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A mobile health model supporting Ethiopia's eHealth strategy

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INTRODUCTION

Critical health information technology (IT) system deficiencies have left many low-income countries (LICs) the inability to support locally sustainable communicable and non-communicable disease prevention and screening initiatives and new therapeutic treatment plans that could save millions of lives. This is due, in part, to a lack of timely clinical intelligence from their peers at the point of care and the implementation of effective post-visit patient engagement tactics for self-care and treatment compliance.[1–7]

The current solutions in LIC healthcare and Life Science domain are primarily third-party vendor systems, which require unsustainable IT infrastructure and software management support, or heavily paper-based processes supplemented with standard IT desktop applications and databases. Collectively, these systems do not enable the robust capabilities needed to sustain near-real-time and offline patient engagement and clinical innovation or meet the regulatory standards for local, national, and international collaboration efforts. As a result, LICs cannot transition effectively from manual administrative efforts to participate in

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There are no conflicts of interest.

multi-national clinical trials and public health innovation, which directly impedes their ability to mature as an organization.[1–7]

This has left most public health analysts and health care teams that perform population health surveillance and treat high-risk patient population groups in these regions of the world, with little to no alternative but to reactively address disease outbreaks with inadequate biosurveillance and care management intelligence. Ultimately, this results in poor outcomes for preventive health and wellness programs. This impacts LIC's ability to increase their capacity and take a more prominent role in collaborative research efforts with their peers internationally. As a result, they suffer from lost opportunities for expanded innovation and thought leadership initiatives that enrich the entire global research community in the advancement of public health worldwide.[8–13]

Key drivers that impede sustainable adoption of information, communication, and technology in low income countries

As a result, global health organizations, such as the WHO, and their member organizations, have been promoting the development and adoption of scalable health IT solutions that are sustainable in low-resource care settings to mitigate these healthcare disparities. The use of mobile technology has been shown to provide the most promising impact, given the ubiquitous use of mobile phones in the most resource constrained areas of the world. The introduction of mobile health (mHealth) capabilities for preventive health programs and patient engagement efforts that bridge gaps in care for vulnerable patient populations, are gaining momentum in all global health communities. However, their impact and sustainability are still uncertain due to the following factors as identified by the WHO:[9–13]

- Conflicting health-care priorities
- Unsustainable operating costs
- Inability to consistently measure clinical and cost effectiveness
- Lack of harmonized health-care policy and governance models to support mHealth initiatives
- Lack of knowledge concerning the possible application of mHealth and public health outcomes
- Lack of IT infrastructure to support mHealth programs
- Patient literacy, privacy, and cultural issues.

This is evident in the current trend of health disparities associated with cervical cancer in LICs, due to low-resource constraints. According to the World Cancer Research Fund International 2012 report:[14]

- Cervical cancer is the fourth leading cause of cancer death in women worldwide
- About 84% of cervical cancer cases occurred in less developed countries
- The highest incidence of cervical cancer was in Africa and Latin America and Caribbean and the lowest incidence in Northern America and Oceania.

PROGRESS IN CERVICAL CANCER SCREENING AND TREATMENT IN ETHIOPIA

There is progress in LICs such as Ethiopia, that are developing national initiatives to overcome infrastructure and policy-based barriers to improve the outcomes of the preventable spread and prognosis of cervical cancer, with revitalized public health efforts. In spite of Ethiopia's health care infrastructure constraints, its Ministry of Health is shaping a progressive approach to addressing health disparities by embracing mobile health technology, as an extension of their eHealth strategy to address these gaps in care.

Demographic profile of cervical cancer within Ethiopia

Ethiopia has an estimated 7000 new cases of cervical cancer each year, and nearly 5000 deaths from cervical cancer yearly.[15] This data is collected primarily from those who present to Addis Ababa for treatment, as currently Addis Ababa is the only oncology treatment center in the country with radiation capacity. The number of women with cervical cancer identified in Addis Ababa was inversely related to the distance the woman lived from the capital (Abate, 2015).[16] Women at risk for the development of cervical cancer are primarily those without access to screening and preventive measures. In Ethiopia, 0.8% of the eligible population have ever been screened for cervical cancer.[16] Further risk factors relevant in the Ethiopian region include exposure to chronic smoke inhalation, as Edelstein *et al.* 2008[17] reported 80% of the rural women in the Gondar region have exposure to chronic smoke inhalation with poor ventilation due to cooking practices. High-fertility increases the cervical cancer risk, as does young age at first pregnancy.[18] According to the Ethiopia's Demographic and Health Survey (EDHS), the fertility of Ethiopian women is 4.8 children per woman, with more children born in rural areas per woman than urban. In addition, the median age of first birth in Ethiopia ranges from 18.1 in Amhara to 23 years old in Addis Ababa. In sum, there are significant risk factors for cervical cancer in Ethiopia, an already apparently high incidence, and yet missing data.

