Integration and Application of Mobile Technology into Malaria Control and Intervention: The Case of Indoor Residual Spraying (IRS) Operation

A Thesis Submitted

by

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ACCEPTANCE

Accepted by the Faculty of Informatics, St. Mary's University, in partial fulfillment of the requirements for the degree of Master of Science in Computer Science

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DECLARATION

I, the undersigned, declare that this thesis work is my original work, has not been presented for a degree in this or any other universities, and all sources of materials used for the thesis work have been duly acknowledged.

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List of Acronyms

ICT	Information Communication Technology
IRS	Indoor residual Spraying
FMoH	Federal Ministry of Health
HMIS	Health management Information System
HSTP	Health Sector Transformation Plan
HIS	Health Information System
GC	Gregorian Calendar
mHealth	Mobile Health
EC	Ethiopian Calendar
IOM	Institute of Medicine
GSM	Global System for Mobile communication
GPRS	Global Packet Radio Service,
PDA	Personal Digital Assistant
SMS	Short Message Service
HIMSS	Health Information Management Systems Society
ORHB	Oromia Regional Health Bureau
HEW	Health Extension Workers
JSI	Hohn Snow incorporated
L10k	Last ten kilometer
M&E	Monitoring and Evaluation
ANC	Antinatal Care
EDD	Expected Delivery Date
3G	Third Generation
4G-LTE	Fourth Generation
WiFi	Wireless Fidality
WiMAX	Wireless
ISO	International Standard Organization
CEN	European Committee for Standardization
ICT4D	Information Communication Technology for Development
PV	Photovoltaic
eHMIS	Electronic Health Management Information System
PHEM	Public Health Emergency
EMR	Electronic Medical Record
E.H.R	Electronic Health Record
CHMIS	Community Health Management Information System
HRIS	Human Resource information System
IFMIS	Intigrated Financial Management Information System
IS	Information System

CBHIS	Community Based Health Information System
MIS	Management Information System
WHO	World Health Organization
ITU	International Telecommunication union
ACM	Association for Computing Machinery
CSV	Comma Separated Values

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Abstract

The dynamic nature of information communication technology especially mobile and wireless technologies have greatly contributed to the improvement of health care and service delivery in developing countries. Countries where limited resources and remote locations with reasonably organized telecom infrastructure are the main reasons for using mobile phones, Therefore, implementing mHealth system in the health sector specially for malaria prevention and control intervention is not only a good choice for a country like Ethiopia with around 46 million mobile users [1], but also with its low cost and universal availability, now a days mobile bases data collection for public health programs become crucial for progress tracking and intervention monitoring and mHealth recognized as an important piece of communication technology in health service delivery.

Real-time data collections, summary and reporting are essential for early correction and decision making purpose during indoor residual spraying operation. In Ethiopia there are many mhealth initiatives operated by institutions to supplement their program activities However, the existing mHealth implementations in Ethiopia needs standardization and frame-work to follow.

The main objective of this study is to investigate how mHealth help the implementation of IRS and develop mHealth system implementation framework with a prototype mobile based application to aid IRS supervision. A cross sectional study was carried out with purposive sampling research method to select representative districts. The data were then collected by using pre designed questionnaire, observational checklist, government policies and document review.

Though there are significant institutional level mHelath projects going on for different health programs via support from local and international non-governmental organizations but there is no mHealth implementation identified working for IRS activity. It is also learnt that these projects are facing many challenges. Amongst them intermittent network coverage, limited technological literacy of implementers and users, dynamic nature of host application platforms and high users turnover are taking the lead. Developing user-friendly system, revising periodically, pilot assessment and having framework are some lessons taken from some of mHealth projects.

As many of the mHealth initiatives published shows success in their small scale implementation and the impact addressing the target the researchers largely agreed that mHealth projects have a significant impact in delivering robust healthcare services. And the initiatives should consider the implementation coverage, technological design, and capacity of target users to be monitored and evaluated against their initial target.

Chapter 1: Introduction

1.1 Background

There is considerable enthusiasm for mobile health (mHealth) interventions and it has been argued that there is huge potential for mobile-health interventions to have beneficial effects on health and health service delivery processes, especially in resource-poor settings. While a number of innovative mHealth projects have been launched in Ethiopia and other developing countries in the past years, many have been short-term or have covered a limited geography [1]. Recently, the Ethiopian Federal Ministry of Health (FMoH) through growth and transformation program has identified the need to develop a scalable and comprehensive mHealth platform and strategy that could meet long-term needs and strengthen the primary health care system [5].

mHealth is a term used for interventions and programs designed to support medical and public health through the use of mobile technology [4]. The term commonly refers to mobile communication devices, such as mobile phones, PDA's and smartphones, to deliver health services and transmit health-related information. mHealth ranges from simple mobile-based phone applications for the transfer of health information on basic handsets via short message service (SMS) to highly sophisticated diagnostic applications that rely on more advanced equipment (smartphones and tablets) and robust back-end data systems [1], [4], [5]. The 2011 mHealth in Ethiopia report identified five priority areas where mHealth could best help to strengthen the primary health care system: referrals, data exchange, supply chain management, training, education and consultation [5].

Ethiopia's fight against Malaria started more than half a century ago. The intervention began as pilot control project in the 1950's and then it was launched as a national eradication campaign in the 60's followed by a control strategy in the 70's which is still in action [8]. The malaria control program has different interventions, and one of the major activity is Indoor residual Spraying (IRS).

IRS is a process of spraying appropriate insecticide on the inside wall of houses in the targeted areas. The Government of Ethiopia strives to strengthen the health management information system (HMIS) and improve the quality of IRS operation and related interventions data management through different information communication technology mechanisms.

One of the biggest challenges of IRS campaigns is the monitoring of operational quality via robust supervision with information sharing and documentation. Traditionally, implementation of these components relied on paper-based processes due to a lack of good technological infrastructure, low exposure to technology, and high equipment costs. However, as equipment costs drop and the telecommunication service provider ethio telecom expands the network

coverage throughout the country >85% [30], the possibility of moving away from paper-based systems has augmented. For example, as of 2014 GC, 78 percent of mobile phone consumers worldwide reside in low-income developing countries [2].

Mobile technology has many potentials, way of technologies on how to expand the scope and usability for IRS. It can make IRS data easily accessible and distributed information between different levels of supervisors and stakeholders.

The ubiquitous computing hand held devices like mobile phones and tablets become popular and integrated in to the day to day activity of individuals, and this integration comes from the advancement of model, processing and storage capability of the devices. This global opportunity augments the public health interventions to meet their target by adopting the technology appropriately on time through a well-structured implementation framework.

1.2. Statement of the Problem

Supervision of IRS campaigns and monitoring the implementation quality are vitally important for maintaining safe and effective spray performance and protect the target community. Supervisors used to collect data on paper forms on topics such as Geographical areas to be spray, spray preparations performance, spray technique, and stockroom management to keep track of the IRS operation complete on time and successfully. However, the use of paper forms had several problems, including untimeliness and data reporting errors. Challenges to promptly submit the forms prevented the IRS team from processing and sharing information on time, and efficiently identifying and correcting systematic shortcomings. These activities takes a lot of time to be identified and corrected within the limited operation time, therefore it is so important to have a comprehensive mobile application platform that helps to handle a successful supervision and timely data transfer to the next level and giving easy access to users in real-time. Thus the major questions in this research are:

1. What are the current active mHealth initiatives for IRS?
2. What are the challenges and lessons associated with the initiatives implementation?
3. What are the opportunities to establish mHealth to Improve IRS operation

Based on literature review the researcher learns that limited researches are made in this area to assess the implementation status of the mobile aided supervision on IRS; to know where we are now this study yielded a number of findings that may be applicable to other public health interventions using similar mobile phone technology.

1.3. Objectives

1.3.1 General Objective

The overall objective of this study is to analyze the challenges, failures and successes encountered in implementing mHealth system in Ethiopia specifically for malaria control intervention Indoor Residual Spraying.

1.3.2 Specific Objective

- To investigate how mHealth help the implementation of IRS in improving the quality of progress monitoring, supervision and documentation in line with spray preparations, spray technique, and stockroom performance.
- To assess the success and challenges of the mHealth system implementation for IRS
- Based on the lessons learned Develop mHealth system implementation framework
- Develop a mobile based prototype application to aid IRS supervision

1.4. Significance of the study (contributions)

This study serves as a base for the assessment of the mHealth system implementation regarding public health intervention specifically IRS to identify the strength and weakness of the system. And the findings and recommendations of the study would contribute towards the ongoing efforts of developing better mobile based application for any public health intervention; furthermore the new mobile application helps supervisors to improve their IRS operation quality. During each spray day, supervisors and stakeholders in the field use the application to complete and submit their forms to a cloud-based open-source platform. This data is then sent via email to all supervisory staff to allow them to take corrective measures and others to be aware of the problem seen by supervisors for precaution. FMoH, ORHB, stakeholders and the community would also be benefited from the research as it helps them to get quality information real-time from the field and service delivery.

1.5. Scope/limitations

The research focusses on the investigation and assessment of mHealth projects related to IRS operation and proposes an implementation framework with developing sample smart phone based mobile application. The research will focus on Oromia regional state one zone 5 districts.

Chapter 2: Literature Review

2.1. Introduction

Mobile based services especially mHealth is an emerging field, many researchers have been devoted to conduct studies in various mobile based health service improvement application areas. However in Ethiopia few studies have been carried on mhealth applications.

We performed a literature review to gain an understanding of the existing mHealth system implementation challenges, how mHealth improve the public health intervention specially IRS and the need for implementation framework in general, for mobile based health service delivery. Thereafter we put our literature review focus on the mobile technologies implemented for malaria prevention and control especially IRS and available open source frameworks that can be used to improve health data collection and reporting process.

The review helped to gain understanding which addressed on statement of the problem. Introducing new technologies in health system environments such as district and Facility level will always be challenging. mHealth applications are complex interventions that require changes to the behavior of health care professionals who will use them and changes to systems or processes in delivering service to the community.

Information communication technology has tremendous impact in improving the daily life of individuals by supplementing values in service delivery and management, mobile health or mHelath has become the major tool for improving the health management information system.

Any electronic health information system including mHealth has many implementation constraints, The Ethiopia's health sector challenges range from the macro-level concerns of funding, human capital, infrastructure and cultural norms to specific health sector challenges such as equipment and supply shortages, insufficient quantity of skilled healthcare workers, and a relatively uneducated population [9]. Over the past six years, the Ethiopian government has rolled out significant national telecommunications infrastructure; this has enabled the Federal Ministry of Health (FMoH) to use ICT to improve data exchange within hospitals and to support the national cadre of Health Extension Workers (HEWs) in remote areas [4]. According to Vital wave report [1] countries are moving from the established paper based implementations of district health information to the second generation HIS, where health encounter data is used to not only inform policy but to improve care at the point of service [1]. This implies that mHealth can contribute much in getting real time data from the source for early detection and improvement of implementation approach in health service and intervention activities.

According to Vital Wave Consulting 2009, [14] low-and middle-income countries work to meet the health need of their populations. mHealth can facilitate and support key processes, ranging from patient monitoring to client-centered heath information to supply chain management. mHealth also offered unprecedented opportunities for real time data collection to a degree never before possible in public health [10]. In traditional paper-based reporting systems, collecting and exchanging quality and timely health data remains a challenge, as the process can consume the time and attention of health workers who are meant to be providing services instead, and can result in inaccurate or incomplete data.

