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RAPIDCARE: STRENGTHENING HEALTH SYSTEMS IN AN URBANIZING WORLD

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ABSTRACT

Today, rapid urbanization in Africa and Asia outpaces the development of essential urban infrastructures, resulting in the expansion of informal settlements. These crowded areas of entrenched poverty are particularly prone to infectious diseases, such as cholera, malaria, and Ebola. Furthermore, such populations are highly mobile and often out of reach of formal health systems, making infectious disease management remarkably challenging. This not only puts local residents at great risk, but also entire cities, countries, and regions given the interconnectedness of populations across rural and urban spaces and international borders. To address this global health challenge, our innovation RapidCare leverages the existing capacity of informal healthcare providers to better treat and monitor infectious disease in informal settlements. First, RapidCare improves malaria care in informal settlements by increasing the rate at which malaria is correctly confirmed with diagnostic testing. Second, this innovation makes data from the informal sector discoverable through improved data collection to better plan and allocate resources in these communities. Lastly, RapidCare enhances disease surveillance to enable the early identification of disease outbreaks in informal settlements. Overall, this diagnostic and disease surveillance solution will strengthen urban health systems and contribute to making cities more livable and healthy for those who reside in them.

THE TEAM



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Natalie is pursuing an MPH at Columbia University with a specialization in Public Health Research Methods and completed an H.BA in Peace, Conflict, and Justice studies from the University of Toronto. She is experienced in developing evidence-based recommendations for global health and humanitarian aid funding, with a specific focus on gender equality and sexual and reproductive health. Natalie is Canadian.



Anna Fechtor, Partnerships & Finance Lead

Anna is a graduate student at Sciences Po in the Governing the Large Metropolis program and completed her H.BA in Peace, Conflict, and Justice Studies at DePaul University. Previously, she developed E-Learning Interventions for incarcerated individuals in the United States and has successfully been awarded a number of National Institutes of Health grants. Her key skills include product development and cross-sector partnerships. Anna is American, from the U.S.

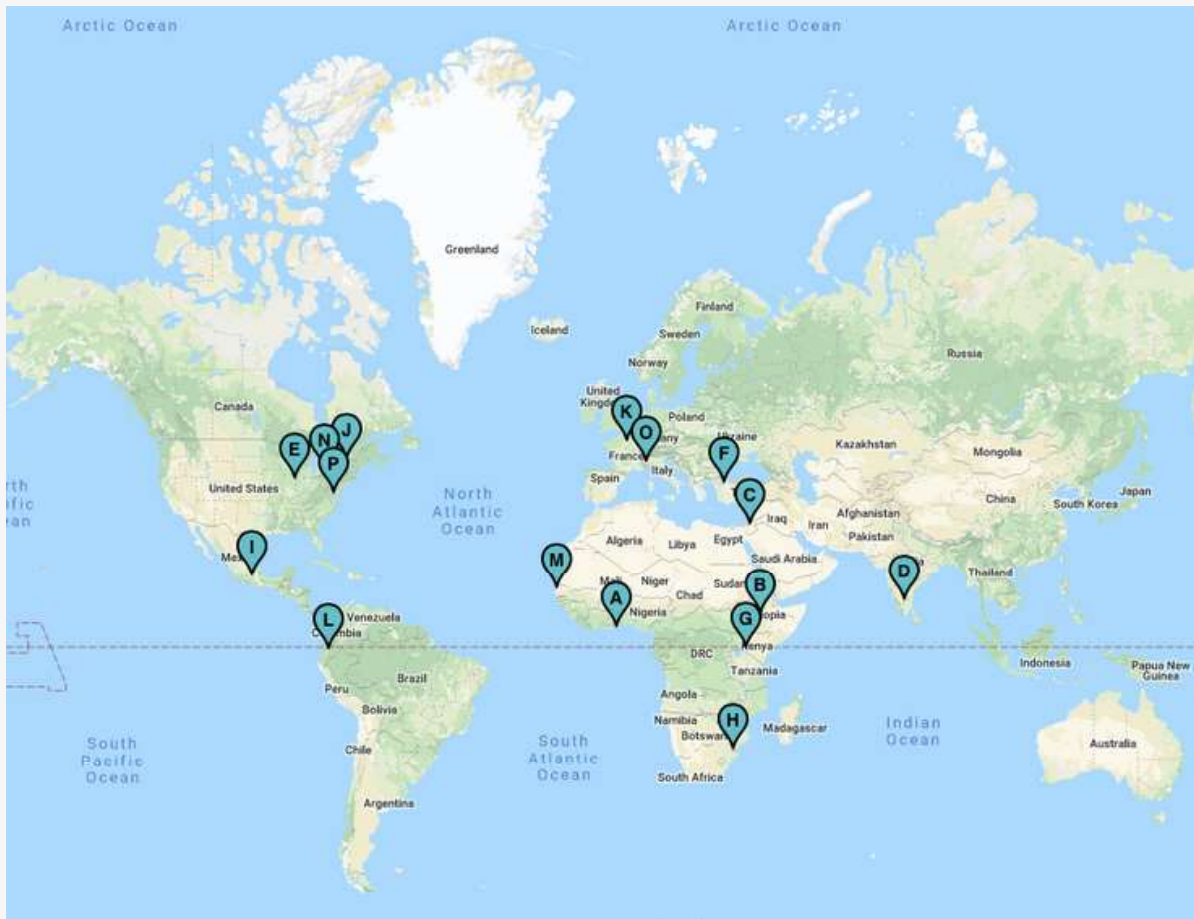


Maria Giorda, Technology & Data Security Lead

Maria completed a BSc in Business Management at King's College London and is currently completing her Master's degree in Governing the Large Metropolis program at Sciences Po. She has a specialization in Marketing and Product Innovation. Maria was previously the lead in launching and troubleshooting a web-based startup and is experienced in the application and analysis of geolocation data solutions. Maria is Italian.

THE TEAM IN THE FIELD

THE RAPIDCARE TEAM HAS WORKED IN 17 CITIES:



- Accra, Ghana
- Addis Ababa, Ethiopia
- Amman, Jordan
- Bangalore, India
- Chicago, USA
- Istanbul, Turkey
- Kisumu, Kenya
- Manzini, Swaziland
- Mexico City, Mexico
- Montreal, Canada
- Paris, France
- Quinto, Ecuador
- St. Louis, Senegal
- Toronto, Canada
- Turin, Italy
- Washington, USA

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SECTION 1

THE PROBLEM



Jamestown Fishing Village in Accra, Ghana on October 11, 2015. Photo © Dominic Chavez/World Bank

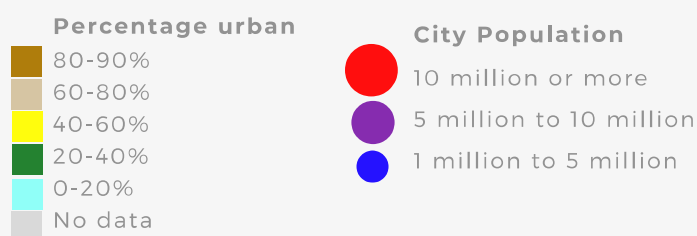
1.1 URBANIZATION, POVERTY, AND DISEASE

The world passed a key landmark in 2017: for the first time, more than half the people in low and middle-income countries live in cities (Bollyky, 2019). It has been suggested that urbanization was the single most important demographic change to face populations worldwide during the 20th century (Schell and Ulijaszek, 1999). As urbanization continues to accelerate in the world's poorest countries so too does the urgent need to ensure urban spaces are livable and healthy for those who reside in them.

Cities have long been vulnerable to infectious diseases. Today, rapid urbanization in the African and Asian continents is outpacing the development of urban infrastructures such as sewage, electricity and proper housing, resulting in the expansion of informal settlements, also known as slums. By 2030, the population of slum dwellers is expected to reach two billion globally (UN, 2018).

These crowded areas of entrenched poverty are often out of reach of national health systems, making infectious disease management remarkably more challenging. Not only are local residents at risk of illness, but so are entire cities, countries, and regions, given the interconnectedness of populations across rural and urban spaces and international borders. The risk of disease outbreaks will only increase in an era of climate change due to greater incidence of water-related disasters and changing patterns of vector-borne infectious diseases, such as malaria, dengue, and Zika (WHO, 2018a).

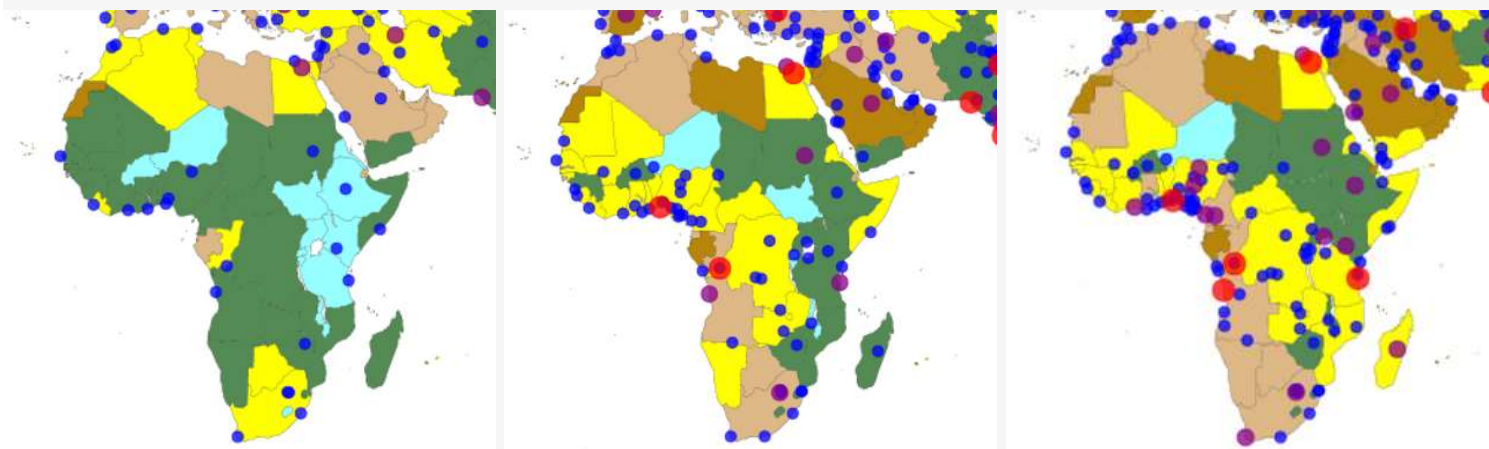
Percentage urban and urban agglomerations by size class



1990

2018

2030



Source: United Nations, DESA, Population Division, 2018



1.2 INTERNATIONAL FRAMEWORKS FOR ACTION

The international community has mobilized to address this crucial intersection of urbanization and health. The most important framework for action is the Sustainable Development Goals (SDGs) developed by the United Nations (UN).



Goal 3 of the SDGs aims to ensure healthy lives and promote well-being for all by 2030 by ending the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases, improving the capacity of the health force in least developed countries and strengthening the capacity for early warning, risk reduction and management of national and global health risks.



The SDGs, through Goal 11, also recognize the need to make cities inclusive, safe, resilient and sustainable by enhancing participatory, integrated and sustainable human settlement planning as well as protecting the poor and people in vulnerable situations affected by disasters, including water-related disasters.

Additionally, the Shanghai Declaration put forward by World Health Organization (WHO) in 2016 recognizes that cities are crucial settings for health. Specifically, the WHO recognizes that the path towards sustainable development must include prioritizing policies that create co-benefits between health and wellbeing and other city policies, making full use of social innovation and interactive technologies.

Cities must promote equity and social inclusion through strong community engagement and ultimately, health and social services must aim to optimize fair access by putting people and communities at the centre of policies.

1.3 URBAN HEALTH: AN INTERDISCIPLINARY GLOBAL HEALTH CHALLENGE

A key global health challenge of our time is achieving healthier cities for all. This challenge emerges from combined risks associated with rapid urbanization, continuing poverty and rising inequality, exemplified by the proliferation of informal settlements in resource-poor areas that are placed at an even greater risk due to climate change (DePaul, 2012). Inhabitants of informal settlements in large cities—today one billion people worldwide – are vulnerable to health risks associated with poor living conditions such as inadequate housing quality housing, lack of access to safe water and sanitation, and overcrowding. Informal settlements offer the “perfect breeding ground” for highly infectious diseases, such as cholera, malaria, and Ebola Virus Disease (EVD) and their populations are highly mobile and hard-to-reach by formal health systems (Snyder et al., 2014).

1.3.1 VULNERABILITIES IN URBAN HEALTH SERVICES

While cities often possess higher quality health services than rural areas, fragmented governance leads to inefficiencies in care delivery. Primary care health services are ill-adapted to the needs of the working poor, driving an increased dependence on emergency services that creates pressure on over-crowded, under-resourced hospitals to act as primary care providers (WHO and UN, 2010). This incurs high costs for both the state and users of the health care system, especially the urban poor. When inhabitants of informal settlements venture to use formal services, they face long distances, high out-of-pocket costs for travel and care, long wait times and stigmatization by health care providers in public hospitals (Barua and Pandav, 2011). Perceived poor quality, inconvenience, mistrust and, in some cases, bribery, serve as disincentives for the urban poor to use formal services, and contribute to the rise of an informal sector of unregulated, unaccredited, commercial health care (WHO and UN, 2010).

1.3.2 EMBEDDEDNESS OF INFORMAL PROVIDERS IN WEAK HEALTH SYSTEMS

The informal health sector has become a feature of urban systems across cities, and offers a convenient alternative to formalized care (WHO and UN, 2010). For example, informal practitioners provide a large portion of outpatient healthcare in India (Das et al., 2016) and Bangladesh (Ahmed et al., 2008) and play a significant role in health care provisioning across the continent of Africa (Oshiname and Brieger, 1992); (Bloom et al., 2011). Practitioners are often trusted members of the community and patients can receive quick care for minor ailments or fever (Sudhinaraset et al., 2013). While filling an important service gap, these markets feed into the inefficiencies of the formal system. Left unmonitored and unregulated, the work of informal workers poses serious risks to users, including “poor quality, inappropriate and sometimes potentially dangerous medical care” (Bloom et al., 2011). Informal providers often receive only limited formal training and this can pose challenges with regard to misdiagnosis, over prescribing, and adherence to national health guidelines (Sudhinaraset et al., 2013). Despite this, Bloom and colleagues (2011) find that informal providers in Bangladesh and Nigeria want to receive training to improve the quality of their care, but are often excluded from government information about updates to best practices in infectious disease treatment.



Daily life in Mamobi neighborhood in Accra, Ghana on October 15, 2015. Photo © Dominic Chavez/World Bank

Informal service providers are also important, but often ignored, sources of information in disease surveillance. Harmon (2010) notes that as the speed at which people and animals move increases, there is an imperative to rely on informal healthcare providers as a form of “participatory epidemiology” in order to increase the efficiency of disease surveillance, as traditional pathways can take weeks to validate information on emerging epidemics.

