, where the pregnancies can be seen according to their classification.

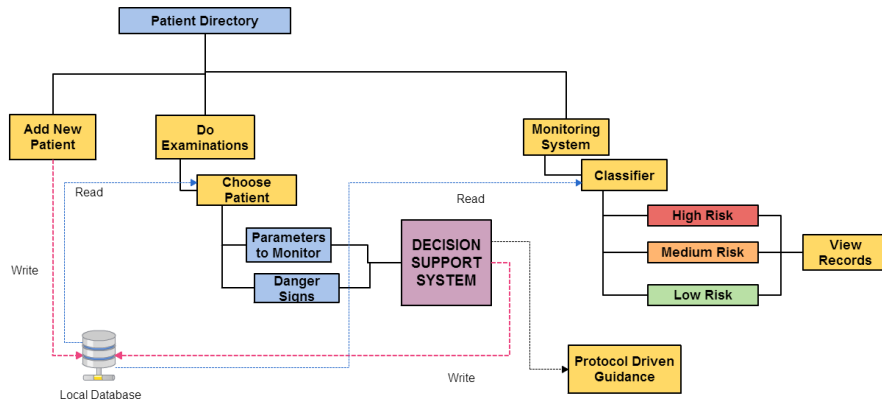


Figure 43: Pregnancy Monitoring System Diagram

<i>Pregnancy Related Complication</i>	<i>Symptoms</i>		<i>Risk factors</i>	<i>Potential Complications</i>	<i>Parameters to monitor</i>
	<u>Mild</u>	<u>Severe</u>			
<i>Hypertensive disorder and (Pre)Eclampsia</i>			First pregnancy with new husband	Infant and mother death	Blood Pressure
	BP > 140/90 mmHg	BP ≥160/110 mmHg	Prim gravidae	Preterm delivery	Proteinuria
	Proteinuria > 1+	Proteinuria >3-4+ on dipstick	Age > 35 years' old	Low weight baby	Weight
		Severe fetal growth restrictions	Multiple pregnancy	Gestational Diabetes	Pulse
		Evidences of HELPP Syndrome: Headache, vision changes, rapid weight gain, nausea or vomiting, racing pulse and stomach pain	Chronic hypertension	Kidney mal function	Fetal Growth
		Signs of respiratory problems		Anemia	
				Increased risk of hemorrhage	
				Abruptio Placentae	
<i>Anemia</i>	Weakness or dizziness		Teenagers	Preterm birth	Hemoglobin levels
	Difficulty concentrating		Multiple pregnancy	Low birth Weight	Iron levels
	Irregular/rapid heartbeat		Women with heavy menstrual flow	Post-Partum Depression	
	Shortness of breath		Closely spaced pregnancies	Need of Blood Transfusion	
	Low Hemoglobin levels		Experienced severe vomiting	Neural tube defects	

		Lack of dietary iron		
--	--	----------------------	--	--

Table 24: Anemia and (Pre) Eclampsia: Symptoms, Risk factors, Potential Complications and Parameters to Monitor

### 6.5.1 Do examinations

According to previous requirements, the prototype introduces a functionality to register patients in the database, introduces results of examinations that the decision support system will analyze to detect symptoms of anemia and pre-eclampsia. This functionality, is thought to equip health workers with portable equipment, which will allow them to do these examinations in home visits and in the facility. Hence, patients with low income level or in remote communities can be monitored and receive some treatment if needed.

The process to access this functionality in the prototype is as follows:

1. **Patient Directory -> Add a new Patient.** If the patient has not been registered before, the patient has to be registered in the App. This information is saved locally in an ORMLITE Database when clicking on Submit Button.

If the patient has already been registered, user can go directly to step two.

Figure 44: Add New Patient

2. **Patient Directory -> Do Examinations:** It accesses the Database and shows all the patients that have been registered on the system. The user will choose on which patient the Examinations do.

Figure 45: List of Patients

3. **Introduce Results of Examinations:** In this interface, the health worker introduces the

The screenshot shows a mobile application interface for capturing patient vital signs. At the top, there is a status bar with a battery icon and the time 10:14. Below that is a purple header with the text 'CAPTURE PATIENT VITALS'. The main content area contains several input fields, each with a label and a corresponding input line: Location, Height (cm), Weight (Kg), Temperature (C), Pulse, Blood Pressure (mm/Hg), Proteinuria, Hemoglobin Levels, and Fundal Height. Below these fields is a section titled 'Check for Danger Signs' which contains seven questions, each followed by 'Yes' and 'No' radio button options. The questions are: 'Does the patient has a headache?', 'Does the patient has changes in Vision?', 'Does the patient suffer from abnormal nausea or vomiting?', 'Does the patient has stomach pain?', 'Does the patient has any sign of respiratory problems?', 'Does the patient feel weak or dizzy?', and 'Is the patient short of breath?'. At the bottom of the form are two buttons: 'SUBMIT' and 'RESET'.

results of the examinations done to the patient either in the community or in the facility. The Interface allows to capture the parameters to monitor specified in Table 24. It also includes a checklist, which allows to check for danger signs that could be symptoms of Eclampsia and Anemia.

When the health workers submit this information, it is saved on a Database, the application automatically records the date of the examinations and create a new table with the patient name and the results of the examinations. This will allow to visualize the variation of this parameters over time.

In addition, when the information is submitted, the Decision Support System will classify the patients in High Risk, Medium Risk and Low Risk Pregnancies. A dialog will pop out letting the user know the patient classification, and depending on the symptoms identified, go to the protocol driven guidance for

further action.

### 6.5.2 Decision Support System

The Decision Support System, classifies patients in High Risk, Medium Risk and Low Risk Pregnancies. Not all the factors in Table 21 have been included. The goal was to develop a simple decision support system to detect symptoms of mild-eclampsia, severe-eclampsia, possible cases of anemia and women with some risk factors. When a woman shows any of this symptoms, she will be categorized as High Risk Pregnancy, when some parameters are very close to a threshold the patient is categorized as Medium Risk Pregnancy, and if the woman does not have any symptoms or risk factors she is categorized as a Low Risk Pregnancy. The system is not ready to use in clinical trials, just to proof a concept. The logic of the system is explained in the next tables.

Detect Danger Signs and Some Risk Factors		
High Risk Pregnancy	Medium Risk Pregnancy	Low Risk Pregnancy
Age younger than 15 or older than 35	Age between 15 and 18 or between 33 and 35.	Other values
Weight: Less than 50 kg	Weight between 50 and 60 kg	Other values
Height: under 1.52 m	Height between 152 and 160 cm	Other values
Any of the danger signs is positive		



Table 25: Classification Criteria to detect danger signs and Risk Factors

Table 25 shows the logic of the decision support system to classify women depending on the danger signs and risk factors they have. When the patient is classified as High Risk Pregnancy, the Dialog in Figure 47 pops up and shows the possibility of going to the education services to check what to do when danger signs are detected.

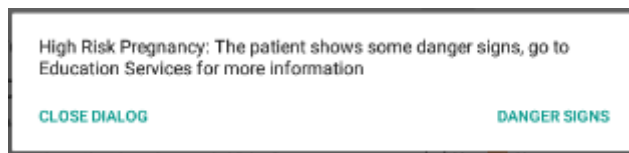


Figure 47: High Risk Pregnancy Dialog

Detect Signs of Eclampsia		
High Risk Pregnancy		Medium Risk Pregnancy
Mild	Severe	
BP >140/90 mmHg	BP >160/110 mmHg	BP between 130/80 and 140/90 mmHg
Proteinuria > 1	Proteinuria > 3-4	
	Headache	
	Vision Changes	
	Nausea or Vomiting	
	Pulse > 100 beats per minute	
	Stomach Pain	
	Signs of Respiratory Problems	

Table 26: Logic to Detect Signs of Eclampsia

In Table 26, the conditions to detect cases of mild and severe pre-eclampsia are presented. To identify a case of mild eclampsia both conditions have to be true, then the dialog in Figure 48 pops out. To identify cases of Severe Pre-eclampsia, the dialog pops out when the BP is higher than the threshold and any of the other conditions is true, then the dialog in Figure 49 is shown. In any case the user has the option to go to the protocol driven guidance section.