Electronic Health Information Systems including mobile based applications can help minimize time spent recording data, and It is implemented in many African countries such as Botswana, South Africa, Mozambique, Ethiopia, Malawi and Tanzania [7],[9].

Most of the literatures and reports stated that, the telecommunication infrastructure in Ethiopia has shown a great improvement in the past five years and this shows that Ethiopia is favorable to the implementation of mHealth system [6]. Ethiopia as many of developing countries can benefit from these sector if government and stakeholders use the existing favorable infrastructure and contribute to the successful implementation of ICT and mobile applications through advocating the community to adopt new technology.

mHealth systems has a low range wireless networking capability to send information to a smartphone with an mHealth application. The application then sends information via mobile telecommunications network, using an internet protocol, to a mHealth platform which needs an interoperability of different systems. In healthcare, the Health Information Management Systems Society offers the following definition of interoperability “The ability of different information technology systems and software applications to communicate, exchange data, and use the information that has been exchanged.” Hence the interoperability between systems becomes a challenge. Wondwosen Shiferaw [18] states the three successive levels, each of which relies upon the lower level to ultimately achieve full interoperability foundational, structural and semantic [6].

2.2. Electronic Health and mHeath in Ethiopia

eHealth generally is defined as the use of ICT for health and in a broader sense the World Health Organization defines eHealth as “a method concerned with improving the flow of information, through electronic means” to support the delivery of health services and the management of health systems. The Federal Ministry of Health (FMoH) of Ethiopia has developed and tried various national eHealth applications that contribute to the improvement of health system efficiency.

Mobile communication technologies are tools that can be implemented to support existing workflows within each of the health service delivery and disease prevention and control interventions. mHealth can be a means to deliver the right health information to the right person at the right place and time in a secure, electronic form to optimize the accessibility and quality of health care delivery, research, education and knowledge for health system.

There is insufficient impact data about how mobile technologies are influencing health outcomes, creating challenges to identify and replicate best practices [23]. Impact evaluation is necessary to move beyond discussions of the potential impact that such technological solutions might have and subjective examples of how they are already being used for health. Mobile technologies are only as good as the information and communication to which they provide access [25]. Access to reliable and relevant content at the right time is a critical consideration hence e-Health and mHealth should be viewed as both the essential infrastructure underpinning information exchange between all participants in a healthcare system and as a key enabler and driver for improved health outcomes for a population. And finally, there is a need to move away from pilot programs and case studies to more formal application and learning to set the foundation for national programs and policies.

2.2.1. Ethiopian National eHealth Strategy

According to FMoH Ethiopia HSTP [15] to fulfill the information demand for decision making towards quality and equity, digitizing the existing health information system, strengthening accountability, involving stake holders and strictly followed the eHealth strategy (Figure 12) is vitally important.

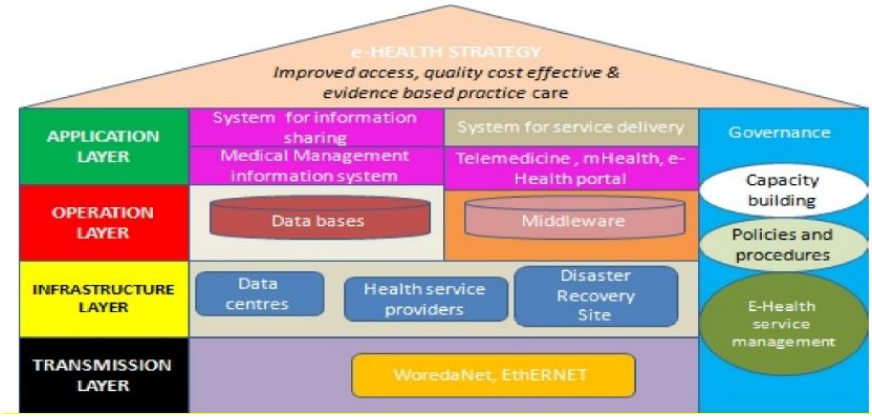

Figure 1: FMoH Ethiopia eHealth Strategy

2.2.2. mHealth In Ethiopia and related works

To date, it's estimated that there are roughly 2.16 billion smartphone users in the market globally [2]. A full 64% of all mobile phone users can now be found in the developing world [14]. This growing ubiquity of mobile phones is a central element in the promise of mobile technologies for health. Health programs are taking advantage of the opportunity of the mobile communication revolution to strengthen health systems to maximize program outcomes. Use of m-Health can improve the efficiency of a program Management Information System by minimizing the time required to collect data from remote program areas, converting data into information, and making it available to program managers for actions.

In Ethiopia the use of mHealth for strengthening the health systems is promising, because an extensive mobile network that reaches 85% of the population and provides web access which allows very efficient transmission of data [2]. There have been many small scale mHealth projects run institutional based for a short period of time, reports shows that some initiatives were successful in meeting the organization need. JSI research and training institute Inc. through Bill and Melinda Gates foundation funded project L10k have implemented a successful mHelath initiative focusing on maternal and newborn health in four regions of fifteen districts from June to December 2012 [13].

The system was developed by adapting EpiSurveyor, a web-based mHealth platform developed by DataDyne (https//www.episurveyor.org). The system aim was to support the project M&E system through supportive supervision and it was mainly focused on to measure the contribution of community-based strategies by completing mobile based questions for HEWs, pregnant women and recent mothers in the community [13]. The EpiSurveyor platform includes a data analysis tool that allows end users to analyze the data uploaded on the server. Thus, the time between data collection from remote areas and the time taken for programmatic action is drastically reduced.

A text-based mHealth project implemented as a pilot by Clinton Health Access Initiative called “Enat Messenger System” was executed in two regions of Ethiopia from January 2011 to September 2012 [31]. The system runs text-based confirmation and transmission services via an automated message manager. The system consists of a server, modem, Nokia 2700 mobile phones with solar chargers and a web-based application with a database. It was a semi-automated system which needs a data entry clerk at the health center. Each week, HEWs sent ANC data from their health post to the nearest health center via a formatted hard copy. The health center clerk entered the data (Pregnant women following ANC at the health center level) into the “Enat system” manually.

Based on the data entered, which includes last menstrual period or gestational age, the system automatically calculated the expected delivery date (EDD) and sent text message reminders to the respective HEWs one month and one week before a pregnant woman's EDD. The reminder served as a prompt for the HEW to visit the mother examination. After each visit, the HEW was expected to send an SMS confirmation back to the system to confirm the visit [31].

Cell phones and supervisory visits are helping analyze malaria trends throughout Ethiopia's Oromia region, and the related project was presented at the 61st American Society of Tropical Medicine and Hygiene annual meeting in November 2012. The presentation occurred during a U.S. Agency for International Development (USAID)-organized symposium titled, "Every Last Case: Innovations in Malaria Surveillance in Low-Income Settings."

The project is a collaborative effort led by the Ethiopian Federal Ministry of Health, the Oromia Regional Health Bureau, Tulane University School of Public Health and Tropical Medicine, USAID/President's Malaria Initiative (USAID/PMI), the Addis Continental Institute of Public Health, and MEASURE Evaluation [31]. The project was designed by using Short Message Service (SMS) or texts technology, to build on the existing reporting systems in Ethiopia and monitor malaria diagnostic, treatment, and control activities. The SMS project began in late 2009, with data collection taking place in April 2010. The project is anticipated to end in October 2013.

2.3. mHealth targets and Standards

Early in its development, in 2003, mHealth was defined as wireless telemedicine involving the use of mobile telecommunications and multimedia technologies and their integration with mobile healthcare delivery systems [12]. Since then it has come to encompass any use of mobile technology to address healthcare challenges such as access, quality, affordability, matching of resources, and behavioral norms [14]. Thus it can involve using mobile technology to improve the public health interventions a tremendous opportunity for a country like Ethiopia and communities to advance through the process of information in many forms.

The root of these benefits is the connections and exchange of information. Mobile technologies carry and process information including, coded data, text, images, audio, and video. That said, other mobile devices such as laptops and tablet computers are becoming increasingly important in mhealth [12].

The main technologies carrying m-health information are GSM, GPRS, 3G, and 4G-LTE mobile telephone networks; WiFi and WiMAX computer based technologies; and Bluetooth for short-range communications. These technologies operate on hardware networks that include mobile phones, mobile computers, tablets and remote sensors.

For successful implementation of a mHealth strategy, technical standards are required to ensure national and international compatibility, interoperability, open architecture, modularity and capacity for upgrade. Nationally adopted standards should enable the procurement and implementation of affordable, cost effective and accessible technology that complies with these standards. While internationally a wide range of eHealth standards developed by standards development organizations like ISO and CEN are available [18], there is limited work done in localization of these standards and formally adopted to Ethiopia.

The implementation of mHealth system needs to be handled with care in a formalized manner as different sectors have invested substantial resources in developing different new systems, hence constructive engagement between the Government, private and the public sector will be very important.

2.4. mHealth an Input for HIS

This review of health information systems process has shown that mHealth is one of the inputs for the FMoH collective decision making process. The HSTP HIS framework identified possible data sources with appropriate measures to ensure data security as well provisions for data confidentiality based on appropriate legislation and/or policies that aim to protect the privacy of patients and healthcare providers.

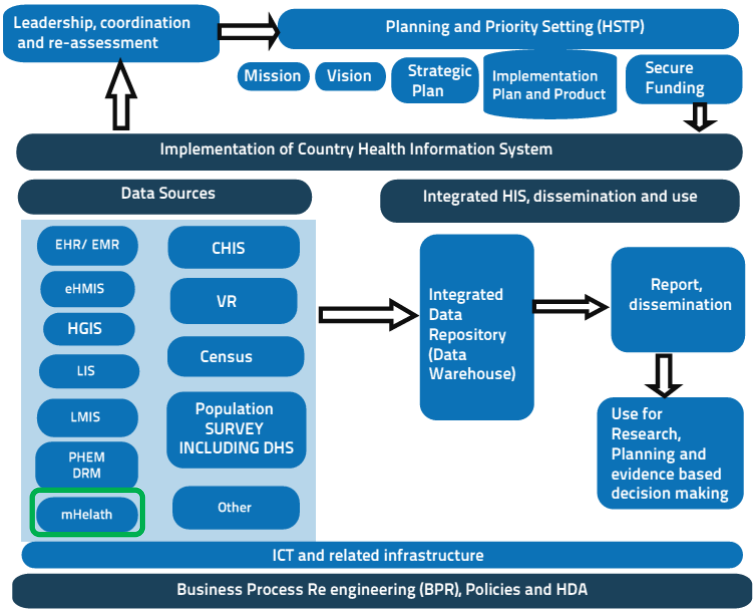

Figure 2: HSTP HIS framework

The FMoH Ethiopia [15] health sector transformation plan HIS framework Figure 1 indicates the bases of the HSTP information system development components that aimed to support the

existing monitoring and evaluation system with an effective cycle of data gathering, sharing, analysis, understanding, reporting and application in decision making process whereby data are transformed into information and knowledge for action [15]. The ministry evidence based decision making system targets to gather data from various eHealth sources and will be kept in an integrated data repository for easy access, triangulation and made accessible to all stakeholders, so that self-generated reports and analytical reports will be produced by responsible agencies and disseminated. mHelath is listed as one of the data source and to get the best result of this important data source the researcher found important the need of implementation framework.