1.3.3 THE CHALLENGE OF TECHNOLOGY AND DATA CAPTURE

Addressing the issue of disease outbreaks in urban spaces involves both risk reduction and crisis management through timely identification, active monitoring and rapid follow-up of medical cases. This cannot be easily done in resource-poor informal settlements. For example, while location data is an essential requirement to effective disease surveillance, the mapping of informal settlements is challenging as their mere existence is not always acknowledged by the government and buildings are subject to sudden and rapid changes.

Mobile phones enable healthcare authorities to capture, store and analyze data from otherwise hard-to-reach populations. Unfortunately, discussions around mHealth often see governments, humanitarian organizations and universities as the only important stakeholders, whereas technology users are not adequately included (Cinnamon et al., 2016). Therefore, data capture must be considered as a social technology that can build more resilient communities and strengthen health systems through trustworthy relationships between clients and services providers and continuous dialogue between healthcare authorities and technology users (Ryan et al., 2019).

The effective use of data capture technologies that engage with the necessary stakeholders have the potential to improve the quality, quantity and timing of information necessary to limit the rapid spread of infectious disease in informal settlements (Oyelere et al., 2018).

1.3.4 THE URBAN BURDEN OF MALARIA



Photo: John Hogg / World Bank

The Global Technical Strategy for Malaria, which was adopted by the World Health Assembly in 2015, demonstrates that eliminating malaria is a global priority (WHO, 2016). However, malaria remains a significant global health challenge, and decades of progress in eradicating the disease are beginning to slow. In 2017, there were 219 million malaria cases, in which 435,000 people died and the WHO World Malaria Report 2018 reports that no significant progress was made in the last three years (WHO, 2018b). The burden of malaria is highly concentrated and approximately 85% of malaria deaths, occur in Africa, primarily in young children (Hay et al., 2005).

Malaria also has a significant impact on human capital and economic growth, for example, the burden of malaria costs the African continent an average of USD \$10-12 billion a year in gross domestic product losses (Dako-Gyeke and Kofie, 2015).

Rapid urbanization in the African continent will exacerbate the problem of malaria infection in urban informal settlements, especially for the poor (Klinkenberg et al., 2006). It has previously been estimated that 200 million people are at risk of malaria in urban Africa and this will increase due to the growing risk of urban flood and changing precipitation patterns in an era of climate change (Huq et al., 2009). In Africa, coastal towns are among the most vulnerable to climate change impacts such as flooding and sea level rise, raising the risk of greater malaria prevalence due to new urban breeding grounds for mosquito larvae, as well as outbreaks of waterborne diseases and neglected tropical diseases.



Photo: Farhana Asnap / World Bank

SECTION 2

THE SOLUTION



Ghana. Photo: © Arne Hoel/The World Bank

2.1 ANSWERING THIS GLOBAL HEALTH CHALLENGE

To address the complex challenge of creating healthier cities in the context of rapid urbanization, our innovation will leverage the existing capacity of informal healthcare providers to better treat and monitor infectious disease in informal settlements. Our innovation will use a proven rapid diagnostic testing tool to improve malaria case-management while also contributing to more robust disease surveillance in hard-to-reach urban communities.

Overall, our solution will ensure that the urban poor have better access to lifesaving health services while also limiting the risk of rapid, unchecked disease outbreaks in cities with high levels of informality. Our intervention not only empowers informal communities with technology and improved data capture to inform more robust risk reduction strategy, but also lay a solid foundation for the implementation of future emergency responses to disease outbreaks in cities.

2.2 ACCRA, GHANA

Ghana, in West Africa, has a total population of 28.8 million in 2017 (World Bank, 2017). West Africa is a region prone to infectious disease as illustrated by the recent Ebola epidemic that spread throughout Guinea, Liberia, and Sierra Leone in 2014-16.

While EVD did not occur in Ghana, the country faces a number of vulnerabilities to disease outbreaks including porous borders between neighboring countries that makes national disease surveillance a particular challenge. Furthermore, the national health system faces significant challenges including limited financial investment in healthcare, shortage of healthcare workers, medications and medical supplies, poor information systems, and overall weak governance (Nyarko et al., 2015).

Ghana's Ministry of Health has oversight over national health policies and the Ghana Health Service is responsible for delivery of public health and clinical services. Ghana's National Health Insurance Scheme (NHIS) provides a comprehensive benefits package to the population. However as of 2016, only about 40% of the Ghanaian population was enrolled with the NHIS, suggesting that the program is not fully embraced by communities due in part to clients' concerns on service quality in NHIS-accredited health facilities (Alhassan et al., 2016).



Figure 1: Map of Ghana in West Africa.
Source: World Atlas.

Ghana's Telecom sector has experienced rapid growth and substantial liberalization. By 2017 almost 39% of the population in Ghana regularly had access to the Internet and unique mobile phone subscriptions reached 19 million (World Bank, 2017).

Both international mobile service providers, internet companies and international aid organizations have been supporting Internet penetration in Ghana's largest cities, whereas rural areas remain underserved (Endert, 2018).

In Accra, 3G signal is particularly good for all six main mobile service providers operating in Ghana and consistent across all districts of the Capital (NCA, 2016). Price is one of the most relevant barriers to access to the Internet as the cost of 1GB of data corresponds to over 2% of a person's average monthly income.



Photo: "Malaria medication" by World Bank Photo Collection is licensed under CC BY-NC-ND 2.0

2.2.1 THE CHALLENGE OF TREATING GHANA'S ENDEMIC MALARIA

Ghana is considered to be a stable endemic area for malaria, with *Plasmodium falciparum* being the prevailing species, accounting for between 90 to 98% of infections. Malaria is the leading cause of morbidity and mortality in the country, reported to be responsible for 20% to 30% of deaths in children under five years of age and 11% of maternal deaths (Ghana Urban Malaria Study, 2013). According to the 2016 Ghana Malaria Indicator Survey, nationally, 21% of children ages 6 to 59 months tested positive for malaria by microscopy (Malaria Indicator Survey, 2016).

Even though more than half the population is insured through Ghana's national healthcare scheme, over 50% of children who had recently had a fever sought treatment from the private sector rather than the public sector, a trend that has increased substantially in recent years (Ghana Malaria Operational Plan, 2016).

This is in part because poor informal workers in the country are often not able to pay the premiums for membership to the national insurance scheme and therefore seek services outside the formal sector (Alfers, 2016). Overall, diagnostic testing for malaria of children under five years of age is very low, ranging from 35 to 27% depending on location (Malaria Operational Plan, 2016). However, in spite of the low rate of testing, clinical staff diagnosis approximately 40–50% of all sick children who have a fever with malaria, suggesting high rates of misdiagnosis and overprescribing in the country (Stoler, et al., 2015).

2.2.2. UNEQUAL VULNERABILITY TO MALARIA INFECTION IN ACCRA

Ghana is urbanizing rapidly: the 2010 census documents over 50% of the population living in urban areas (Malaria Operational Plan, 2016). Accra, the country's capital and biggest city, is located in the south, along the coast of the Gulf of Guinea, with a population of approximately two million (Malaria Operational Plan, 2016).

There is significant spatial disparity with regard to malaria prevalence in Accra, the average prevalence is 14.8% but this ranges from 6% to 22% depending on community (Klinkenberg et al., 2006).

This variation is caused by proximity to urban agriculture and by household socio-economic status. For example, the prevalence of malaria parasite among children living in the poorest households in Accra was 50% to 100% higher than the average for children elsewhere in the city (Ghana Urban Malaria Study, 2013).

Not only does urban poverty increase the likelihood of malaria infection, urban poverty is associated with lower rates of adherence to antimalarial treatment guidelines and less use of laboratory testing (Ghana Urban Malaria Study, 2013). Furthermore, the built environment is a key determinant of malaria risk. In a study by Fobil et al. (2012) three hotspots were identified in Ghana where the risk of malaria infection was high.

These malaria hotspots were near an open lagoon, as well as in poorer neighborhoods of southern central and northern Accra, suggesting that large water bodies and water accumulation in the communities also impacts malaria risk.

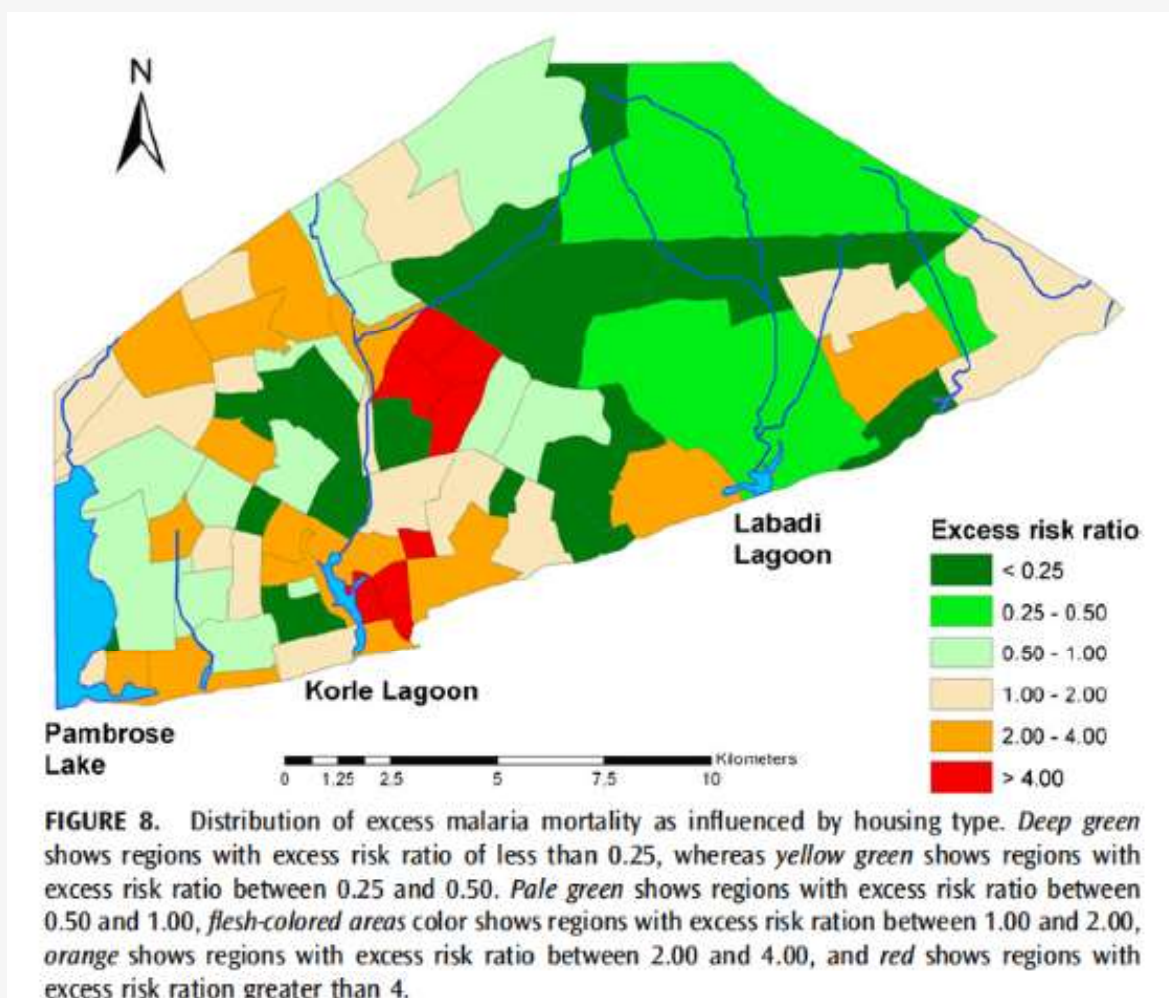


Figure 2: Distribution of excess malaria mortality in Accra as influenced by housing type.
Source: Fobil, Julius N., et al. 2012.

2.2.3. URBAN LAUNCH SITE: JAMES TOWN & USSHER TOWN, ACCRA

James Town and Ussher Town are two informal settlements located in these hotspots that are particularly prone to malaria risk (see Figure 3). These communities constitute the Ga-Mashie Traditional Area home to 100,000 people, predominantly inhabited by indigenous Ga people (Accra Poverty Map, 2010).

Both areas characterized by poor sanitation and drainage systems that make the area prone to flooding and breeding of mosquitoes, especially during the rainy season (Atiglo et al.). The communities are some of the poorest in Accra, with an average monthly income of GH¢126 (USD \$78) compared to the average of GH¢544 (USD \$340) in the rest of the city (Oteng-Ababio, 2014).

A recent study by Awuah et al. (2018) of these two communities suggests that 61% of people who experience malaria like symptoms sought treatment outside of the public healthcare system, going to private providers.

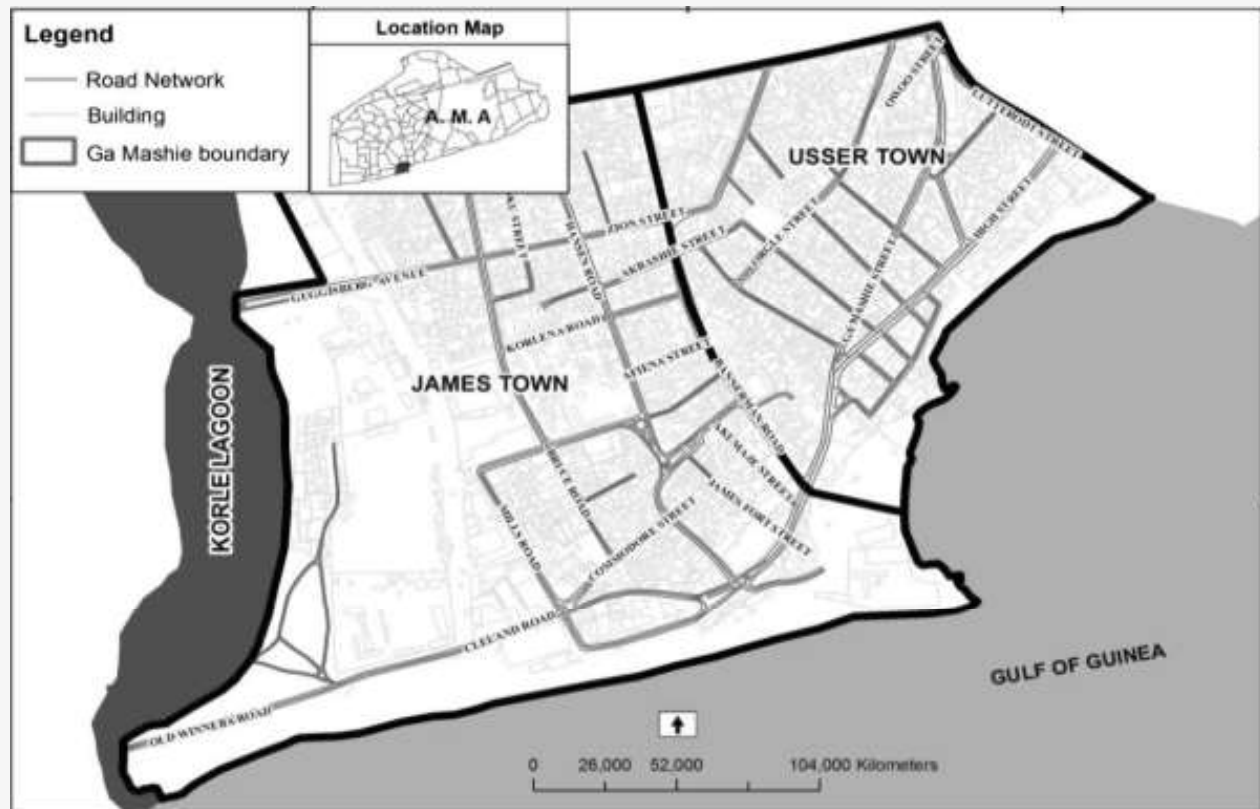


Figure 3: Map of James Town and Ussher Towns, Accra Ghana.