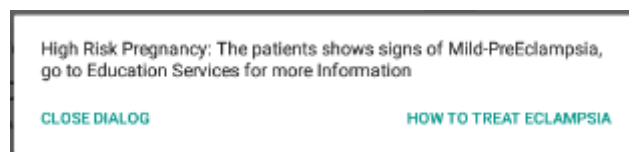


Figure 48: Mild Pre-Eclampsia Dialog

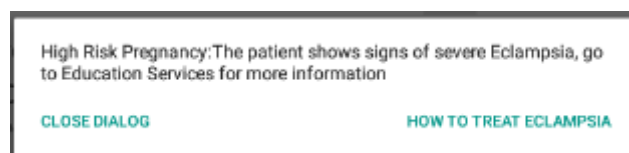


Figure 49: Severe Eclampsia Dialog

Detect Possible Signs of Anemia	
High Risk Pregnancy	Medium Risk Pregnancy
Hemoglobin lower than 13	Hemoglobin between 13 and 15

Weakness or Dizziness	
Heartbeat > 100 beats per minute	
Respiratory problems	

Table 27: Logic to detect signs of Anemia

Anemia is more complicated to detect if the iron or vitamin B12 levels are not measured. However, there are symptoms than can show that the patient might have Anemia. When any of this symptoms is true (Table 27), the patient is classified as high risk pregnancy and the dialog in Figure 50 is shown.

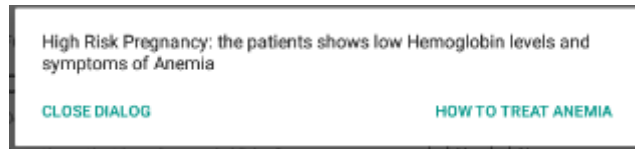


Figure 50: Anemia Dialog

### 6.5.3 Monitoring Interface

The output of the decision support system adds a new entry on the database, and each patient is classified as High Risk, Medium Risk or Low Risk. Health workers can access to this information clicking in the Patient Directory -> Monitoring System. The interface can be seen in Figure 51. It consists of three buttons simulating a traffic light. When any of this buttons are clicked, the system reads the database and loads all the patients that are classified as the label states.



The objective of this interface, is to allow health workers to track the pregnancies in their catchment area. It will allow them to see how many high risk pregnancies are in the area, and track them in the community visits. The User, can click on the name of the patient and see their records. How the records are visualized is explained in the next section.

### 6.5.4 View Patient Records

After clicking on any of the buttons in Figure 51, the systems read the database and obtain the name of the patients that have been categorized as the label of the button. When the user clicks on the name of the patient the records of the last visits are loaded. The interface has been designed on a way that the variation of the values to monitor can be seen over the pregnancy timeline.

Figure 51: Monitoring System Interface

The first views in Figure 52 allows to see the patient name, her classification, the last visit date which is recorded automatically, last value of Height, Weight, Temperature and proteinuria. All the values use unit measure of the SI, the same used right now in the maternal health books.

VIEW PATIENT RECORD	
Name	Akosua Gynah
<input checked="" type="checkbox"/> HIGH RISK	<input type="checkbox"/> MEDIUM RISK <input type="checkbox"/> LOW RISK
Location	
Last Visit Date	Mon Jun 06 16:03:07 GMT
Height (cm)	168
Weight (Kg)	65
Temperature (C)	36

In the next sections of the interface, different graphs have been included so the health workers can see how the different parameters have changed during the home visits and identify risk patterns in these values. The graphs included are:

Figure 52: View Patient Record General Information

1. **Blood Pressure Graph:** In the graph in Figure 53, the health worker can see how the blood pressure varies during pregnancy. The graph includes two thresholds, the red line is the threshold for high blood pressure that can indicate severe pre-eclampsia, the yellow one is the threshold for values of mild pre-eclampsia. Both values have been set according to the values in Table 26. This graph allows health workers to detect when the values are abnormal.

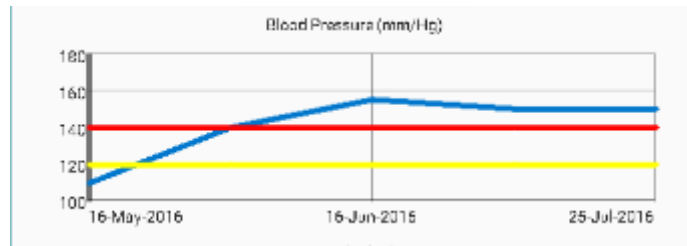


Figure 53: Blood Pressure Graph

2. **Weight Graph:** On each home visit the weight have to be checked. Health workers need to identify if the patients weight gain is normal, therefore, the graph in Figure 54 will allow them to detect any danger pattern. The graph also includes the thresholds that are used to categorize the patient as high risk and medium risk pregnancy according to the values in Table 25.

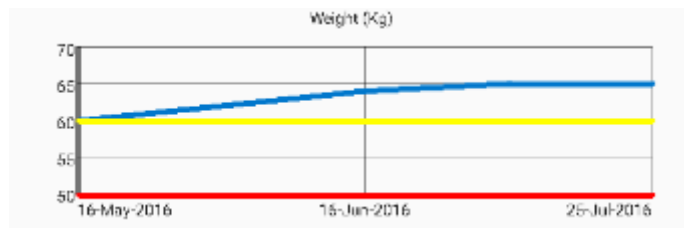


Figure 54: Weight Graph

3. **Fundal Height Graph:** The fundal height graph in Figure 55 allows to see health workers how the baby is growing. Health workers will need to check that the growth is normal.

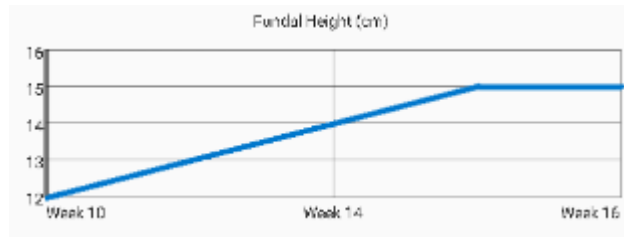


Figure 55: Fundal Height Graph

4. **Hemoglobin levels Graph:** The graph in Figure 56, represents how the hemoglobin levels have changed over time. When the level is below the red line threshold, it means that the hemoglobin levels are very low and the patient could have anemia.



Figure 56: Hemoglobin levels Graph

5. **Pulse Graph:** Figure 57 is representation of the pulse graph. Health Workers can see the previous and actual value of patient pulse. It includes two thresholds to show when this values are abnormal.

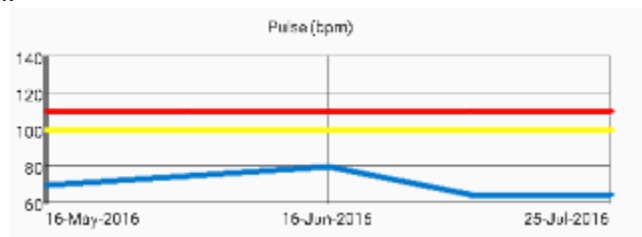


Figure 57: Pulse Graph

The final indicator included in the View Records Interface is to show the previous and actual dangers signs that have been recorded. This can be seen in Figure 58.