Ethiopia's healthcare strategy for women's health and cancer

The National Reproductive health strategy of federal democratic republic of Ethiopia emphasized the need to address noncommunicable disease, especially gynecologic cancers, including cervical cancer, as top priority focus. Furthermore, in Ethiopia's Growth and Transformation plan II, the country intends to incorporate visual inspection with acetic acid (VIA) and cryotherapy at 100% of its hospitals.[19] This decision is based from the WHO recommendations. Additional strides are made to consider the incorporation of human papillomavirus (HPV) screening into the system, though these are not yet out of the research phase. In 2010, Ethiopia's Ministry of Finance and Economic Development provided financial support for the development of five oncology centers, each will start providing holistic cervical cancer treatment and rehabilitation service. Among the five hospitals, University of Gondar comprehensive and specialized hospital is selected as an oncology center for Amhara region. The University of Gondar currently provides screening and treatment for precancerous lesion of the cervix using VIA and cryotherapy and loop electrosurgical excision procedure, respectively. It is the only hospital in the Amhara region

where treatment for cervical cancer exists including radical hysterectomy, a well-established chemotherapy center, and a fellowship program on gynecology oncology. Importantly, the Institute of Public Health at the University of Gondar has strong research team, Health Demographic Surveillance at both the rural and urban population level, and strong research collaboration with obstetrics and gynecology department.

BARRIERS AND FUTURE OUTLOOK OF THE ADOPTION OF A SUSTAINABLE MHEALTH PLATFORM IN ETHIOPIA

Despite the political will to have an effective cervical cancer screening and prevention program, there are seven significant barriers that prohibit the support of a sustainable health IT infrastructure for national public health initiatives.

Inconsistent access to electric power

According to 2016 (EDHS), 20.8% of the population (93% of urban households and 8% of rural households) have access to electricity.[20] In rural areas, very few *Kebele* (the lowest administrative unit)-level-facilities, including health posts (HPs), have electricity, limiting the ability to recharge mobile phones. About 5% of HPs access to electric power. About 90% of health extension workers (HEWs) [HEWs are locally based health care workers, sponsored by the FMOH, that are specifically trained to provide basic, primary and preventive health care services at household levels, and clinical referral support for patients in low resource regions across Ethiopia.] have mobile phone. Unfortunately, only 23% of them have consistent access to charging stations.[21] Interruption of electric power to these facilities can last from a few hours to days;[22] mainly for smart phones with battery lifetime got shorter when Internet connection, Global positioning system (GPS), and Bluetooth functions used simultaneously.[23]

Shortage of health-care workers and lack of eHealth literacy-health extensions workers

In the early age of mHealth adoption within Ethiopia, retaining experienced professionals in the field has been challenging. The HEWs are the front-line workers in the country's health system and generally have 1 year basic in-school training. HEWs make up 47% of the country's health workforce with approximately 38,000 (two for every 600 households) across Ethiopia.[24] HEWs are severally resource constrained as it pertains to labor intensive health information tasks associated with patient engagement. They are expected to record both the existing paper-based data collection efforts in addition to performing electronic data entry to support this dual system of medical record management. This is compounded with limited access to health IT and keyboard training, to address gaps in health IT literacy for HEWs. These factors directly contribute to the attrition challenges Ethiopia faces for new ICT initiatives for public health.

To assess the impact of these constraints on mHealth initiatives, the Federal Ministry of Health (FMOH) sponsored a research study to evaluate the performance impacts of mHealth programs on HEWs. The study found that 78.3% of HEWs mentioned time-consuming nature of both manual and electronic mHealth recording as a reason for stopping to use electronic forms.[23–25] According to the study, HEWs had poor English proficiency and

usually preferred local language, although the working language in the Ethiopian health system is English.[23–25] This clearly highlighted the need for mHealth solutions to support local languages and dialects for optimal use. Finally, one focus area was to report its findings on the use of mHealth solutions by HEWs and the impact on patient care based on their employment status and availability. They observed inconsistency in the use of mobile solution due to an inability to backfill gaps in HEW coverage or when workers left a care program or were unavailable due to personal commitments or conflicting work assignments.[23–25] For example, the report highlighted within the 6-month period of the study, 82.6% health workers had been away from their health facility at least once for attending training outside of their working station.[25]

Data governance and standardized technology conformance

In Ethiopia, health information systems designed to collect data are required to align with the processes, goals, and objectives of the national Health Management Information System (HMIS). Unfortunately, there is no centralized enterprise architecture governance body or regulatory system that verifies compliance to HMIS interoperability standards of new electronic health systems from the inception to end. This creates significant gaps in system-level integration and data exchange protocols between systems, which create poor access to patient and population-level data. As a result, there is a great need within Ethiopia for a common health data governance model and technical reference architecture that supports national policies and business rules associated with health information management, data stewardship accountability for key stakeholders, and system-to-system interoperability for reliable data exchange,.[26] For a common mHealth strategy to be sustainable across Ethiopia, will require strategic, integrated national efforts based on common goals.[26–28] A committed partnership between the government, local authorities, health-care systems, universities, private sector and donors is essential in the planning phase to identify common goals. Coordination between Ethiopia's ministries, national authorities, academia, health-care providers, and private business are a prerequisite for success. It is particularly important to ensure consensus between the Ministry of Health and Ministry of IT and Telecoms[26–28] or Ethiopia will not be able to achieve sustainable success for their mHealth strategy.