Source: Oteng-Ababio, 2014.



Photo © Dominic Chavez/World Bank

2.3 THE INNOVATION: RAPIDCARE

2.3.1. OVERVIEW OF THE PROGRAM

Our innovation, RapidCare, is a new diagnostic and disease surveillance solution that will contribute to tackling the challenge of the provision of healthcare services in informal settlements. It is an app suite, android and web-based, that will leverage the role of healthcare providers embedded in hard-to-reach informal settlements to improve treatment for malaria and monitor for other infectious disease.

The RapidCare mobile app will be used by Over the Counter Medicine Sellers (hereafter called Medicine Sellers) operating in the communities of James town and Ussher Town in Accra, the capital city of Ghana. RapidCare mobile app will improve the use of rapid diagnostic testing (RDT) of malaria by Medicine Sellers at their shops and will also include behavioural ‘nudges’ with case-management guidelines for malaria and other commonly occurring illnesses. In addition, through this app, Medicine Sellers submit patient symptoms and patient locations in the community to the RapidCare web-based platform for data aggregation and analysis, which serves two purposes. First, data collected on malaria cases will help to identify hotspots and trends in malaria prevalence over-time. Second, collection and assessment of clinical signs of other infectious diseases such as cholera and Ebola, will offer a new opportunity to monitor for disease outbreaks in these informal settlements.

The RapidCare program consists of three core technologies:



A standard malaria test



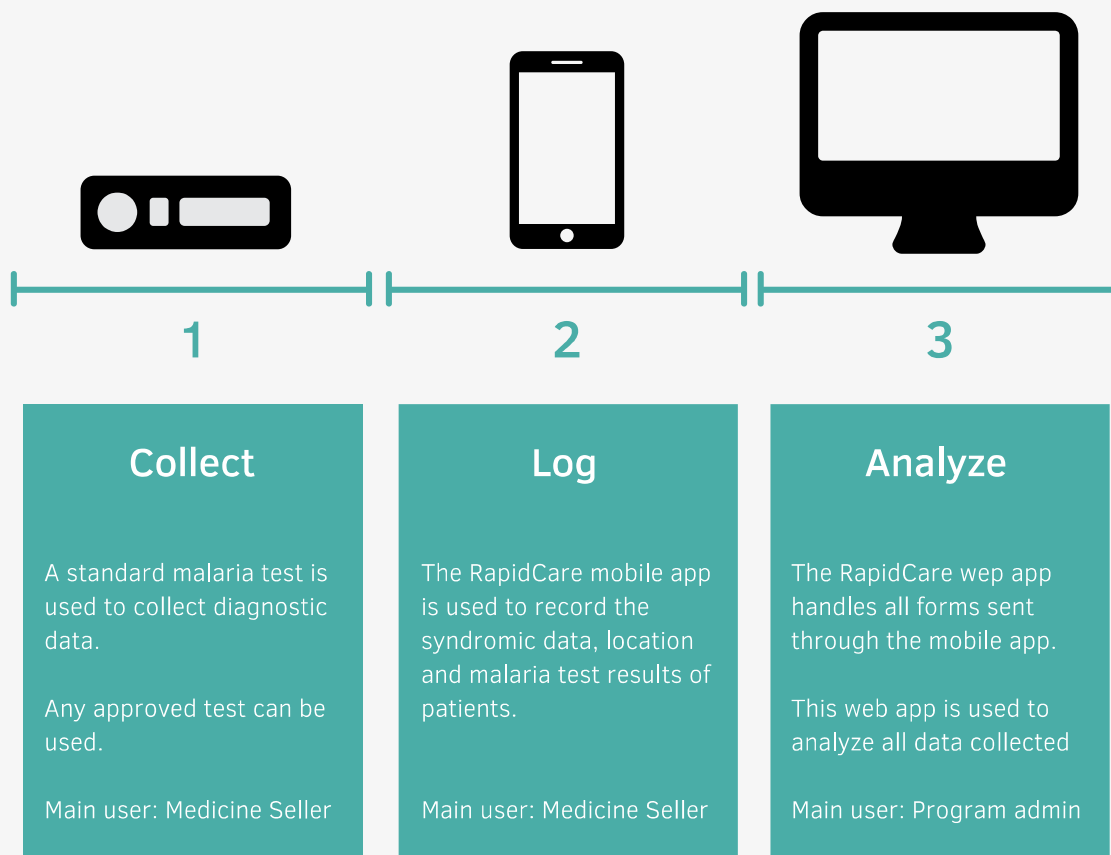
A digital data capture tool
(a native, android-based app)



A digital data monitoring tool
(a web-app)



The components function as steps in a process to collect, log, and analyze malaria test results conducted by Medicine Sellers in a systematic and continuous way. The digital components make up the RapidCare suite. Both apps would be developed using Open Data Kit (ODK), a free and open-source software for creating, storing and analyzing data surveys.



2.3.2. IMPACT OUTCOMES

The proposed innovation seeks to strengthen urban health systems. It achieves this through three principal impact outcomes:



Improve malaria care in informal settlements of James Town and Ussher Town in Accra, Ghana. Use of RapidCare will increase the rate at which malaria is correctly confirmed with diagnostic testing.

Make data from the informal sector discoverable through improved data collection to better plan and allocate resources in these communities. This will improve reporting on the burden of malaria in Accra's informal settlements, ensuring the urban poor are prioritized when designing health services.

Enhance disease surveillance to enable the early identification of disease outbreaks in Accra's informal settlements. Data collection from these hard to reach communities will enable better emergency responses to outbreaks.

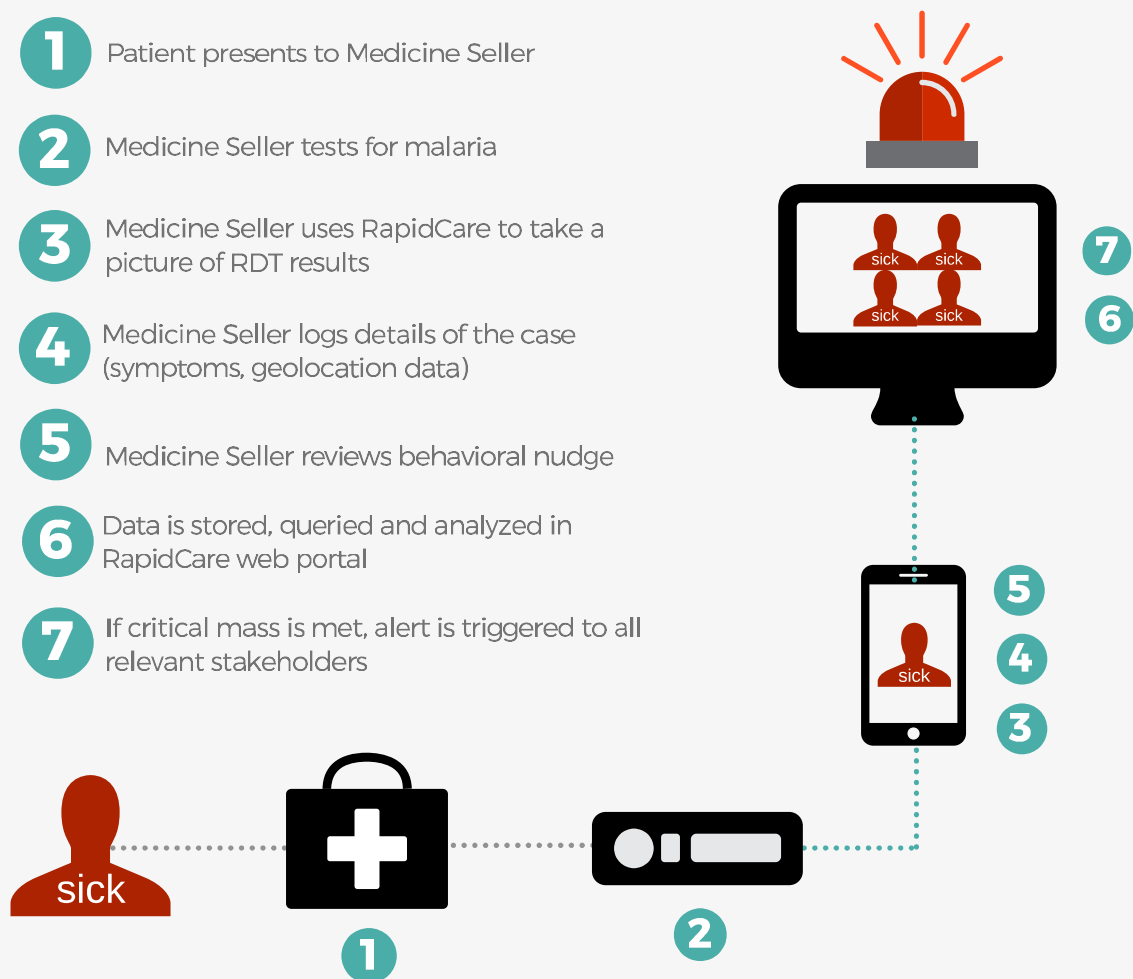


STRONG HEALTH SYSTEMS

in an urbanizing world must partner with the informal sector to achieve better health for all.

2.3.3. HOW IT WORKS

RapidCare assembles various actors and technologies into a one-stop shop for disease surveillance in informal settlements. This program is poised to radically increase government capacity to monitor to disease outbreak, promote improved care practice by Medicine Sellers in the informal sector, and integrate one of the most at-risk and hard-to-reach populations into a health system through improved data capture.



2.3.4. INNOVATION

RapidCare harnesses digital technology and modern data analytics to transform the way urban health systems address infectious disease and the needs of the poor. Concretely, the solution offers three critical innovations on existing malaria programs.

1 RapidCare assembles existing technology in a new app suite specifically designed for disease and outbreak monitoring in a challenging urban environment.

In addition to custom app architecture and functionalities, the RapidCare suite also mobilizes the following available resources:

- **Image-processing software.** Designed by Vanderbilt University, approved by the Federal Drug administration in the United States, and integrated within a new, mobile app interface. To date, the technology has been used for at-home malaria testing only.
- **Malaria rapid diagnostic tests.** Any standard malaria test can be detected by RapidCare, permitting transferability and program scale.
- **OpenMapKit.** An open-source mapping software (connected with ODK) that allows communities to add geospatial data to a map.
- **Evidence-based methodology to analyze symptoms.** Data for negative malaria test results is analyzed using a methodology developed and tested by the Southern Africa Centre for Infectious Disease Surveillance to monitor for other infectious diseases (Karimuribu et al., 2017).

2 RapidCare embeds education modules and behavioral nudges within the malaria testing process.

Education modules and accompanying behavioral nudges offer incentive for Medicine Sellers to improve the quality of care they provide for malaria and other commonly occurring illnesses.

3 RapidCare offers an unprecedented system level contribution to disease monitoring and surveillance.

By capturing aggregate data on clinical symptoms of emerging or other high-risk infectious diseases in hard-to-reach informal settlements, this innovation offers a unique opportunity to build the necessary local capacity to find and limit disease outbreaks as quickly as possible.

This is particularly important in the context of quickly urbanizing cities such as Accra, not only because of the prevalence of common infectious diseases but also due to the risk of emerging diseases in the region that spread rapidly through informal settlements. To insist on local data ownership, the central server collecting and analyzing the information sent through the app is hosted by a local actor (University of Ghana or the Ministry of Health).

2.3.5. TECHNOLOGY



Photo: © Arne Hoel/The World Bank

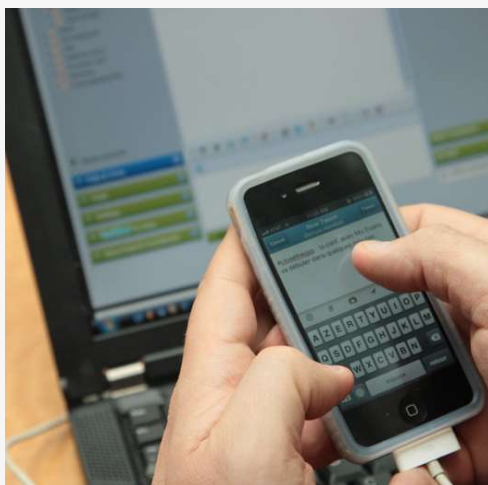


Photo: Simone D. McCourtie / World Bank



Photo: © Arne Hoel/The World Bank

MALARIA TEST



A key challenge in diagnosing and treating malaria is its prompt diagnosis, especially in resource-limited areas where microscopy is unavailable. Rapid diagnostic tests (RDTs) assess blood for specific proteins produced by malaria parasites and generally produce results in 15-30 minutes, meaning that they have “the potential to greatly improve the quality of management of malaria infections” (Rapid Diagnostic Testing, WHO). For example, a 2017 study on the impact of the usage of malaria RDTs by health providers in Senegal found that incorrect prescription of antimalarial treatment for patients who do not have malaria decreased by 41.4% (Thaim et al., 2011).



Photo: "2010-09-15%20at%2008-50-45" by Pan American Health Organization PAHO is licensed under CC BY-ND 2.0

RAPID CARE APP SUITE

Native Android-Based App

The mobile Android-based app is a tool to collect and analyze malaria tests, and record patient symptoms. It is designed for use by Medicine Sellers. It consists of eight modules, which are outlined below:



Home Page

From here the user can start scanning a test or navigate to other pages of the app. Thumbnails at the bottom and on the top left corner of the screen allow the user to access the other app modules and change his/her personal and contact details.