2.5. mHelath initiative in Ethiopia

According to The federal democratic republic of Ethiopia, HSTP [15] Telecommunication is a central infrastructure in the implementation of eHealth programs. Without addressing the telecommunication infrastructural issues, it will be virtually difficult to realize the goal of e-Health implementation. The Government of Ethiopia as part of the ICT4D process is currently implementing a number of major projects and initiatives including the SchoolNet, WoredaNet, AgriNet, EthERNet, rural connectivity and the E-government program. It is also stated that Ethiopia is performing massive electrification that includes the rural electrification program which aims to increase the number of towns and rural villages which have access to electric power from 648 to 6,000. In addition to this the FMoH has mobilized resources and performed electrification of 400 Health Centers and 1,654 Health Posts through PV sola and planned 900Health Centers and 13,000 Health Posts in the year 2014/2015. Necessary ICT hardware that includes computation devices such as computers, Servers, Laptops, Tablets, Mobiles, Scanner, GPS handheld and other related accessories have been made available to all levels [15]. Therefore these environment become favorable for eHealth system implementation specially mhealth.

Though there is no stated mobile health application on the HSTP the FMoH have developed various national e-health applications; electronic health management information system/ Public Health Emergency, Electronic medical record/ electronic health record, community health management information system, human resource information system, Intigrated Financial Management Information System, are under implementation in different parts of the country. Laboratory information system, hub Store IS, drug dispending, CBHIS, Achieving/indexing IS, Fleet MIS, Stock MIS, are also developed and waiting a full scale implementation.

There are encouraging government policies and strategies that create favorable opportunities for eHealth implementation in Ethiopia [4]. In the past five years the government of Ethiopia

revised ICT & Health Policy, Educational Curriculum with IT embedded syllabus and a great human resource improvement have shown in the field of ICT [24].

2.6. Common mHelath initiative

In many African countries are using mobile technology to address health needs. The mHealth field is remarkably dynamic, and the range of applications being designed is constantly expanding [19]. The key applications for mHealth in many countries are:

- Education and awareness
- Remote data collection
- Remote monitoring
- Communication and training for healthcare workers
- Disease and epidemic outbreak tracking
- Diagnostic and treatment support

According to WHO, ITU [19] report mHealth programs are more prevalent in some countries than others for reasons that have not yet been assessed by the academic literature. In particular, India, South Africa, Uganda, Peru, and Rwanda stand out for their level of mHealth activity. However mHealth programs are gaining strong support in many countries, as well as sectors as diverse as governments, technology providers and academia.

Mobile phones in Public Health intervention together with activities to improve health outcomes need demanding efforts to reduce the digital divide. Regarding the digital divide, the world has witnessed significant increases in the numbers of internet users as well as mobile and fixed-line telephone subscribers in the past five years [21]. It is at the cross section of health and technological domains that eHealth initiatives have evolved, creating an unprecedented opportunity to improve access to services and efficiency within the health sector in low and middle income countries. Electronic health is broadly defined by the World Health Organization as the “use of information and communication technology for health” [2].

The increasing availability of free and open source software will more affordably extend the benefits of a broad range of higher quality targeted mHealth solutions to low and middle income countries [17]. In Ethiopia many organizations have benefited from this resource.

According to Gashaw Lulie [23], the use of mobile devices in low and middle income countries like Ethiopia is become improving and Ethiopia has been showing improvement over the past five years in the infrastructure development. There are various pilot projects where mobile devices are being used to collect health data, facilitate Telemedicine, provide health messages to clients, follow-up children and women to reduce drop-out from service, manage logistics to reduce stock-outs [23][1]. The implementation of mHelath to supervise the health service

delivery and conduct routine activity tracking by form based mobile systems is identified as a gap.

Based on WHO, ITU [19] report the analysis of four aspects of mHealth: adoption of initiatives, types of initiatives, status of evaluation, and barriers to implementation. Fourteen categories of mHealth services were surveyed. The survey has found that mHealth initiatives have been established in many countries, but there is variation in implementation levels. The most common activity was the creation of health call centers, which respond to patient inquiries using SMS for appointment reminders, using telemedicine, accessing patient records, measuring treatment compliance, raising health awareness, monitoring patients, and physician decision support . Africa had the lowest rate of mHealth adoption while North America, South America, and Southeast Asia showed the highest implementation levels. A number of countries have initiatives in the pilot stage or have informal activities that are underway. This implies that Ethiopia needs mhealth system implementation framework to support and augment the mobile system implementation at all level.

2.7 Gaps found in the literature

Since mobile systems have been introduced in many organizations for different health care system delivery projects, we are motivated to draw our requirements from the literature and researcher experience in the area for a way to improve the reporting mechanism using the advantage from newer technologies based on mobile technology. Despite of several institutional based mHealth initiatives have been observed to augment the health care service delivery challenges using mobile technology, the demand for improvement in implementation technique is vital. The introduction of newer technologies opens new opportunities of improvement. The following are the gaps found in the previous way of mHealth application and technology selection and identifying target users.

Gap 1: There is fragmentation of mHealth system due to un-coordination between different organizations and implementation technique [22].

Gap 2: The current IRS implementation supervision isn't supported by mobile technology and there is a need of mobile application.

Chapter 3: Methodology

3.1. Study Period and Coverage

Research methodology is defined as general guideline for solving a problem or systematic way of solving a problem through design of novel solution [15]. There are different kinds of research approaches; these include qualitative approach, quantitative approach, design science approach and mixed approach (a mixture of qualitative methods and quantitative methods).

In this study, a combination of (design and creation and qualitative study) methods have been used because of the nature our research questions that require multiple methods to get them answered. Combining methods offers great promise on flexibility of the research and draw strengths from multiple methods and therefore allow the research to answer broader questions that are not confined to only one method [12]. We performed a literature review, design and creation and finally we conducted a qualitative study to evaluate the results of our creation.

The participants of this study were selected by the criteria of being the supervisor for the IRS implementation at the district and with the assumption that they have some knowledge of smart phone use. Therefore we targeted all senior supervisors in the selected districts. We found contacts of the participants through the zonal health office and researcher colleagues. The participants were from Oromia regional state Jimma zone five districts (Kersa, Sokoru, Omonada, Tiro Afeta and Seka Chekorsa). However all of the contacted people were directly working with health system and had knowledge of how IRS and other health systems supervision work. The study was conducted from July 2016 to April 2017 in Ethiopia and focused on mobile Health initiatives.

Due to the fact that a mobile and ubiquity is an emerging field, many researchers have been devoted to conduct studies in various application areas. Although a lot of research is done in Ethiopia to show the mHealth progress it is not appropriate to address mhealth problems, because resources are scarce and shared by small community [1]. We performed a literature review to gain an understanding of the challenges of paper based and mobile based health related supervisions. Thereafter we put our literature review focus on the mobile technologies and available open source frameworks that can be used to improve public health interventions supervision and reporting process by districts.

The process of reviewing literature started with searching the literature from several digital libraries such as Google scholar, Science direct and ACM library by using the keywords which was extracted from the research goals. The keywords used in our search were “Mobile technology”, “mobile Data collection and reporting”, “Mobile Health in Ethiopia”, “Open source frameworks”, “Health data”, “Health information system in Ethiopia” and “Electronic Health care system”. We then assessed the found literature by going through the abstract and the

conclusion parts to see if they suit our study. We also use “reference follow up” technique to obtain the materials which were referenced in the found literature; this helped to expand our understanding by getting more explanations on the reviewed concepts. The priority for reviewing articles of the same concept was given to the latest published articles to ensure that knowledge of the state of art is gained. Finally we read and record the review of the concepts from each of the selected literature. The sources of materials reviewed are mostly academic papers, government policy briefs, books and technical reports.

3.2. IRS organizational structure and roles

As shown below there is one district level IRS coordinator and there might be one up to five team leaders under his supervision. One team leader might have three to four squads under his supervision and a squad leader will have four spray operators and one porter as a supervisee. Each district will be organized in this manner to conduct IRS for some period of time in a year. Except the team leaders and district coordinator most of the time others are daily casual workers employed for the activity sometimes community volunteers are involved as a spray operator.

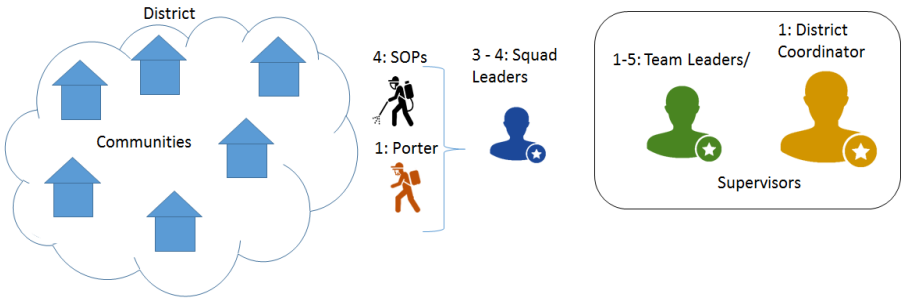

Figure 3: District Level IRS organization and target prototype users

All the supervision and coordination is managed by the district coordinator (resource monitoring, quality control/ supervision and monitor IRS progress) and the team leaders will also be responsible for all activities to be acomplished by their superisees (quality control/ supervision, covering all the targeted villags, maintaining the daily expected output per squad and check materials in each spray operator cutody). Squad leaders are the primary superisors of spray operators and porters and they are the one who tregister all the sprayed houses on the daily reporting format. Based on this information we develop a mobile based supervision system to be used by the two supervisors (Team leader and District Coordinator as shown above.

3.3. Human resource allocated for 2016 IRS

The districts in collaboration with the zonal IRS experts plan all the logistics and the human resource needed for the implementation of IRS in respective districts. Below (Table 1) shows the planed kebeles/communities and the human resource needed for 2016 IRS campaign. Out of the personnel's needed for the activity supervisor's account 5%. According to prior target to conduct the assessment and test the prototype on district, we implement the survey for all individuals who have a supervisory role. All are from the sampled five districts.

Zone	District	# of kebeles	SOP	SQL	Porters	Supervisors / Team Leaders	MFP	Total HR
Jimma	Sekoru	18	45	11	11	3	1	71
	Omo Nada	16	75	19	19	5	1	119
	Tiro Afeta	17	55	14	14	4	1	88
	Seka Chekorsa	14	51	13	13	3	1	81
	Kersa	20	80	40	20	5	1	146
Total		85	306	97	77	20	5	505

Table 1: Human resource allocated for 2016 IRS under study districts

3.4. Design and creation

The nature of this study is to design a prototype for mobile health supervision and reporting for a malaria prevention intervention, indoor residual spraying. This follows a design and creation approach, an attempt to create things that serve human dedications; it is technology oriented. Based on Deo Shao [17] activities like build, evaluate, theorize and justify are the core concepts to develop mHealth applications. In this study we followed this framework to properly conceptualize and represent all the techniques to the solution. The activities are building and evaluating the installation of the prototype for mobile based IRS supervision.

The procedure of developing a prototype started by studying the existing android based open source application platforms that suit the IRS supervision and reporting system implementation. CommCare framework have thoroughly studied and thereafter followed by design of custom functionalities for mobile based supervision and reporting.

The process of designing the proposed prototype followed all steps of a prototyping model [17]. We started by identifying the users through a real case scenario of the IRS implementation supervision and reporting systems at the district level. We identified the requirements of the users through document review, questioning the users and also using author experience on the

health system. The prototype was then developed through a series of customizing, testing and debugging of the source code to suit IRS supervision. The prototype has tested by users in the actual environment. We evaluated the prototype through questionnaire by asking the users at the district about functionality and feasibility of the prototype in their IRS implementation.

