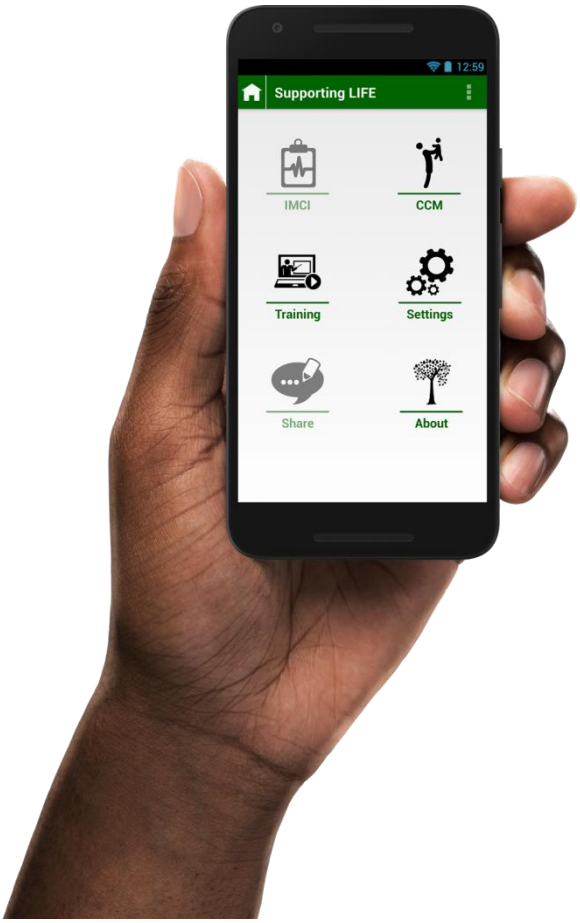
# Supporting LIFE

## Supporting Low-cost Intervention For disEase control – Low-cost interventions in resource poor settings

## Project Final Report

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# 1 EXECUTIVE SUMMARY

The vast majority of health care for children with acute illnesses in sub-Saharan African countries is provided by community health care workers who receive a limited level of training. In Malawi, these are known as Health Surveillance Assistants (HSAs). HSA's, a group of outreach workers who serve as frontline health care staff in the battle against largely preventable childhood diseases. To support HSAs in this battle, the WHO and UNICEF developed the Community Case Management (CCM) strategy, now adopted as standard practice in many countries in sub-Saharan Africa, including Malawi. CCM is a paper-based clinical decision tool, utilizing a traffic light triage system, enabling first-level health workers, such as HSAs in Malawi. This enables them to promptly identify children from 2 months up to 5 years of age requiring urgent referral to higher level facilities, and direct the treatment and advice at the point-of-care for children who can be treated at home.

The *Supporting Low-cost Intervention For disEase control* (Supporting LIFE) project is designed to support HSAs at the patient point-of-care as well as larger epidemiological bodies to manage and control diseases through the utilization of cost-effective technologies. The overarching objective of the Supporting LIFE project is to assist HSAs in delivering an intervention to improve and manage disease control, targeting children aged ≥2 months up to 5 years. This project endeavored to utilize established technology to circumvent the absent or limited healthcare infrastructure by exploiting the cellular telecommunications network and point of care decision support systems. The expansion of information and communication technologies to low and middle-income countries (LMIC) such as Malawi has offered the potential for CCM to be delivered as a mobile health (mHealth) solution.

The Supporting LIFE consortium achieved the following key outputs:

- **Developed a mobile digital decision support toolkit dedicated to support HSAs** with the adherence to and implementation of CCM guidelines. This decision support toolkit, in the form of an Android-based smartphone application, known as Supporting LIFE electronic Community Case Management Application (**SL eCCM App**), leverages current CCM protocols for disease control.
- **Conducted a technology/clinical feasibility study** in July 2015 to assess the acceptability of the app to HSAs and the feasibility of following-up children in the community to collect clinical outcomes. HSAs reported that the SL eCCM App improved their adherence to the CCM protocol, in addition to being perceived better within the community by parents and caregivers.
- **Conducted the first clinical trial to investigate the effectiveness of a mobile version of CCM**. A pragmatic stepped-wedge randomized trial comparing referral rates, patient re-consultations at village clinics and attendances at referral facilities/hospitals was conducted from October 2016 to January 2017, with 101 HSAs from 2 districts in northern Malawi enrolling over 7,000 children. Preliminary results reveal that referral rates were similar in the intervention and control phases, but re-consultations at village clinics and presentations to higher-level facilities and hospital admissions were higher in the control phase.
- **Designed disease surveillance guidelines** for a national disease surveillance information system to address the challenges faced by the Malawian Ministry of Health. In order to achieve an integrated surveillance platform with complete, timely, valid and consistent data - a service corridor approach connecting silo systems is recommended.
- **Presented progress and results to stakeholders** at multiple meetings. The most notable was the Malawi mHealth sub-technical working group meeting, which included individuals from the Ministry of Health, other mHealth projects and donors in the week of 24$^{th}$ April 2017.
- **Built research capacity within Malawi**. Mzuzu University's involvement as an active partner in the Supporting LIFE project has equipped university staff with experience of an international research collaboration.

## 2 SUMMARY DESCRIPTION OF PROJECT CONTEXT AND OBJECTIVES

To support frontline workers, the WHO and UNICEF developed the Integrated Management of Childhood Illness (IMCI) in the mid 1990's as a strategy to reduce morbidity and mortality from common and potentially serious childhood illnesses such as malaria, pneumonia, infantile diarrhoea with dehydration, meningitis and sepsis. The IMCI strategy involves a stepwise and structured approach to the assessment and management of children presenting with acute illness in developing countries. The strategy involves three foci: 1) improving the performance of health care workers through training with a set of clinical guidelines, 2) strengthening health care systems for delivery of child health, including availability of medications, supervisions, and health information system (HIS) data, and 3) developing and encouraging family and community interventions. The briefer version of IMCI, called Community Case Management (CCM), is aimed for use by health care workers with even lower levels of training in resource poor settings. As a result of this, the Supporting LIFE project focuses on CCM over IMCI guidelines as we wish to maintain the overall focus of the project (i.e. supporting HSAs in rural settings).

During the project conception period, the under-five mortality rate of children was 77 per 1,000 live births [1]. Internationally most of the 11 million deaths per year of children under the age of five occur in areas where adequate medical care is not available. First-level health facilities, the closest health care services available to most sick children in developing countries, are generally run by HSAs.

The current state of the art for the recognition and management of children with acute illness in sub-Saharan countries such as Malawi involves use of IMCI/CCM as the core strategy. Nearly all countries in the African region have implemented these guidelines [2], and effects on many health indicators have been impressive. However, there are several challenges that need to be addressed to improve the effectiveness and adherence of IMCI/CCM. These include difficulties in training and maintaining skills in IMCI/CCM, deficiencies in adherence to clinical protocols, and inadequate discriminatory value leading to misclassification of severe illness in children, resulting in over or under diagnosis. Poor clinical outcomes for children can affect the health system, compounding further the resource limitations in referral facilities by either referring children unnecessarily (hence 'wasting' resources), or failing to identify children who do need referral and contributing to excess morbidity and mortality.

The Supporting LIFE project aimed to address key limitations to the provision of health care for children in Malawi and contribute to progress beyond current health care in the following ways:

1) **The SL eCCM App is underpinned by a clinical decision support system (CDSS), which classifies a child's illness and recommends treatment to the HSA based on the data entered by the user at the point-of-care.** Paper-based forms cannot ensure that HSAs are fully adhering to the clinical guidelines. The SL eCCM App has a turnkey form field validation feature which allows all data input fields in the app to be assessed (i.e. all validation rules can be turned on or off), as required. When field validation was turned on, it was found that HSAs were more likely to fully adhere to the clinical guidelines, which aims to promote safer and more effective care provision.

2) **The translation of the CCM protocols to a mobile phone platform (SL eCCM App) offers novel opportunity to train health care workers**. Mobile technology has been cited as a solution to support and empower HSAs to provide care effectively and self-sufficiently [3]. Training modules were integrated into the SL eCCM App with the intention of providing supplementary support to HSAs in an electronic format. These are very much in line with current recommendations for training in the area, such as the WHO's computer based format

for CCM, yet utilises low cost mobile phone technology with all its associated advantages of coverage and cost, rather than more costly computers. Importantly, it also addresses the current difficulties in motivating and retaining health care worker levels of training in CCM, which is widely acknowledged as a current limitation in wider and more consistent implementation of CCM. Lack of sufficient CCM training does lead to a drop off in adherence to CCM thus resulting in a less effective patient care a management of disease control [4].