General Guidelines

This module provides the Medicine Seller with advice from general pharmaceutical guidelines. This content is unlocked by the user as they submit client data for those that do not test positive for malaria. Once unlocked it can be accessed and navigated at any time.

User Account

From here the user can fill in or modify his/her personal information and contact details, and request more malaria tests.



Malaria Case Management

From here the user can access the recommendations from malaria treatment guidelines after submitting a positive test. Once a content is unlocked, it can be accessed and navigated at any time.



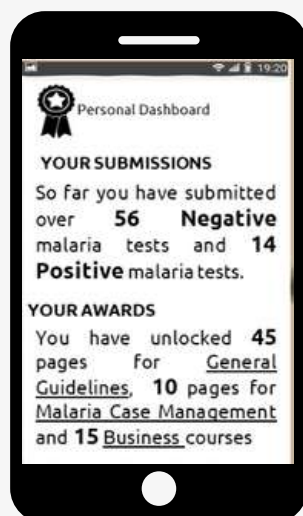
Business Advice

From here the user can access the articles or videos unlocked after submitting a test which are related to important best practices for their small business. The module's content is ordered so to become progressively more complex.

NextGenU

From here the user can access the articles from NextGenU, the world's first free accredited higher education with a focus on the health sciences.





Personal Dashboard

From here the user can consult stats on the number of positive and negative tests submitted and learning achievements.



Alerts

From here the user can access the alerts received by relevant authorities. Alerts functions as the user's inbox. Messages can range from notifications of visits from partner organisations to alerts of malaria peaks or cholera/ebola outbreak. Alerts of an epidemic outbreak are also pushed automatically to a user's homepage.



Recognition Notification

This module notifies the user of having been awarded an accreditation. The certificate is delivered by hand by the local partner organization and recognizes those users that have proved to be trustworthy reporters.



RAPIDCARE APP SUITE

Web-Based App

Data collected by Medicine Sellers feeds into a central database. The server is hosted by the public university in Accra, and, after government uptake, the Ministry of Health. The web-app displays aggregate data in data tables, which can be queried to produce data visualizations.

The web-app is encoded with an alert system, which is triggered by data activity (e.g. spikes in activity, a critical mass of positive test results, etc.).

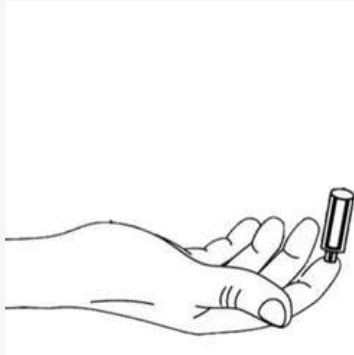
The webpage also allows for different user accesses. Only the development team and partner university will have administrative privileges and be able to add new Medicine Sellers to the database, configure their mobile device, and change use case standards or relevant thresholds.



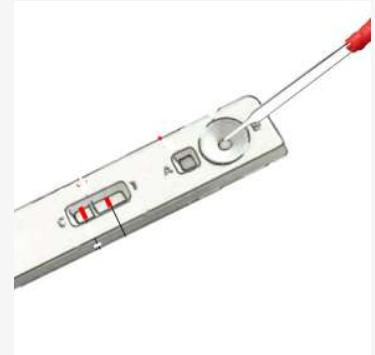
2.3.6 USING RAPIDCARE : STORYBOARD AND BASIC NAVIGATION



Medicine Seller decides whether or not to screen patient for malaria

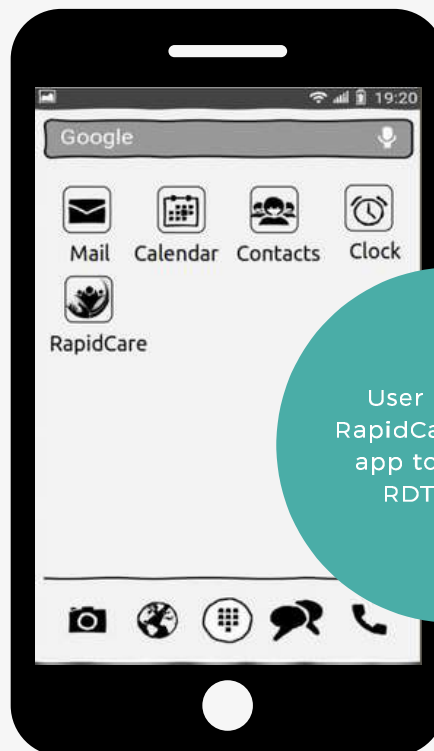


Blood sample is taken from the patient



RDT is initiated. The test result is expressed by the test line. The control line checks the test's validity.

RAPIDCARE IS INITIATED



User accesses RapidCare android app to read the RDT results

HOME SCREEN

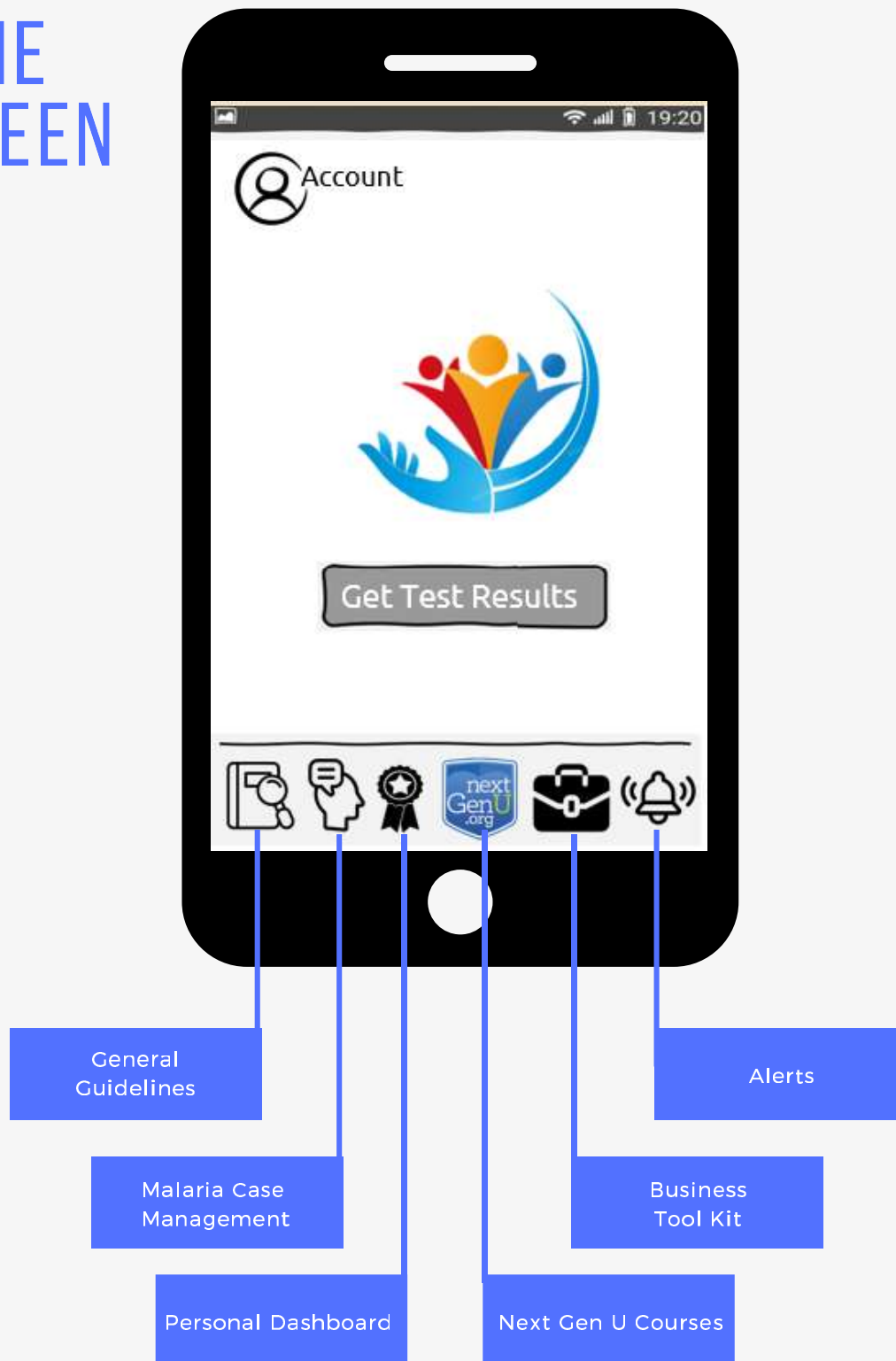
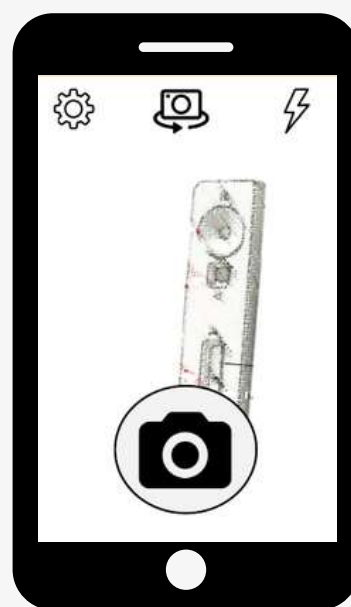


IMAGE PROCESSING

The home page prompts the user to take a picture of the malaria RDT. Touching "Take a Picture" the mobile application initiates the phone's camera. The pixel intensity of the test line is analyzed by an image processing algorithm embedded in the app to identify whether the test is positive or negative. This information is then decoded and presented to the user within a single view. If the quality of the image taken does not allow a correct interpretation of the test, the user is prompted to retake the photo. Pictures unreadable by the software cannot be saved and sent. Users may scan multiple tests at a time. Images take up to 20 minutes to process, and can load in the background of the app.



1

Clicking on "Read Test Results" in the app opens the phone's camera for image processing

Once a picture of the test is taken the app prompts the user to process the image

2



If the image is unreadable (e.g. blurry, out of frame) the button will instead read "Retake Image"

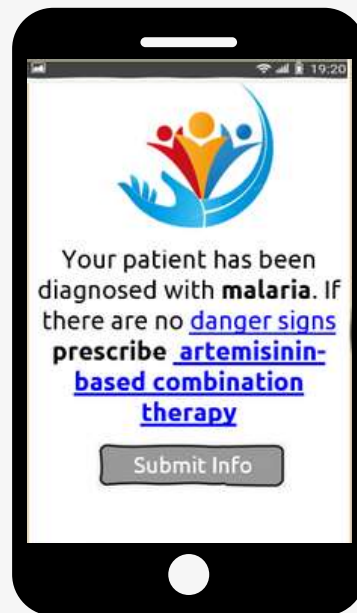
USE CASE: POSITIVE TEST RESULTS

If the test has not expired and the result is positive (the patient is affected by malaria), the user is directed to a questionnaire asking for more details on the patient: sex, age group, if it is the first time the patient is tested, whether he or she works or lives in the area, and the patient's home location. Home location is determined by asking what type of landmark the patient lives the closest to.



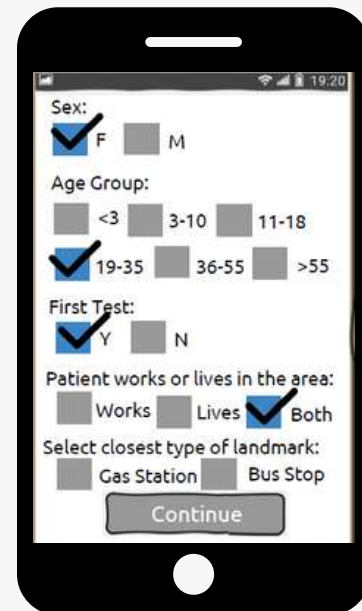
1

After a positive test, the user is reminded of the recommended treatment of *P. falciparum* malaria



2

This page gives links to sources about ART therapy and important information on signs of severe malaria



3

The user is prompted to add information about the patient

USE CASE: POSITIVE RESULTS

Relevant landmarks are then displayed on a map as pins. Users can visualize a photo of each landmark by touching on the pin and can then select the relevant one for them. The questionnaire is then sent or saved offline until an internet connection becomes available. After the positive test has been successfully completed the user can access the recommendations specific to the diagnosis, treatment and prevention of malaria through the malaria case management module.



USE CASE: NEGATIVE RESULTS

If the image processing returns a negative result, the user is asked to select the symptoms from which the patient suffers from on a list. After this, whether he/she works or lives in the area, and home location. Home location is determined by asking what type of landmark the patient lives the closest to.

1

If the result is negative, the user is prompted to submit additional information about the case



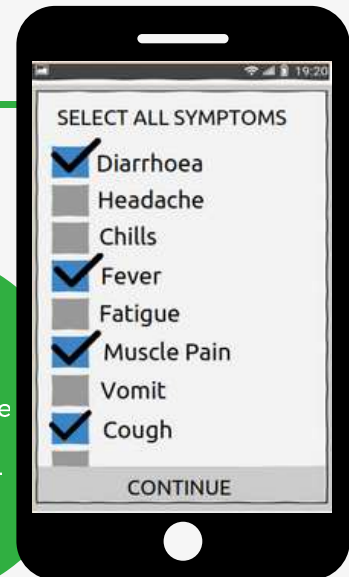
Test Line: **Negative**

The patient does not appear to have malaria.
Do not prescribe anti-malarial drugs

Add Symptoms

2

User selects symptoms displayed by the patient in a 'check-all-that-apply' format



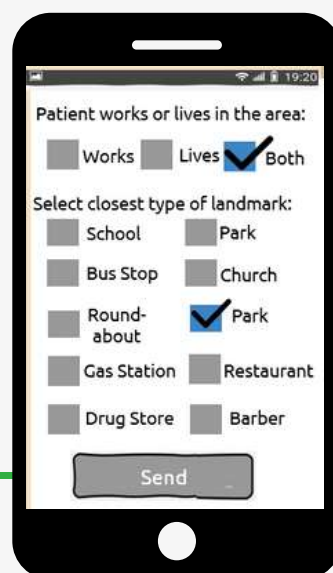
SELECT ALL SYMPTOMS

- ☒ Diarrhoea
- ☐ Headache
- ☐ Chills
- ☒ Fever
- ☐ Fatigue
- ☒ Muscle Pain
- ☐ Vomit
- ☒ Cough

CONTINUE

3

User is prompted to provide further information about the patient's home and work location



Patient works or lives in the area:

☐ Works ☐ Lives ☒ Both

Select closest type of landmark:

☐ School ☐ Park

☐ Bus Stop ☐ Church

☐ Round-about ☒ Park

☐ Gas Station ☐ Restaurant

☐ Drug Store ☐ Barber

Send

The choice of landmark will define the list of places showed to the user on the following page

USE CASE: NEGATIVE RESULTS

Relevant landmarks are then displayed on a map as pins. The questionnaire is then sent or saved offline until an internet connection comes available. This information is then sent to the central server and the user is redirected to an information card unlocked within the General Guidelines module, and displaying relevant legal, pharmaceutical or medical information.