Danger Signs	
Headache	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
Changes in Vision?	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
Abnormal nausea or vomiting	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Stomach pain	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
Respiratory problems	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Weakness or dizziness	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
Short of breath?	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No

CLOSE

Figure 58: Danger Signs

### 6.5.5 Usability Test

In order to evaluate the usability of this feature, two different test were done. First of all, the DSS algorithm was tested introducing 50 different values of parameters and study if the

classification was done appropriately. Some errors in the logic were found and the study was repeated. The actual DSS detects symptoms of Anemia, mild pre-eclampsia and severe pre-eclampsia appropriately with no error. When the patient shows symptoms of both Anemia and pre-eclampsia it shows both dialogs. Secondly, the monitoring system was tried in two different facilities by 8 health workers, with an average duration of 20 minutes each test. Health workers measured the vitals to each other and in some cases introduced abnormal values to see if the system classified them correctly.

### 6.5.5.1 User Interfaces and tablet

Among the different user’s profiles that tested the application, most of them were able to introduce the information correctly without big issues. The user profile was Community Health Nurses between 25-40 years old. The results are:

- All the participants found it easy to go through the interfaces, include new patients, do examinations on them and visualize the results. When including the results, all of them knew which typical values are normal and abnormal.
- When visualizing the records, the users found the interface clear and the graphs appropriate, no changes were suggested.
- The tablet was placed in the table or in a chair while they did the examinations. In any case the tablet was placed in an insecure place where it could break. All the participants treated the equipment with caution but with confidence.
- The main problem was that the facilities did not have all the equipment needed to do the examinations. However, the aim is to support the facilities with the equipment needed to gather all the information. In Table 28, the equipment available in the facilities is presented. However, some of this equipment is not viable to be used in community visits. The Sphygmomanometer and bascule are too big to be carried to the communities. New equipment need to be provided that can be used in home visits. Proteinuria strips and Hemoglobin meter are not available in the facilities, however, portable equipment could be provided that will allow health workers to do these examinations in the communities.

Parameter	Equipment Needed	Available in the facility?	Easy to use in community visits?
<b>Blood Pressure</b>	Sphygmomanometer	Yes	No, too big
<b>Proteinuria</b>	Strips to measure proteinuria	No	Yes
<b>Weight and Height</b>	Bascule	Yes	No, big and heavy
<b>Pulse</b>	Stethoscope	Yes	Yes
<b>Fundal height</b>	Meter	Yes	Yes
<b>Body Temperature</b>	Thermometer	Yes	Yes
<b>Hemoglobin Levels</b>	Hemoglobin meter	No	Yes

Table 28: Equipment available in the facilities

### 6.5.5.2 Opinions and Suggestions

After the usability test all the users were asked for their opinions and suggestion on how to improve the prototype and state their satisfaction with the features presented. Most relevant general conclusions based on the participant's opinions and suggestions are:

- Users stated that the prototype is easy and simple to use. It didn't take them long time to be familiar with it.
- The monitoring system is a very valuable feature to be used in community visits, especially to provide examinations to women that cannot travel or afford to travel to the facilities. They stated that after the rainy season there are more pregnancies in the area. However, after the rainy season they stop coming to the facilities. The monitoring system, will be very useful to help this woman throughout their pregnancies.
- When asked about the potential impact of the solution they stated that it will have a great impact in those facilities where there is not a midwife, because they will be able to gather data and show it to the midwife when she comes. In addition, the protocol guidance and DSS will allow them to identify cases that require more attention and prioritize and track these patients.
- Users showed some concerned about the security issues and privacy of patient information. They were asking how this issues were going to be handled. User suggested that the system should include in the future more information about other complications that the woman could have. Include birth preparedness plans and finish including all the information of the maternal health books.
- Finally, one user suggested that the maternal health books should not be replaces with the tablet, since it is important that patients can take these books with them.

## 6.6 *FireBase Cloud Service*

One of the needs of the solution, is to store patient information in a server and retrieve this information when needed by the user of the application. In order to do that, a new application was developed to try the cloud functionality of our prototype and test whether it's possible that a cloud service will work properly in the network conditions of our study areas. The server selected was Firebase, the reason to select this server are:

- Integration with the development tool Android Studio
- Allows free cloud storage until 10GB
- Offline Capabilities: The service automatically detect when there is connection available. When the app is working offline saves the information locally and upload it automatically when network is detected even though the app stopped or the session expired without writing any logic in the app.
- Security and Authentication: The information stored locally can easily be removed. User access permission can be defined writing simple write and read commands in the web interface.
- The information stored in the database can be accessed easily from a web interface.
- Compatibility with Google Cloud: It will allow our data to be analyze remotely and ensure security of the data.

The architecture of the app to test the cloud service can be seen in Figure 59. The Application includes the same form to collect patient information as in Figure 46, when submitted, the information is stored in the firebase cloud service if network is available, if not, a local copy is created in the local storage of the tablet. When network becomes available, automatically the

information is send to the cloud service. The application also introduces the feature to retrieve all patient information from the database and show it on a list. When online, the system retrieves the information automatically, if not the system retrieves a copy from the local storage.

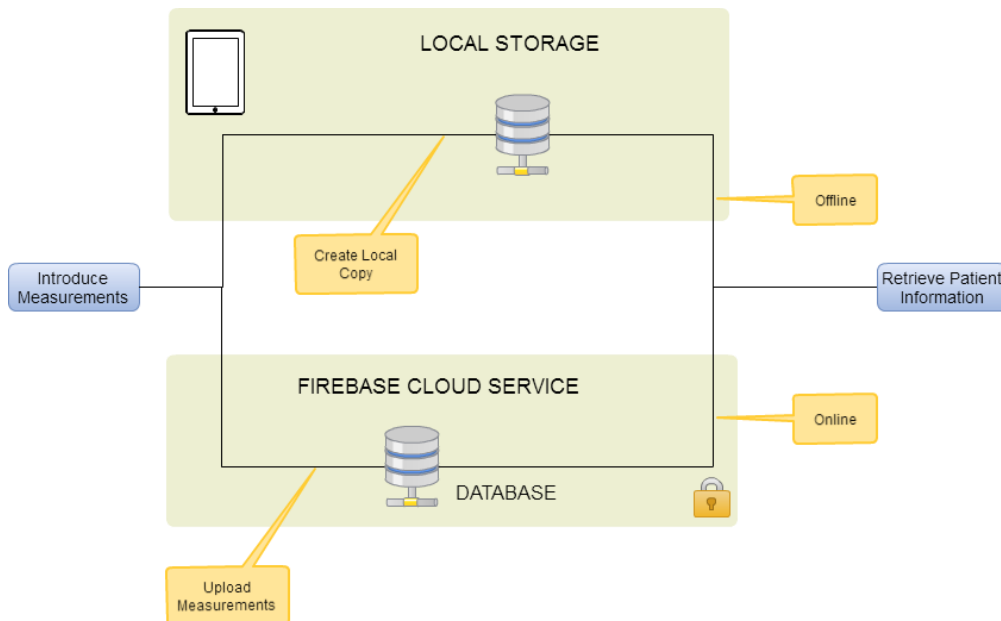


Figure 59: Firebase Cloud Service

### 6.6.1 Test Results

In order to test the appropriateness of the service to be used in our setting the next test was performed. When travelling between facilities and in those facilities where network is not available, we created 20 different patient forms, in order to create significant amount of data. We observe the tablet while travelling between facilities and check if when network becomes available the system is able to upload and download the information. The results have been the next ones:

- The application uploads and download the information instantaneity when network becomes available. It works perfectly under 2G and 3G conditions.
- Download and upload a patient form from the server has a size of 13kb. The time it takes to download and upload the form cannot be measured since it's almost immediate.
- Offline capabilities of the service allow us to work with the forms included when network is not available.