3) **The Supporting LIFE project investigated the use of wireless vital sign devices to support the diagnostic value for correct classification of children with serious illness.** Vital signs are considered as basic measures of overall physiological wellbeing in children, and CCM guidelines currently recommend measuring temperature and breathing rate. We know that currently even these vital signs are not measured consistently or accurately, which leads to failure to identify children with severe illness, and may contribute to morbidity and mortality. Therefore, a systematic review was conducted to evaluate existing evidence for the diagnostic value of vital signs for diagnosis of (and/or prediction of prognosis of) important child diseases relevant to the FP7 call e.g. malaria, infantile diarrhoea. Findings revealed that breathing rate demonstrates the most promising diagnostic value, and thus the Supporting LIFE project incorporated a breathing counter in the App to enable HSAs to capture respiration rates more accurately and efficiently.

   The SL eCCM App integrated a vital sign sensor into the App to enable the reading of patient heart and respiratory rates. Improving access to diagnostics is one of the major limitations of health care in Malawi, and has been acknowledged as a key priority by the WHO for improving implementation of CCM. However, the utility of the vital sign sensors was not tested in the field due to its cost and unsuitability for children under 10kgs.

4) **The Supporting LIFE project proposes design guidelines for improved disease control surveillance.** Single disease approaches pose a challenge in low resource settings particularly for the management of timely and accurate response to communicable diseases. The move from a vertical, disease-orientated (or silo) approach to a horizontal, child centred approach was initially realised in the development of the CCM guidelines. The WHO also developed the Integrated Disease Surveillance and Response (IDSR) [5] approach for improving public health surveillance and response promotes the integration and streamlining of common surveillance activities. Upon evaluating the information flow within Malawi, it was determined that one of the main problems related to effective integrated disease surveillance is the vertical silos of information. Thus, in line with the IDSR approach, the Supporting LIFE project developed design guidelines for a national disease surveillance information system. This involves the development of a national service platform ‘service corridor’ where a web service is used to communicate between systems.

   Other major barriers to effective integrated disease surveillance include delays and data quality. The use of mobile phone technology enables fast communication of data to district health offices and regional zones to assist Ministry of Health officials to react more quickly and be equipped with detailed disease surveillance information. Additionally, CDSS and form field validation minimizes human error during data entry, thus improving data quality at the source.

Overall, the Supporting LIFE project has demonstrated: the usefulness of the mobile phone based eCCM to support HSAs, the added value of the SL eCCM App on referral, re-consultation and higher-level facility attendance rates of children under-5, the further utilisation of this rich dataset to support regional and national Ministry of Health officials to monitor and control disease outbreaks of malaria and other serious infections, and the value of capacity building by creating a technological base of mobile phones in the hands of trained HSAs to enable further development of mHealth applications.

# 3 A DESCRIPTION OF THE MAIN SCIENTIFIC & TECHNICAL RESULTS/FOREGROUNDS

The Supporting LIFE project was divided into seven work packages (WP). WPs 1, 6-7 are sketched as background layers to the four core work packages: WP 2 Technical Feasibility, WP 3 Clinical Feasibility, WP 4 Adherence to eCCM, and WP 5 Disease Control Surveillance. Figure 1 highlights the WPs and their respective relationships.

In preparation of the design of the eCCM solution, intensive literature reviews were conducted on 1) feasible technic practices and 2) the diagnostic value of vital sign sensors (WP 2). Stakeholders were also identified to provide feedback on the proposed Malawi-based work plans. Once the SL eCCM App was developed, a feasibility study was conducted to assess the usefulness and acceptability of implementing eCCM in Malawi (WP 3). Findings from this study informed the design of a larger clinical trial to assess the impact of eCCM on referral rates, patient re-consultations at village clinics and attendances at referral facilities/hospitals of children under-5 (WP 4). Simultaneously, the Supporting LIFE project also investigated the current state of disease control surveillance in Malawi in order to develop design guidelines for an integrated disease surveillance information system (WP 5).

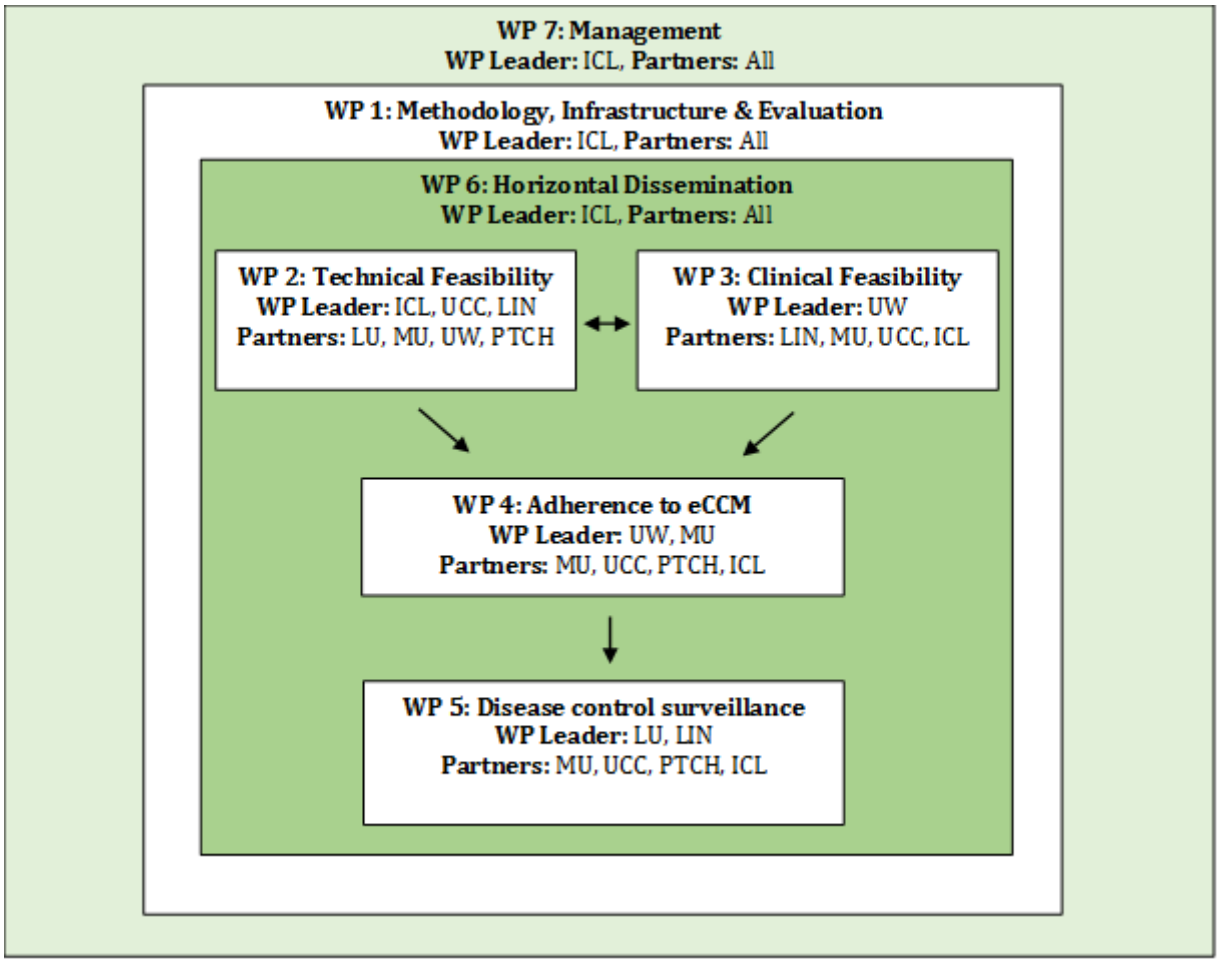


*Figure 1: Supporting LIFE work packages and their interdependencies*

## 3.1 The Supporting LIFE eCCM App

The objective of WP 2 was to develop a low-cost mobile phone based application of CCM. Two key differences between IMCI and CCM guidelines are (a) the level of healthcare for which they are utilised and (b) the healthcare provider who uses these guidelines. A review of the literature revealed that IMCI was designed to be carried out within first level health clinics by nurses/clinicians, whereas CCM is utilised by HSAs within village health clinics. CCM is a reduced and simplified version of IMCI, to support HSAs who tend to have limited training and poor literacy skills in comparison to their tertiary clinical counterparts. The CCM guidelines were selected over IMCI as the core objective of the project was to improve the delivery of paediatric healthcare services in rural communities by HSAs. During the project conception and initiation, it was incorrectly assumed that IMCI guidelines were delivered in remote settings. However, once the consortium became aware of CCM being delivered in remote settings, CCM guidelines were selected as the focus of the SL project.

### 3.1.1 Software Development

Development commenced on the SL eCCM App in month three, after the development of the functional specification and completion of design analysis in months one and two. In total, six iterations of the SL eCCM App were released throughout the project lifetime. Details regarding SL eCCM App release dates are shown in Table 1.