4

Landmarks selected are displayed on a map. E.G: If the user chooses "Park" the map will show all parks in the area

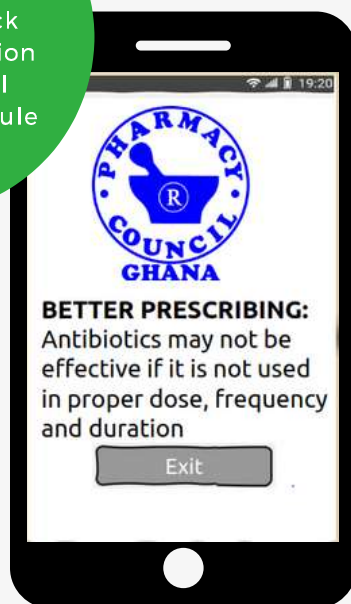
Clicking on a specific pin/landmark the user can visualize a picture of it and select it if it is the correct one



After submitting a negative test, the user will unlock useful information in the General Guidelines module

5

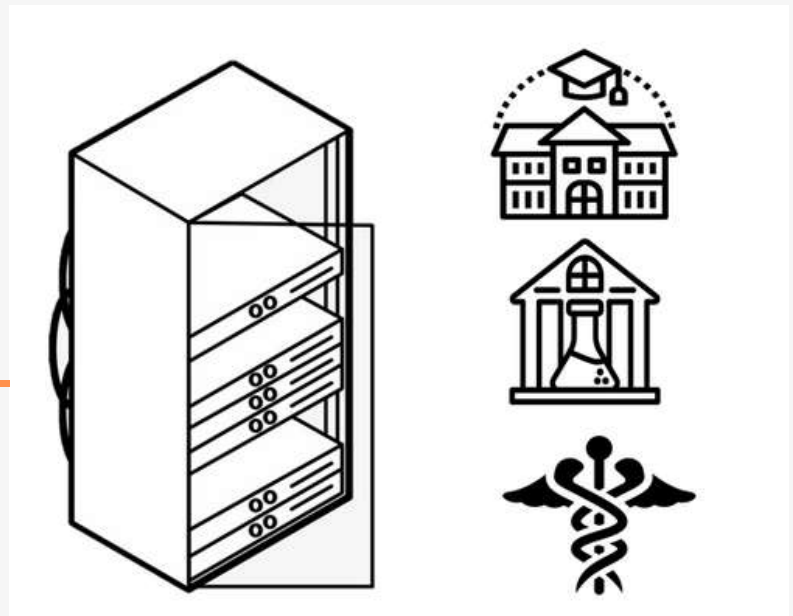
General Guidelines will include messages ranging from law, ethics and best practice standards from trusted sources



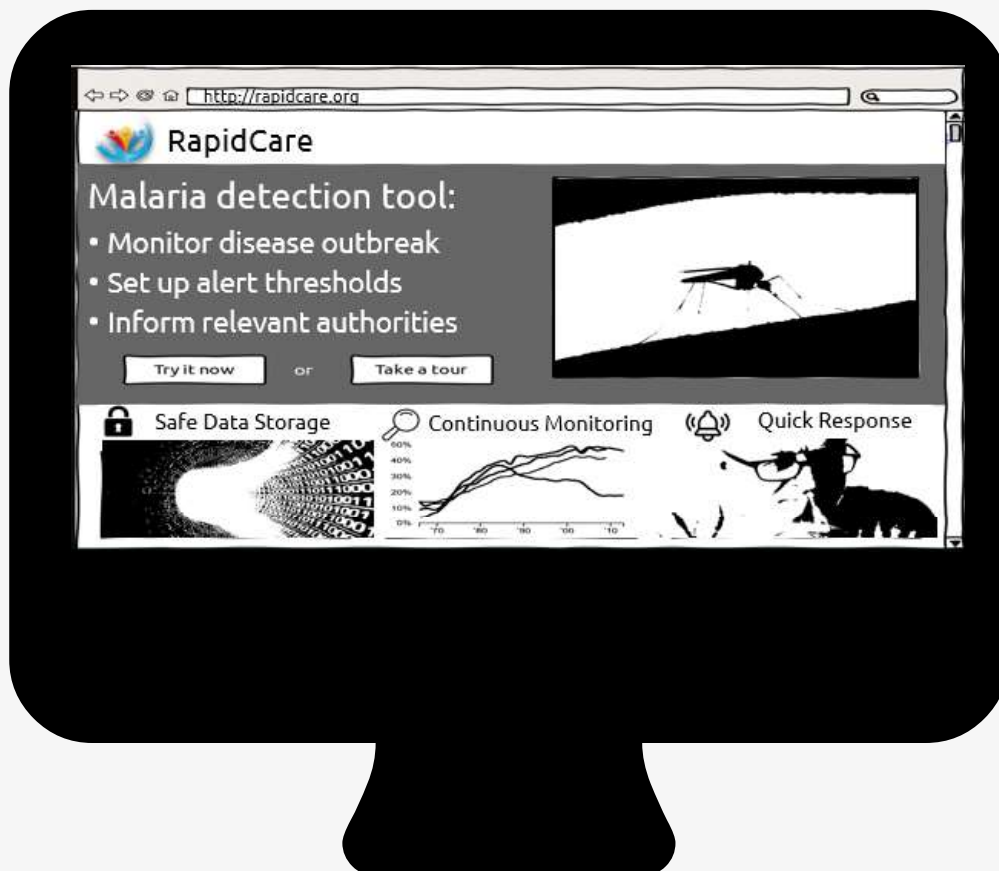
DATA AGGREGATION

The data collected by the user is transmitted to a centralized server that allows real-time data monitoring to all relevant stakeholders.

Data is stored in server located in University of Ghana

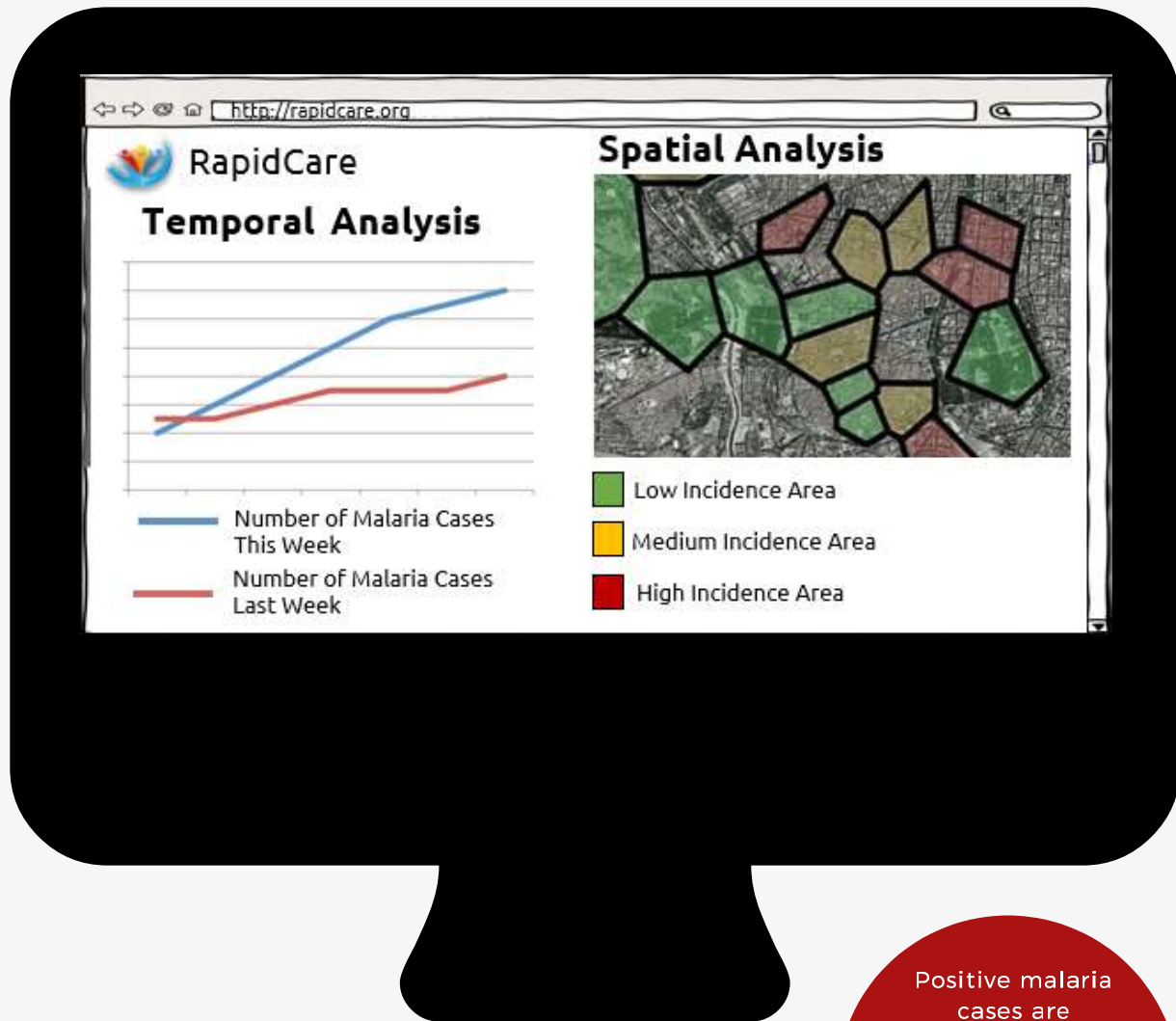


Data is analysed automatically and can be consulted from a web-based page



DATA ANALYSIS: POSITIVE RESULTS

Data points coming from positive tests are collected separately and monitored on an ongoing basis to identify malaria peak seasons, and the areas and people most affected. In order to do this, malaria instances can be displayed by age and gender or geo-localized on a map.



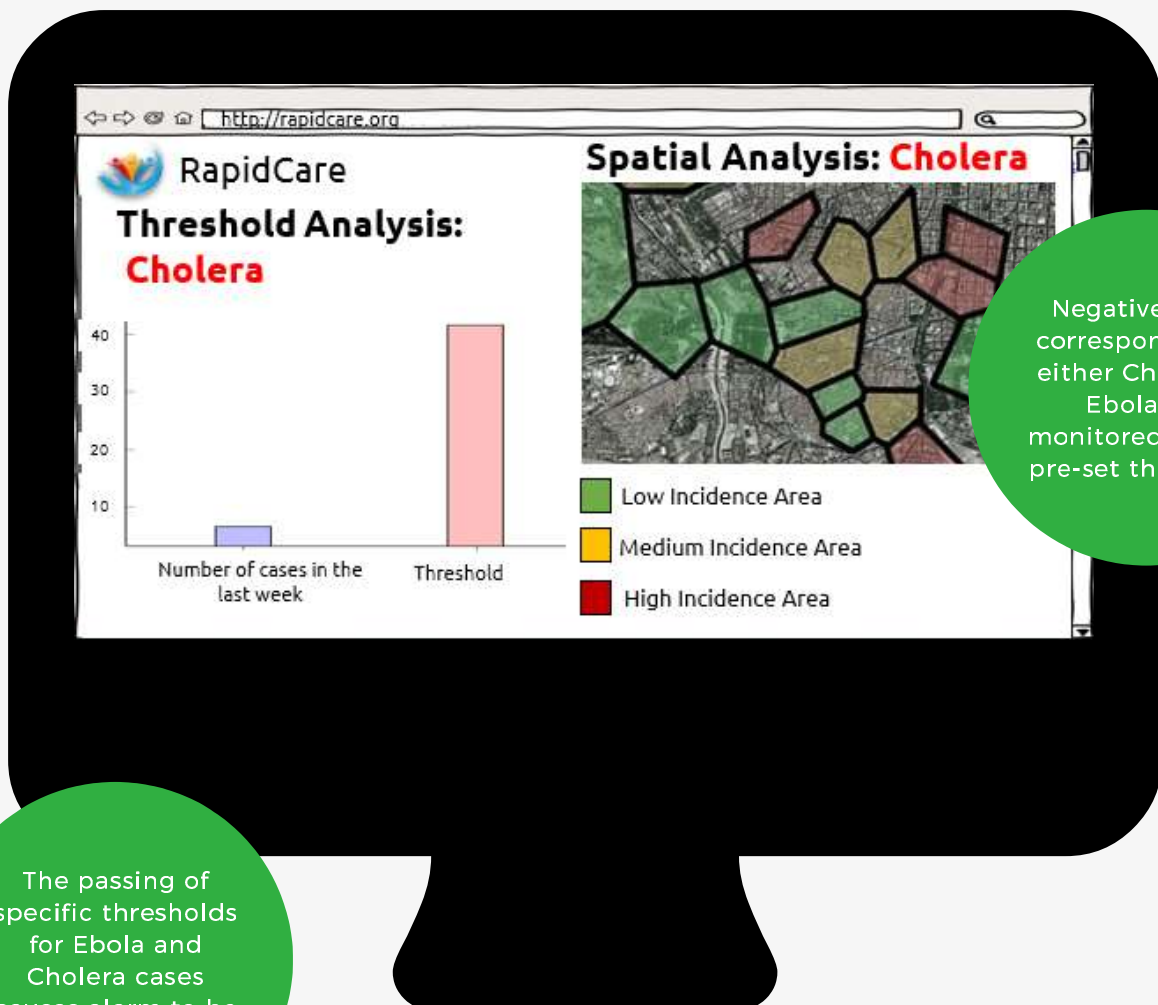
Positive malaria cases are constantly monitored to identify peaks in time and patterns in spatial distribution

DATA ANALYSIS: NEGATIVE RESULTS

A Knowledge Repository (KR) assigns case definitions for Cholera and Ebola based on clinical signs as symptomatic data coming from negative tests is automatically cross-checked against the preset weighted clinical manifestations stored in the server's KR.