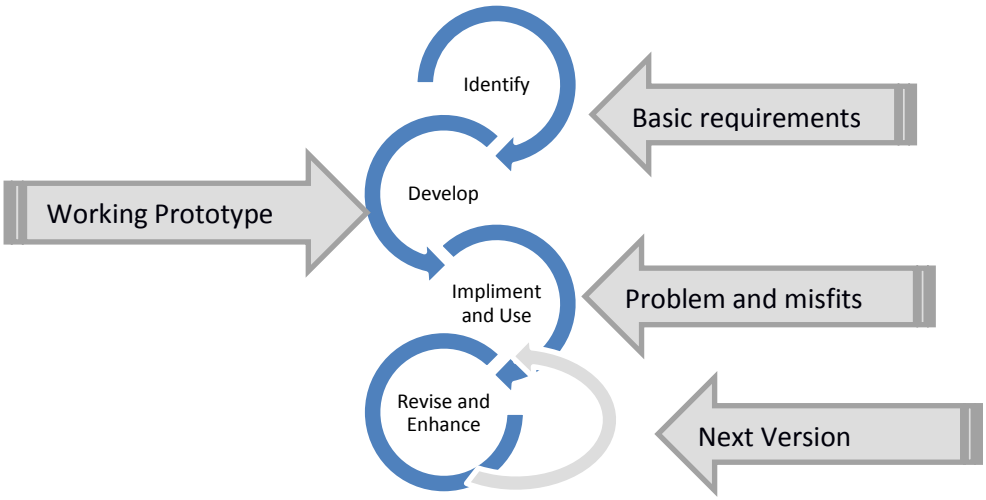

Figure 4: Prototype development cycle [17]

3.5. Evaluation study

There are different ways in which information technology products can be evaluated, the ways are functionality, completeness, usability, consistency, accuracy, performance, reliability and how it fit with the context. The evaluation process of this study aimed to evaluate the functionality and usability of the proposed prototype through a semi structured questioner. The evaluation results helped us to reveal the challenges of the mobile based supervision methods and also pin point the user's suggestions that could be used for improving the prototype in future.

3.6. Planning and preparation of the evaluation

The execution of the evaluation study started with planning and formulation of questions that assess the current situation of IRS implementation specially supervision and possibility of improving the situation through mobile technology. The main objective was to evaluate the feasibility of the proposed prototype implementation at the districts. Out of the evaluation techniques, we use an observational study with the actual users of the prototype and a questionnaire that included the description of the prototype to help respondents to get knowledge of the prototype before answering the questions. The questionnaire was divided into four sections; the first section presented the background demographic questions about the respondent information and. The second and third sections presented general IRS implementation related questions including the geographical coverage frequency of IRS, human resource and existing supervision system questions that aimed to understand the challenges of

IRS regarding supervision and reporting and assess feasibility of mobile applications for IRS supervision. The fourth section presented a set of questions that aimed to evaluate the new proposed prototype. The questionnaire is presented in Annex I. Based on (Table 1) the human resource plan by under study districts as a supervisor the prototype evaluation focus on those personnel's. All users got two hour training before they use the system and a short description with screenshots of the proposed prototype have been given to familiarize the respondents with the main objective of the prototype and its functionality.

3.7. Data Collection Procedures

As part of quantitative data collection method, a self-administered questionnaire survey was used; before the data collection was commenced, the data collectors were given detail training and orientation and they were supervised by the researcher while collecting data. After collection of data was over, questionnaires with missed values and inconsistency were rejected. A detailed structured observation checklist were intended to elicit the participant's thoughts on their challenges IRS supervision and documentation system challenges, lessons learnt and success factors. After quantitative data collection completed, data entry, cleaning, and analysis was made using MS Excel 2010 and SPSS 20 version.

3.8. Data Analysis Procedure

Frequency tables were used for the descriptive analysis. For the data presentation, different tables were employed. Responses to the evaluation qualitative data were organized based on the category.

Chapter 4: Design/Implementation/Experimental Results

4.1. A prototype for mobile based supervision and reporting

This chapter present the proposed prototype with basic information's collected from the users during assessment, literature review and the set-up of how IRS supervision and reporting systems work for IRS based on the previous experience of the researcher in the area.

4.2. Open source frameworks

There exist several mobile based open source framework projects that seek to improve the data collection, process, reporting and documentation. A number of data collection toolkits have been developed and released under general public license.These frameworks have a large community developer and reviewers support worldwide that share source code and improve them. Based on Deo Shao [17] assesment of open source platforms there are seven SMS based and electronic form based data collection frameworks which have been used in various scenarios of data collection. We review these frameworks and compare with one aditional open source platform in the following subsections.

Based on the literature review and researcher assesement of eight frameworks shown below (Table 2), we selected Commcare framework backed with the Android platform. The reason for this selection is motivated by the features such as unlimited capability of capturing data of all types and openness of its source code. In budget-limited settings such as at lowe level of admintration (District/Zone), open source technology solutions could be more relevant.

Tool	License type	Data type collected	Handset support	Network protocol supported	Data storage
Eapid SMS	Open source	Test (SMS)	Basic Phones	GSM (SMS)	Local Storage
Frontline SMS	Open Source	Text (SMS)	Basic Phones	GSM(SMS)	Local Storage
Open X Data	Open source	Text, Images, Video, audio and GPS	Java Phones	GSM (SMS), GPRS (WAP), Bluetooth	Hosted Storage
Open Data Kit	Open Source	Text, Images, Video, audio and GPS, Barcode	Android	GPRS, Wi-Fi	Hosted Storage
Nokia Data Gathering	Open Source	Text, Image, Video, Audio, GPS	Nokia Phone (Java enabled)	GPRS, Wi-Fi	Local Storage
Java Rosa	Open Source	Limited by handset and network	Java enabled phones	GPRS	Local and hosted Storage
EpiCollect	Open Source	Text, Images, GPS	Android, iPhone	GPRS, 3G, Wi-Fi	Hosted Storage
CommCare	Open Source	Text, Images, Video, Audio, multimedia, GPS, Barcode	Android, J2ME, Web, Windows	GSM, GPRS, 3G, Wi-Fi	Local and Hosted Storage

Table 2: Comparison of mHealth platforms

4.3. CommCare Technology platform

CommCare is an opensource mHealth platform designed for data collection, client management, decision support, and behavior change communication [21]. CommCare can support a large numbers of users and provides performance management to create actionable insight from collected data. This platform takes full advantage of mobile infrastructure and capability, from text entry to photo capture and integration with GPS.

The android based CommCare framework includes a feature-rich mobile application, data reporting tools, and an application-building platform through an online portal called CommCareHQ (www.commcarehq.org). CommCareHQ allows users to open an account, register new users, customize a CommCare mobile application for the project, and download the application onto the phones. then users can log into the mobile application to submit data in real-time to CommCareHQ, where it is privacy-protected, backed up, and immediately made accessible to supervisors and program managers through automated, pre-planned reporting and data exports.

All mobile versions allow applications to run offline and collected data can be transmitted to a cloud server when wireless network GPRS, 3G or WiFi internet connectivity becomes available. CommCare mobile includes two-way data synchronization with CommCareHQ and is equipped to restore a user's data in case of phone damage or loss. Multiple modules and forms can be deployed to devices, which enable a single CommCare application to serve various needs [21].

CommCareHQ is the cloud-based server user friendly application for building mobile applications, submitting forms, managing users, and viewing data analytics. Literatures [21] states that Dimagi's CommCare Exchange is the first open-licensed "app store" for mobile health and allows organization to access pre-built applications from previous projects. In addition to the mobile application, CommCare suports computer based entry tool called CloudCare. CloudCare provides a web-accessible slim version of the application, where users can input data from any wher.

Figure 5: CommCare Data flow [22]

Regarding the reporting module CommCareHQ generates many pre-canned reports to provide actionable insights for supervisors. These reports which include form submissions, form completion times, and individual activity aggregate data and carry out automated performance analytics to identify strengths and weaknesses of individuals who are part of the program, which enables better supervision and mentoring. These reports can be viewed online or configured to send as automated emails on several different available schedules. Additionaly all of the data submitted to CommCareHQ can be either downloaded (to either CSV or Excel file types) or accessed through a CommCare API to be forwarded to another server application [22].

4.4. Design of the proposed prototype

From the gaps identified through investigation and literature review about IRS implementation, supervision and reporting system, we are motivated to design a prototype for IRS supervision and reporting by using opensource frameworks alongside newer technologies. The aim is not only to bridge the gaps but also to test the newer technologies in solving public health problems. The specific target that this study attempt to hit is enhancing the supervision and and reporting of IRS operation among the supervisory team in the district and beyond. We attempt to bridge the information gap between supervisors to allow sharing on findings during supervision, gaps identification and documentaion and consistency in reporting the outcomes.

4.5. Functional Requirement

Functional requirements are the specific statement of service that defines how the system should react to particular inputs and how it should behave in particular situations. In this section we present these statements of functionalities which correspond to the need assesement collected during document review at the district and literature review.

1. The prototype shall provide action points for any redflag identified during supervision.

   Motivation: The action points help the supervisors to get basic clue to correct the gaps identified, the feedback to be given to IRS implementers will be the same and it helps the program to run as per the national standard.

2. The pre-designed forms in the application should accommodate all supervision checkllists with the ability of GPS feature of the mobile system.

   Motivation: Usability, portability and ability to store different size data are the key features that qualify mobile phones in using for decesion making system from remote areas and where geo taging is imprtant to monitor the coverage of the intervention. The proposed prototype will provide a way of addressing the needs through mobile phones using pre-designed forms and offer a feature to capture the geo coordinate of the supervisor.

4.6. Non Functional Requirements

In this section we describe and explain the need of some non functional requirements of the prototype the statements will help understanding of the pattern and development process of the proposed prototype. Non functional requirements are the system quality related statements that define the constraints on the services offered by the system (17).

Availability: The mobile health data collection prototype shall operate in Android mobile device. A web application shall operate in any HTML enabled web browser of a computer or mobile phone.

Motivation: Android framework as stated earlier is the underlying platform that has been used to develop the proposed prototype; therefore we are limited to Android enabled devices and HTML browsers for web application interfaces.

Security: The mobile health data collection prototype shall provide access to only authorized users with username and password authentication method.

Motivation: Security is an important aspect of any information system. Users of the proposed prototype will be registered in a web server and authenticated using username and password when they want to have access to server services such as downloading blank forms from the server and sending finalized forms to the server.

Usability: The mobile health IRS supervision decesion support prototype shall be easy to use and not require special computer skills.

Motivation: Mobile phones are nowadays common devices and are used by many people without any technical skills. The proposed prototype shall be easy to use as it will stand as other mobile applications. There will be an introduction of the electronic forms with discriptive labels to guide users on what and where to fill data including the data types.

4.7. Prototype development

The prototype development started based on the assesment, functional and non functional requirements stated above, in designing of the proposed prototype, we have made decision on the technologies, either develop ofline on excel template and upload to commcareHQ or use the online version of form development by using the interactive tools and controls. However due to the fact that we developed this prototype on top of the CommCare framework, we prefer to use the default application development option which is the online form development tool, that helps instant testing of the controls fllow and validity.

4.7.1. Architecture of the prototype

In the development of the prototype, we used an Android version of CommCare framework. The module and forms are created directly on the CommCare form developer interface and a customized code and validation have defined for each control as necessary. The prototype was tested in a both Android virtual device and real device. To install the prototype in a real Android device first we downloaded the CommCare platform executable file (.apk file) from Google play store and use the application barcode or text code to install the application from the project folder. In this study we have tested the prototype in two phoned Huawei Ascend Y511 and TECNO C7 smart mobile phones.

