E-HEALTH APPLICATIONS IN LOW- AND MIDDLE-INCOME COUNTRIES

SCALING UP E-HEALTH APPLICATIONS IN LOW- AND MIDDLE-INCOME COUNTRIES: AN EXAMPLE THAT SUCCEEDED

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LAY ABSTRACT

This study explored eHealth project implementation and scale-up in Low-and Middle-Income Countries (LMICs), with a specific focus on the cStock eHealth project in Malawi. The intention was to identify key lessons learned from the successful national-level scale-up of cStock in Malawi and its implications for eHealth projects in LMICs. This study contributes to the literature by examining barriers and facilitators to eHealth project implementations, scale-ups, and sustainability; in addition, evaluating the impact of the COVID-19 pandemic on eHealth projects in LMICs; and the role that paper records continue to play in LMICs. Amongst other conclusions, it was found that financial constraints in public health systems in many LMICs lead to a heavy reliance on foreign aid to finance eHealth projects which all-too-frequently lead to financially unsustainable projects; and strong national government commitment at policy, regulatory, human resource, and administrative levels are facilitators to achieving eHealth project success.

ABSTRACT

Background: Despite barriers such as financial and infrastructural challenges, there are many successfully implemented eHealth projects in Low- and Middle-Income Countries (LMICs). However, project scale-up and sustainability remains a pressing issue. This study analyses in detail an example of one such successful eHealth project: cStock in Malawi, an eHealth tool used to improve child health. This study aims to identify lessons that can be derived from our study of cStock, with support from the literature.

Methods: In this research, a literature review was first conducted to scope existing literature on LMIC eHealth projects. Secondly, a qualitative study was conducted using five Key Informant interviews of individuals directly involved in the cStock case. Thematic content analysis of these interviews was conducted to identify themes.

Findings: Six major themes were identified from my view: (1) facilitators and barriers to cStock implementation; (2) facilitators and barriers related to the scale-up and sustainability of cStock; (3) the impact of the COVID-19 pandemic on cStock operations; (4) the continuing role of paper records in cStock; (5) the transition of cStock and other health systems to full electronic systems in Malawi; and (6) a related set of recommendations for improving cStock operations and future LMIC eHealth projects.

Conclusions and Implications: Despite the strong commitment of the Malawi government to the cStock project, it is widely recognized in Malawi public health system that cStock does not, at this time, have a sustainable financial model. Similar practices of financial precariousness may apply to most LMIC eHealth projects with reliance on external international finance. This study contributes to the growing literature on eHealth and

focuses on enabling characteristics and barriers to LMIC eHealth project implementations, scale-ups, and sustainability. Further research is needed to investigate sustainable financial models that are more likely to achieve success for future LMIC eHealth projects.

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LIST OF ABBREVIATIONS

CCM – Community Case Management

CHW – Community Health Worker

DH – Digital Health

DHMT – District Health Management Team

DPAT – District Product Availability Teams

DTC – Drugs Therapeutic Committee

EHR – Electronic Health Record

EM – Enhanced Management

EMR – Electronic Medical Record

EPT – Efficient Product Transportation

FHW – Frontline Health Worker

HPAT – Health Facility Product Availability Teams

HSA – Health Surveillance Assistant

ICCM – Integrated Community Case Management

ICT – Information Communication Technologies

LMIC – Low- and Middle-Income Country

MoH – Ministry of Health

MoHP – Ministry of Health and Population

SC4CCM – Supply Chains for Community Case Management

SCM – Supply Chain Management

SDG – Sustainable Development Goal

DECLARATION OF ACADEMIC ACHIEVEMENT

This thesis and its research content have been completed by Damsadie Kaluappuwa Hannedige, recognizing the valuable guidance from her Supervisor, Dr. Christy Gombay and Supervisory Committee member, Dr. Norm Archer.

CHAPTER 01 – Introduction

Digital Health technologies, including eHealth and mHealth, have proven effects in improving accessibility of healthcare in Low- and Middle- Income Countries (LMICs) (Olu et al., 2019). Benefits of eHealth technology also include managing communications and information dissemination for health workers, monitoring health programs, and managing healthcare initiatives during infectious disease outbreaks (Fanta & Pretorius, 2018; Olu et al., 2019; Oza et al., 2017). Despite many challenges to implementing eHealth projects in LMICs, there is a plethora of donor-funded pilot-level implementations that are operating in isolation (Fanta & Pretorius, 2018; Luna et al., 2014). Although these pilots have improved community health, they often fail, and there is a growing concern of scaling-up and sustaining these eHealth projects in the long-term (Fanta & Pretorius, 2018; Huang et al., 2017; Luna et al., 2014). This has raised questions in LMICs in terms of financial sustainability of eHealth projects, foreign aid dependency, infrastructure development, system interoperability, and health system strengthening.