However, the actual design of the application has the next limitations:

- The system has been tested for a user with administrative privileges, therefore, no rules to enforce security by users have been created.
- Firebase is introducing encryption services for the information stored in their databases. However, currently no encryption or security for the information stored in the Firebase server is available. In order to ensure encryption, it should be done in our application.
- The system has commands to delete the information of the local device automatically, however this is not done in the current version of the prototype.

## 6.7 *Technical Limitations and Solutions Proposed*

The current prototype has several limitations. It has been developed as a proof of concept, and therefore, it is not ready to be used in clinical processes. However, the current limitations of the prototype are explained in this section, solutions and protocols to overcome these limitations are presented.

### 6.7.1 **Prototype Architecture Limitations**

In this section, the limitations of each feature are explained. The system designed as a proof of concept does not support yet full functionality of all its features. For instance, the interface to collect patient information is not connected to store data into the database. That was due to the time limitation to develop the prototype and the big amount of logic needed to store all this information in the database. This limitation, condition the rest of the features of the application.

The current decision support system is designed to detect cases of eclampsia and anemia according to a table of few conditions. In order to complete the system, more conditions should be included, in order to create algorithms that could help to predict cases of pre-eclampsia. The system classifies pregnancies in a risk scale of three levels, the system has to include more conditions according to Table 21 and the parameters collected in Collect Patient Information.

Not all the information in the maternal health books and routines for the 4 recommended ANC visits are included. Right now, the system is thought to support community visits and collect basic patient information remotely. However, in order to allow the system to be used in the facilities, it needs to introduce information about malaria treatments, current treatments that the patients are receiving, and an appointment scheduler to automatically identify when patient miss the appointments. The system should also include relevant information about birth preparedness, to give information to woman in late stages of pregnancy. This features should be developed before clinical implementation of the system.

#### 6.7.1.1 **Solution Architecture**

In Figure 60, the current solution architecture is shown. The app is installed in the tablets. It offers offline capabilities to work with all the features of the tablet. The devices are connected with a MBaaS to store and retrieve patient information from the cloud. The system gives access to the community level health workers to the patient information.

The local database used in the devices is ORMLITE, and the database in the cloud server use JSON tree as data format. We have two options in order to connect this system, the first option is to use JSON tree to store information locally and in the cloud, that is the simplest option. The second option is to use a convertor to convert JSON tree format in SQLite tables to be stored locally. Due to the time limitation, this has not been done in this prototype. That is the reason in order to try the cloud server we created a parallel application within the prototype.



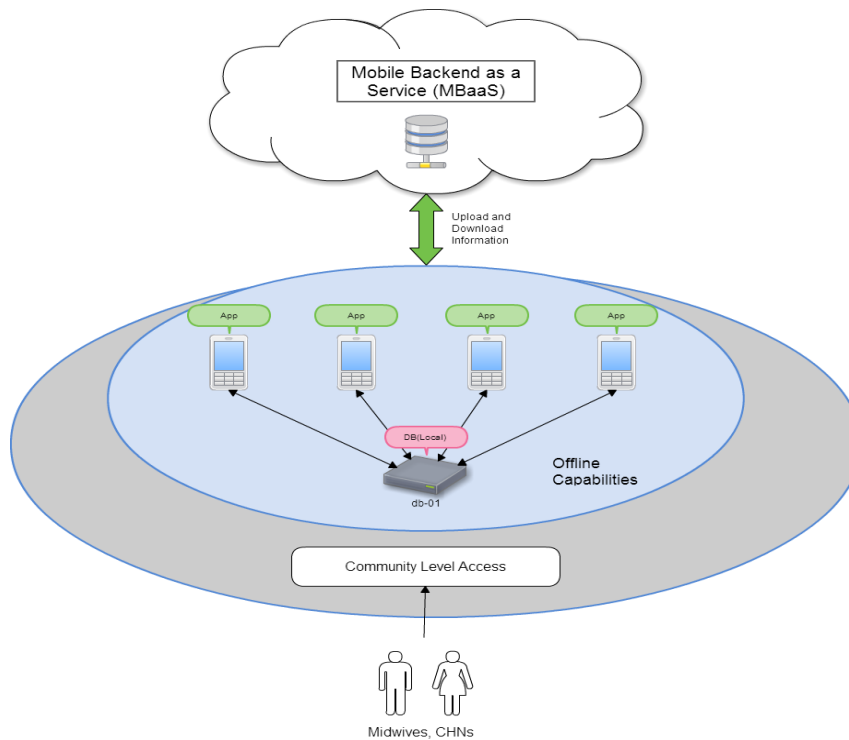


Figure 60: Solution Architecture

Interoperability is another limitation of the prototype, no data standards are used to exchange information between devices and the server. The data stored in the MBaaS is not encrypted, however a proposed security protocol is explained in the next section.

In Figure 61, a network proposal that improves the limitations of the actual prototype is proposed. This network architecture is proposed for implementation of the solution in the research area. The network is divided in two different levels, the first level is the Community Level and the second one is the Data Management and Interoperability layer to give access to health administrators and Governmental Agencies.

The Data Management and Interoperability layer includes an HL7 server and Data Center where all the information of the solution is stored. The HL7 server will be used as an interoperability server to be used with other application, for instance, with Hospitals that have EMR systems. The Data Center will store the data of the service. Data Mining and Data Prediction Engines should be implemented to improve Disease Surveillance in the Area. This data can be shared with Healthcare Delivery Organizations and other governmental agencies. One of the advantages of this layer is that this data could be used to economically sustain the project.

The Community Level Layer receives relevant data from the Data Mining and Data Prediction Engine, this data can be used to detect trends in patient health, such as prediction of pregnancy related complications. The MBaaS, will store the patient information as it does now, will push notification to the users about missing appointments and patient health status and finally, it will implement strict user management control to follow security protocols. The offline capabilities and app functionalities remains the same as the current prototype.