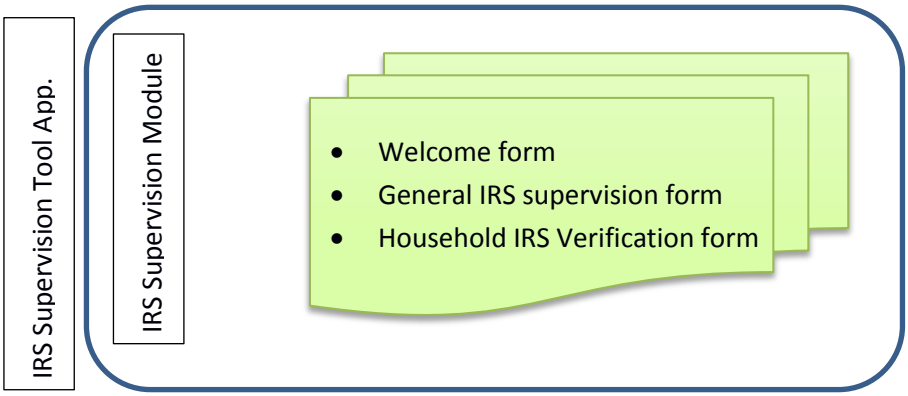

Figure 6: General architecture of proposed Prototype

The prototype consists of a compund module with three independent forms. These are (IRS supervision Tool, Welcome form, General IRS supervision form and Household IRS Verification form.

4.7.2. Prototype documentation

Login Form: This is the default verification by CommCare platform, Login form consists of user name to identify the user and password text box to authenticate which enables the user to login to the system. Log in button execute the given username and password. Any user whose crediteials defind in CommCareHQ can login and use the application.

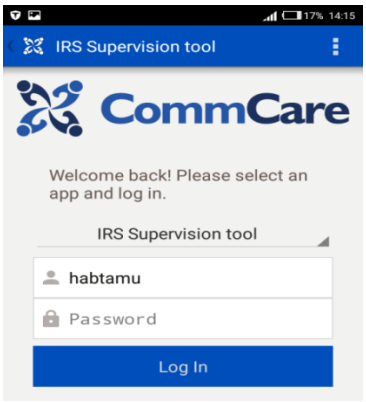

Figure 7: Login Form

CommCare Main screen: Once a user is autenticated and entered to the system the following main form with four ComCare default control modules which contains links to perform different operations on forms. The operations include, getting in to the application, compliting previously saved forms and sending finalized report forms to the server**.**

Figure 8: CommCare platform Home Screen

Start: This is where you enter the application and access the forms.

Incomplete: If you are unable to complete a form at any time you can click on this control and see the list of incomplete forms. You can select one of these forms and complete it at any time.

Sync with Server: This is a control that helps to synchronize the phone with the server then the forms complited and saved on the phone will be transferred to the server. If the phone is connected via data or wifi it will happen automatically, otherwise it is possible to sync manually when there is a connection.

Log out of Commcare: Log out of the application, return to the login form.

Supervision checklists: as shown bellow (Figure 8) there are three forms in the proposed prototype, the blue icon “Welcome” form is an introduction and a brief explanation of how to

use the application controls and navigation. The other two forms with a pencel icon are the supervision checklists developed to augment the IRS operation.

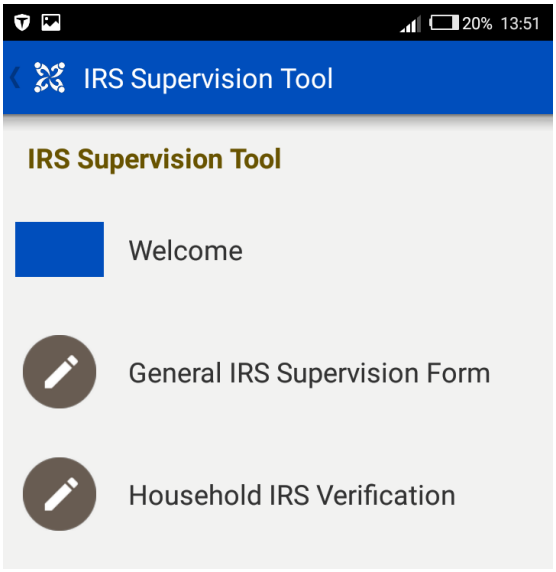

Figure 9: Screenshot of the forms (supervision checklists and a welcome introduction)

Supervision Checklists: in the proposed prototype there are different kinds of data types, (Date, Geo Coordinate, text, number and Photo). The flexibility of the form design allows the prototype to work with various datatypes. Terminologies used to label the datasets in the form are taken from the sample form reviewed during the study and district experts suggestions to integrate different supervision checklists. The flexibility on terminologies used in supervision forms for questioning and actions to be taken allows easy way of setting uniformity of feedbacks and corrective measures. Which increase coordination and understandig of different levels of supervisors. Therefore, the proposed prototype may be used to other inervention of various types depending on the demand. Figure 9 shows the sample form display in a mobile phone.

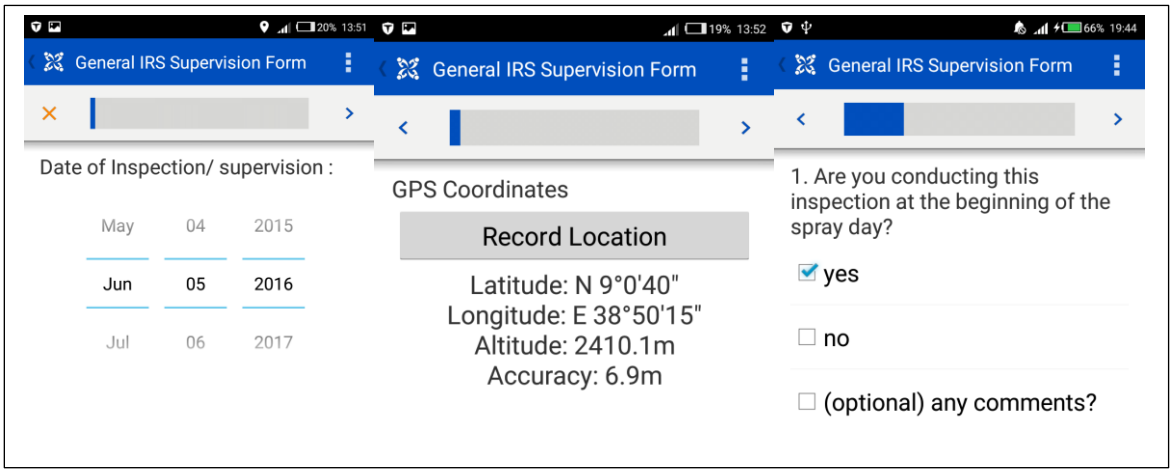

Figure 10: Sample supervision questions

CommCareHQ: The main web based dashboard of CommCare at (https://www.commcarehq.org) is web application that provides interfaces to manage application forms and the collected data. The operations include application development, report setup, users management and setting up project level configurations. Furthermore, collected data can be exported to Comma Separated Values (CSV) format and visualized in other applications such as MS excel.

Figure 11: CommCareHQ Dashboard

Applications: All applications in a given project are listed here; developers can navigate from project to project to update build and deploy applications.

Reports: This control helps to develop a customized report based on the application content and provides different options to visualize the contents.

Data: Export and manage data, scheduled customized reports are configured and programed in this module

Users: Manage accounts for mobile and CommcareHQ users, details of the individual users (username and passwords) are defined here

Exchange: The CommCare Exchange (https://www.commcarehq.org/exchange/) is a way for CommCare users to share their applications with the CommCare community. It's like the Apple "app store" or the Google "play" marketplace, only all the apps are free.

Settings: Set project wide settings like time zone, privacy and security and manage subscriptions, CommCare have a paid service with a more advanced features

Help Site: This will direct to CommCare's knowledge hub, where all the details about the platform and a well-organized introduction on how to get started application development are explained and arranged by category.

Figure 12 below shows a screenshot of web form interface in CommCareHQ. This web interface can be accessed through any web browsers. We have tested this application in both computer and phone browsers. The phone HTML browser seems to have not comfortable on the visualization of contents because of the screen size.

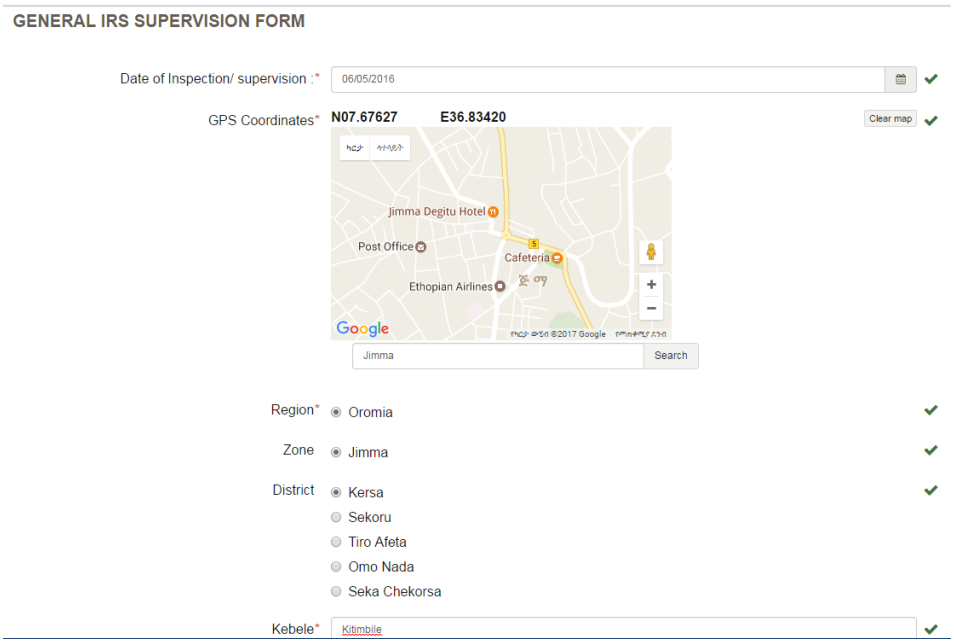

Figure 12: CommCare Web version interface for supervision

Chapter 5: Proposed framework

5.1. Developing mHealth implementation framework for IRS

Technology adoption is one of the dominant research areas in the field of information systems. However, given that adoption is a post-implementation behavior, poor system implementation strategies consequently lead to poor adoption [28]. According to Stephen Mburu & et al., failure to consider critical factors prior to implementation of a system leads to failure of the system.

Experiences on mHealth adoption should be a learning point for subsequent mHealth projects to put into place effective deployment approaches. One possible way of addressing fundamental mHealth deployment challenges is a multidimensional approach that integrates principles of socio-cognitive theories into design science [28].

Therefore, against the background of multiple systems challenges identified in the literature and considering Ethiopian organizational challenges, we identified the need for a framework with a more explicit focus on the health system dimensions of implementing mHealth. FMoh Ethiopia [4], 2011, stated the need of mHealth system implementation framework that will move Ethiopia toward mHealth interventions that make an impact on health outcomes. Based on the components in the above literature and input from qualitative data we developed a mobile health systems implementation framework to guide our reflection on the potential challenges of scaling up mHealth for the monitoring and evaluation of IRS based on the current demand. The proposed framework uses the concept of Alain B Labriqueais & et.al, 2013, conceptual definition of how mHealth projects become successful.