Adaptability of technology infrastructure and telecommunication connectivity within Ethiopia

Ethiopia dedicated 10% of the Gross Domestic Product to telecommunications investments and retains an extensive mixed-capability ICT infrastructure that provides a blended coverage of 85% of the country's population. However, the mobile subscription rate of Ethiopia was 8%, which was 4–6 times lower than Kenya (51%), Uganda (30%), Tanzania (31%), and Rwanda (36%).[29]

Smart phone cost and availability of internet connectivity

According to EDHS 2016, overall 56% households have access to mobile phone; 88% of urban households and 47% of rural households own a mobile phone. About 27% of women and 55% of men owned mobile phones at the time of the survey. About 71% of urban women own a mobile phone, compared with 15% of rural women.

Ethiopia uses Global System for Mobile communication and Code Division Multiple Access (2G and 2.5G/GPRS) mobile and fiber technologies. Over 500 cities have related to fiber up to 2Mbps connectivity.[29] Overall, only 4% of women and 12% of men age 15–49 have used the Internet in the past 12 months in Ethiopia.[29] Airtime (voice, SMS, and data use) costs are one of the most significant cost categories associated with any mHealth deployment. Anticipating costs requires creating mHealth capacity models that can predict the airtime associated with any application, which would require adjustable volume procurement rates with Ethio Telecom, Ethiopia's primary telecom supplier.[29]

From a regional cost perspective, a prepaid air time for voice call per minute costs in $.06 Ethiopia, in $.04 Kenya, in $.06 Uganda, $.04 in Tanzania, and $.07 in Rwanda. Whereas SMS per unit costs in $.02 in Ethiopia, Kenya, and Uganda which is lower than $.03 in Tanzania and $.04 in Rwanda.[29] Interviews conducted during this study indicate that they typically spend 10–20% of their monthly income on airtime, 50% of which was used for work-related calls and messaging. While device costs constitute a smaller percentage of project costs than is often assumed, the cost of acquiring (and replacing) devices on a large scale is considerable. As with airtime, negotiating lower prices or volume discounts with providers can reduce costs.[29] A price for basic handset was $24.24 in Ethiopia, $12.12 in Kenya, and $14.54 in Tanzania.[29]

Prohibitive service management costs to maintain mobile health software and hardware

Short battery lifetime of the smartphones, insensitivity of the phones' touch screens with time, and poor mobile network connectivity in the study areas were technical bottlenecks that require cost-effective measures that are not readily available. These are examples of typical IT service management items that Ethiopia must find a scalable model for uninterrupted user and infrastructure support, which does not exist currently across all areas of the country. IT service management may constitute a quarter or more of the total cost of ownership for a technology deployment. However, mHealth programs within Ethiopia are addressing the most common issues to maintain availability of their solutions.[30,31]

Local IT human resource constraints

In the Ethiopian health system, Health Information Technicians (HITs) there are specific levels of knowledge and required skill sets for specific care settings, from health centers to hospitals and health administrations, to meet critical health information efforts. However, there is a persistent shortage of HITs, health informatics professionals, and health IT postsecondary and graduate-level students to support very complex health information management efforts, which slows the progress of adoption of new mHealth or related ICT solutions.

ETHIOPIA'S STRATEGIC GOAL AND IMPLEMENTATION READINESS FOR THE ADOPTION MOBILE HEALTH SOLUTIONS

Despite these barriers, there is still great potential for national adoption of mHealth capabilities across Ethiopia. The mobile penetration in Ethiopia has been growing exponentially. In 2016, the number of mobile subscriptions was at 51.22 million which

doubled by half in short periods since 2013 [Figure 1]. It is planned that in 2020, mobile service subscription will reach 103.7 million and that of Internet and fixed line will be 56 million and 10 million, respectively.[31]

The current eHealth applications in Ethiopia are delivering promising results in different health programs. More than eight mHealth projects have been implemented and four (50%) of them were on maternal health program.[32] There were challenges facing implementations mHealth projects. Because of the outcomes of these efforts in 2014, the Government of Ethiopia initiated the development of a national eHealth strategy for coordinating and streamlining the active eHealth initiatives in the country, as a basis for establishing a foundation for sustainable eHealth implementation model.[33] Ethiopia's FMOH, under its 5-year health sector transformation plan, also stipulated the importance of harnessing eHealth technologies as one of the top agenda items at national level. To achieve this vision, the FMOH has ranked mHealth as one of the five priority areas of the country's eHealth strategy.[32,34] The following are among the opportunities for improving sustainable adoption of mHealth interventions in Ethiopia[32–35]

Collaboration of stakeholders

There is promising support from nongovernmental organizations with mHealth projects in different areas to support a national governance model to standardize mHealth implementations and service management across the country. This includes collaborating with the FMOH in supporting the integration of mHealth initiates with the existing health system.[32–35]

Capacity building of health workers

The Ethiopian Government has been increasing their investment additional human resources in ICT to support its expanding communications network.[35]

Information, communication, and technology infrastructure

The Government of Ethiopia has made the development of information and communications technology as one of its strategic plan priorities and has been investing in communications infrastructure to offset low communications penetration, especially in rural areas. 90% of Ethiopia's geographic area have access to mobile service. The mobile network coverage comprises 3G and 2G services and 4G LTE technology deployment. Over 500 cities have been connected to fixed-line Internet and every regional capital has fiber connectivity with up to 2Mbps connectivity. In terms of electricity, the national power provider EEPCo has accelerated its progress in connecting towns and cities to the national grid infrastructure.[35]

Current efforts and opportunities to expand the use of mobile health for cervical cancer screening

The Pink Ribbon Red Ribbon program is a major initiative working in Ethiopia that led and supported by Ethiopia's FMOH and several NGOs. The Pink Ribbon Red Ribbon program has four major cervical cancer screening goals:[36]

- Launch the HPV vaccination demonstration program to support the coverage of 80% of girls covered in the target population
- Support the dissemination of the National Cancer Control Plan (NCCP)
- Open 58 “screen and treat” sites in order
- Reach at least 80% coverage of the appropriate target populations with screening and treatment for preinvasive cervical-cancer cases.