*Table 1: SL eCCM App releases*

| SL eCCM App version | Description | Release date |
|---|---|---|
| **1.0** | CCM functionality | 31/10/2013 |
| **2.0** | Training material | 28/02/2014 |
| **3.0** | Patient data encryption and user analytics | 20/06/2014 |
| **4.0** | Disease surveillance and sensor integration | 30/09/2014 |
| **5.0** | Validation and automated disease surveillance | 17/12/2014 |
| **6.0** (final) | Updated CCM guidelines and updating of codebase as older APIs had become redundant. | 30/08/2016 |

Requirements and specifications for the software were gathered through a series of workshops with project stakeholders and end users in Malawi. Storyboarding, brainstorming, and role playing techniques were employed during these workshops to elicit and fine-tune requirements. These high-level requirements were translated into a functional specification document which described the expected behaviour of the SL system. This document was circulated amongst all project stakeholders for review and sign-off, to ensure a common understanding and agreement of the intended functionality of the SL software artefact.

Following sign-off, the development team decomposed the functional specification document into high-level features and more granular tasks. These items were captured into the Atlassian JIRA planning tool to facilitate planning of agile sprints. The development team used a scrum-based agile approach for managing the project. This resulted in an iterative and incremental development strategy targeting a quarterly release of the software solution to all project stakeholders following each development sprint. This facilitated a constructive feedback loop between project stakeholders and the development team whereby advice and feedback following each quarterly release was captured and incorporated into a subsequent iteration of the software.

### 3.1.2 The SL eCCM App Features

The App was developed for use on Android devices with OS 3.0 Honeycomb or above. Clinical information is entered directly into the SL eCCM App by selecting the appropriate option or entering numerical or free text through a dynamic touch-screen interface. The SL eCCM App has a turnkey form field validation feature which allows all data input fields in the app to be controlled. When the form field validation is turned on, the user is required to follow all CCM steps and input all necessary data before moving forward with the assessment. The CDSS thus aims to help HSAs make more appropriate decisions at the point-of-care when assessing under-5 child with the CCM protocol. Consistent with standard paper-based guidelines, the default language setting of the application is English.

The primary functions on the App home screen are: CCM, Training, and Settings. In the early developmental stages of the App, there were plans to integrate an IMCI function as well as a social media function. However, CCM was the clear priority as HSAs were the targeted end users. The training function featured videos developed by the WHO for assessing children. These videos could be conveniently viewed offline. The settings feature allowed the user to turn the validation function on/off as well as amend the duration of the breath counter. The most important function, the CCM function, mirrored the paper-based CCM protocol. When beginning the assessment, the App requires that patient details to be inputted before moving onto the 'Ask and Look' Assessments. Once the assessment is complete, a review screen is displayed with all fields.

All completed assessments are saved on the device until the assessments are synced to the cloud. Screen shots of the App are shown in Figures 2 through 9. Further information on the technical architecture of the App is illustrated in Figure 10.


*Figure 2: SL eCCM App Navigation Page*

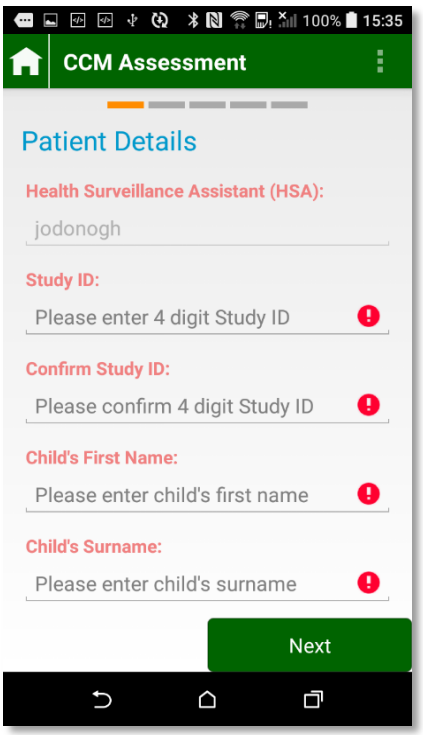


*Figure 3: SL eCCM App Patient Details*

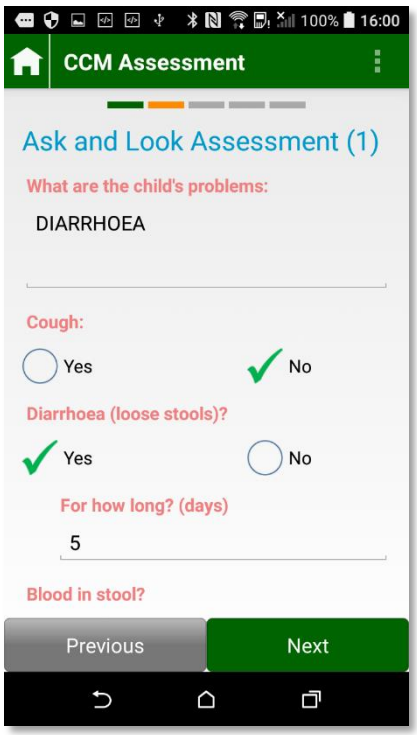


*Figure 4: SL eCCM App Ask and Look Assessment (1)*

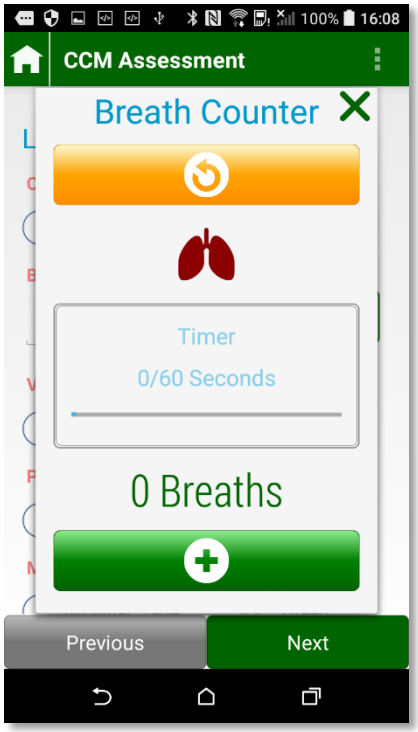


Figure 5: SL eCCM App Breath Counter

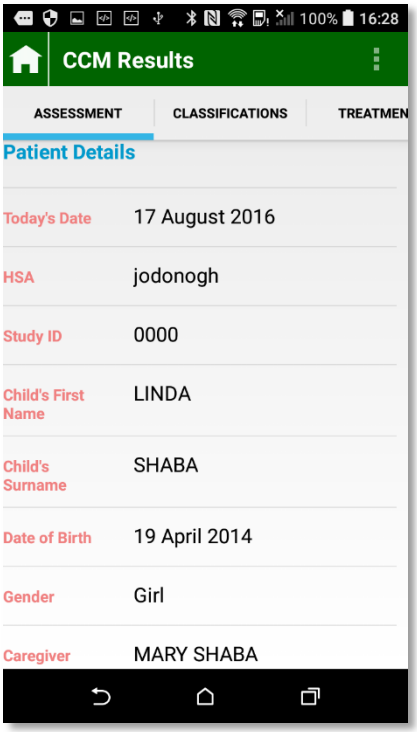


Figure 6: SL eCCM App Results (Assessment)

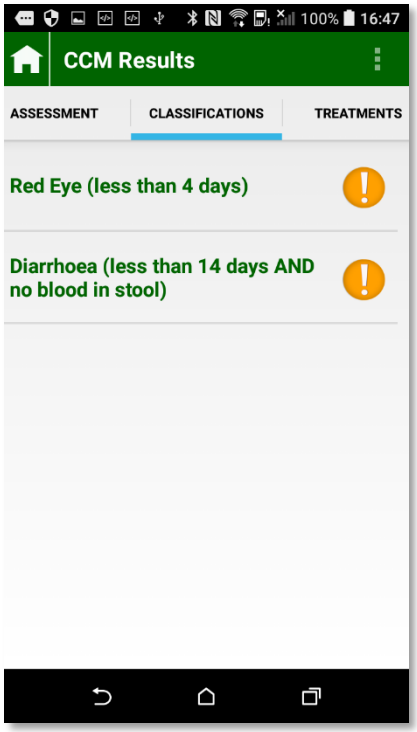


Figure 7: SL eCCM App Results (Classification)

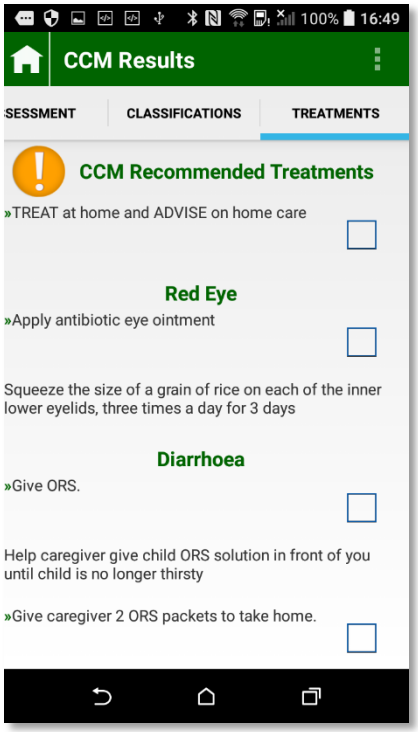


Figure 8: SL eCCM App Results (Treatment)