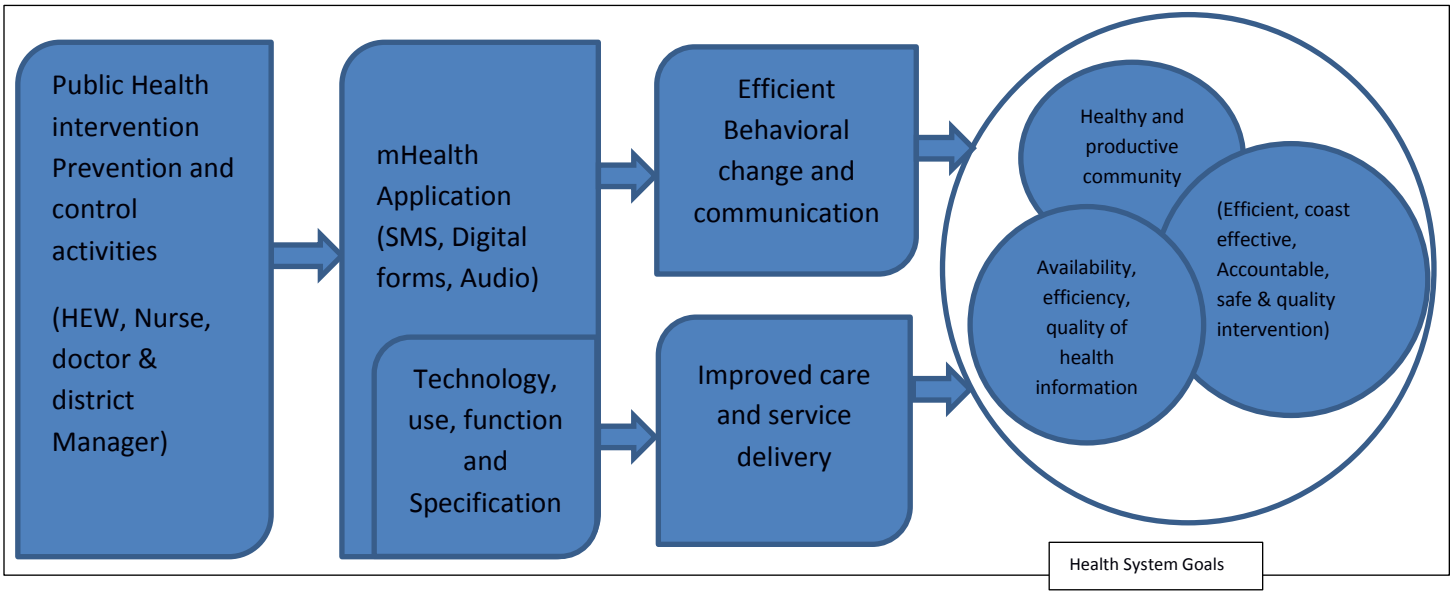

Figure 13: Proposed mHealth Implementation Framework

Based on literature review, in Ethiopia the use of mhealth system isn't supported by a defined implementation framework and most of mHealth initiatives target the use of simple SMS based approach. The proposed framework Figure 13 illustrates the abstraction of interconnection between the health service intervention, the need of mHealth and expected outcome. According to Alain B Labriquea et al. [27] conceptual definition, applying a health systems lens to the evaluation of mHealth initiatives requires different indicators and methodologies, shifting the assessment from whether the mHealth initiative "works" to process evaluation or proxy indicators of the health outcome(s) of interest. This new way of thinking would facilitate selection of mHealth tools that are appropriate for identifying and overcome implementation challenges.

Based on this particular study the framework would drive people to first identify the key obstacles, or constraints, to delivering proven health interventions effectively, and to then apply appropriate mHealth strategies that could overcome these health system constraints. Presenting mHealth as a range of tools for overcoming known health system constraints, as a health systems promoter, may also improve communication between mHealth innovators and health program implementers. Hence, rather than sticking on stand-alone solutions, mHealth strategies should be viewed as integral systems that should fit into existing health system functions and complement the health system goals of: health service provision; a well-performing health workforce; a functioning health information system; cost-effective use of medical products, vaccines, and technologies; and accountability and governance [27].

Chapter 6: Data Analysis and Summary

6.1. Demographic characteristics of respondents

One hundred seventeen questionnaires were distributed and one hundred eleven were returned. Among returned questionnaires, one discarded because of inconsistent and overlooked values. Thus, the remaining one hundred ten were used for analysis purpose of this study.

The majority, 108 (98.2%), of the respondents were government employees of health professionals, regarding the qualification of respondents all are health professionals working in different departments of the health office and facilities. The educational background of respondent's ranges from diploma to second degree were the majority, n=102 (92.7%) was accounted for diploma and first degree holders. More than half of the respondents, 68 (61.8%), were serving the government institution between 1 and 5years. Most of health workers n=90 (82%) replayed for the questioner serve the operation as squad leader.

Source of participants (n=110)	**Frequency**	**%**
Permanent Government employees	**108**	**98.2**
Seasonal Temporary workers	**2**	**1.8**
		100
Position of respondent for IRS (n=110)	**Frequency**	**%**
Squad Leaders	**90**	**82**
District level Supervisors	**20**	**18**
		100
Educational background of Respondent's (n=110)	**Frequency**	**%**
Diploma	**92**	**83.6**
1st degree	**10**	**9.1**
2nd degree and above	**8**	**7.3**
		100
Respondent service year(n=110)	**Frequency**	**%**
Less than 1 year	**13**	**11.8**
Between 1 and 5 years	**55**	**50.0**
Between 5 to 10 years	**28**	**25.4**
10 and more than 10 years	**14**	**12.7**

Table 3: Socio Demographic Characteristics of the Respondents

IRS operation demand very high commitment from the human side and logistics to get the best out of it and to integrate the two resources supervision is vital, based on entomological studies result in Ethiopia there are two main malaria transition seasons i.e. after the main rainy season (October to November) and the minor transition season between (February and march), hence to tackle the malaria transmission IRS is mostly conducted by considering the start and end of the rainy season hence mostly IRS operation conducted during the rainy season to use the

residual effect of the insecticide used for the high transmission season. From the sampled districts 100% (n=5) has one round of IRS operation and the kebeles targeted for the operation range from 14 to 20. Because of the seasonality of malaria transmission the IRS operation is always have a bounded time frame which ranged from one to two months.

6.2. IRS background information

Table 6 below depicts the districts IRS background and supervision experience, the respondents of this specific section are senior district supervisors

No	Question	Answer	Frequency (n=20)	Remark
201	How many IRS rounds do you perform per year	One round; 100%,	20	
202	How many kebeles are targeted for IRS	Sekoru = 18		
		Omo Nada = 16		
		Tiro Afeta = 17		
		Seka Chekorsa = 14		
		Kersa = 20		
		85 Kebeles		
203	How long does IRS take to complete? (in weeks)	4 - 8 Weeks	20	Budget constraint
204	How many personnel are involved? (in total)	84 - 170		depending on the target
205	How many supervisors are involved during IRS?	4 - 6 Experts		
206	Do you have standardized IRS monitoring /Supervision tool?	Yes; 100%	20	
207	If yes for Q 206 is there any way to see the status of a supervisor in completing his/her assignment?	No; 95%	19	
		Yes; 5%	1	
208	If yes for Q 206 Any automated system in place for supervision?	No; 100%	20	
209	If yes for Q 206 Does the existing IRS monitoring procedure have defined reporting channel?	Yes; 90%	18	
		No; 10%	2	
210	If yes for Q 206Is there any way of aggregating the supervision results?	No; 100%	20	
211	How likely do you have access to the other supervisors' supervision status/result?	1; 25%	5	
		2; 65%	13	
		3; 10%	2	
		4; 0%	0	
		5; 0%	0	Not seen

212	How do you rate your challenge in this regard	1	0	
		2	0	
		3	0	
		4	0	
		5; 100%	20	
213	If yes for Q206 Do you have a documentation system for the tools?	No; 95%	19	
		Yes; 5%	1	
214	If yes for Q213 how many years document do you have?	1 year	20	
215	How likely do you share your supervision result for others? (1--5)	1; 95%	19	
		2; 5%	1	
		3; 0%		
		4; 0%		
		5; 0%		

Table 4: District IRS Implementation summary

6.3. IRS team organization and Supervisors

To accomplish the IRS operation on targeted areas on time the district team required to hire additional seasonal personnel's 80 – 100 personnel's depending on the budget and the geographical area to be covered to assist the regular government officials and to coordinate the overall operational activities 4 -6 district level supervisors were deployed fulltime through the course of the operation. As showed below in table 5 the supervisors from the district assigned for unmanageable number of seasonal workers.

Zone	District	Number of seasonal workers	Supervisors	Average seasonal workers per supervisor
Jimma	Sekoru	67	4	17
	Omo Nada	113	6	19
	Tiro Afeta	83	5	17
	Seka Chekorsa	77	4	19
	Kersa	140	6	23

Table 5: supervisors Vs supervisee during IRS

6.4. District's IRS supervision Processes

Supervision has to be conducted in a planned manner, and districts has prepared a supervision plan for the supervisors and disseminated earlier the IRS operation commencement and the district vice head is leading the coordination together with the district malaria and NTD focal person but once the IRS operation is started everybody is going to the field to carry out the responsibility and the supervision is done based on the hard copy template and there is no way

of knowing the status of supervisors until they return to the district office after ten to fifteen days. On top of that to get lesson learned and the way forward no one is responsible to aggregate the findings of the supervision checklists because of cumulated backlogs cumbersome nature.

The access to get colleagues supervision checklist is a challenge and most of respondents 90% (n=18)rated their likely hood of seeing others checklist is 2 out of 5, and they all 100% (n=20) agree and rated 5 out of 5 this is a real challenge in IRS operation process. Regarding the documentation95% (n= 19) of the respondents they didn't document the hard copies for further reference. As the respondents rating 1 (n=20) out of 5 there is no experience of sharing supervision result to others.

No	Question	Answer : (n=20)	Frequency	Percentile
301	Does the district collect supervision checklists regularly?	No	20	100%
302	Are checklists categorized by type of activity?	Yes	20	100%
303	Do you think the existing system is enough for IRS supervision?	No	20	100%
304	Are there a clear supervision plan and easy to implement?	No	19	95%
		Don't Know	1	5%
305	Does your supervision tools revised periodically to address changes in IRS?	No	18	90%
		Don't Know	2	10%
306	How do you rate the supervision data use for decision making purpose? (1-5)	1	16	80%
		2	4	20%
		3	0	0
		4	0	0
		5	0	0
307	Is there a system in place for feedbacks and feedforward of supervision given for supervisors?	No	17	85%
		Don't Know	3	15%
308	If yes for question 307, how frequently do you get the feedback?	No	17	85%
309	Do you agree that the supervision feedbacks by your existing system are timely?	1. Strongly Agree	12	60%
		2. Agree	2	11%
		3. Disagree	4	20%
		4. Strongly Disagree	2	9%
		5. Not sure	0	0%
310	Do you agree that the supervisions done by supervisors are consistent?	1. Strongly Agree	7	35%
		2. Agree	8	40%
		3. Disagree	3	15%
		4. Strongly Disagree	0	0%
		5. Not sure	2	10%

Table 6: District's IRS supervision Processes summary

5.4. Presentation of prototype data

The findings of the study were presented in an incorporated manner of qualitative and quantitative data. The quantitative results on each outcome measure used in the assessment are reported and explored by the qualitative results. This approach in reporting the results helps in understanding the results of the study and especially that the two methods (quantitative and qualitative) were designed in such a way that the results would be complementary. Based on the summary result shown Table 7: majority of the respondents 95% agreed that the prototype is a well-organized tool that can help the IRS team to perform a successful operation, based on the application friendly interface and appropriate selection of free and open source framework it satisfies the users 100%, and they highly recommend the application to be rolled out in full scale in the future.