NATIONAL READINESS FOR OPEN SOURCE TECHNOLOGY AND FRAMEWORKS FOR SUSTAINABLE MOBILE HEALTH INITIATIVES WITHIN ETHIOPIA

The national momentum within Ethiopia for health IT adoption provides a fertile ground to lay the foundation for a sustainable mHealth architecture that can be incrementally adopted across care settings. Ethiopia’s health-care system can position them as a country to embrace the value of Open Source technology and Open Science frameworks for a financially sustainable and technically reliable mHealth infrastructure.

The movement toward Open Source-Open Science solutions is evident with the new e-health platforms that are taking shape to address these challenges. As the Global Health community enters into a broader range of eHealth adoption efforts, we see pioneering growth and expansion of mHealth solutions that are taking a progressive approach to enabling more effective patient engagement and peer-to-peer clinical decision support at the point of care. This has also led to supporting new patient engagement research models for public health biosurveillance and education efforts related to infectious disease prevention and control and medication adherence in LICs worldwide. As a result, some mHealth initiatives have moved the needle with the adoption of new patient engagement efforts, simply due to leveraging this new technology.[37]

The goal of an integrated Open Source-Open Science platform is to take mHealth one step further, by enabling reusable clinical intelligence that can be shared and redistributed in the context of clinical innovation before, during and after care is delivered. As a result, mHealth becomes an essential building block to this framework, by providing a timely data and clinical intelligence for prevention, treatment, and clinical innovation efforts. When mHealth is coupled with an Open Source-Open Science virtual collaboration environment, it will enable LIC care teams and research scientists to engage more effectively, in interactive population health initiatives and global knowledge sharing that contributes to improved outcomes in care and clinical innovation.

PROPOSED MOBILE HEALTH PLATFORM FOR ETHIOPIA: PROJECT ORCHID–PROOF OF CONCEPT FOR CERVICAL CANCER SCREENING INITIATIVES

Our research team has developed a conceptual mHealth architecture model and Open Source technology platform to address the barriers and opportunities presented in this paper, for a method of introducing sustainable mHealth architecture within Ethiopia. The scope of our proposed pilot is to test and validate our hypothesis that the platform can support the NCCP strategies for cervical cancer as a point of validation to provide a scalable solution that can grow at the pace of technology adoption that aligns to their national eHealth strategy. Our specific aim is to partner with the University of Gondar's Institute of Public Health and the University of Gondar's School of Medicine and Health Sciences, to configure and test our mHealth screening application and platform with local health care providers and regional health centers within the Amhara Region, in support of the NCCP cervical cancer strategic goals and objectives. Our initial focus is to support their goal to provide cervical cancer screening using VIA for all women aged 30–49, every 5 years.[38]

In addition, it is our goal to align and integrate our solution to the current efforts supported by the Pink Ribbon Red Ribbon project and other successful mHealth initiatives, in support of centralized governance and system-level interoperability, for sustainable adoption. The mHealth platform will also provide data exchange capabilities to enable Ethiopia's researchers to expand their participation in international oncology research cohorts and optimize their contributions to the African Cancer Research Network (AFCRN).[39] The potential impact of our platform will enable Ethiopia to:

- Achieve significant progress for providing 80% coverage for VIA cancer screening goal
- Improve cervical cancer research capacity
- Strengthen monitoring and evaluation of cervical cancer and its risks, in low resource areas
- Improve evaluation of cervical cancer control intervention activities.

PROJECT ORCHID MOBILE HEALTH CAPABILITIES

Our platform [Figure 2] will address the gaps in coordinated data collection methods and dissemination of clinical intelligence that support population health strategies. Our core features will consist of the following:

- Smartphone, Tablet and Desktop Configurable Assessment Tool, for real time and offline data collection
- Remote data integration for home devices (i.e., blood pressure devices, digital scales and glucose monitoring, etc.)
- Clinical Imaging Workflow and Protocol Management Tool
- Two-dimensional-three-dimensional Interactive Imaging Viewer.