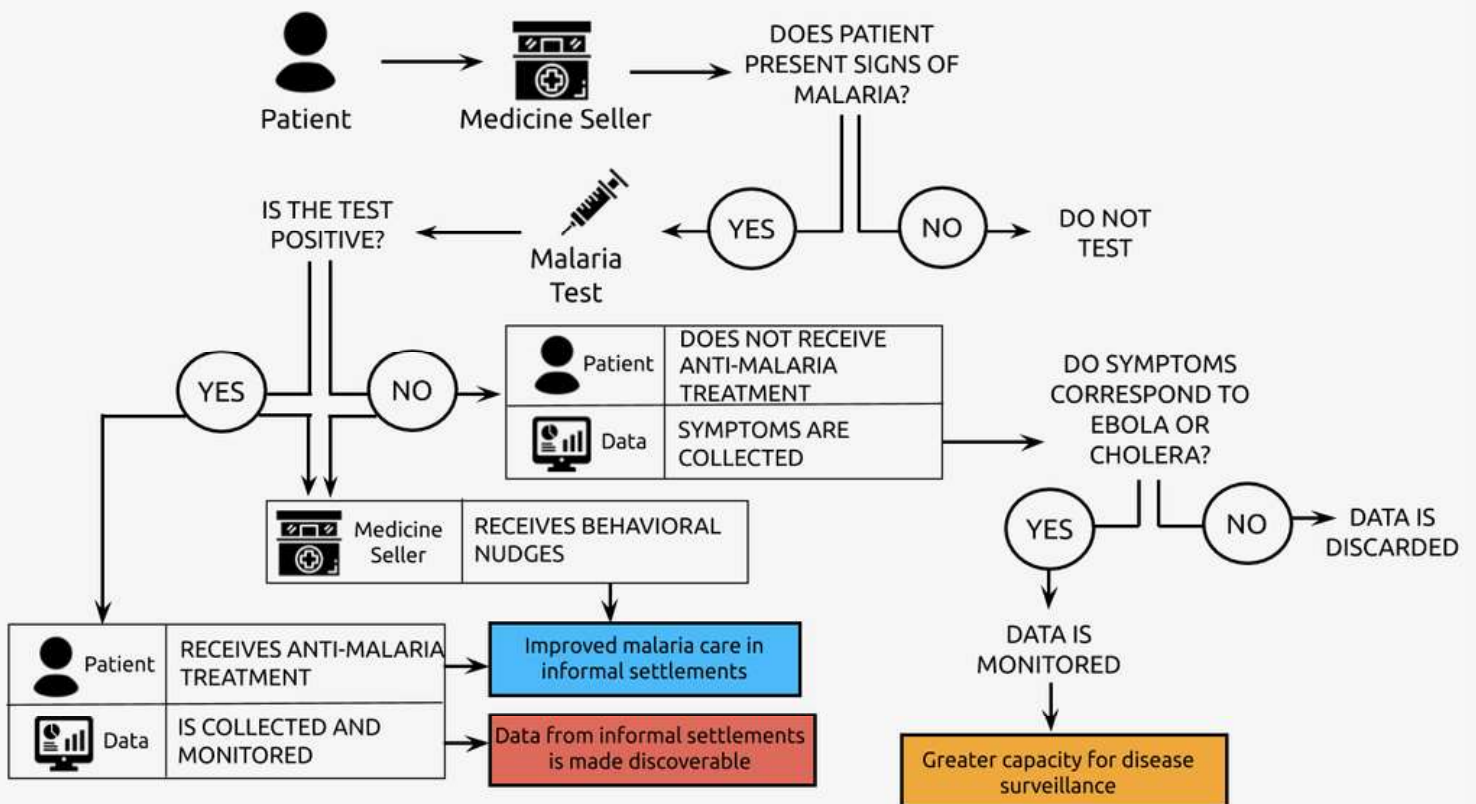
Disease-specific alerts are triggered when a predefined number of either Cholera or Ebola data points are collected, sent both to the local partner research center and relevant health authorities if the relevant epidemic threshold is passed. This is based off of a proven methodology from the Southern Africa Centre for Infectious Disease Surveillance (Karimuribu et al., 2017).

In addition, the web-based app engages the user further in the diagnosis process as suggested by automatically sending out health alerts to all app users operating in the proximity of a malaria hotspot or whenever Ebola or Cholera outbreaks are identified.



RAPIDCARE

Process to Outcomes



2.3.7. BUILT-IN ADVANTAGES OF RAPIDCARE

DATA SECURITY

mHealth solutions need to ensure confidentiality, integrity and security. For this reason specific administrative safeguards will be set up to manage the accessibility of the data collected, and ensure Privacy by Design (Gejibo, 2015).

At no point of the form's submission process will Medicine Sellers be asked to identify the patient by name or any other unique identifier. Medicine Sellers' personal information and contact details are only available to platform users granted administrative privileges, namely the project staff in charge of recruiting and on-boarding program participants.

Outside of usage analytics, ODK software does not transmit or communicate any information back to ODK's maintainers. Submitted forms will be encrypted to avoid hosting servers viewing the information sent and data for visualization will be aggregated to further guarantee patients' privacy.

BEHAVIORAL NUDGES FOR BETTER CASE MANAGEMENT

Case management guidelines for combination treatment is necessary to treatment success for malaria. However, non-compliant prescribing, dosing, and dispensing of drugs is often reported at outpatient facilities. In order to address this, RapidCare incorporates behavioral nudges to enhance compliance with national malaria treatment guidelines of the Ghana National Health Service, as well as other training manuals.

Nudges' are sent to Medicine Sellers after each submission of a positive malaria test. They are notifications containing educational messages covering topics such as prevention of malaria infection, signs and symptoms of the illness, and treatment course after a positive test.

A model for this can be found in the work of Zurovac et al. (2011), who developed a set of one-way text message reminders about pediatric malaria for health workers' mobile phones. This intervention demonstrated significant improvements in health workers' adherence to national guidelines. Examples of this messaging includes:

- *Check ALL sick children <5yrs for any severe signs! Also check for fever, cough, diarrhea, pallor & any other problem.*
- *Remember, always do FIRST DOSE under observation at facility even if no food is available - if vomited within 30 min REPEAT dose.*

If the patient tests negative for malaria, the pharmacists will still receive a message with information on best pharmaceutical practices as established by the Pharmacy Council Ghana and other relevant organizations. This will include messages ranging from law, ethics and practice standards; antimicrobial resistance; medical storage; and common illnesses such as coughs. The objective is to ensure better case-management for patients presenting with malaria like symptoms but who do not have the parasite, such as those illness included in Figure 4.

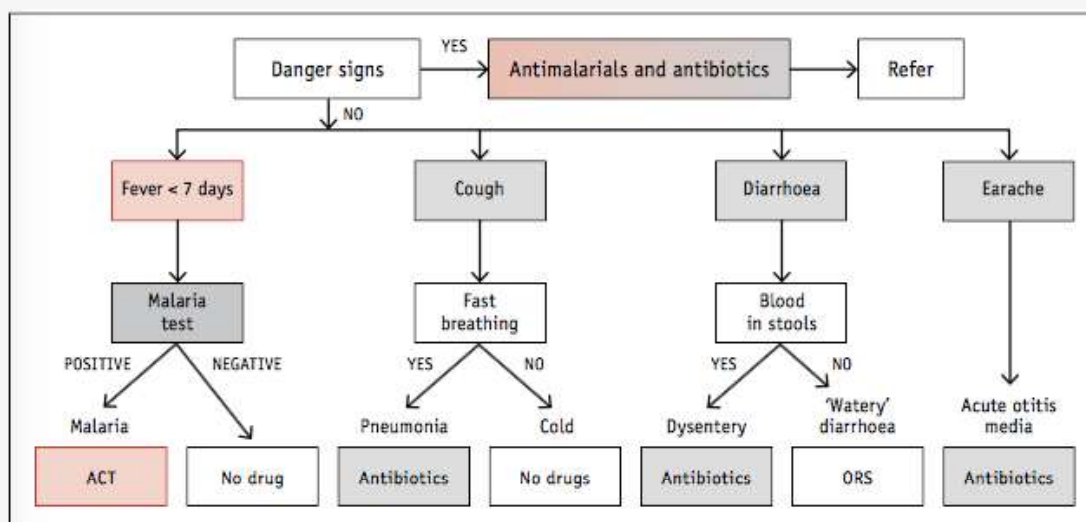


Figure 4: Malaria case-management for better prescribing practices.
Source: WHO, 2011.

Educational messaging like this have previously demonstrated success. For example Kafle et al. (2010) demonstrated that simple messages pertaining to commonly used drugs can increase knowledge and improve drug use practices.

- The antibiotic may not be effective if it is not used in proper dose, frequency and duration
- Cough medicines containing codeine is addictive

Importantly, we will partner with NextGenU for content creation of the education nudges. NextGenU is the world's first free accredited higher education with a focus on the health science, funded by a diverse set of partners, including the Center for Disease Control, Harvard, NATO, and the WHO. The model has demonstrated identical knowledge gain to a traditional course, as well as positive effects on health worker stigma and other attitudes. Furthermore, using NextGenU content in our app is the opportunity for providers to pursue full courses or a complete Masters of Public Health (MPH) degree completely free and online.

BUSINESS TOOLKIT

In addition to the need of improved case management, our innovation understands that drug sellers manage a small business at the fringes of the formal economy which can lead to a clash between the imperatives of maximizing profits and providing the most effective care (Smith, 2004; Das, 2016). As a first step towards engaging with financial incentives, RapidCare will include a business 'toolkit' to provide these workers with advice on how to operate a successful healthcare business. Topics in this module will include tools that can be used immediately by the Medicine Sellers such as knowledge and skills of business operations; exposure to information regarding local and external resources; and suggestions on how to access sources of finance to stimulate growth. Access to various topics through the module will be unlocked with consistent data submissions, serving as an incentive for continued participation over-time.

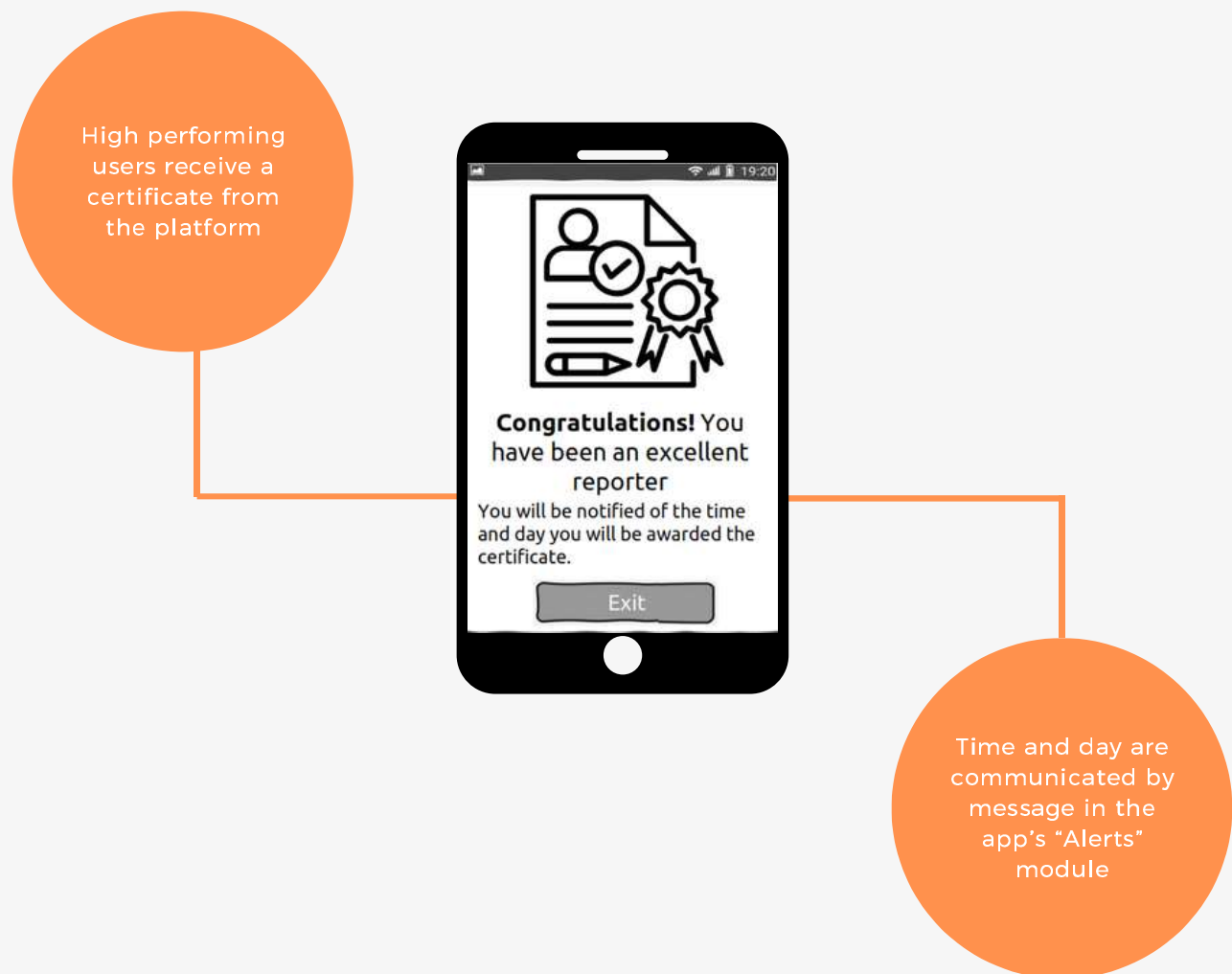


RECOGNITION FOR QUALITY SERVICE

Our innovation seeks to provide incentives to adopt more effective treatments by linking this with a public recognition of good quality malaria care. For Medicine Sellers that use our application regularly and demonstrate good reporting practices, we will provide a sign that they can place on the front of their shops indicating that they use cutting-edge RDT technology to test for malaria.

Through this signage, participating Medicine Sellers will be able to increase their reputational advantage, serving as a form of advertising for their small business as well as a means of quality assurance for community members seeking care.

Additionally, depending on relationship building and collaboration with the relevant government agencies such as the Ghanaian Food and Drug Agency, the Ghanaian Police and Pharmacy Council, this signage could also ensure that these well performing shops are not shut down during raids of chemist shops and arrest unauthorized informal vendors.



SECTION 3

IMPLEMENTING RAPIDCARE



Overlooking the central Kumasi market at closing time in Kumasi, Ghana, June 22, 2006. Photo: Jonathan Ernst / World Bank

3.1 ALIGNING WITH NATIONAL AND INTERNATIONAL INITIATIVES

This project will adhere to the goals of the Ghanaian President's Malaria Initiative and the WHO Guidelines for the Treatment of Malaria (3rd ed.). A major objective of this project is to integrate data from urban settlements into the national malaria surveillance programme, to ensure that cases in urban settlements are not being missed in health policy planning and programs.

RapidCare will also align with the Ghanaian National eHealth Strategy, for which a core objective is to build capacity in the health sector to utilize information and communication technology. Furthermore, the President's Malaria Initiative outlines the key objective of transition from a malaria-specific to an integrated approach; this project will improve integrated disease surveillance efforts by using algorithms to detect cases in which a patient presents with another high-risk infectious disease. Our project will also directly contribute to the objective of improving social and behavioral change communication by providing pharmacists with prescription recommendations and other relevant information.