No	Question	Answer	Frequency (n=20)	Remark
401	Do you agree that The tool is appropriate for IRS and capture all indicators?	1. Strongly Agree	19	95%
		2. Agree	1	5%
		3. Disagree	0	0%
		4. Strongly Disagree	0	0%
		5. Not sure	0	0%
402	Do you agree that the tool is well designed and capture the existing supervision format fields?	1. Strongly Agree	19	95%
		2. Agree	1	5%
		3. Disagree	0	0%
		4. Strongly Disagree	0	0%
		5. Not sure	0	0%
403	Do you agree that The training time allocated is enough and staff able to fill out the formats?	1. Strongly Agree	18	90%
		2. Agree	1	5%
		3. Disagree	0	0%
		4. Strongly Disagree	0	0%
		5. Not sure	1	5%
404	Do you agree that the application need a special skill to complete?	1. Strongly Agree	2	10%
		2. Agree	2	10%
		3. Disagree	1	5%
		4. Strongly Disagree	15	75%
		5. Not sure	0	0%
405	Do you agree that the tool is friendly and Easy- to-Visualize?	1. Strongly Agree	18	90%
		2. Agree	2	10%
		3. Disagree	0	0%
		4. Strongly Disagree	0	0%
		5. Not sure	0	0%
406	Do you agree that the application use appropriate technology for data capturing, reporting, analysis, transfer and presentation?	1. Strongly Agree	16	80%
		2. Agree	2	10%
		3. Disagree	0	0%
		4. Strongly Disagree	0	0%
		5. Not sure	2	10%

407	Please rate your overall satisfaction with the mHealth system Implementation	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	0	0%
		4. Satisfied	3	15%
		5. Very Satisfied	17	85%
408	How satisfied are you by the mHealth application?	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	0	0%
		4. Satisfied	2	10%
		5. Very Satisfied	18	90%
409	Do you satisfied with the technical support provided when need arise?	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	1	5%
		4. Satisfied	18	90%
		5. Very Satisfied	1	5%
410	How do you rate the frequency of the application being malfunctioning/ not working as expected?	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	0	0%
		4. Satisfied	17	85%
		5. Very Satisfied	3	15%
411	How do you rate the application functions to aid your job on IRS implementation?	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	0	0%
		4. Satisfied	17	85%
		5. Very Satisfied	3	15%
412	How do you rate the application functions to aid the overall IRS implementation?	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	0	0%
		4. Satisfied	19	95%
		5. Very Satisfied	1	5%
413	Ease/ Simplicity of use buttons/Controls	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	0	0%
		4. Satisfied	0	0%
		5. Very Satisfied	20	100%
414	Speed to open the Application	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	0	0%
		4. Satisfied	16	80%
		5. Very Satisfied	4	20%
415	Design and layout of the Application	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	0	0%
		4. Satisfied	0	0%
		5. Very Satisfied	20	100%

416	Consistency and fault tolerance (Does the application run/works well at all time as expected)	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	0	0%
		4. Satisfied	1	5%
		5. Very Satisfied	19	95%
417	The ability of addressing the need of data transfer	1. Very dissatisfied	0	0%
		2. Not Satisfied	0	0%
		3. Neutral	2	10%
		4. Satisfied	2	10%
		5. Very Satisfied	16	80%

Table 7: Prototype evaluation summary

6.5. Discussion

This study revealed that the majority of respondents (80%) confirm that necessary supervision checklists have been used for many years regularly but an organized compilation and use of the supervision output wasn't practiced. A well-organized IRS monitoring and evaluation guideline have been developed by the federal ministry of health, and distributed to regions since 2014. Which consider mhelath as a sub component of the existing HIS framework. Frame-works concerning the implementation of mHealth is not available, but, the HIS framework focused on district HMIS focal person to accomplish any HIS related technology implementations. Personnel specifically assigned for HMIS system coordination has no, necessary equipment, trainings on basic mobile technology training, as well as coordination mechanisms highlighting the mhelath system were not sufficiently allocated at the district level.

Districts	General Supervision Checklist	Household IRS Supervision	All Forms
Sekoru	12	19	31
Omo Nada	20	16	36
Tiro Afeta	21	13	34
Seka Chekorsa	22	10	32
Kersa	21	20	41
Total	96	78	174

Table 8: Submitted Forms by type

According to this study majority of respondents reviled that the system has helped the IRS implementation, 90% of respondents (n=18) have satisfied by the mobile application. It is also indicate that majority of the respondents satisfied 995%) by the design, layout and consistency of being fault tolerance. Respondents also strongly agree the need of mobile health for IRS and all the features and functionalities from the host framework and application. Because of the application friendly interface and no need of computer literacy to operate a total of 174 forms have submitted by users which shows the significant acceptance and functionality of the proposed mobile system.

Chapter 7: Conclusion and Recommendation

7.1. Conclusion

The research explores and assessed mHealth initiatives regarding supporting public health interventions particularly IRS, and their implementation techniques towards the successful result. Special focus was given to the current mHealth initiatives, challenges which are associated with those initiatives, the lessons learnt and the factors that are considered for the scalability and sustainability of mHealth projects.

There are many examples of m-Health projects identified in this study, and the systems used from a simple SMS text to a well-organized smart phone and web based platforms to support patients, healthcare professionals and healthcare systems, towards to improved patient centered care and results. However, in order to realize the full potential of m-Health and to stimulate scaling up of m-Health services across Ethiopia, important barriers need to be addressed, in particular technology selection, implementation size and target users' literacy.

Generally, we may conclude that mHealth projects have a significant impact in healthcare services delivery if government commitment, collaboration, capacity building of health workers, financial support, infrastructure, Monitoring and Evaluation of projects and user-friendly system are in place.

7.2. Recommendation

Mobile technologies are proven in improving the health service and delivery process, mobile technologies allow health managers to more quickly and reliably have access to data which can help identify where there issues in the service delivery. Achieving a strong sense of ownership and empowerment among health workers is a prerequisite for a successful introduction of any mobile health program.

As a guiding principle it is essential to put the users and patient at the center of the design, development and implementation of solutions, as well as the supervisory frameworks that surround these processes. Based on the study the researchers recommend the following actions:

1. Stimulate and facilitate collaboration between Health, Telecoms and Finance sources
2. Build a common understanding and agreement on the role and socio-economic value of mobile technologies and services in addressing current healthcare challenges
3. Promote collaboration and centered all the development and implementation of accessible m-Health solutions and address device regulation, data protection and users privacy regulation.

4. Promoting interoperability and standards that enable scalability and a plug-and-play experience.
5. Sharing eHealth related policies and regulation, stimulating innovative business models allowing for funding and reimbursement of m-Health services, by means of identifying and facilitating sharing of good practices/case studies.
6. Support initiatives/projects aiming to develop and roll-out m-Health education and training programmers/campaigns for healthcare professionals and patients.

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Annex I

Questioner

Structured questioner for The Integration and Application of Mobile Technology into Malaria Control intervention, in the case of Indoor residual Spraying (IRS) operation in jimma zone of oromia region

Subject: information sheet

Greetings:

My name is HABTAMU BERHANU; currently I am a post graduate student in St Mary's University, Department of Informatics. The objective of the study is to investigate the challenges on IRS implementation, supervision and quality and how mHealth help to improve the challenges of IRS implementation regarding, supervision data collection and documentation. Finally how the proposed mobile application improves the routine IRS implementation system with respect to the above challenges, additional benefits in spray preparation, technique and stockroom performance.

For this purpose three districts are selected randomly from jimma zone of Oromia region. In each districts, individuals whose works involve in IRS planning, supervising and providing technical assistance activities (District health office staffs) are selected. And you are selected just because of your position.

Even though study is conducted for the partial fulfillment of master degree in computer science, it is believed to contribute much for the understanding of the current information system utilization for public health interventions. This in turn is hoped to give insight as to how to improve the IRS implementation by supplementing the program via mHealth applications.

You will be asked to fill a questionnaire that will help in investigating the existing system issues and the new system improvements. Your co-operation is very helpful. Your name will not be written on the questionnaire and all the information you will provide will be kept strictly confidential. You will be facing no harm by participating and you are also not obliged to answer any question you don't wish to answer. To fill the questionnaire 25-30 minutes will be required. If you wish to comment feel free to use the contact address.

Consent Form

Considering the information you get from the general information sheet, we would be thankful if you spend some time with us solving questions related to the IRS implementation.

Are you comfortable to participate in this study?

Signature: _____ Date:_____/_____/_____

- If yes, continue to next page
- If no, skip to other participant

Contact

Name: HABTAMU BERHANU

Tel: 251-911-419969

E-mail: habtamu19@gmail.com

Part one: Background Information

No	Question	Answer
101	Region	Oromia
102	Zone	Jimma
103	District	
104	Sex	
105	Age	
106	Educational level	○ Diploma ○ 1st Degree ○ 2nd and Above
107	Role/occupation in your district	
108	Year of service (In years)	
109	Year of experience in Health system/IRS	○ <1Yrs ○ 1-.5 Yrs ○ 5-10 Yrs ○ >10Yrs
110	Do you have exposure of smart phone use	○ Yes ○ No
111	If Yes for Q110; How long do you use smart phone	○ 1Yrs ○ 1-1.5 Yrs ○ 1.5-2 Yrs ○ >2Yrs
112	If Yes for Q110; How often you use smart phone	○ Occasionally ○ Daily
113	If Yes for Q110; Have you had a chance to use Mobile based supervision/ Data collection application	○ Yes ○ No
114	If Yes for Q113 is the application used for IRS?	○ Yes ○ No

Part two: Baseline information

No	Question	Answer	Remark
201	How many IRS rounds do you perform per year		
202	How many kebeles are targeted for IRS		
203	How long does IRS take to complete? (in weeks)		
204	How many personnel are involved? (in total)		
205	How many supervisors are involved during IRS?		
206	Do you have standardized IRS monitoring /Supervision tool?		
207	If yes for Q 206 is there any way to see the status of a supervisor in completing his/her assignment?		
208	If yes for Q 206 Any automated system in place for supervision?		
209	If yes for Q 206 Does the existing IRS monitoring procedure have defined reporting channel?		
210	If yes for Q 206Is there any way of aggregating the supervision results?		
211	How likely do you have access to the other supervisors' supervision status/result? (1-5)		
212	How do you rate your challenge in this regard (1-5)		

213	If yes for Q206 Do you have a documentation system for the tools?		
214	If yes for Q213 how many years document do you have?		
215	How likely do you share your supervision result for others? (1--5)		

Part three: District's IRS supervision Processes

No	Question	Answer	Remark
301	Does the district collect supervision checklists regularly?	Yes No Don't Know	
302	Are checklists categorized by type of activity?	Yes No Don't Know	
303	Do you think the existing system is enough for IRS supervision?	Yes No Don't Know	
304	Are there a clear supervision plan and easy to implement?	Yes No Don't Know	
305	Does your supervision tools revised periodically to address changes in IRS?	Yes No Don't Know	
306	How do you rate the supervision data use for decision making purpose? (1-5)		
307	Is there a system in place for feedbacks and feedforward of supervision given for supervisors?	Yes No Don't Know	
308	If yes for question 307, how frequently do you get the feedback?	Daily Weekly Biweekly Monthly	
309	Do you agree that the supervision feedbacks by your existing system are timely?	1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not sure	
310	Do you agree that the supervisions done by supervisors are consistent?	1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not sure	