We will be integrating two Open Source-Open Science technology solutions with the original developers as our team members: Radiology Protocol Tool Report (RAPTOR) and Data Collection Application Suite (DCAS). RAPTOR was a U. S. Veterans Affairs Innovation Project for radiology protocol management and workflow optimization and was selected as one of the “Top 5 Medical Imaging IT Projects of 2012” by the Society of Imaging and Informatics in Medicine. DCAS is a cloud-based mHealth and metadata platform that has been used for national public health initiatives for National Institutes of Health (NIH), Center for Disease Control (CDC), and state-level public health assessments. The mHealth platform will provide near real-time and offline data management capabilities across the Amhara region to mobile users. They consist of the following core features:

- Configurable data collection instruments (Windows, Web, mobile) for the mHealth platform
- Support multiple (17+) languages and separate instrument screen layout, logic and flow from language dependent fields or translation, including Amharic
- Configurable metadata repository management and instrument authoring system for each designated organization within Amhara and its collaborators, that will correspond to studies that require unique or re-usable surveys
- Configurable data management features that will preserve organizational and survey data hierarchy, which aligns to Ethiopia’s data governance model for public health
- Provide clinicians and researchers to create data collection instruments through Wizards or import instrument metadata from external sources, including Word, XML, Excel, text, and Blaise
- Support live preview of instrument content, flow, static and dynamic ranges, and validations
- Support instrument versioning and collaborative development with check-in/check-out capability
- Generate instrument deployment package for Windows, Web, and mobile devices
- Generate instrument specifications and codebooks and codebooks with statistical frequencies
- Integrate mobile data collection platform with device hardware, including GPS, camera, and barcode scanning
- Integrate mobile data collection platform with bio-medical equipment, (i.e., blood pressure measuring devices and digital scales,
- Support instrument workflows driven by the data received from integrated biomedical equipment
- An optional medical equipment and specimen tracking system for cervical cancer screening and treatment protocols

- Automated data reports to support day-to-day operations, data delivery and data quality
- Location/facility grouping support to provide data reports based on physical location, administrative division, or a specific facility
- Open Source RESTful API (application programming interface) for system-to-system integration, such as laboratory information systems, EHRs, and case management systems
- Develop a repository of standardized survey instruments and electronic forms, based on prevalent best practices and customized for local needs, that can be used across different health-care facilities
- Figure 3 is a conceptual model of DCAS. Dr. Volynski, our research team member and the chief architect of DCAS, is our designated implementation consultant for this effort. DCAS was successfully implementing for the following U. S. Federal programs for the NIH and the CDC:
- U. S. Census Bureau, Census 2020 Program
- The National Children's Study IMS (NCS)–NIH
- The National Children's Study Vanguard Sites (NCS)–NIH
- The National Health and Nutrition Examination Survey–CDC
- Pubertal Maturation Study CDC/NCHS, Children's Hospital
- The National Criminal Justice-Drug Abuse Treatment Studies–NIH.

ASSESSING MOBILE HEALTH ENTERPRISE-LEVEL PERFORMANCE MANAGEMENT AND VALUE OF INVESTMENT

It is imperative that Ethiopia's Ministry of Health can measure their return on investment for mHealth programs by aligning qualitative and quantitative outcomes from industry recognized Health IT bodies of knowledge. Ms. Harding, Principal Investigator of this effort, has developed the Project Orchid Innovation Engagement and Collaboration Maturity Model,[40] to enable ICT sponsors to assess stakeholder-level technology disruption, associated with the adoption of new technology and their targeted success criteria. The model is designed to assess local, regional, national, and multinational public health and clinical research engagements. The model is based on three integrated aspects of collaboration:

- Program and policy harmonization – This domain consists of addressing regulatory and cross-cultural organizational dynamics, process adoption, and motivation models
- Ideation and strategy – This domain consists of addressing medical innovation modeling and clinical trial bridging strategies

- Operational engagement – This domain consists of the identification of service-level and key performance indicators, knowledge management, and delivery system optimization efforts after the launch of their medical innovation.

Table 1 outlines the scope of the model that can be tailored based on the goals and objectives of the organization and their collaborative partnerships.[40]

RISK-ADJUSTED IMPLEMENTATION APPROACH FOR THE PROJECT ORCHID MOBILE HEALTH PLATFORM

In addition to the innovation engagement and collaboration maturity model, we will also incorporate the following risk mitigation practices to ensure for a stable deployment outcome that is scalable across the country:[41,42]

- Assess stability of in-place system interfaces to remediate data exchange and referential integrity issues across interdependent systems
- Provide Open API capabilities, internationally recognized open source architecture frameworks and health interoperability standards for financially and technically sustainable, system-level integration with legacy, and future procurement of ICT solutions
- Verify the reliability and adherence to Ethiopia's health data governance model to ensure consist data quality standards
- Perform data export integration testing incrementally, to minimize loss of referential integrity between send and subscriber systems
- Verify reliability of business continuity and disaster recovery strategies that would impact access to the platform to prevent avoidable data loss due to unplanned telecommunication and electricity outages.

TELECOMMUNICATION DEPLOYMENT MODEL

The configuration of the telecommunication infrastructure will be designed and tested to send patient engagement alerts via text, video, static and dynamic images, and audio messages from the care team to the patient, that align to evidenced-based protocols supported by the NCCP and the WHO guidelines for cervical cancer.[43] This pilot will be designed to test a set of open source unified communication tools that are optimized for both mHealth and telehealth in high and low-bandwidth areas, using current industry standards for unified communications and health interoperability standards.[44–51] This data will include telemetry or other portable medical device, text, audio files and any other patient information that is available for electronic capture.