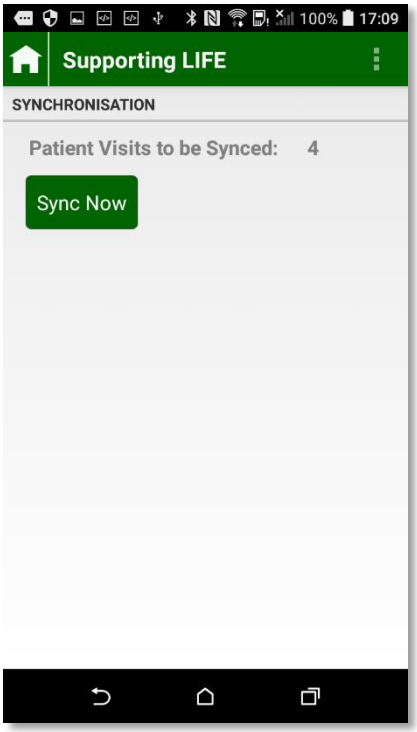


Figure 9: SL eCCM App Data Syncing

### 3.1.3 SL eCCM App Technical Architecture

SL eCCM App uses RESTful web services communicating over JSON to a cloud-based web server running on an Amazon Elastic Compute Tomcat instance (see Figure 10). The web-server comprises a middle-tier Spring Model-View-Controller framework and uses Java Persistence API to communicate to a back-end MySQL database running on an Amazon Relation Database Service instance. MySQL database, also referred to as SL central database has been created to store SL eCCM data uploaded during clinical testing. It is supported by Amazon web services cloud solutions.

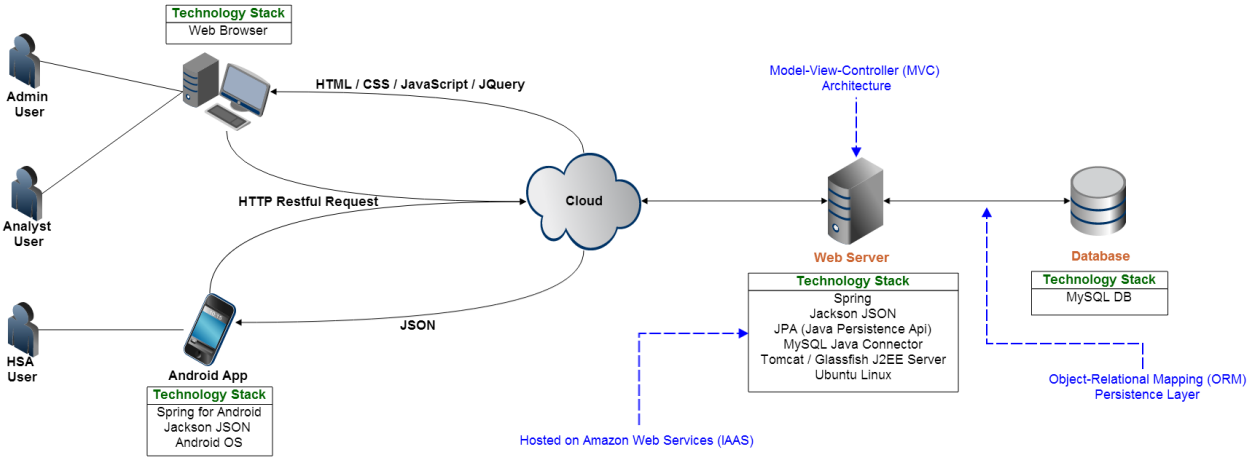


*Figure 10: System Architecture for SL eCCM App*

### 3.1.4 SL technology website

A complementary component to the SL eCCM App was the 'Supporting Website Technology' website (www.sl-technology.eu), which served as an access point for conducting disease surveillance and executing CCM related reports. All synced cases were de-identified and made available to authorised users.

## 3.2 Health Information System

The potential role of the SL eCCM App in relation to the information flow within the Malawi health information system is of great interest to the Ministry of Health, as it presents the potential for more reliable and efficient reporting and consequential decision-making. WP 5 concerns design proposals for disease surveillance and response. Within this WP are three different subtasks: 1) to develop design guidelines for the use of mobile phone based data on disease surveillance at a regional level, 2) to develop design guidelines for a national disease surveillance information system, 3) to develop design guidelines for robust information management for disease control surveillance, and to explore information-based disease outbreaks and control.

### 3.2.1 Malawi HIS policy

In 2015, the Malawi Ministry of Health released a Health Information System Policy with the overall guiding principle of “information for action, action for improving efficiency, quality, and equitable coverage.” This policy was developed in response to: 1) the increased use of ICT within the health sector and 2) the vertical and fragmented systems that compromise data integrity, collection, and consolidation for decision support [6]. In line with the Malawi HIS policy, the SL eCCM App would contribute to the efficiency and quality of data generated at the community level.

### 3.2.2 Implications of SL eCCM App on Reporting and Disease Surveillance

At present, human error poses a major risk to data quality, as data is manually recorded and entered into the District Health Information System 2 (DHIS2), the Malawi’s health management information system. Although the data entered into SL eCCM App did not feed directly into DHIS2, individuals from all levels of the health system including HSAs, district health officers, zonal officers, and the IMCI coordinator acknowledged the potential benefits that the App could contribute to data quality and integration. In terms of completing child assessments, the CDSS and validation feature ensure that all relevant fields are properly filled in, thereby reducing the risk of noncompliance and incomplete data.

Additionally, a disease surveillance email alert system was developed and integrated into v4.0 of the App. This automated email alert system sent daily emails to stakeholders on levels of malaria, pneumonia, and infantile diarrhoea cases recorded and synced in the App. This readily available information can alert relevant parties to potential or existing outbreaks and enable the MoH to anticipate potential low drug stocks in villages at risk of outbreaks. Most importantly, an aggregate view of these cases can be viewed through the SL technology website in real-time, as soon as the patient record is synced. This data would then be made immediately available for analysis, decision-making, and further action. At present, HSAs submit standard reporting forms on a monthly basis to health facilities, where summaries are aggregated and sent onward [7].

Upon recognizing an outbreak, HSAs travel to villages experiencing higher levels of cases to sensitize the village on symptoms and care of the associated outbreak. Interviews with HSAs revealed that their compliance to IDSR guidelines was low due to lack of training at the community level. However, an automated disease surveillance system supported by the SL eCCM App could potentially provide a top-down mechanism in which District Health Officers (DHOs) are able to support HSAs in recognizing and managing outbreaks.

### 3.2.3 Stakeholder Feedback on Health Information System

In May 2016, project partners from Lund University and Luke International met with the Ministry of Health in Lilongwe to gain a better understanding of the flow of patient information in Malawi. Stakeholders, including WHO officials and the Ministry of Health, unanimously reported that information quality was low in Malawi.

The information flow of within the Malawi health system is illustrated in Figure 11. Semi-structured interviews were also conducted with clinical staff at a health centre in Lilongwe. While bottom-up reporting and top-down feedback procedures have been developed, it is generally acknowledged that compliance to these procedures is quite low. Stakeholders report that timeliness in reporting and feedback are often challenges.

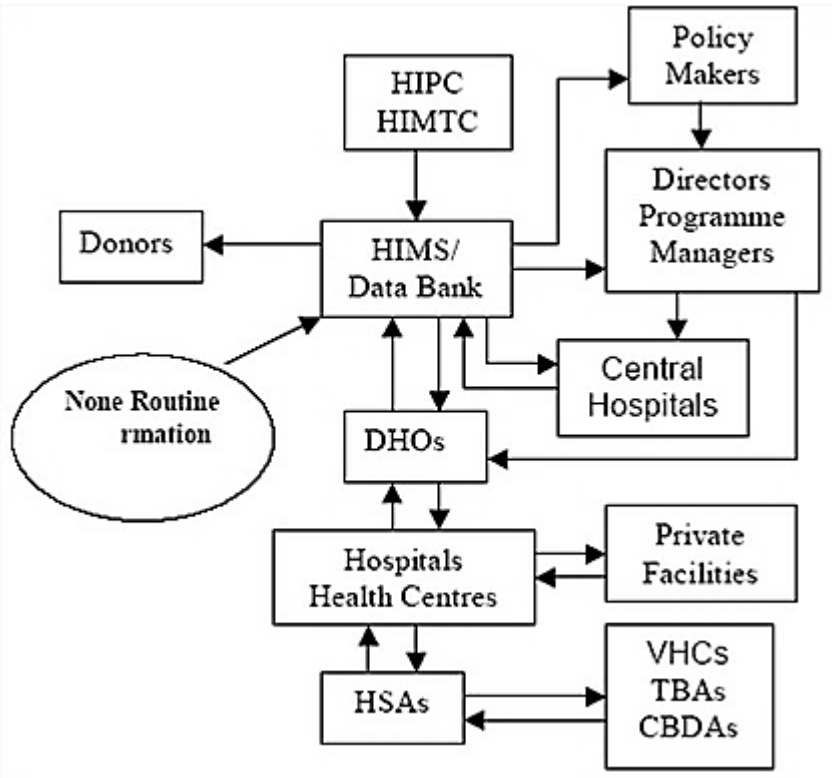


*Figure 11: Information Flow in Malawi Health System*
*www.aho.afro.who.int/profiles_information/index.php/Malawi:Overview_of_the_flows_of_information*

### 3.2.4 Design Recommendations

Two major problems are identified regarding disease surveillance in Malawi: 1) complete, timely, valid, and consistent data and 2) different initiatives in silos. As previously mentioned, the SL eCCM App has the potential to address concerns of complete, timely, and valid data through its validated, mandatory field approach. The number of vertical programmes in Malawi creates challenges for the health information system. That is, if different regions or diseases use specific and designated systems, such as one for influenza, one for HIV and one for malaria, it is cumbersome to acquire an overview of the health situation on a national level.