Part four: mHealth system for IRS the new system

No	Question	Answer	Remark
401	Do you agree that The tool is appropriate for IRS and capture all indicators?	1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not sure	
402	Do you agree that the tool is well designed and capture the existing supervision format fields?	1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not sure	
403	Do you agree that The training time allocated is enough and staff able to fill out the formats?	1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not sure	
404	Do you agree that the application need a special skill to complete?	1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not sure	
405	Do you agree that the tool is friendly and Easy- to- Visualize?	1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not sure	
406	Do you agree that the application use appropriate technology for data capturing, reporting, analysis, transfer and presentation?	1. Strongly Agree 2. Agree 3. Disagree 4. Strongly Disagree 5. Not sure	
407	Please rate your overall satisfaction with the mHealth system Implementation	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	
408	How satisfied are you by the mHealth application?	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	
409	Do you satisfied with the technical support provided when need arise?	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	
410	How do you rate the frequency of the application being malfunctioning/ not working as expected?	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	

411	How do you rate the application functions to aid your job on IRS implementation?	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	
412	How do you rate the application functions to aid the overall IRS implementation?	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	
413	Ease/ Simplicity of use buttons/Controls	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	
414	Speed to open the Application	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	
415	Design and layout of the Application	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	
416	Consistency and fault tolerance (Does the application run/works well at all time as expected)	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	
417	The ability of addressing the need of data transfer	1. Very dissatisfied 2. Not Satisfied 3. Neutral 4. Satisfied 5. Very Satisfied	

Physical observation Checklist

Region: Oromia Zone: Jimma District: _____

Supervision tools, Format used _____

- Skill/Competence/experience/of the staff (by observing filled supervision checklists and documentation their Completeness and precision

  _____
  _____
  _____
  _____.
- Number of staff involved in the IRS supervision: _____.
- Availability of IT /Communication equipment (Computer, Mobiles, Printer, fixed telephone line, internet, Local area network, etc)

  _____
  _____
  _____.
- Availability of office space:

  _____
  _____.
- Software used for data capturing and reporting related to IRS:

  _____
  _____
  _____
  _____
  _____.
  - Backup archive system: _____.

  Other observations:

  _____
  _____
  _____
  _____
  _____
  _____
  _____
  _____
  _____.

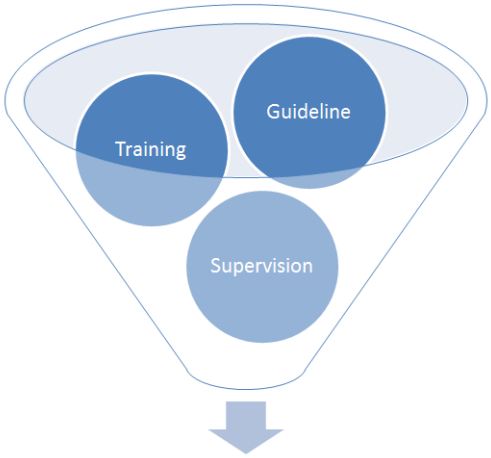
Annex II

CommCare Tutorial

WELCOME

Welcome to IRS Supervision Tool on CommCare!

Before you get to work, please read this tutorial to learn how to use your mobile application.

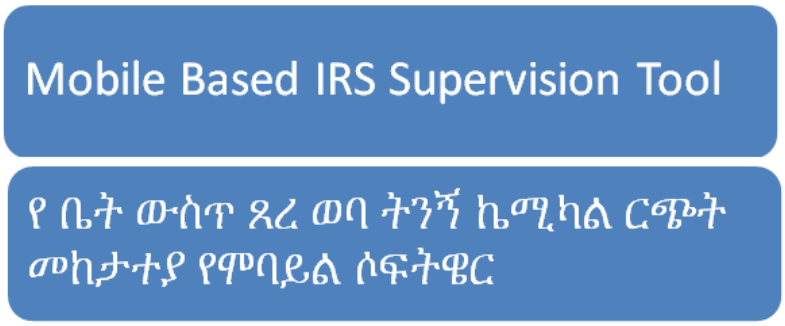


About Indoor Residual Spraying Supervision Tool

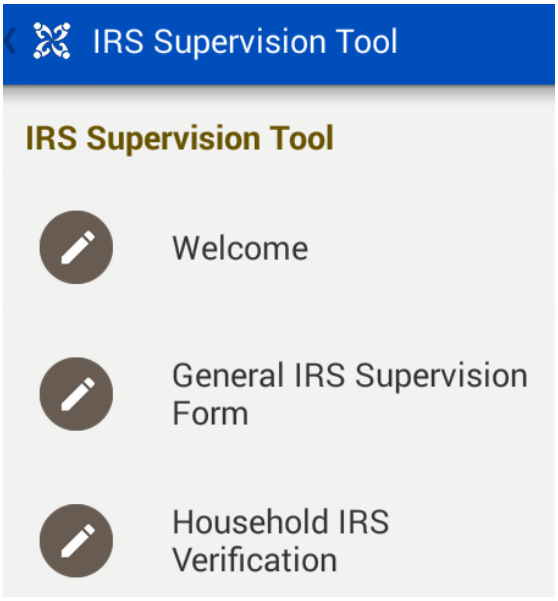
The Indoor Residual Spraying application (IRS) is a decision support tool to reinforce the supervision and monitoring of IRS campaign activities.

The App includes a welcome tutorial, General supervision checklist and a Household IRS verification form.

It will be introduced in Oromia Region Jimma Zone Selected Districts as a part of a prototype.



You will be responsible for completing the forms with the **pencil icon**.



This application is designed to :

Collect observations from routine supervision of the IRS campaign. Identify red flags that do not follow national IRS guideline and standard operating procedures Guide the inspector to provide immediate corrective actions when red flags are detected Measure campaign progress and share among the team

You will be responsible for completing the following forms.

Click on each form you would like to learn more about.

- ☐ General IRS Supervision Form
- ☐ Household IRS Verification
- ☐ None

Application Fundamentals

If a user check “None” from the above lists

Now that you know a bit more about the IRS app content, let's start with the

Fundamentals of CommCare:

This tutorial will introduce how to:

1. Enter data for different question types. (number, date, GPS)
2. Synchronize your survey with database
3. Submit your survey

ok

Question types
Checklists have a variety of question types.

This tutorial will introduce 3 types of questions:

- Number questions
- Date Questions
- GPS Questions

ok

Register your supervision team
This is a number question. Use the number pad to enter your answer.

What year were you born?
Number

ok

Date

There are 2 methods to change the day, month, or year

1. Swipe up and down to scroll to the dates

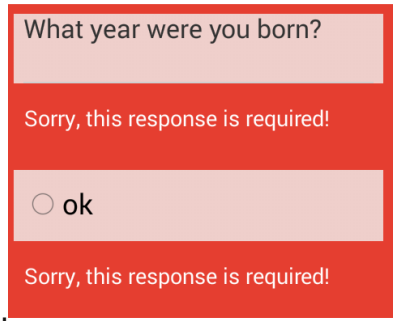
2. Press and hold, and enter the date using the number keypad.

Enter the date August 1, 2016

If you enter a date that is not valid, your screen will turn **red**, and **you will have to change your answer in order to proceed.**

In this example, the date of the inspection is a year in the future. This is not a valid response, so the date should be changed to show the year 2016

This is a number question. Use the number pad to enter your answer.

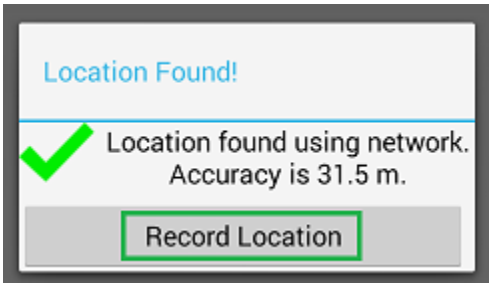


.

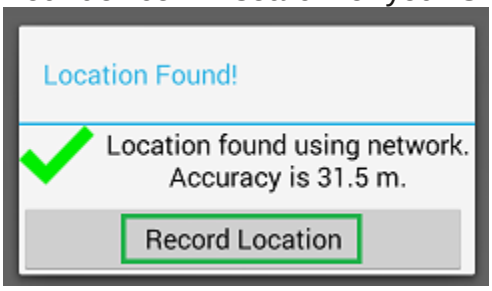
ok

GPS coordinates
First select **"Collect GPS"**

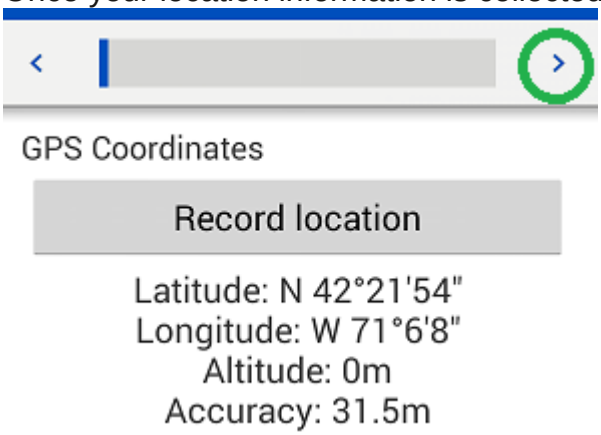
Now your device will search for your latitude and longitude, and you will see the screen below.



Your device will search for your GPS coordinates



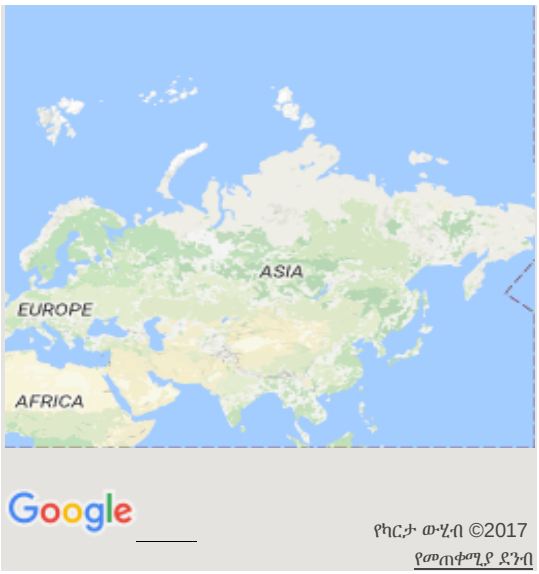
Once your location information is collected, continue to the next question.



ok

Please collect your GPS coordinates

To review the steps, return to the previous screen.



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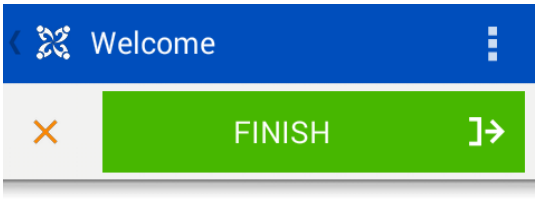
Coordinate

Sync with Server
You have completed your form and are now looking at the Home Menu.

1. To synchronize your data to the database, make sure that you have **an active data connection**.
2. Select the **blue** button, that says **"Sync with Server"**
3. Once the data connection is active, your form will be submitted automatically.

ok

You did it!
You have reached the end of the tutorial!



Do you feel comfortable entering data and submitting forms CommCare?

- Yes
- No

Thank you for your participation, and best wishes for a successful IRS campaign!

Now submit your form.