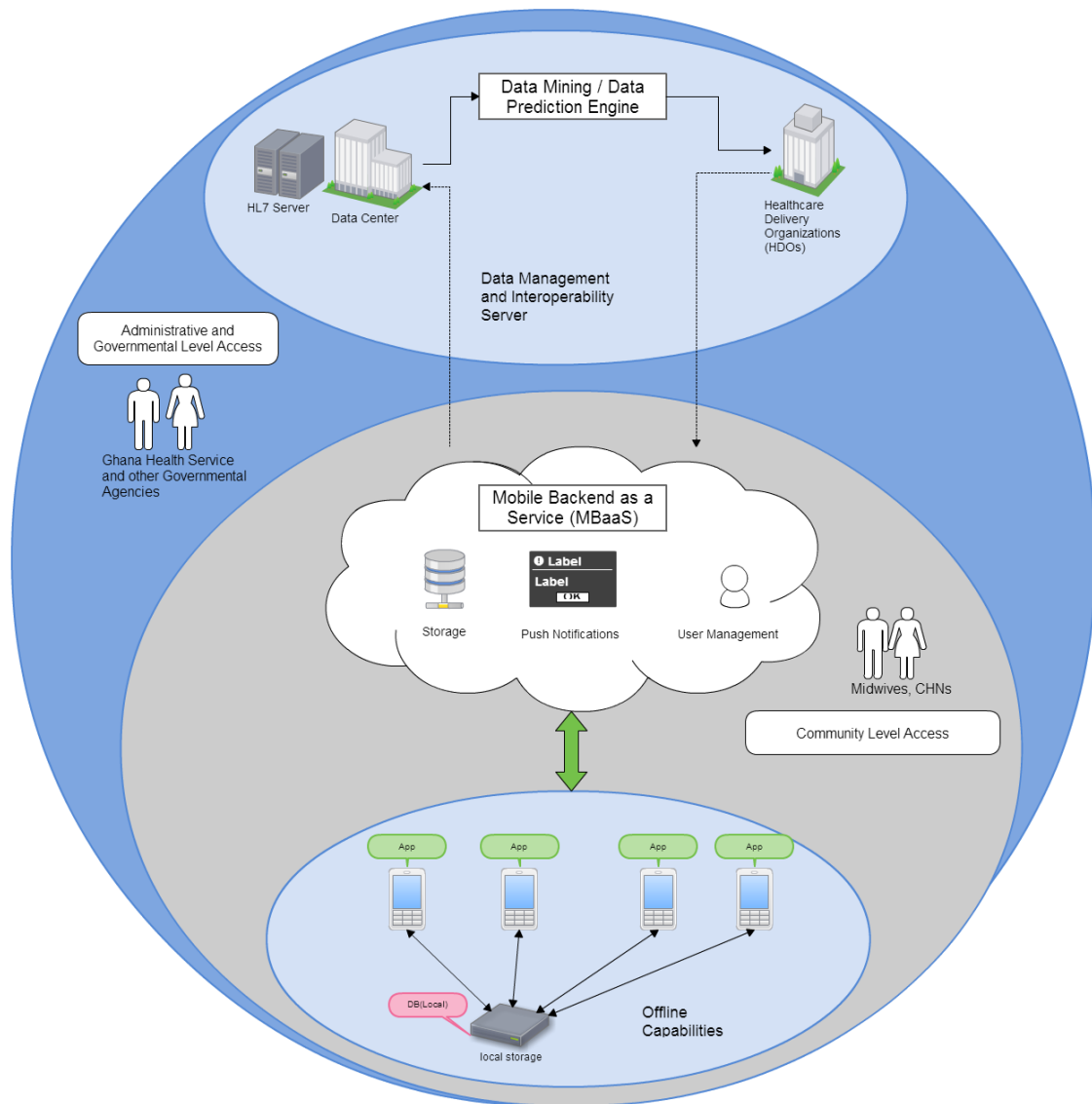


Figure 61: Network Architecture Proposal

### 6.7.2 Security Limitations

In Ghana, there is no mHealth security regulations such as the Health Insurance Portability and Accountability Act (HIPAA) in the US [65]. However, this does not mean that the application should not follow any security rules or protocols. Therefore, in this section, security protocols that should be implemented are suggested. These protocols are suggested according to the HIPAA compliance. It is supposed that shortly, these legislations will be available in Ghana and all mHealth applications should follow a security protocol.

The application will handle protected health information of patients, and this information will be shared with Covered Entities such as doctors, midwives, community health nurses. All the Covered Entities and Business Associates need to follow four rules: privacy rule, security rule, enforcement rule and breach notification rule.

### 6.7.2.1 Security Rule

According to the HIPAA Security Rule: “The HIPAA Security Rule requires appropriate Administrative, Physical, and Technical Safeguards to ensure the confidentiality, integrity and security of protected health information (PHI)”. The security rule is divided into three parts:

1. **Technical Safeguards:** protects and control access to PHI.
  - a. **Access Control:**
    - i. A Unique User Identification needs to be created for every user of the application. Midwives, CHNs and Doctors should only have access to patient information in their catchment area.
    - ii. During emergency situations, users can require access to obtain necessary PHI during the emergency.
    - iii. Encrypt and decrypt information stored locally, and when it is sent to the cloud service
  - b. **Audit Controls:** Record and audit logs from the table and the server to record and review activity in the tablets and system.
  - c. **Integrity:** Ensure that data is not altered.
  - d. **Authentication:** User should use strong passwords and personal information can be asked eventually to verify that identify of the user.
  - e. **Transmission Security:** Implement methods of encryption and Integrity to ensure that PHI is not modified.
2. **Physical Safeguard:** It focus on the physical access to PHI.
  - a. **Facility Access Controls:**
    - i. **Contingency Operations:** With the cloud service, in case of disaster the information can be restored appropriately. However, if the information is lost before uploaded it cannot be recovered.
    - ii. **Facility Security Plan:** The devices should be stored in a secure environment protecting them from unauthorized physical access and theft.
    - iii. **Access Control:** Control the access to the information to all the users.
    - iv. **Maintenance Records:** An inventory of the tablets should be done once a month to ensure their correct functionality and that they have not been stolen or lost. Including a service such as Google Cloud will allow us to remotely uninstall the application and clear data from a stolen device.
  - b. **Tablet Use:** Health workers have to be properly informed that the tablet is only for medical use. Any use of the tablet for personal used is forbidden. The data consumption of the tablet can be monitored to identify if the user is using other applications. In that case, the tablet can be programmed to only allow the use of the designed application.
  - c. **Tablet Security:** Complex passwords to unlock the tablet should be deployed.
  - d. **Data Backup and Storage:** One of the problems encountered is that health workers can work in areas with no network for longer than 24 hours, when the amount of data to upload to the cloud server this could be a problem. Local information should be encrypted and automatically deleted every 48 Hours. The data retrieved from the server will be downloaded by the health workers before the community visits, planning according to the schedule to clean the local information.
3. **Administrative Safeguards:** Policies and procedures to analyze the conduct of the workforce and the security measures.
  - a. **Security Management Process:** Perform risk analysis annually to evaluate were the information is used and stored in order to identify risks. According to this results, implement policies to reduce this risks. If employees failed to follow these policies, they should be punished. Regularly, review system activity, logs, etc.

- b. **Assigned Security Responsibility:** Make sure that the cloud server used is HIPAA compliance and there are designated officers in charge of the security of our system.
- c. **Workforce Security:** Employee migration is very common in Ghana, these movements need to be registered immediately to guarantee access to the system to new health workers and remove access to transferred personnel.
- d. **Information Access Management:** When collaborating with multiple organizations or business partners, ensure only authorized access to the PHI.
- e. **Security Awareness and Training:** Train users in appropriate security measures such as password management and secure login.
- f. **Security Incident Procedure:** Appropriate report security incidents such as stolen or lost devices.
- g. **Contingency Plans:** Ensure that backups are accessible, review the contingency plans regularly to adapt to new threads and situations.
- h. **Evaluations:** Evaluate regularly if new security policies are available in Ghana and adapt this policy to this plans.
- i. **Business Associate Agreements:** Ensure compliance of Business Associates, such as Ghana Health Service, UNiTED and other organizations that could be part of the project in the future.

To sum up, with these rules we aim to introduce policies that will protect the PHI in our system. To do that, strong security policies, administrative safeguards, business agreements with partners and contingency plans need to be implemented.

## 6.8 Budget

In this section we analyze a hypothetical budget to implement the solution in 6 facilities for one year. Only network costs are going to be included, no cost of personnel or labor.