The system will be scalable to support near real time communications in areas where network access is available and reliable, and to store the information for future transmission when it is not, in offline mode. All communications would be GPS location tagged with the location stored in a database. The location data would be acquired using standard cellular GPS tracking data which would be able to provide health-care provider location information,

even when the health care provider is not aware of his or her location. These event messages will be launched from preapproved, authenticated sites utilizing the same basic processes and protocols that are used today in the United States to launch Amber and Silver Alerts over the Individual Personal Alert Warning System.[44–51] A full suite of Unified Communications tools, including instant messaging and presence, would be embedded in the application. These tools would use recursive messaging systems in which the device selects the best means of conveying the information depending on network conditions and capabilities. If no reasonable method is available, the application stores the message for automatic delivery once a network link is re-established. The location tagging would occur at the time of the message initiation regardless of when or from where the message is eventually sent. The applications needed to support these tools can be developed for Windows, IOS and Android operating systems. The system would also be designed to be able to support emergency alert messages to targeted individuals, if mass notification is required due to an emergency event.

LEVERAGING EVIDENCED-BASED METHODS AND BEST PRACTICES FOR SCALABLE MHEALTH MODEL

We will tailor the implementation approach for the mHealth platform, from best practices for LIC mHealth deployment from our research team member and LIC mHealth specialist, Dr. Shashank Garg, who developed the HANDSREL's mCollect Electronic Data Capture Platform. Dr. Garg's platform was designed to address a similar challenge for high risk TB patients for one of India's national TB initiatives. A recent mHealth implementation achievement by Dr. Garg, was a comprehensive data management solution they developed for the Public Health Foundation of India Safe Childbirth Checklist Evaluation Study (involving data collection and management of over 300,000 retrospective records from Labor Rooms in 13 districts of Rajasthan State over a 2-year period. Dr. Garg and his research team utilized the Unified Theory of Acceptance and Use of Technology (UTAUT) model, developed to investigate the antecedents and challenges in the adoption and use of the mobile-based IT solution.[52,53] His mHealth study for TB surveillance contributed to the UTAUT literature and expanded the understanding of the implementation of IT solutions in a public healthcare service delivery context. In addition, it provided measurable insight to determining the influence of four independent variables in the UTAUT model – effort expectancy, facilitating conditions, performance expectancy, and social influence – on health professionals' intention to use the proposed mHealth solution.[53] These validated insights will be leveraged for our proposed efforts to provide a sustainable mHealth infrastructure across disparate systems.

ENGAGING LOCALIZED INFORMATION, COMMUNICATION, AND TECHNOLOGY EXPERTISE FOR SUSTAINABLE MOBILE HEALTH SERVICE MANAGEMENT WITHIN ETHIOPIA

The eHealth Innovation and Research center's eHealth Lab Ethiopia (www.eHealthLab.org), at the University of Gondar, will be an extension of our research

team. It is recognized as FMOH's center of excellence for health information system education and research. The focus of eHealth Lab is to support multi-disciplinary research, development and evaluation of eHealth solutions which includes public health efforts for immunizations, TB, and HIV care. There are currently 14 faculty, three PhD and nine masters level students who are studying health information system at the University of Gondar, to expand Ethiopia's capacity to support mHealth and as a sustainability strategy in the future.

CALL TO ACTION: A PERFORMANCE–BASED STRATEGY FOR A RE-USABLE MOBILE HEALTH PLATFORM TO SUPPORT ETHIOPIA'S PUBLIC HEALTH AGENDA

The proposed Project Orchid mHealth platform and implementation approach that we have detailed in this paper, can support the progressive vision that Ethiopia has for mHealth adoption across the country. This proposed effort will address the need for technology enabled population health surveillance, digitized screenings and patient follow-up efforts for controlling infectious and chronic diseases. In addition, the outcome of adopting these methods will enable health-care workers based in local villages, regional health-care facilities that support national public health surveillance efforts, a more reliable method of health information management than the dual data collection process that they currently use. The scope of this effort will be the first of its kind in Ethiopia, demonstrating concurrent data collection and data exchange for multinational cancer research efforts and Ethiopia's partnership with AFCRN and their international research partners. The result of this level of innovation, will pave the wave for Ethiopia to leverage this platform across strategic public health initiatives and increase Ethiopia's capacity for collaborative clinical research globally.