3.2 PROGRAM OVERSIGHT AND ACCOUNTABILITY

Embedded in our innovation are a number of 'checkpoints' which will allow project staff to ensure the Medicine Sellers in the program are providing a reasonable standard of care for clients and are using RapidCare consistently. First, in order to identify reliable Medicine Sellers for the program, we will engage existing drug shops in James Town and Ussher Town through fake customers. These fake customers will assess the Medicine Sellers according to the Good Pharmacy Practice standards laid out by the International Pharmacists Federation.

The mystery client method is considered the “gold standard” in assessing clinical quality and only shops that meet a reasonable threshold of good practice will be invited to enroll in the program (Sudhinaraset et al.). Additional measures to determine which Medicine Sellers to invite to the program will include qualitative interviews with community members regarding which drug shops they consider trustworthy and frequent often without any adverse side-effects or complications.



Photo: © Arne Hoel/The World Bank

Throughout the cycle of our intervention, project staff will conduct spot-checks on participating drug shops. In addition to random spot-checks at various dates, the program includes two crucial moments for quality assurance, one when RTD strips are resupplied and another when a medicine seller receives the recognition certificate for the front of their shops.

At both points, a project staff member will visit the drug shop and observe the practices of storing, distributing and administering of medical products. Bad practices that put clients at risk will automatically disqualify the Medicine Sellers from the program, as will any instances of intentional misreporting.

3.3 ENSURING LOCAL DATA OWNERSHIP

Data ownership by the Ghanaian government is a priority for this project. All data collected as a part of the RapidCare program will be hosted on-site, with the University of Accra and, later, the Ministry of Health. Benefits of this approach include: ensure a unified data archive, avoid data fragmentation and gaps, and ensure sensitive data is governed by the public authority.

Local, public data ownership is the best way to operationalize insights from data in a systematic way, and create an environment in which the government can optimize and adapt the program according to their needs over the long term, as has been evidenced by successful mHealth programs deployed in countries such as Kenya (Map Kibera, 2018).



Photo: © Stephan Cladieu / World Bank



Photo: © Curt Carnemark / World Bank



Photo: © Arne Hoel/The World Bank

3.4 EMBEDDING INCLUSIVITY AND A GENDER APPROACH

RapidCare has been designed to consider the needs of people who are marginalized as the utmost priority. Therefore, all content developed for the app, including the interface of the android app and all educational materials will be co-created with in-country partners and will be pre-tested to ensure relevance and acceptability. Also, our data security strategy will ensure that no individual in these informal settlements will be at risk of discrimination or government prosecution.

Our innovation also makes an important gender contribution. Mobile ownership is lower among women than men, in Ghana only 47% of women reported they owned a mobile phone in comparison to 80% of men (Barnett & Faith, 2019). By targeting Medicine Sellers with a mobile app directly, it is possible to overcome barriers women face in benefiting from interventions as a result of their inequitable access to mobile devices.

Additionally, women are often primary caretakers when a person becomes sick and most often interact with Medicine Sellers. Despite this, women are often not trusted as valid sources of information in primary care, and inequalities exist in the quality of advice women receive from health providers (Govender & Penn-Kekana, 2008). RapidCare seeks to improve patient-provider relationships by emphasizing the crucial role of trust and listening to patients' lived experiences in the community-oriented primary care lessons of the app. In this way, we seek to generate trust between provider and patient, improving the ways Medicine Sellers communicate with women patients and ultimately, the quality of care they provide.



Photo: Daily life in Conakry, Guinea on December 3, 2014. Photo © Dominic Chavez/World Bank

3.5 PARTNERSHIPS AND PATH TO SCALE

The partnership model of this project is designed to collaboratively leverage existing capacities at multiple levels to better treat and monitor infectious disease in informal settlements.

Following recommendations from the World Health Assembly (2011) on strengthening national health emergency and disaster management capacities, the partnership model seeks to engage the local health workforce, mobilize local expertise, promote regional collaboration, and ensure a path to scale through government uptake of RapidCare.

Partners identified for the start-up period can be grouped into four main categories:

- **Knowledge and Development Partners**
- **Technology Partners**
- **Funding Partners**
- **Governance Partners**

3.5.1. KNOWLEDGE AND DEVELOPMENT PARTNERS



Ghana Health Informatics Association:

Operates out of the Department of Biostatistics at the University of Ghana. It is an association of over 300 health informatics professionals. Their cross-country expertise in planning, design, development, deployment, and maintenance of safe eHealth solutions will support RapidCare and lay the groundwork for program uptake in the Ghanaian context.



Ghana Federation for the Urban Poor:

A network of community savings groups in informal settlements and poor communities in Accra and seven other urban areas of Ghana. Their partnership will help us design RapidCare around community-led solutions and culturally-relevant insights.



Pharmacy Council, Ghana:

The Ministry of Health agency responsible for regulating pharmaceutical practitioners, staff, and facilities where pharmaceutical services are offered. They will serve as the main training partner in this project to advise and facilitate the incentive component, as well as the monitoring and quality assurance of Medicine Sellers.



NextGenU:

Provides free, accredited, online higher education program with a focus on the health sciences. Their online model has been tested with community health workers and primary care physicians in Kenya and India. NextGenU is a strategic partner to guarantee the validity of educational nudges on RapidCare, and to open the possibility for Medicine Sellers to pursue full courses with the organization or a complete Masters of Public Health (MPH) degree.



Photo: "2010-09-14%20at%2007-53-04" by Pan American Health Organization PAHO is licensed under CC BY-ND 2.0

3.5.2. TECHNOLOGY PARTNERS

Organizations that support the design, development and installation of core hardware and software components of this innovation.

As mentioned, the mobile app architecture will originate from the Open Data Kit software. Noguchi Memorial Institute for Medical Research will assist in the mapping of informal communities through the use of OpenMapKit. In addition, we will work with the team of mLab App, a mobile web app software built by mLab at Vanderbilt University, to secure technologies needed to implement our innovation.

In a partnership model drafted for this proposal, mLab App has already demonstrated an intent to 1) license their FDA approved RDT image processing algorithm, and 2) build a server on-the-ground in Accra to store and secure data collected as a part of our program.

3.5.3. GOVERNANCE AND IMPLEMENTATION PARTNERS

University of Ghana:

Will serve as a trusted, public university partner for research and data monitoring support. The Noguchi Memorial Institute for Medical Research (NMIMR), within the College of Health Sciences is involved with numerous research studies on sociocultural determinants of malaria and malaria monitoring in Southern Ghana.

As a research institute, the NMIMR is equipped to host the server for our program. We believe the unique, aggregate data collected through RapidCare could advance the research and funding objectives of this institute, and provides strong incentive for partnership.

Ghana Health Service:

Responsible for implementing national health policies at the regional, district and sub-district levels, under the purview of the Ministry of Health. The GHS is an important actor in Ghana's efforts to develop and establish effective disease surveillance strategies, including through the National Malaria Control Programme.

As our main government partner on-the-ground, their partnership will serve as the linchpin between our program and the Ministry of Health, helping us align our program to national health policy and objectives.

Ghana Statistical Service:

The main governing body on population statistics and data, and an advisor to the government on all matters related to statistics.

Their partnership will inform the nature and form of data collected within RapidCare, and determine a path forward for data collection and monitoring activities involved in the program.

3.5.4. FUNDING PARTNERS

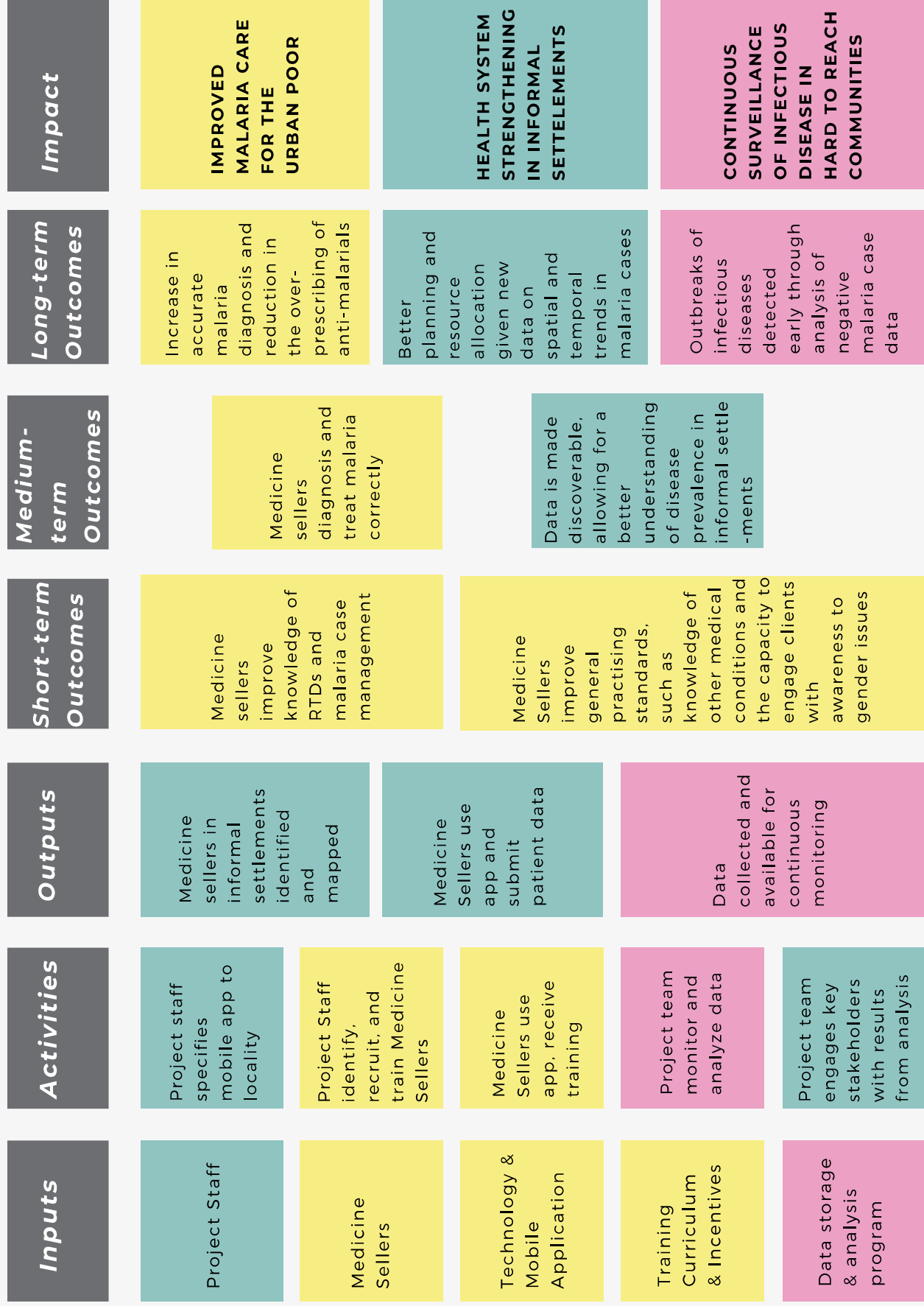
Funding partners are earmarked for the short, medium and long-term phases of this project.

Short-term funding opportunities would support the start-up period of the project, including conducting needs assessments, app development, software licensing, hardware costs, and early-stage testing for proof of concept. We have identified possible grants from the U.S. National Institutes of Health, Office of Disease Prevention for this stage.

Medium-term funding partners would allow us to attract government actors as a scale-up partners, and to facilitate program hand-off to the Ministry of Health. These include Vodaphone Ghana, the United States Agency for International Development, and The Global Fund to Fight AIDS, Tuberculosis, and Malaria.

Long-term funding will be sought and secured through government initiatives, such as The National Malaria Control Program and other disease prevention programs.

3.6. LOGIC FRAMEWORK FOR RAPIDCARE



3.7 PRELIMINARY MONITORING & EVALUATION PLAN

The following monitoring and evaluation (M&E) plan for this innovation has been developed with the Global Fund to end AIDS, Tuberculosis, and Malaria in mind, as we consider the Global Fund's performance-based funding a potential route for scale-up for this project.

Indicator	Rationale	Metric	Data Collection Method	Frequency	Person or agency responsible
Retention rate of Medicine Sellers invited to use the app	To understand whether the app is taken up by pharmacists and make potential changes to the app's functionality	Numerator: Number of pharmacists in test area who continue to use the app at midpoint and endpoint of the program Denominator: number of all pharmacists enrolled in the program at the project start date	App analytics	At the midpoint and endpoint of the project	Project team
Number of malaria cases inputted by Medicine Sellers through the app	To understand whether Medicine Sellers use the app's image processing technology	Numerator: number of positive malaria cases identified by the image processing tool Denominator: prevalence rate of malaria in a given area	App analytics	Quarterly	Project team
Percent of participating Medicine Sellers reading educational content	To understand whether health and business information is an appropriate incentive for user participation	Numerator: Number of pharmacists who open educational content more than once per week Denominator: total number of pharmacists using the app	App analytics	Quarterly	Project team
Improved Medicine Seller knowledge of proper RDT usage, accurate prescribing, and community-oriented primary care (especially for women and other marginalized individuals)	To understand whether the educational component of the app increases Medicine Seller knowledge	Numerator: Score on in-app quiz after using the app Denominator: score on in-app quiz at baseline (before reading content)	App quiz results	Quarterly	Project team
Number of new malaria cases identified and sent to national health authorities	Understand whether the project effectively reduces gaps in national health surveillance coverage	Number of additional malaria cases sent to national health authorities that were not previously accounted for based on geographic demographic survey data	App analytics	Bi-annually	Project team



Photo: "2010-09-13%20at%2009-13-08" by Pan American Health Organization PAHO is licensed under CC BY-ND 2.0

3.8. PROGRAM REVIEW, EVALUATION, AND SURVEYS

Program reviews will occur at the mid- and end-points of the project. At the project external evaluators such as Results 4 Development will assess our monitoring and evaluation systems and model future impact of the project.

Program reviews will answer the following key questions:

- *Is the app being used by pharmacists?*
- *Does the app improve provider knowledge/capacity?*
- *Is this increased knowledge improving malaria detection, diagnosis, and ultimately, malaria mortality rates?*

3.9. COORDINATION

The project team will lead the M&E process and manage the coordination of data into streamlined reports for stakeholders and funders, as well as leading data analysis on improved provider knowledge.

Technical data will be collected and monitored by the project team with the expertise of Vanderbilt's mLab and an external app developer in order to ensure sound app functionality and data collection.

3.10. LONG TERM MONITORING AND EVALUATION: AN OPPORTUNITY FOR UNIVERSITY PARTNERSHIP

The University of Ghana's School of Public Health teaches courses in advanced epidemiology and disease outbreak response. There is an opportunity to partner with the Department of Epidemiology and Disease Control to conduct epidemiological studies in the pilot community in order to measure changes in malaria morbidity and mortality in the long-term. In the short-term and medium-term, monitoring and evaluation will focus on the appropriateness of the app for Medicine Sellers in Accra and its potential to improve Medicine Seller knowledge of primary care and prescription best practices.