In the case of Supporting LIFE, a technological base of mobile phones in the hands of trained HSAs is an opportunity to further develop other mHealth applications. As each new application installed on

the same device lowers the cost for each application, economies of scale make the mobile phone an attractive alternative to paper based systems.

Following the advice from Van Aken [8], a technological rule is formulated: in order to achieve an integrated surveillance platform with complete, timely, valid, and consistent data, implement a service corridor and connect silo systems to this and furthermore, and roll out a mobile platform. Using web services, a service directory can be set up where the surveillance system can be fed via a “mash up” of different servers. This would allow for all systems to be reachable within the service corridor (Figure 12), and would also allow for new systems to be easily added to the service platform without requiring all systems applying the same data structure.

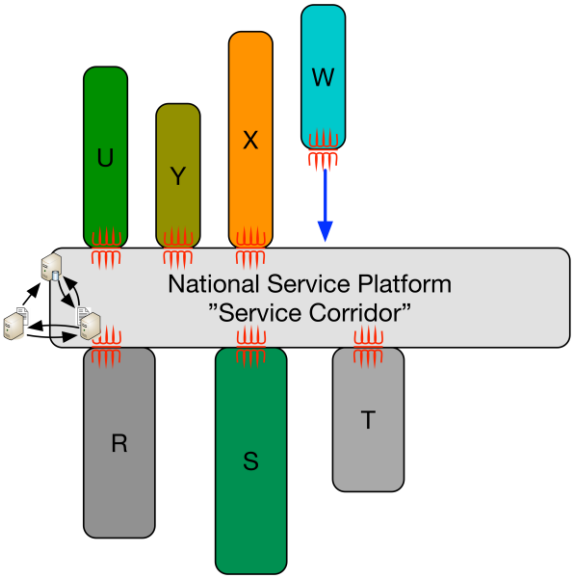


*Figure 12: National Service Platform via a service corridor: R, S, T, U, X, Y are examples of different systems (information silos) that can communicate in a controlled manner via the service corridor. New systems (W) can easily be added to the service platform.*

From the Ministry of Health, strong recommendations that all new eHealth initiative should confirm to the service corridor approach, should be explicit and most likely mandatory. And within an agreed deadline existing systems should conform to the initiative. By these activities, the Ministry of Health with little effort could fulfil the obligations to the International Health Regulations agreement [9], and increase the effectiveness of disease surveillance at a national level.

## 3.3 SL eCCM App in the Village Health Clinics

WPs 3 and 4 focused on the impact of the App on the care provided in the village health clinics and the overall health system in Malawi. The objective of WP 3 was to understand the feasibility of using SL eCCM App in the village health clinics through literature reviews and clinical trials in the field. WP 4 aimed to assess optimal adherence to SL eCCM App as well as the wider implementation and sustainability of the App.

### 3.3.1 Vital signs

**Diagnostic value of vital signs for infectious diseases**

From the onset, the project aimed to investigate how vital signs for malaria, pneumonia and dehydration could be assessed in developing countries to improve the provision of care for children under CCM. At present, IMCI and CCM incorporate only two vital signs (temperature and breathing rate) in its clinical protocols; however, most other paediatric clinical assessment tools recommend the measurement of four or five vital signs, such as capillary refill time (CRT), heart rate, breathing rate, temperature, and oxygen saturation. Thus, a systematic review was conducted on the diagnostic value of vital signs for acute illness in children in low-resource settings. It was determined that the most promising vital sign for identifying children with serious infections and illnesses is breathing rate (albeit with limitations). Findings suggested a need for further research to be conducted in low-resource settings such as village health clinics, and thus supported the planned feasibility and acceptability studies under the Supporting LIFE programme.

**Clinical Feasibility of Measuring Vital Signs Using Sensors & Breath Counter**

Following the systematic review on the diagnostic value of vital signs, an evaluation and market assessment of commercially available wearable vital sign technology was conducted. This revealed that little research had been conducted on the use of wearable vital sign technology in children in low-resource settings. Additionally, it was recognized that there were no commercially available wearable vital sign sensors suitable for children in Malawi.

Given the use of breathing rate vital sign in IMCI and CCM, and the robust clinical evidence for its diagnostic value, the SL team had prioritized methods to incorporate a simple tool to accurately measure breathing rate into the SL eCCM App. A breath counter feature was developed and integrated into the SL eCCM App, which allows the user to tap on a screen in time with a child's breathing rate for a defined period of time. The SL eCCM App then calculates the breathing rate (breaths per minute) and displays this on the eCCM algorithm and populates the screen with this required value. However, findings from the feasibility study suggested that HSAs did not use the embedded breath counter feature in the SL eCCM App. Nearly all HSAs continued to use their stopwatches (standard practice) to measure breathing rate. HSAs reported lack of awareness in addition to forgetting to use the feature.

### 3.3.2 Feasibility study

From July to September 2015, a feasibility study entitled 'Usability, acceptability and feasibility of an electronic Community Case Management decision aid for management of childhood illness in rural village clinics in Malawi' was conducted to assess the acceptability of the SL eCCM App to HSAs and the feasibility of re-identifying children in the community to collect clinical outcomes. Twelve HSAs from Mzimba North District in Malawi were selected by the District Health Office to participate. During the study, 12 HSAs received training and then subsequently used the app (in addition to paper CCM forms) to evaluate sick children in their village clinics for up to two weeks. Feedback

was gathered from the HSAs using focus groups and interviews (Tables 2 and 3). Recruited children were also followed-up within seven days to ascertain their clinical outcomes. It was decided that HSAs would continue to use the village registers (paper CCM forms) for reporting purposes.

The main findings of the feasibility study were as follows:

- HSAs had a positive experience using the SL eCCM App, and felt it would improve their ability to perform their care-provision duties.
- Using SL eCCM App in addition to entering the child's data on the Village Register (standard practice) seemed to duplicate work.
- Following up children using mobile phones and outreach to the village clinics to ascertain their outcomes after acute illness was possible.
- Minor updates to the SL eCCM App were required to align with the latest CCM version.

**Facilitators to using SL eCCM App**

HSAs reported to perceive the SL eCCM App positively. They all preferred the SL eCCM App to their usual way of using the Sick Child Form and Village Register. They noted several areas where they felt that SL eCCM App had improved (or had the potential to improve) the care they provide (Table 2):

- Improved adherence to CCM protocol.
- Increased accuracy and speed of assessing children.
- Improved motivation and confidence.
- Potential for better and more efficient record keeping.
- Potential for more efficient reporting of monthly data.
- Improved perception in the community by parents/caregivers.
- Support with other duties within the community.

*Table 2: Summary of facilitators to using SL eCCM App in village clinics*

| Facilitator | Exemplary quote |
|---|---|
| Improved adherence to CCM protocol | *"The phone is more direct and it even makes the decision of what you are supposed to do after entering the data." (P3)* |
| Increased accuracy and speed of assessing children | *"if these phones were permanently ours to use all the time I think it would really help to speed up our work than the sick child recording form." (P12)*<br>*It gives us a clear picture of what to do next after completing a particular step. Following those steps makes us assess the child accurately." (P7)* |
| Improved motivation and confidence | *"…Sometimes you may make a mistake [using the village clinic register] but you cannot make such mistakes when using the phone" (P3)* |
| Potential for better and more efficient record keeping | *"Here in the village we don't have anywhere to properly keep information. So I think a phone and a laptop can help." (P7)* |
| Potential for more efficient reporting of monthly data | *"We can also use it to send information to the DHO because when we do it on paper-based, sometimes transport may be a problem but we just sent the information direct to the office through the phone." (P10)* |
| Improved perception in the community by parents/caregivers | *"Another good thing about the phone is that when a patient arrives, we explain to the caregiver how the phone works and we take her through the steps up to treatment. This makes them satisfied that they are indeed getting accurate treatment instead of just telling* |

| | |
|---|---|
| | *them [the treatment] like we used to do in the past." (P7)* |
| Support with other duties within community | *"Yes it can help us. We do house rate around the village. We check things like the environment sanitation, so if the phone has a camera, you can take pictures of such things and use them in your report". (P3)*<br><br>*"We use the same phone when assessing children. Apart from that we keep data of catchment population, number of household and so on. But we keep this information in our notebooks. But it would be easier if we kept this data in the phone so that we know the exact number of people or under 5 children in my catchment." (P6)* |

**Barriers to using SL eCCM App**

Some HSAs commented on improvements that could be made to the SL eCCM tool and the process of the study, which would further improve its use in the future (Table 3):

- They expressed a desire for children's records to be stored (and retrieved) within the phone, allowing them to review clinical records if/when children re-attend with the same illness.
- HSAs recommended including child immunization and updated treatment recommendations for fever (malaria rapid diagnostic test) and pneumonia, according to the latest Malawi IMCI/CCM guidance.
- They felt that having to fill in the Sick Child Form and Village Register *as well as* the SL eCCM App was not efficient, and would prefer just to use the app.
- The need for the HSAs to take informed consent from each parent was time consuming and sometimes was not correctly done.
- The mobile phone network was not perfect, so sometimes HSAs were not able to synchronize their data to a central server.
- HSAs sometimes changed phone settings; did not charge phones for clinic days; used device for reasons other than the purposes of the study (take photos, surf the internet and make personal phone calls).