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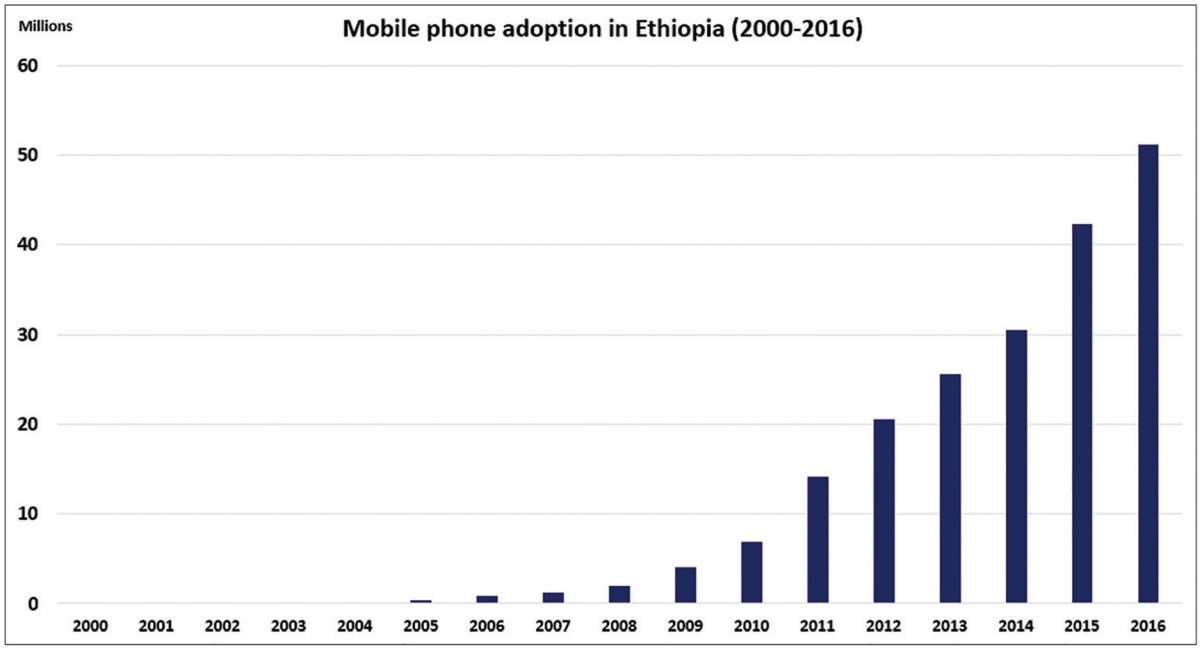