As there are only limited number of scaled and sustained eHealth projects, it was determined to be important to analyse a successful eHealth application scaled-up at a national level in an LMIC. Hence, this exploratory research study aims to learn lessons from the use of an eHealth application in a LMIC by focusing on the implementation, scale-up, and sustainability of a specific Digital Health (DH) platform designed to support Community Health Workers (CHWs) with case management. I will be looking more specifically at a platform called CommCare created by Dimagi, Inc. which has been

deployed in 80 LMICs with more than 2000 projects using CommCare for mobile data collection and reporting needs (Dimagi, 2021). I will be focusing on a case study of an implementation of CommCare called cStock, in Malawi. This system is being used for supply chain management (SCM) of essential medicines at national level for treating children under five years old.

This research will help further understand underlying challenges and experiences of using eHealth applications by project implementors and system users across various work positions, including central-level project implementors and district-level project officers. The cStock case study is an example of a successful implementation and scale-up of an eHealth application in a resource-limited setting. The research findings will aid in understanding: (1) challenges with the implementation and use of an eHealth application in an LMIC environment; (2) how to incorporate sustainability into project development in LMICs; and (3) what perceived benefits can be derived by using eHealth applications in the context of COVID-19. This will help support future research focused on implementing eHealth applications to improve quality of care offered to patients in need and collectively improve population health in resource poor settings.

This study has three main purposes:

1. To provide an overview of existing literature on eHealth project implementations in LMICs with a specific focus on project implementation, scale-up, and global and regional partnerships in the project context.
2. To record the lessons learnt from the implementation, scale-up, and use of cStock in Malawi in terms of describing: (1) facilitators and barriers to the implementation of

cStock; (2) facilitators and barriers related to the scale-up and sustainability of cStock; (3) the perceived benefits of using cStock during the COVID-19 pandemic; (4) the continuing role of paper records in cStock; and (5) the transition of cStock and other health systems to full electronic systems in Malawi.

3. To contribute to future research and implementations of eHealth applications in resource-limited settings in order to improve quality of healthcare offered to patients and thus collectively improve population health.

Research Question(s)

This research aims to answer the following primary research question followed by four secondary research questions.

> *What lessons can be learned from the implementation and use of cStock eHealth application in Malawi?*

Secondary Research Questions:

- What factors can contribute to the sustainability and transition to scale of eHealth applications in resource limited settings?
- What are the perceived benefits of using eHealth applications in the context of COVID-19?
- What are the potential benefits and challenges of transitioning fully to electronic records? And how feasible would it be to transition fully to electronic records in the context of Malawi?
- Is there a point in the hierarchical communication chain (organizational work chain) where paper records become more beneficial than electronic records?

This thesis is presented in seven chapters. Chapter One provides a brief introduction to the thesis. Chapter Two provides key background details on eHealth applications in LMICs to provide context to the literature review and the case study in Malawi. Chapter Three presents the literature review findings focusing on barriers and facilitators to project implementation, barriers to transitioning to scale, and global and regional partnerships in eHealth projects of LMICs. Chapter Four presents the methodology of the qualitative primary research conducted based on Key Informant interviews for the cStock Malawi case study. Chapter Five presents the findings identified from the qualitative research on the cStock case study as six key themes. Chapter Six discusses the findings presented in Chapter Five with support from the findings of the literature review, other existing literature, and personal insight. Finally, Chapter Seven, presents concluding lessons learned from the literature review, and primary research, including recommendations for achieving sustainability for eHealth projects in LMICs.

CHAPTER 02 – Background

The previous Chapter provided a brief overview of the core material that will be presented in this thesis. In this Chapter, I will provide background context for the literature review and the primary research that will be presented in following chapters. In more detail, this Chapter outlines the core definitions central to understanding digital health for the thesis (2.1), benefits of eHealth technology (2.2), adopting eHealth projects in LMICs (2.3), the situation after implementing eHealth projects (2.4), the ultimate transition to scale for eHealth projects (2.5), and the cStock Malawi case study description (2.6).

2.1 eHealth and definitions

Adoption of electronic health (eHealth) systems and technology align with Sustainable Development Goal (SDG) 3 focused on achieving universal health coverage particularly in LMICs; SDG 9 focused on improving infrastructure and accessibility to innovative technology, especially in LMICs and specifically countries in Africa; and SDG 17 focused on global partnerships fueling international projects (United Nations, n.d.). The use of various Digital Health technologies contributes to improving quality of patient care and accessibility to healthcare in LMICs, with specific benefits such as improving efficiency in health care and reductions in financial costs (Olu et al., 2019).