*Table 3: Summary of the barriers to using SL eCCM App in village clinics*

| Barriers | *Exemplary quote* |
|---|---|
| Treatment recommendations for fast breathing/fever need updating | *"…you should update the phone according to the guidelines of maybe World Health Organization because as I was saying that in the phone, there is cotrimoxazole which is recommended for fast breathing but in our register there is amoxicillin. So…sometimes it can give confusions as we go." (P2)*<br><br>*"only that there is no mRDT system in the phone they should include the new system of how to do mRDT. When it's negative, it means no treatment is given, we just give advice. The phone uses the old system where we used to give treatment to any child who has got fever" (P12)* |
| Lack of record retrieval/storage facility | *"But I still can't tell the number of children I have assessed from the phone because once I have synced the data, then that's the end of it […] I think it would be better if the phone was able to keep records for us to see." (p6)*<br><br>*"the phone should be able to keep the data after we sent it, in case we will stop using the registers where we write, it means we will not have any data at the end of the month." (P5)* |

The SL eCCM App v5.0 was used during the feasibility study. Upon evaluating the feedback received from HSAs, it was realized that minor amendments had been made to the CCM protocol in Malawi. Therefore, the updates were integrated into version 6.0 to ensure that treatment guidelines were current and correct before deploying into the clinical trial the following year. Thus, another version of the SL eCCM App was developed by the project (version 6.0) and was released in August 2016.

Positive feedback from the feasibility study supported the decision to conduct a clinical trial to further assess the impact of the app.

### 3.3.3 Clinical trial

From October 2016 to January 2017, the project conducted a clinical trial (led by UW) entitled 'The Added Value of a Mobile Application of Community Case Management on Under-5 Referral, Re-consultation and Hospitalization Rates in Two Districts in Northern Malawi: a Pragmatic Stepped-wedge Cluster Randomized Trial' (ClinicalTrials.gov Identifier: NCT02763345).

The trial focused on investigating the impact of using SL eCCM App in addition to paper-based CCM, compared to using paper-based CCM alone. The primary objective of the trial was to investigate the added value of the SL eCCM App on referral, re-consultation and higher-level facility presentation rates in children aged ≥2 months up to <5 years in Rumphi and Nkhata Bay districts in Malawi. Other objectives were to explore HSA and parent/caregiver attitudes towards the use of the app for assessing and treating acutely unwell children in village clinics, including an exploration of the constraints of delivering/following referral recommendations, as well as to compare the costs of seeking care following the index consultation, including the role of the app in increasing/decreasing costs.

102 HSA clinics from two districts in northern Malawi were recruited to participate in the trial. 48 study sites were located in Rumphi district while 54 sites were located in Nkhata Bay district. These districts were chosen due to their proximity from Mzuzu. A map of the clinic locations is shown in Figure 13. The clinics were conveniently grouped into six clusters based on geographical location. 33 data collectors were recruited from a cohort of recent graduates from Mzuzu University. The data collectors were tasked with visiting the village clinics to collect case report forms, following up with parents/caregivers, and following up with clinics, hospitals, and health facilities to ascertain re-consultation and attendance rates.

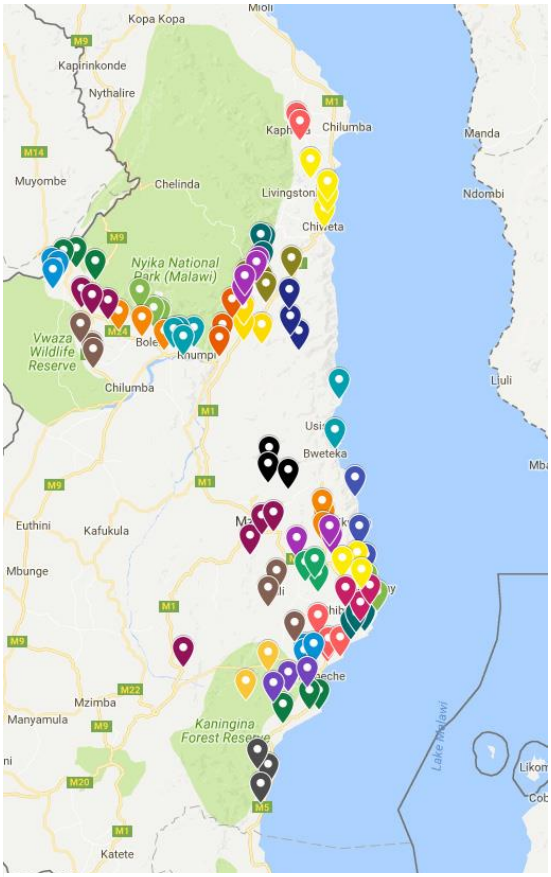


*Figure 13: Map of study sites in Rumphi (48) and Nkhata Bay (54)*

The trial ran for a total of thirteen weeks. A stepped-wedge design was chosen for pragmatic reasons, but also because all HSAs were able to participate in both the control and the intervention phase. A diagram of the trial design is illustrated in Figure 14. The first two weeks were allocated to training. During that period, HSAs were trained by study staff to use

the Android smartphone as well as the SL eCCM App. All HSAs then proceeded into the control phase at week 0 and enrolled children into the study using paper-CCM (standard practice). Following the control phase, HSAs were provided a second training course to further strengthen their knowledge of the smartphone and SL eCCM App. Clusters were randomly allocated to a time to cross from the control to intervention phase. All clusters ended the trial in the intervention phase, which involved the use of the SL eCCM App in addition to paper CCM. Following completion of the trial, the HTC smartphones provided to the HSAs were donated to Rumphi and Nkhata Bay DHOs for capacity building purposes.

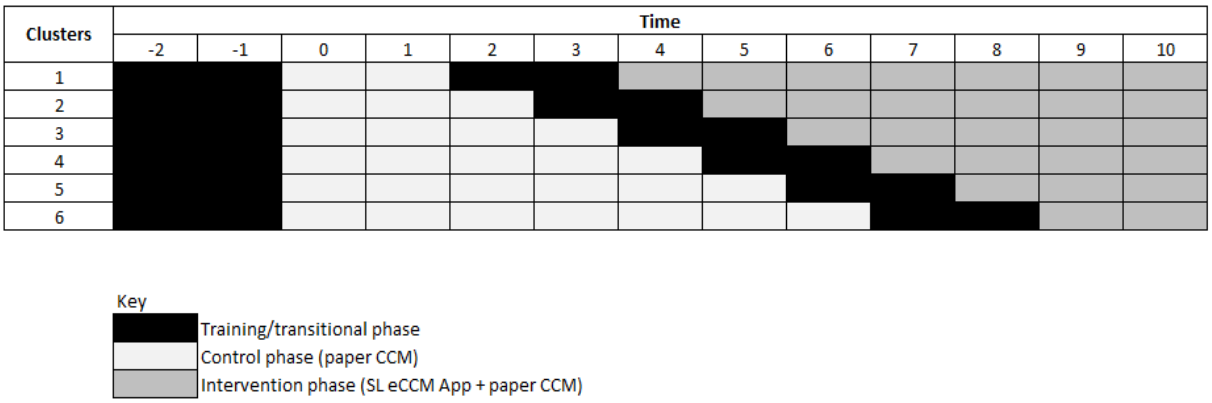


*Figure 14: Diagram of cluster randomized stepped-wedge study design*

**Preliminary Qualitative Results**

Interviews were conducted with HSAs as well as parents and caregivers regarding their experience with the App.

**HSAs**: HSAs felt that the app helps them to adhere to the CCM protocol, by not allowing them to skip any vital step when assessing a child, as well as to provide accurate diagnosis and treatment recommendations. HSAs noted an overall increase in confidence, as the communities' perceptions of HSAs using the app were improved. Many HSAs reported that community members trusted and respected them more due to using the app. Additionally, SL eCCM App allows them to reach more children as they can carry the phone easily with them wherever they go.