### 1. Network Equipment:

- a. **Tablets:** We implement the project in 6 facilities with 2 tablets on each facility. The cost of one tablet is 100\$ so the total budget for tablets is  $100\$ \times 12 = 1200\$$ .
- b. **Data Subscription:** Each facility attends an average of 40 different pregnancies per year. For each pregnancy, we are going to do at least 4 examinations, which means that 4 patient forms will need to be uploaded and downloaded per pregnancy. However, a few pregnancies will be high risk and will require more forms. Hence, we assume an average of 6 forms to be uploaded and downloaded to the cloud service per pregnancy. That is a total of 1440 forms per year, with a size of approximately 37 Mbytes. The information will be cleared from the device regularly, we assume that in a year, each device will need to upload and download all the information a total of 120 times (one every three days). That gives us that the total amount of data in one year to be used in 4,4 GB. Each tablet will need a monthly data subscription of 40 MB, however the minimum bundle is 200MB and has a cost of 1,5\$. Which gives us a total cost of **216 \$ per year in data bundles.**
- c. **Sim cards:** 12 sim cards, a unit cost 0, 5\$. **Total cost 6\$.**
- d. **Cloud Storage:** The Firebase cloud storage is free up to 10GB, we will not reach this amount of data. Hence, the cloud storage is free.
- e. **Server:** The price of server to be able to store and analyze this amount of data would be **200\$.**

- 2. **Medical Equipment:** The facilities need extra medical equipment to be able to perform all the examinations needed. In Table 29.

Device	Price (\$)	Amount
Blood Pressure and Pulse Monitor	50	6
Thermometer	2	6
Bascula	10	6
Hemoglobin meter	120	6
Proteinuria Strips	10	6
<b>TOTAL</b>	<b>1152\$</b>	

Table 29: Medical Equipment Budget

Therefore, the total budget needed for one-year trial of the project would be  $1200\$+1152\$+216\$+6\$+200\$=2774$  US Dollars

## 6.9 Discussion

In this master thesis a deep and extensive background of the maternal health care situation as well as eHealth status in Ghana with focus on rural areas and remote communities was performed. Thereafter the pre-requisites of an eHealth solution for improvement of maternal care in remote the communities of Kpando South Tongu and South Adfajato in Ghana were investigated. Based on needs and prerequisites and with a strong involvement of the different stakeholders an eHealth solution aimed to improve maternal healthcare through early detection and referral of possible and actual complications during and after pregnancy was developed and tested.

It was determined that MHC in Ghana is affected by different factors: shortage of medical staff, inequality between rural and urban areas, poor emergency and referral systems, and lack of accurate datasets. MHC utilization is affected by various socio demographic factors (education, culture, economic status and geographical location). The combination of all this factors is the reason why MMR rate is still very high in rural areas. E-health solutions are a p to improve the quality of care provided, enhance the capacity of the health care system in rural areas and increase MHC utilization.

Integrating eHealth solutions on developing countries faces many challenges. The methodology followed in this thesis aimed to identify and solve this challenges. Therefore, the maternal health challenges have been identified through the perspective of local stakeholders. Semi structured interviews and focus group discussions we used to identify these challenges. Both are suitable methods that allows participants to give their honest opinion and allow the interviewer to identify new influential factors in MHC. However, information gathered during interviews could have been biased on what the interviewer wanted to hear. To solve this, focus group and triangulated research methods were used. Applying Use Cases helped to organize the results and identify errors in medical practices, common challenges in the area and plan for solutions that solve the problems of different stakeholders.

The aim has been to design a solution that will have the biggest impact on MHC in the studied areas. A priori, it could seem that a solution that focuses on reducing the delay on deciding to go to the facility could be more effective. However, including a solution like that in the area

could create conflict with current practices that are having a positive outcome, such as health education programs in rural areas. In addition, mobile phone penetration in rural communities and the lack of connectivity hinder the implementation of an eHealth solution to reduce the first delay in the TDM model.

The design process of the prototype followed a Human Centered Design approach, which allowed user to freely define requirements of the solution. Involving local stakeholders in the design creates a sense of pride and ownership of the project that can be key for the success of further implementation. The strategy followed of simulating the demonstrator allows to identify, re-design and plan solutions for major challenges. Hence, making the future implementation stage smoother.

The solution includes a CDSS. The lack of institutional data about health status of pregnant women in rural areas have been a big limitation in the design of the solution. However, during the Use Cases, common symptoms of pregnant women from these areas were identified. A symptom based analysis was developed to identify the possible underlying conditions that have been causing these complications. This system will allow to collect patient data and identify cases of Anemia and pre-eclampsia, helping government institutions to know the real MMR and the complications women are having. However, it is important to make the users understand that the final diagnosis has to be done by a professional and not by a computerized system; the CDSS is an aid.

The solution proposed is cloud based. A cloud based solution always arise many questions and concerns about security of the data. The solution has been chosen to be cloud based due to the lack of infrastructure in the area. A cloud based solution will be easier to implement and maintain. On the other hand, we cannot assure how the data will be handled by the cloud provider. For that reason implementing a wired network could seem a more secure option. However, due to lack of infrastructure and security in the area it is not recommended, environmental conditions could destroy the servers and Hospitals and healthcare facilities lack of effective security measures. No computer system or network is 100% secure, therefore a cloud service is more suitable for the area. Apart from that, the lack of regulations in Ghana about health data should never be an excused for not implementing security protocols.

An eHealth project of this characteristics, will need of local organizations and partners that will be able to sustain and manage the project in the future. The devices used for the simulations are provided by local partners that can and are willing to provide training and technical support in a national scale. However, finding organizations that are ready to sustain a project like that after a possible pilot stage is a challenge. These questions, will have to be addressed and an implementation strategy developed in the future. Since the software is open source, business models and strategies will have to be relative to it.

Under this conditions, there are two different possibilities. The main possibility is to use the data to obtain income from it. That does not mean selling personal data. The solution, will allow data collection about maternal mortality rates and complications in rural and remote areas. Currently, Ghana Health Service and the World Health Organization does not have any data available of these areas. If the solution is able to work efficiently and collect accurate data, this data could be the way to obtain funding to sustain and expand the project to other areas. Another option, is to create a service more complex for a bigger variety of users. Right now the solution is thought to serve the poorest people. Implementing new functionalities such as ultrasound images, could allow to obtain revenue from the service from patients with higher incomes that are willing to pay for the service. And with that money, cover the treatment for rural and remote areas.

To sum up, the research methodology followed allowed a deep understanding on the setting and local stakeholders' perspective. Hence, the solution developed shows great potential to improve maternal healthcare in remote communities. The project has two major strengths, the first one is that the solution have been designed with the potential users, the second one is that is a simple solution adapted to local culture and current practices. Therefore, including the solution in the current work practices will be easier than another solution that will change completely local practices and is not adapted to the local situation.

## 7 Conclusions

Maternal health care in rural areas is affected by three delays that affect the outcomes of care. These delays are affected by socio-economic status, accessibility to the facilities and quality of care provided. Health workers in remote areas are not well trained and stigma is common in all the social statements. The prototype developed showed a great potential to reduce the delay in receiving adequate care, especially for women living in remote areas and to be used in community visits. Health workers showed great satisfaction and enthusiasm about the prototype. The simplicity of the prototype, the adaptation to the local culture and work routines were the main factors that satisfied the users. Finally, the research methodology followed during this process was key to the success in the design of the prototype. The setting was fully understood and that allowed to create a prototype adequate for the setting.

## 8 Limitations of the research

One of the limitations of the research is the health worker's attitude when providing the answer. The information gathered could have biased based on what the interviewer wanted to hear. Health worker's answers could have been influenced expecting to receive something in exchange in the future.