Figure 1:
Ethiopia's mobile phone adoption rate

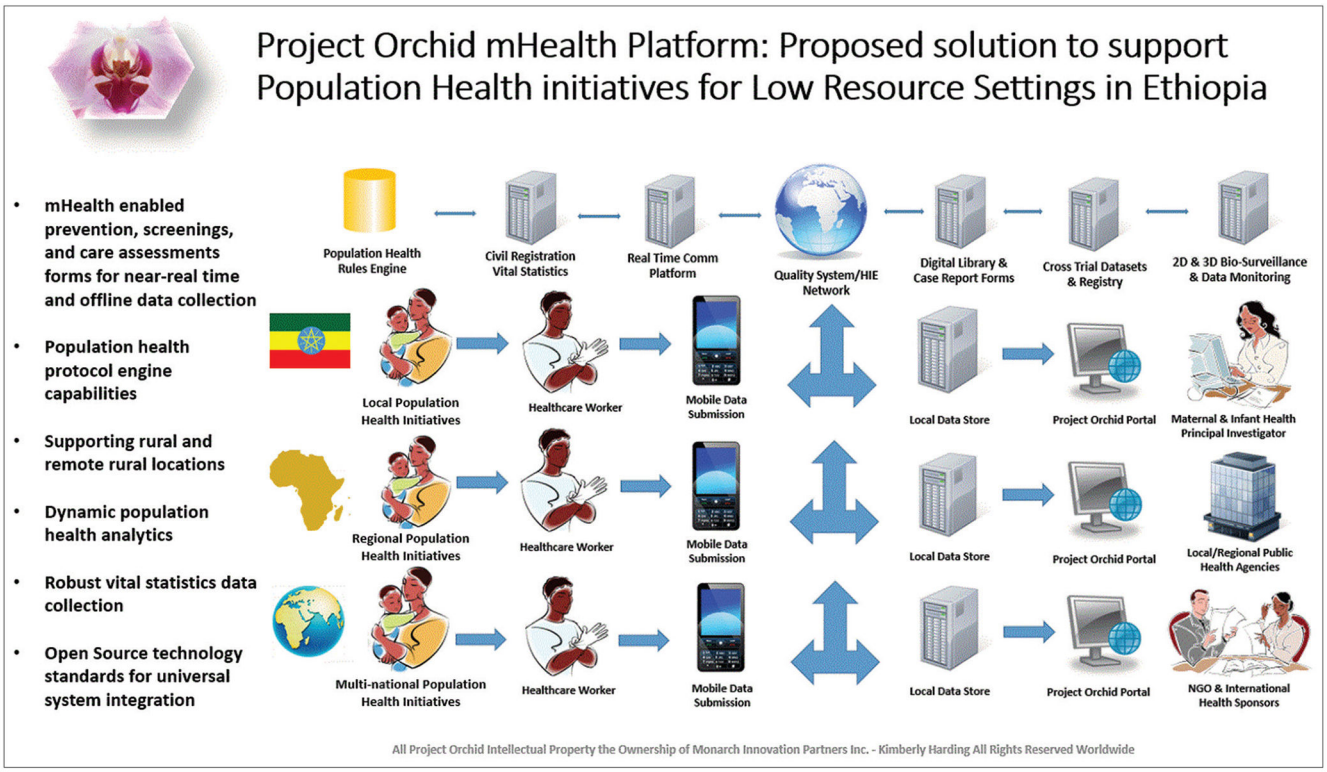

Figure 2:
Project orchid concept model

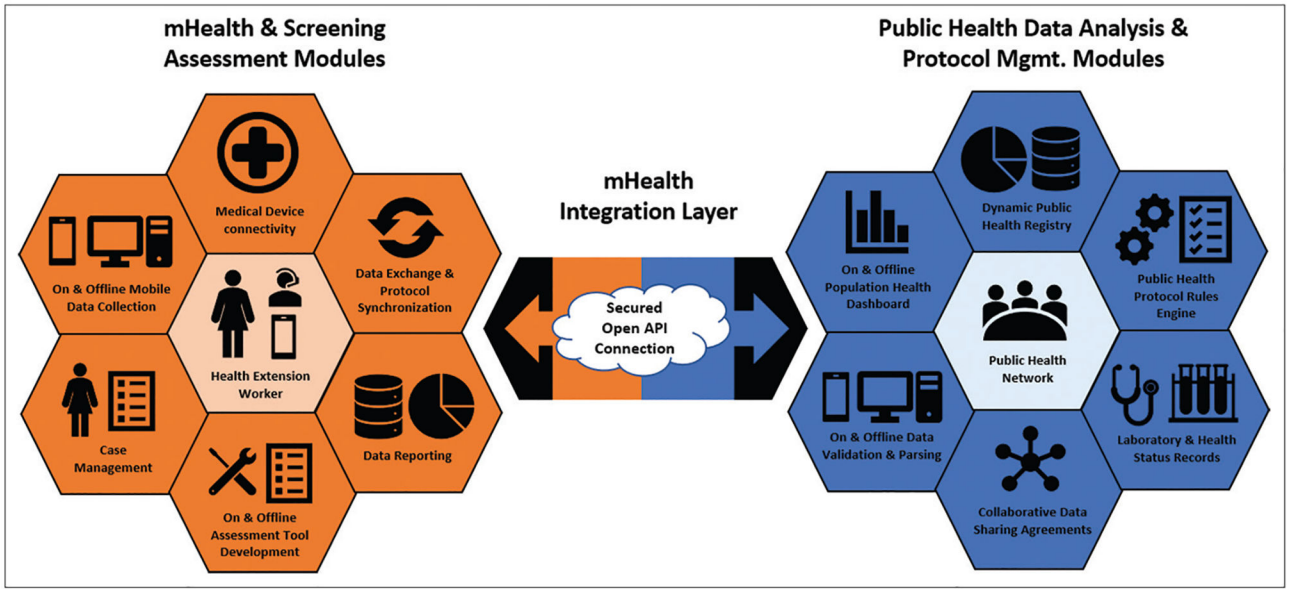

Figure 3:
Project orchid system diagram

Table 1:

Scope of innovation and collaboration model

Collaboration Level	Measure Attributes for Level	Method for Assessing Harmonization for Level	Application to Collaboration Domains	Timing in Engagement Lifecycle
Policy	• Local, Regional, National, • International Regulatory • Standards and Guidelines	• Self-audit and program-level audit exercises per the specifications of the regulation(s)	• Program and Policy • Harmonization • Ideation and Strategy • Operational Engagement	• Recurring, per the specifications of the regulation(s)
Organizational Ethics	• Business Value Statements and Public Policy Guidelines	• Self-audit and program-level audit exercises per the specifications of the adopted set of organizational ethics	• Program and Policy • Harmonization • Ideation and Strategy • Operational Engagement	• Recurring, per the specifications of the adopted set of organizational ethics
Business Rules	• Standard Operating Procedures, Workflows and Protocols	• Workflow re-engineering and synchronization across stakeholders, resulting in measurable process optimization	• Program and Policy • Harmonization • Operational Engagement	• Key role-based performance efforts across each business domain of the program
Technology Conformance	• Infrastructure, Security and • Data Architectures, System-to System integration and process automation, Inbound and • Outbound Connectivity Channels	• Vendor attestation for technical conformance via interoperability assessments and the use of Open Source tools	• Program and Policy • Harmonization • Ideation and Strategy • Operational Engagement	• Ideation and Strategy, • Operational • Engagement phases of the initiative
Service Level Agreements/ Operational Level Agreements	• Business, Operations and • System-level • Performance Agreements	• Customer engagement key performance indicators (KPIs) and system-level non-functional requirements that directly impact business and system-level operational performance	• Operational Engagement	• Project Initiation and revisited on a recurring basis in Operational engagement through service management efforts
Excellence	• Continuous improvement targets for business and system-level key performance indicators	• Targeted customer engagement KPIs and system-level nonfunctional requirements that have been designated as market differentiators in overall	• Ideation and Strategy • Operational Engagement	• Project Initiation and revisited on a recurring basis in Operational

Collaboration Level	Measure Attributes for Level	Method for Assessing Harmonization for Level	Application to Collaboration Domains	Timing in Engagement Lifecycle
		performance improvement for the initiative		engagement through service management efforts
Inspiration	• The intrinsic reward of achieving the goals of partnership and its impact on the recipients of the product/ service and industry as a whole	• Revisiting the mission and vision statements of each stakeholder, highlighting the ideals they promote and incorporating them within the culture of the initiative	• Program and Policy • Harmonization • Ideation and Strategy • Operational Engagement	• Throughout the course of the partnership as a method of team building and fostering trust across organizational and geographical boundaries