**Parents/caregivers**: Caregivers found SL eCCM App an acceptable tool. Nearly all said that the use of mHealth should be continued. Many, though not all, also said that HSAs were able to work faster thanks to the phone and the SL eCCM App.

**Preliminary Quantitative Results**

**Referral rates**: referral rates were similar across study phases. Home treatment accounted for 94.7% and 94.4% of all referrals in the control and intervention phase, respectively. Urgent referral rates were also similar (5.3% versus 5.6%, respectively).

**Re-consultation rates**: In the control phase, 7.6% of patients re-attended at village clinics within 7-days of enrolment. In the intervention phase, this proportion was reduced to 3.3%.

**Presentation higher-level health facilities**: In the control phase, 10.1% of patients presented to a higher-level health facility and 1.1% were admitted to a hospital within 7-days of enrolment. In the intervention phase, this number decreased to 7.6% and 0.8%, respectively.

### 3.3.4 Sustainability of SL eCCM App mHealth intervention

Following completion of the clinical trial, the project conducted a series of interviews with relevant stakeholders to assess the facilitators and barriers of sustainably implementing the intervention on a national scale.

Stakeholders included: 2 HSAs, 2 DHOs, 2 IDSR programmers, a zonal officer, a Ministry of Health Central Monitoring and Evaluation Division (CMED) official, 4 NGO officers (from Luke International, D-Tree International, and Baobab Health Trust), and the IMCI coordinator.

The Framework for Conceptualizing Programme Sustainability [10] was used to guide the stakeholder interviews on the topic of sustainability. This framework suggests that community-based health programmes are strongly influenced by the following three factors: 1) project design and implementation, 2) organisational setting, and 3) broader community environment.

All stakeholders reported that Supporting LIFE was welcomed in Malawi, from the community level up to the Ministry of Health. During the project initiation, the Supporting LIFE consortium established a strong working relationship with key stakeholders in Malawi to ensure that the needs of the community were taken into consideration. Malawi-based project partners played a major role in maintaining this relationship throughout the project duration. However, when considering the broader community environment, there are several issues that need to be resolved before scaling up the SL eCCM App. These include integration with the DHIS2 system, alignment with the strategic goals and interests of the MoH, engagement with national and international stakeholders, local capacity building through training of trainers, and achieving vertical and horizontal integration.

Stakeholders were eager to learn what the next steps are for Supporting LIFE in Malawi. CMED within the Ministry of Health indicated an interest in the wider implementation of the app, however, acknowledged the lack of resources required for scaling up. Therefore, it was suggested that wider implementation of the SL eCCM App would not be feasible without support from external partners especially in the initial stages.

# 4 IMPACT

Since the overarching objective of Supporting LIFE was to assist HSAs in delivering health interventions to improve and manage disease control, dissemination and exploitation measures aimed to contribute to this very same goal. They did so by:

- Informing funding bodies, policymakers and the general public about the importance and impact of mHealth (Section 4.1.1).
- Sharing results on the effectiveness of the SL eCCM App among the scientific community (Section 4.1.2).
- Sharing results regarding the effectiveness of mHealth solutions and recommendations for effective and efficient Health Information Systems to those stakeholders who are most in need of such information: policymakers in Malawi (Section 4.2.1).
- Increasing the sustainability of Supporting LIFE by finding funding for follow-up research or implementation projects (Sections 4.2.2, 4.2.3).

## 4.1 Dissemination measures (Section A)

Supporting LIFE dissemination measures pursued the following overall objectives:

- Making the project results transparent and accessible to the general public.
- Increasing awareness among funding bodies, the general public and Malawi policymakers for the potential impact of community health in resource-poor settings.
- Assisting exploitation measures by providing up-to-date, informative and attractive communication material.
- Advancing scientific knowledge about the impact of an mHealth application like the SL eCCM App on health outcomes in resource-poor settings.

All partners used their network of contacts to reach these objectives and thus disseminate Supporting LIFE to funding bodies, policymakers and the general public. Dissemination measures and dissemination material to support these efforts are described in Section 4.1.1. Scientific dissemination is documented in Section 4.1.2.

### 4.1.1 Dissemination to funding bodies, policymakers and the general public

The following dissemination material was created to support the Supporting LIFE consortium when presenting the project and its results to stakeholders.

**Website:** Two websites were created. The first website (www.supportinglife.eu) is targeting the general public, funding bodies and policy-makers. Initially, it described project goals, partners and work plan, before it was incrementally expanded with the up-to-date project status, interim results and links to first releases of the Supporting LIFE eCCM App. At the very end of the project, this website will be updated with final results, points of contact for enquiries and, if applicable, links to any follow-up projects. The second website (www.sl-technology.eu) is technology-oriented, targeting health professionals and users of the Supporting LIFE app by providing an access point for conducting disease surveillance and executing CCM related reports.

**Infographic & Factsheet:** When Supporting LIFE started, an infographic was created to quickly explain and visualize the project's objectives and course of action (www.supportinglife.eu/infographic.html). Similarly, a project factsheet summarized the key objectives and motivation of the Supporting LIFE project.

**Newsletter:** A newsletter was sent to ~150 stakeholders working for funding bodies, NGOs, governments and research organisations with interim results of Supporting LIFE in September 2014 and 2016.

**Online demo:** Although the Supporting LIFE eCCM App is freely available on SourceForge to be installed on an Android device, some users prefer to instantly try the app to get a feel for what it is and how it works. Therefore, an interactive online demo of the app was created and published on the Supporting LIFE website.

**Videos:** To document the project outcomes and attract the attention of policymakers, funding bodies and potential users of the app, two documentary videos were created. The first video described the purpose and potential benefit of the Supporting LIFE eCCM App, while the second video was created at the very end of the project in order to include the latest results and final state of the app. In addition, an explainer video was produced to promote the project.

**Trial factsheets:** For meetings with Malawi stakeholders, two factsheets were created to highlight the results of the Supporting LIFE feasibility study and larger clinical trial. Both factsheets are available on the downloads section of the Supporting LIFE website.

**FAQ:** Some of the most frequently asked questions from users, policymakers and funding bodies were collected, answered and the result published on the website.

### 4.1.2 Dissemination to the scientific community

The consortium members have successfully published a number of journal and conference papers (Appendix A). More publications, using the data collected from the trial, are currently being prepared and will be submitted following analysis of the trial data.

## 4.2 Exploitation measures (Section B)

Exploitable results of Supporting LIFE include

- The Supporting LIFE App
- Results regarding the effectiveness and acceptability of mHealth intervention in Malawi
- Recommendations for Health Information Systems in Malawi and other low to middle income countries
- Data for secondary analysis

Supporting LIFE exploitation measures pursued the following main goals:

- Make Malawi policymakers aware of Supporting LIFE recommendations regarding the Health Information System.
- Communicate the results regarding the impact of the SL App on clinical outcomes to Malawi policymakers, funding bodies and the scientific community.
- Facilitate the exploitation of the SL App and scientific results via follow-up research and implementation projects.

These objectives were pursued mainly by exploitation meetings with influential stakeholders (Section 4.2.1) and applications for follow-up research and implementation projects (Section 4.2.2).

### 4.2.1 Exploitation meetings

Supporting LIFE made an effort to establish a sustainable relationship to the Malawi Ministry of Health and to include their requirements in the project from the start. This task was tackled mainly by local partners in Malawi, namely Mzuzu University and Luke International Norway. Their efforts included the following meetings:

- Trial preliminary findings workshop (9 February 2017): Hosted by the SL consortium and attended by delegates from the Department of HIV, Department of Epidemiology, Zonal Health Support Office, District Health Offices, the Central Monitoring and Evaluation Division (CMED) of the Ministry of Health, Baobab Health Trust, Cooper/Smith, University of Malawi, I-TECH, JHPIEGO, Dignitas International, and D-Tree International.
- mHealth Technical Working Group (TWG) meeting (25th April 2017): Hosted by the Central Monitoring and Evaluation Division of the Ministry of Health. Supporting LIFE, through Luke International, Lund University, accelopment AG and Mzuzu University, participated in the meeting. Other participants included authorities from the Ministry of Health, University of Malawi, Village Reach, D-Tree International, MSH, Baobab Health Trust, I-TECH, NiTEL, Partners in Hope, Digintas International, Cooper/Smith and USAID. The mHealth TWG is the official platform for mHealth development partners to share their progress and assist the government to align different efforts to harmonize with national policy. The SL partners presented the trial findings and experiences with the mHealth implementation and discussed future design considerations.
- M&E Technical Working Group meeting (20 April 2017): Hosted by the Ministry of Health. SL partner Luke International Norway participated in the meeting to brief participants about the successfully finished SL trial. Participants were also invited to join the coming mHealth TWG

meeting to learn more details of the preliminary findings. The M&E TWG is the highest level TWG meeting concerning health information system development work in Malawi. Participants of the meeting included UNICEF, USAID, GIZ, DFID and most of the development partners in country.