## 9 Future Work

In this section, future recommendation for implementation of the project are presented. The current solution is just a demonstrator and is not ready to implement in a clinical environment. The technical limitations of the prototype are explained in page 79. However, recommendations for future implementation of the project are presented:

- Identify funding and sustainability strategies for long term implementation.
- Local partners that are able to manage and sustain the project. For instance, local universities where students can be trained on eHealth and supervise the implementation process in different areas.
- Address security and ethical issues with the help of Ghana Health Service and other local authorities.
- Agreement with local provider to provide technical support and equipment.
- Identify a medical equipment provider that has technical support in the country.
- Develop a training plan. User's need to receive appropriate training before the application is implemented, besides, this training need to plan ahead for staff rotation among facilities.
- Pilot stage. Ideally this process should last 2 years. During the first year training is provided and the implementation of the project is done in different phases when the different features of the application are developed. During the second year, a monitoring and evaluation plan needs to be applied to measure project outcomes. Some of the indicator recommended to measure the impact are: Number of ANC attendants

that complete 4<sup>th</sup> visits, number of home visits, how many of user's that received home visits gives birth with a SBA, number of patients that develop anemia in rural areas, number of patient that develop pre-eclampsia in rural areas, number of early detection and referral of complications and non-institutional maternal mortality rate.



## References

- [1] J. A. Blaya, H. S. Fraser and B. Holt, "E-Health Technologies Show Promise in Developing Countries," *Health Affairs*, vol. 29, no. 2, pp. 244-251, 2010.
- [2] mHealth Alliance, "Leveraging Mobile technologies to provide maternal & newborn health," The Center for Innovation & Technology in Public Health, Oakland, 2012.
- [3] World Health Organization, International Telecommunications Union, "Ehealth and innovations in women's and children's health: a baseline review," March 2014. [Online]. Available: [http://www.who.int/goe/publications/baseline\\_fullreport/en/](http://www.who.int/goe/publications/baseline_fullreport/en/). [Accessed 13 02 2016].
- [4] World Health Organization (WHO), "Media center, Maternal mortality, Fact sheet N°348," WHO, November 2015. [Online]. Available: <http://www.who.int/mediacentre/factsheets/fs348/en/>. [Accessed 09 02 2016].
- [5] WHO, "Ghana Statistical Profile," Global Health Observatory, 2015.
- [6] United Nations Development Programme Ghana, "Ghana Millennium Development Goals - 2015 Report," September 2015. [Online]. Available: <http://www.gh.undp.org/content/ghana/en/home/library/poverty/2015-ghana-millennium-development-goals-report.html>. [Accessed 11 02 2016].
- [7] The Partnership for Maternal, Newborn and Child Health, "Antenatal Care," in *Opportunities for Africa's newborns: Practical data, policy and programmatic support for newborn care in Africa*, World Health Organization, 2006, pp. 51-62.
- [8] E. M. Der, C. Moyer, R. K. Gyasi, A. B. Akosa, Y. Tettey, P. K. Akakpo, A. Blankson and J. T. Anim, "Pregnancy related causes of deaths in Ghana: A 5-year retrospective study," *Ghana Medical Journal*, vol. 47, no. 4, pp. 158-163, 2013.
- [9] K. Rogo, J. Oucho and P. Mwalali, "Maternal Mortality," in *Disease and Mortality in Sub-Saharan Africa*, Washington, World Bank, 2006, p. Chapter 16.
- [10] UNGAOR, "United Nations Millennium Declaration," in *55TH Sess, UN Doc A/RES/55/2*, 18 September 2000.
- [11] United Nations, "Sustainable Development Goals," UN Web Services Section, Department of Public Information, December 2015. [Online]. Available: <http://www.un.org/sustainabledevelopment/health/>. [Accessed 09 02 2016].
- [12] The World Bank, "The World Bank - Data," 07 05 2015. [Online]. Available: <http://data.worldbank.org/country/ghana>.
- [13] Kpando Health Directorate, "Kpando Municipality - Health Sector," Kpando Municipal Assembly, 2014. [Online]. Available:

[http://kpando.ghanadistricts.gov.gh/?arrow=atd&\\_=123&sa=2590](http://kpando.ghanadistricts.gov.gh/?arrow=atd&_=123&sa=2590). [Accessed 25 07 2015].

- [14] M. de Groot, "A qualitative health research about the challenges during pregnancy, delivery and after delivery on the islands in Kpando Municipality, Ghana," UNiTED, Kpando, Ghana, 2015.
- [15] Ghana Health Service, "GHS Organisational Structure," Ghana Health Service ICT Department, 2015. [Online]. Available: <http://www.ghanahealthservice.org/ghs-subcategory.php?cid=2&scid=43>. [Accessed 25 07 2015].
- [16] Ministry of Health Ghana, "Helath Sector Review Report," Ghana, 2010.
- [17] Ghana Health Service, "GHS - Family Health Division," Ghana Health Service ICT Department, 2015. [Online]. Available: <http://www.ghanahealthservice.org/ghs-division.php?ghs&ghsdid=2>. [Accessed 25 7 2015].
- [18] D. Oehler, UNiTED and African Woman Alliance, "A qualitative research on antenatal care utilization in Kpando Municipality, Ghana," UNiTED, Kpando, Ghana, 2014.
- [19] Ghana Health Service, "Reproductive and Child Health Annual Report 2013," Ghana Health Service ICT Department, Accra, 2013.
- [20] F. W. Dislane, A. Akpalu and H. H. J. Wegdam, "The Medical System in Ghana," *The Yale Journal of Biology and Medicine*, vol. 87, no. 3, pp. 321-326, 2014.
- [21] Ministry of Health: Republic of Ghana, "Holistic Assessment of the Health Sector 2014," 2015 July 06. [Online]. Available: [http://www.moh-ghana.org/pub\\_content.aspx?id=1](http://www.moh-ghana.org/pub_content.aspx?id=1). [Accessed 15 02 2016].
- [22] S. Afagbedzi, H. Obuobi, R. Aryeetey and S. Bosomprah, "A review of Ghana's E-health Strategy," in *8th Health Informatics in Africa Conference*, Eldoret, Kenya, 2013.
- [23] Internation Telecommunication Union, "Implementing e-Health in Developing Countries - Guidance and Principles," ICT Applications and Cybersecurity Division - Policies and Strategies Department, Geneva, Switzerland, 2008.
- [24] S. Akter and P. Ray, "mHealth - an Ultimate Platform to Serve the Unserved," *Yearb Med Inform*, pp. 94-100, 2010.
- [25] M. o. H. Dr. Benjamin Kunbuor, "Ghana e-Health Strategy," Accra, 2010.
- [26] S. Thaddeus and D. Maine, "Too far to walk: maternal mortality in context," *Soc Sci Med*, vol. 38, pp. 1091-1110, 1994.
- [27] P. Drury, "eHealth: A Model for Developing Countries," *eHealth International Journal*, 2005.
- [28] C. Marshall, D. Lewis and M. Whittaker, "mHealth technologies in developing countries: a feasibility assessment and a proposed framework," *Health Inforamtion Systems*

Knowledge Hub, School of Population Health, The university of Queensland, Canberra, Australia, 2013.