CONCLUSION

As urbanization continues to accelerate around the world, so too will the growth of informal settlements that lack the basic provisions and infrastructure necessary for a healthy life. These densely populated spaces have proven to be incubators for infectious diseases, placing millions of people at risk around the world. This risk will only increase with the onset of climate change as water-related disasters become more frequent and the distribution of vector-borne diseases changes with changing weather patterns. To respond to this urgent and growing global health challenge, RapidCare offers the opportunity to strengthen urban health systems through three key areas; improving malaria care in informal settlements, making data from the informal sector discoverable, and enhancing disease surveillance in informal settlements. Altogether, this innovative diagnostic and disease surveillance solution leverages the capacity of informal healthcare providers to reach the urban poor often excluded from the formal health sector. By partnering with the informal sector in rapidly urbanizing cities, RapidCare not only reaches those most vulnerable in informal settlements but also has the potential to achieve better health outcomes for all.



Accra. Photo: © Arne Hoel/The World Bank

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APPENDIX I.I: LETTER OF SUPPORT FROM VANDERBILT UNIVERSITY



July 3, 2019

Dear Geneva Global Challenge Review Committee,

I am happy to provide this letter offering my enthusiastic support of the submission to the Geneva Global Challenge, proposed by Hillary Birch, Natalie Boychuk, Anna Fechter, and Maria Giorda. Their application describes an exciting opportunity to leverage our existing software technology to reach informal health services providers in urban slums. I have had the opportunity on multiple occasions to discuss with the team the details of our technology, with specific regard to how they could adapt it to this particular use case. The team has carefully crafted an impressive proposal with genuine potential to have a positive impact. Allow me to provide some more specific context for my support below.

After conducting a literature search, the team reached out via email to ask questions regarding the original work that I performed with an image-processing algorithm for analyzing point-of-care malaria test (Scherr, T. F. et al. Mobile phone imaging and cloud-based analysis for standardized malaria detection and reporting. *Sci. Rep.* 6, 28645; 2016). Since this publication, we have named our software library "mLab," and it has expanded to include not just malaria tests, but also diagnostics for HIV and schistosomiasis. We have performed several pilots in Zambia (HIV, malaria, and schistosomiasis), Côte d'Ivoire (schistosomiasis), and even in Chicago and New York City in the United States (HIV). **The breadth of these trials demonstrate the platform's underlying flexibility and adaptability – the software can be quickly customized to build a new intervention in a short period.**

The team and I discussed, in great detail, the current status of mLab and how it could fit their intended use case. Admittedly, informal health services providers in urban areas were not part of my originally intended user group – we had primarily focused on formal health care providers. Through the course of our initial conversation, the team made a compelling, statistically-driven, argument of how these providers were responsible for a significant portion of care to a large number of people. **Along with convincing me of the impact and the likelihood for success, I came away particularly impressed with the depth of their planning – it was clear that they had a vision, and had carefully considered every decision.**

Ms. Birch, Ms. Boychuk, Ms. Fechter, and Ms. Giorda make up a dynamic team with complementary expertise and a unified vision. Their proposal outlines a solution that involves all necessary stakeholders over the short-term and long-term course of the intervention to create a sustainable global health impact. **I applaud their ability to craft a proposal that is simultaneously ambitious and aware of the challenging realities in global health – it demonstrates a maturity beyond their years.**

The team has my ardent support for their submission to the Geneva Global Challenge. I look forward to engaging with them in the future concerning this exciting innovation, and to watching their continued growth as young scientists. Please do not hesitate to contact me if I can be of any further support to their proposal.

Sincerely,

A handwritten signature in blue ink, appearing to read "T. Scherr".

Thomas F. Scherr, Ph.D.
Research Assistant Professor
Department of Chemistry
Vanderbilt University
E: Thomas.f.scherr@vanderbilt.edu
P: 1-443-386-3232

APPENDIX I.II: LETTER OF SUPPORT FROM NEXTGENU



the world's first portal to free accredited higher education

email: EFrank@NextGenU.org

Phone: 360 466 8040

Mailing: POB 7, Clear Lake, WA, 98235

To the adjudicators of the Geneva Challenge:

This letter expresses NextGenU.org's intent to partner with the RapidCare team in the development of healthcare curricula for Medicine Sellers in James Town and Ussher Town, Ghana. NextGenU.org is the world's first institution that offers free, accredited courses in 191 (of 193) countries. Courses range from college-level pre-health sciences and community health worker trainings, as well as a MedSchoolInABox, which was co-developed with Stanford University, the University of Toronto, and the University of Central Florida.

As the Founder of NextGenU.org, I was in contact with the project team during the development of their proposal and have been impressed with the creativity of their solution and their thoughtfulness with regards to improving quality of care of informal providers, who play an important role in diagnosing and treating infectious diseases in low-resource settings.

NextGenU.org would be pleased to co-offer curricula to inform the training component of the app, which would be based on the Community-Oriented Primary Care course already offered online. There is an opportunity to co-develop malaria training and to promote free, evidence-based health courses to informal providers who would like to pursue additional credentials.

In my opinion, this project has the potential to improve quality of care among informal providers in urban settlements and increase the number of people being benefitting from accurate diagnosis and treatment of malaria in low-resource settings. I sincerely hope to see this proposal move forward.

Sincerely,

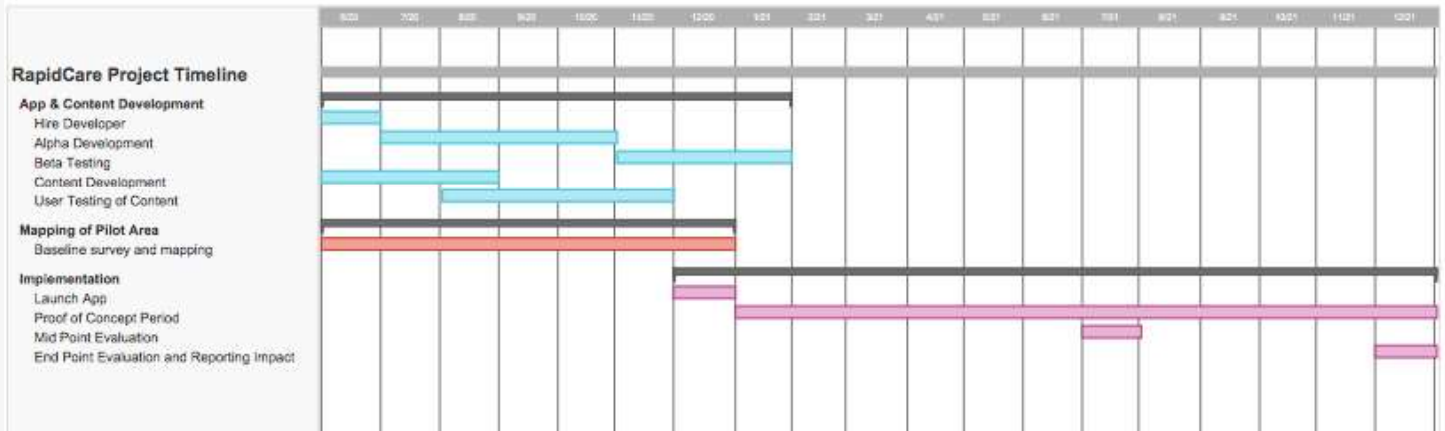
A handwritten signature in black ink that reads "ERICA Frank MD, MPH". The signature is written in a cursive, flowing style.

Erica Frank, MD, MPH

Founder, NextGenU.org

APPENDIX II: PROJECT TIMELINE

The project will be executed in three stages: 1) App and Content Development, 2) Pilot Community Mapping, and 3) Implementation.



App and Content Development

- *Hire Developer (June 2020):* Project team will hire an external developer for the application.
- *Alpha Development (July 2020-October 2020):* Developer begins the first stage in app development, which will be tested by the project team
- *Beta Testing (November 2020-January 2021):* A number of key external stakeholders, including technology partners and local partners, will test the app for functionality.
- *Content Development (June 2020-August 2020):* The project team will work with local partners and NextGenU to develop and adapt existing content for appropriateness to the pilot community.
- *User Testing of Content (August 2020-November 2020):* The content will be tested with select Medicine Sellers and local stakeholders and constantly iterated upon/improved.

Mapping of Pilot Area:

- *Baseline survey and mapping (June 2020-December 2020):* During the app development period, Noguchi Memorial Institute for Medical Research will assist in mapping the pilot community through the OpenMapKit. This baseline survey will be used to determine targets for the project, against which impact will be measured at the End Point Evaluation.

Implementation:

- *Launch App (December 2020):* In this stage of the project, the project team and local partners will distribute the Rapid Diagnostic Tests and smartphones to Medicine Sellers for use and will conduct workshops in the community on how to use the RDT, upload test results, and access content on the app.
- *Proof of Concept Period (January 2021-December 2021):* Medicine Sellers use the app for diagnostics and app analytics are consistently monitored to ensure app is functional for the user and content is appropriate. The app algorithm will enable notifications of malaria outbreak and the project team will analyze diagnostic data during this period.
- *Mid Point Evaluation (July 2021):* The project team will conduct a Mid Point evaluation of the project and will complete a report on progress, interim results, and project roadblocks for stakeholders. Project strategy may be altered at this point to work through roadblocks of the project.
- *End Point Evaluation (December 2021):* The project team will evaluate the project's success based on targets set out in the "Mapping of the Pilot Area" stage of the project. This evaluation will result in a final report for stakeholders and funders with recommendations for scale-up of the project.

APPENDIX III: PROJECT BUDGET

The following budget provides an overview of upfront and ongoing costs required to develop and implement the project. It is important to note that many of the larger costs, including the cost of a full-time developer, enumerators for baseline mapping, and smartphones for Medicine Sellers, are one-time costs incurred by the project.

Key Assumptions:

The budget is based on an assumption of 90 Medicine Sellers participating in the pilot community, which has a population of 100,000 people. There are typically 1.06/10,000 private sector medicine sellers in the general population in Ghana, which would suggest that there are approximately 106 Medicine Sellers in James Town and Ussher Town; our estimate of 90 controls for attrition (Ghana Ministry of Health and WHO, 2012). The budget also assumes that the app development would require one full-time developer for the first six months of the project period. Anticipating the need for constant app updates based on user feedback, we have budgeted for retaining the developer on a part-time basis for the remainder of the project to ensure that the app maintains functionality.

The estimate for RDT cost is based on the fact that malaria cases in health facilities are 300 per 1,000 population as of 2017, suggesting that in a population of 100,000, approximately 30,000 people will present at health facilities with symptoms of malaria (Ghana Malaria Operational Plan, 2018). Of these 30,000 people in James Town and Ussher Town, approximately 61% will present at private providers, suggesting that Medicine Sellers will need approximately 18,300 tests (Awuah et al., 2018). For our purposes, we have rounded up to 20,000 tests to allow for replacements of improperly stored tests and to account for potential outbreaks. The cost of enumeration of the survey area was estimated assuming a rate of \$15.00 USD/hour for each enumerator. We estimate that mapping the survey area would take a team of 15 enumerators approximately two 37.5 hour weeks to complete.

Source of Program Cost	Cost/Unit	Total Project Cost
<i>Physical Infrastructure/Technology</i>		
Rapid Diagnostic Tests	\$1.00 USD/20,000 tests (WHO Western Pacific Region)	\$20,000 USD
SmartPhones (for use by Medicine Sellers)	\$100 USD/90 basic smartphones	\$9,000 USD
Server for data storage	\$10,000/year	\$10,000 USD
Laptops for data analysis	\$750/2 laptops	\$1,500 USD
<i>Ongoing Capital Costs</i>		
Licensing image processing algorithm (from Vanderbilt mLab)	\$100 USD/month	\$1,200 USD
App traffic	\$50 USD/month	\$600 USD
<i>Human Resources</i>		
App developer	\$50,000 USD/1 year	\$50,000 USD
Enumerators for Pilot Community Mapping	\$15 USD/hour	\$16,875 USD
		\$109,175 USD

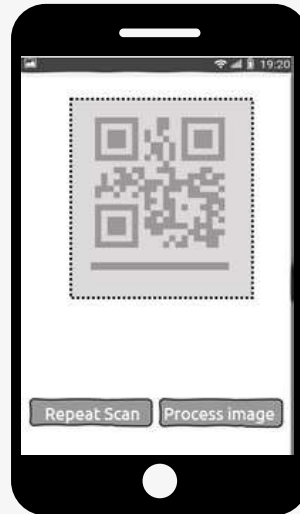
In order to finance the initial startup costs of the project and the pilot in James Town and Ussher Town, the project team will seek short-term financing from the following sources:

- U.S. National Institute of Health (NIH)
- Canada Institute For Health Research (Catalyst Grant)
- Rockefeller Brothers Fund (Program in Sustainable Development)
- Pfizer Foundation
- International Development Research Centre (2020 Research Awards in Global Health)
- Private funders

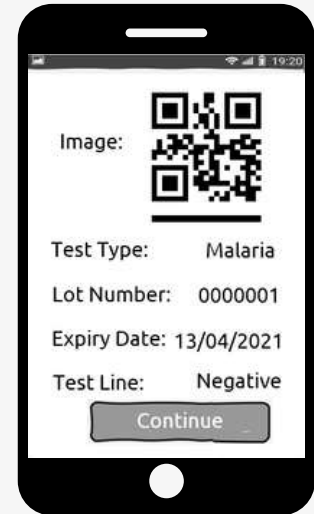
APPENDIX IV: FUTURE DEVELOPMENTS

1. QR Code Implementation

Despite the functionality of rapid diagnostic tests among service providers, there are limitations in the interpretation of results, the quality of which depends highly on the training of providers. An RDT tool with an embedded QR code has been developed and proven by Scherr and colleagues (2017) and has the potential to overcome difficulties in result interpretation.



User scans results from the QR malaria test. An image, including both QR code and test line, is captured.



The pixel intensity of the test line is analysed and the data payload embedded in the QR code is decoded.



2. Telehealth Vouchers

In order to further improve prescribing practices, future app developments would include Telehealth vouchers that could be used by Medicine Sellers for a no-cost telehealth training session. These vouchers would be unlocked by submitting malaria test results.

3. Vanderbilt's own platform for disease surveillance

Vanderbilt University has not only developed an image processing algorithm but also its own health portal app where data from which at-home tests is collected and aggregated. In the medium to long-term it could be a cost-efficient option to partner with the University to migrate our data to their platform. This could help scaling the innovation the moment we need to host on a single platform to better manage data and statistics from different cities and countries.