- National Community Health Strategy Development Workshop – Central West Zone (7 February 2017): Hosted by the Preventive Department of the Ministry of Health. SL partner Luke International Norway participated in the workshop. The aim of the workshop was to assist the government to develop its National Community Health Strategy, which has ICT as one of its main thematic areas of development. LIN shared their experiences with the SL eCCM and the potential of its use for future development of an integrated community health information system.

### 4.2.2 Data for secondary analysis

Data from the clinical trial will be made publicly available on an open data repository. UW will select an adequate hosting organization, prepare data for upload (i.e. selection, annotation and quality control of data), choose an appropriate license and define adequate terms and conditions of use.

### 4.2.3 Follow-up projects

Supporting LIFE partners have also applied for follow-up projects. These include research and implementation projects regarding the future development of the Supporting LIFE App for other communicable and non-communicable diseases and/or for different age groups, as well as its roll-out in selected regions of Malawi. In the first instance, grant applications have been developed and submitted to US funding agencies and foundations, such as the Bill & Melinda Gates Foundation (Global Grand Challenges) and the Center for Disease Control and Prevention (CDC) (FY2017-OADS-01). In parallel, negotiations with key stakeholders, such as the Malawian Ministry of Health and local non-for-profit organisations have started to exploit the Supporting LIFE results for improving health in Malawi and other Sub-Saharan countries.

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# 6 APPENDIX A: SUPPORTING LIFE PUBLICATIONS TO DATE

| | Title | Partner(s) | Authors | Publication Home | Status |
|---|---|---|---|---|---|
| 1. | Examining Contextual Factors and Individual Value Dimensions of Healthcare Providers Intention to Adopt Electronic Health Technologies in Developing Countries. | UCC/ ICL | O' Connor, Y., Treacy, S., O' Donoghue, J. | IFIP WG 8.6 Conference | Published |
| 2. | Community Health Workers Participation in m-Health Pilot Studies within Developing Countries: Expectation Management. | UCC/ ICL | O' Connor, Y. O' Donoghue, J. | HCist - International Conference on Health and Social Care Information Systems and Technologies | Published |
| 3. | Improving Primary Care in Developing Countries: The Potential of Electronic Community Case Management (eCCM) on Low Cost Mobile Technologies. | UCD/ UCC/ ICL | Gallagher, J., O'Donoghue, J., O'Connor, S., O'Connor, Y. | Annual Scientific Meeting of the Association of Departments of General Practice in Ireland | Published |
| 4. | Unique Challenges Experienced during the Process of Implementing Mobile Health Information Technology in Developing Countries. | UCC/ICL/ MU | O'Connor, S., O'Donoghue, J., Gallagher, J., Kawonga, T. O'Connor, Y. | BMC Health Services Research | Published |
| 5. | Ehealth In Low Resource Settings: The Need For Greater Information Communication Technology For Capacity Building. | MU/ UCC/ ICL/UCD/ CUNY | Kawonga, T., O'Connor, Y., O'Connor, S., O'Donoghue, J., Gallagher, J., Wamba, N., Griffin, R. | Irish Forum for Global Health International Conference | Published |
| 6. | Prerequisites For Critical Capacity Development/Enhancement In Low Resource-Settings: An Ehealth And Elearning Case Study. | CUNY/ UCC/ ICL/ UCD/ UKZN | Wamba, N., Griffin, R., Shawa, L., O'Connor, S., O'Donoghue, J., O'Connor, Y., Gallagher, J. Perry, I. | Irish Forum for Global Health International Conference | Published |

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| 7. The Role of Primary Healthcare and eHealth in Malawi Africa | UCD/MU/ UCC/ICL/ CUNY | Gallagher, J. ,Kawonga, T., O'Connor, S., O'Donoghue, J., Wamba, N., Griffin, R. , Watson, C. | Irish Forum for Global Health International Conference | Published |
| 8. Capacity Building and Partnership in the Developing World: Reflections on Partnership-in-Action between Lesotho, Uganda, Malawi and Ireland. | UCC/CUNY /ICL/UCD | Griffin, R., Wamba, N., O'Connor, S., O'Donoghue, J., Gallagher, J. | Irish Forum for Global Health International Conference | Published |
| 9. Contextual Barriers to Mobile Health Technology in Developing Countries: A Perspective Piece. | UCC/ICL/ UCD/LIN | O' Connor, Y., O' Donoghue, J. | Journal of Mobile Technology in Medicine | Published |
| 10. Developing eXtensible mHealth Solutions for Low Resource Settings | UCC/ ICL/UCD | O' Connor, Y., O' Sullivan, T., Gallagher, J., Heavin, C., O' Donoghue, J. | International Conference on Mining Intelligence and Knowledge Exploration | Published |
| 11. First Impressions are Lasting Impressions: Intention to Participate in Mobile Health Projects within Developing Countries. | UCC/ICL | O' Connor, Y., O' Donoghue, J. | Communications of the Association for Information Systems | Published |
| 12. Understanding User Participation in mHealth Pilot Studies within Developing Countries. | UCC/ICL | O' Connor, Y., Heavin, C., O' Donoghue, J., Gallagher, J. | International Journal of Technology Assessment in Health Care | Published |
| 13. Sociocultural and Technological Barriers of Mobile IT across All Phases of Implementation in a Developing Country: An Empirical Study. | UCC/ICL | O' Connor, Y., O' Connor, S., Gallagher, J., Heavin, C., O' Donoghue, J. | Book Chapter (Elsevier Edited Book entitled "Applied Computing in Medicine and Health") | Published |
| 14. Validity and reliability of measurement of capillary refill time in children: a systematic | UOXF | Fleming S, Gill P, | Archives of Disease of Children 2014 | Published |

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| review. | | Jones C, Taylor J, Van den Bruel A, Heneghan C, Thompson M | | |
| 15. Diagnostic value of capillary refill time in children for serious illness: a systematic review and meta-analysis. | UOXF | Fleming S, Gill P, Jones C, Taylor J, Van den Bruel A, Heneghan C, Thompson M. | PLOS ONE | Published |
| 16. Systematic review of the diagnostic accuracy of capillary refill time for serious illness in children. | | Thompson M, Fleming S, Gill P, Jones C, Taylor J, Van den Bruel A, Heneghan C | North American Primary Care Research Group, Ottawa 2013 | Presented |
| 17. Systematic review of the diagnostic accuracy of capillary refill time for serious illness in children. | UOXF | Fleming S, Gill P, Jones C, Taylor J, Van den Bruel A, Heneghan C, Thompson M | Pediatric Academic Societies, Washington DC, 2013 | Presented |
| 18. The Importance of Economic Evaluations of mHealth Pilots: A Proposed Malawian Case-Study. | UCC/ICL | Berkery, T., O'Connor, Y., Ryan, D., Heavin, C., Gallagher, J., & O'Donoghue, J | ECIME2015-9th European Conference on IS Management and Evaluation: ECIME 2015 | Presented |
| 19. Review of Key Stakeholders for an mHealth Pilot Study in Malawi Motivations and Expectations. | UCC/ICL | O'Connor, Y., Heavin, C., & O'Donoghue, J | International Journal of Reliable and Quality E-Healthcare (IJRQEH) | Published |

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| 20. Supporting LIFE: Mobile Health Application for Classifying, Treating and Monitoring Disease Outbreaks of Sick Children in Developing Countries. | UCC/UW/ICL | O'Connor, Y., Hardy, V., Heavin, C., Gallagher, J., & O'Donoghue, J. | New Horizons in Design Science: Broadening the Research Agenda | Published |
| 21. Wearable Vital Sign Sensors and Their Potential within Low and Middle Income Countries. | UCC/UW/UCD/UOM/ICL | McCarthy, S., O'Connor, Y., Thompson, M., O'Sullivan, T., Ryan, D., O'Connor, S., Gallagher, J., Heavin, C., O' Donoghue J. | ECIS 2015 Research-in-Progress Papers | Published |
| 22. The Importance of form field validation: lessons learnt from a feasibility study of an mHealth application in Malawi, Africa | UCC/ICL/UW/MU/LU | O'Connor Y, Hardy V, Thompson M, Mastellos N, Tran T, O'Donoghue J, Chirambo GB, Andersson B, Carlsson S, Heavin C | 20th Pacific Asia Conference on Information Systems (PACIS) 2016 | Published |
| 23. Service Blueprint for Improving Clinical Guideline Adherence via Mobile Health Technology | UCC/LU | O'Connor Y, Heavin C, O'Connor J, Gallagher J, Wu J, O'Donoghue J | International Journal of Reliable and Quality E-Healthcare | Published |
| 24. 'Understanding Community Health Workers' Intentions to Participate In mHealth Studies within Developing Countries | UCC | O'Connor Y, Heavin C, Gallagher J, O'Donoghue J | Behaviour and Information Technology | Published |