- [29] P. N. Mechael, "The Case for mHealth in Developing Countries," *Innovations: Technology, Governance, Globalization*, vol. 4, no. 1, pp. 103-118, 2009.
- [30] K. Kallander, D. J. Akpogheneta, A. H. A. Asbroek and B. R. Kirkwood, "Mobile Health (mHealth) Approaches and Lessons for Increased Performance and Retention of Community Health Workers in Low- and Middle-Income Countries: A Review," *J Med Internet Res*, vol. 15, no. 1, 2013.
- [31] S. Lund, V. Rasch, M. Hemed, I. M. Boas, S. Azzah, S. Khadija, M. H. Makundu and B. B. Nielsen, "Mobile Phone Intervention Reduces Perinatal Mortality in Zanzibar: Secondary outcomes of a Cluster Randomized Controlled Trial," *JMIR mHealth and uHealth*, vol. 2, no. 1, 2014.
- [32] Grameen Foundation, "Motech Lessons Learned," September 2012. [Online]. Available: <http://www.grameenfoundation.org/resource/motech-lessons-learned>. [Accessed 28 02 2016].
- [33] G. Ivatury, J. Moore and A. Bloch, "A Doctor in Your Pocket: Health Hotlines in Developing Countries," *Innovations: Technology, Governance, Globalization*, vol. 4, no. 1, pp. 119-153, 2009.
- [34] C. Noordam, B. M. Kuepper, J. Stekelenburg and A. Milen, "Improvement of maternal health services through the use of mobile phones," *Tropical Medicine & International Health*, vol. 16, no. 5, pp. 622-626, 2011.
- [35] Changamka Health Innovations, "M-Kadi ya Maternity a case for our mothers," Changamka Micro-Insurance Limited, 2015. [Online]. Available: <http://changamka.co.ke/m-kadi-maternity/>. [Accessed 30 April 2014].
- [36] F. Ngabo, J. Nguimfack, F. Nwaigwe, C. Mugeni, D. Muhoza, D. R. Wilson, J. Kalack, R. Gakuba, C. Karema and A. Binagwaho, "Designing and Implementing and Innovative SMS-based alert system (RapidSMS-MCH) to monitor pregnancy and reduce maternal and child deaths in Rwanda," *PanAfrican Medical Journal*, vol. 13, no. 31, 2012.
- [37] K. Krasovec, "Auxiliary technologies related to transport and communication for obstetric emergencies.," *International Journal of Gynecology & Obstetrics*, vol. 85, no. Suppl. 1, pp. S14-S23, 2004.
- [38] J. D. Piette, K. Lun, L. A. Moura, H. S. Fraser, P. N. Mechael, J. Powell and S. R. Khoja, "Impacts of e-health on the outcomes of care in low- and middle-income countries: where do we go from here?," *Bulletin of the World Health Organization*, vol. 90, no. 5, pp. 321-400, 2012.
- [39] N. Mensah, F. Sukums, T. Awine, A. Meid, J. Williams, P. Akweongo, J. Kaltschmidt, W. E. Haefeli and A. Blank, "Impact of an electronic clinical decision support system on workflow in antenatal care: the QUALMAT eCDSS in rural health care facilities in Ghana and Tanzania," *Global Health Action*, vol. 8, no. 25756, 2015.

- [40] A. X. Garg, K. J. Adhikari, H. McDonald, P. Rosas-Arellano, P. J. Devereaux, J. Beyene, J. Sam and B. Hayne, "Effects of Computerized Clinical Decision Support Systems on Practitioner Performance and Patient Outcomes," *The Journal of the American Medical Association*, vol. 293, no. 10, pp. 1223-1238, 2005.
- [41] S. M. Finkelstein, S. M. Speedie and S. Potthoff, "Home Telehealth Improves Clinical Outcomes at Lower Cost for Home Healthcare," *Telemedicine and e-Health*, vol. 12, no. 2, pp. 128-136, 2006.
- [42] S. L. Dimmick, S. G. Burgiss, S. Robbins, D. Black, B. Jarnagin and M. Anders, "Outcomes of an Integrated Telehealth Network Demonstration Project," *Telemedicine Journal and e-Health*, vol. 9, no. 1, pp. 13-23, 2004.
- [43] P. J. Heinzlmann, C. M. Williams, N. E. Lugn and J. C. Kvedar, "Clinical Outcomes Associated with Telemedicine/Telehealth," *Telemedicine and e-Health*, vol. 11, no. 3, pp. 329-347, 2005.
- [44] R. Wootton, "Twenty years of telemedicine in chronic disease management - an evidence synthesis," *Journal of Telemedicine and Telecare*, vol. 18, no. 4, pp. 211-220, 2012.
- [45] J. Dal Molin, "Open Innovation: Transforming Health Systems through Open and Evidence Based Health ICT Innovation.," *Communications and Strategies*, vol. 83, pp. 17-36, 2011.
- [46] A. Ekeland, A. Bowes and S. Flottorp, "Effectiveness of telemedicine: a systematic review of reviews," *International Journal of Medical Informationcs*, vol. 11, no. 79, pp. 736-771, 2010.
- [47] E.-d. Kok, A. VergouweMeijer, Bruijnzeel-Koomen and R. W., "A systematic review of the effects of e-health on chronically ill patients," *Medline*, Vols. 21-22, no. 20, pp. 2997-3010, 2011.
- [48] R. Scott and M. Mars, "Principles and Framework for eHealth Strategy Development," *JMIR Publications*, vol. 15, no. 7, 2013.
- [49] J. D. Sachs, "Macroeconomics and Health: Investing in Health for Economic Development," World Health Organization-Marketing and Dissemination, Geneva, Switzerland, 2001.
- [50] F. S. Mair, C. May, C. O'Donnell, T. Finch, F. Sullivan and E. Murray, "Factors that promote or inhibit the implementation of e-Health systems: an explanatory systematic review," *Bulletin of the World Health Organization*, vol. 90, pp. 357-364, 2012.
- [51] M. Heinen, "Health care before, after and during birth in Kpando, Ghana. A community based assessment on maternal mortality," UNiTED, Kpando, Ghana, 2013.
- [52] S. Jongma, ""When Time Matters" A qualitative Health Research on Delay in Emergency Obstetric Health Care in Kpando Municipality, Ghana," Kpando, Ghana ; Amsterdam, The Netherlands, 2014.

- [53] UNiTED, "Expanding public health and laboratory services to remote areas in the Kpando Municipality," Kpando, Ghana, 2015.
- [54] S. Vink, "Stimulating SMC attendance in Kpando, GHana: Qualitative research into stakeholder influence," UNiTED, Kpando, Ghana, 2015.
- [55] S. Borckink, "Influence of HIV testing on ANC attendance," Athena Institue, VU University Amsterdam & United projects, Amsterdam, 2015.
- [56] C. Adema, "Decision making processes during antenatal period and the influence of the traditional birth attendant," VU University Amsterdam & United projects, Amsterdam, 2015.
- [57] American Telemedicine Association, "Telehealth for High-risk Pregnancy," State Medicaid Best Practice, 2014.
- [58] H. Fraser, P. Biondich, D. Moodley, S. Choi, E. Mamlin and P. Szolovits, "Implementing electronic medical record systems in developing countries," *Journal of Innovation in Health Informatics*, vol. 13, no. 2, pp. 83-95, 2005.
- [59] M. Lagarde, A. Haines and N. Palmer, "Conditional Cash Transfers for Improving Uptake of Health Interventions in Low- and Middle-Income Countries: A systematic review," *JAMA*, vol. 298, no. 16, pp. 1900-1910, 2007.
- [60] F. Williams and S. Boren, "The role of the electronic medical record (EMR) in care delivery development in developing countries: a systematic review," *Journal of Innovation in Health Informatics*, vol. 16, no. 2, pp. 139-145, 2008.
- [61] M. Steen, "Data collection and management," in *Key Concepts in Nursing and Healthcare Research*, SAGE, 1988, pp. 211-217.
- [62] A. Lovell, "Case study research," in *Key concepts in nursing and healthcare research*, SAGE, 1988, pp. 73-78.
- [63] S. Flynn, "Observational research," in *Key Concepts in Nursing and Healthcare Research*, SAGE, 1988, pp. 111-116.
- [64] South Tongu District Health Directorate, "2015 Half year Performance Report," Ghana Health Service, Sogakofe, Volta Region, Ghana, 2015.
- [65] TRUEVAULT, "HIPAA Compliance," TRUEVAULT, [Online]. Available: <https://www.truevault.com/blog/how-do-i-become-hipaa-compliant.html>. [Accessed 07 06 2016].