The term Digital Health (DH) can refer to eHealth, electronic records (Electronic Health Records (EHR), Electronic Medical Records (EMR)), telemedicine, mHealth and other applications of Information Communication Technologies (ICT) in health (Olu et al., 2019). The term eHealth has been described as “an emerging field in the intersection of

medical informatics, public health and business, referring to health services and information delivered or enhanced through the internet and related technologies" (Kernebeck et al., 2020, p. 4184). World Health Organization (WHO) defines eHealth as any ICT technology used in health or health-related areas and applications (WHO, 2021). In this thesis, at times the terms eHealth and DH are used interchangeably. Further, mHealth is a component of eHealth and refers to health supported by mobile devices (Kernebeck et al., 2020). Telehealth or telemedicine is described by the WHO as using ICT for exchanging medical or health-related information over a distance to deliver healthcare to individuals and communities in need (WHO, 2010).

The term EMR refers to the medical information and history of a patient throughout a long period of time collected by their care providers, this can include medical history, laboratory and radiology tests, immunizations, etc. (Heart et al., 2017). The same paper highlights that the term EHR carries a similar meaning to an EMR, yet in contrast, an EHR is a more comprehensive health record that can be used by multiple healthcare providers across institutions. Simultaneously, considering the patient perspective, the Personal Health Record (PHR) refers to a system that enables patient access to their own medical records (Heart et al., 2017). The ultimate objective of digital healthcare would be a combination of EHR, EMR, and PHR where quality of patient care can be improved with rapid access to information by all healthcare professionals involved in patient care and with the contributions of patients (Heart et al., 2017). In the global North there has been steady transition to digital health systems from paper-based systems, with large investments in digital healthcare (Muinga et al., 2020). Even though, in the context of LMICs and

especially in sub-Saharan African countries there has been significant adoption of eHealth systems, all-too-frequently sustaining such systems remains a challenging path (Kiberu et al., 2017; Muinga et al., 2020).

2.2 Benefits of eHealth technology

The use of DH technologies in LMICs can help improve rapid health information dissemination to healthcare workers, by supporting clinical decision making, and monitoring performance of health programs (Olu et al., 2019). In the context of low-resource settings and hard-to-reach areas, eHealth applications can be particularly useful for enabling communication among community members and healthcare providers, chronic disease management, and increase access to health information (Kiberu et al., 2017).

Particularly in an LMIC context, the mobile phone acts as a ubiquitous digital device enabling accessibility of healthcare through the cadre of frontline health workers (FHWs), where timely healthcare would be otherwise inaccessible for communities due to distance and lack of easily-accessible health facilities (Agarwal et al., 2015). The use of such mHealth applications by FHWs includes services such as support for data collection, decision-support, notifications, and emergency referrals (Agarwal et al., 2015). The same paper highlights that using mobile phone applications in the data collection process by FHWs have been shown to reduce the travel time to health centers to transfer client data, ensuring that FHWs can focus more on service delivery; and allows identification and correction of data errors in real-time. Mobile-based data entry can also be viewed as a cost-effective option when compared to paper-based data entry, hence improving the potential for transitioning to scale.

Moreover, in the recent years, EHR systems have been widely implemented in LMICs and also considered as an element of DH infrastructure (Muinga et al., 2018). Several specific benefits of using an EHR system include the efficient access it provides to patient records in remote locations, reduction of medical errors (which are more likely to occur via handwritten prescriptions), and the ability to easily retrieve patient records that aids in providing continuity of care (Akanbi et al., 2012). EHR systems can also be particularly useful in tightly controlled infectious disease settings in which the use of paper records can pose a risk of disease spread (Oza et al., 2017).

Further, the importance of adopting eHealth is emphasized when humankind is faced with life-threatening infectious disease outbreaks such as COVID-19, AIDS, or Ebola. For example, the urgent need to adopt EHRs and the ease of providing healthcare during the COVID-19 pandemic using EHRs was recently highlighted by the Pan American Health Organization (PAHO) (PAHO & WHO, 2020). PAHO pointed out that EHRs can allow easy and rapid access to organized sets of patient records that can aid in using telemedicine to monitor an infectious disease outbreak. Concurrently, PAHO recognized that EHRs can be used in population health and epidemiology to understand disease outbreak patterns to effectively enforce containment measures during an emergency.

At the beginning of the COVID-19 pandemic, lessons learned from previously using eHealth and telemedicine applications for infectious outbreaks such as SARS, MERS, and Ebola were also found to be helpful (Keshvardoost et al., 2020). As an example, the Ebola crisis in Africa from 2014-2016 when a mobile application called Ebola Contact Tracing was used for contact tracing of Ebola cases on a large scale was a similar situation

to the current pandemic (Keshvardoost et al., 2020). Further, the use of eHealth applications in Bangladesh during the COVID-19 pandemic, where eHealth and telehealth technology were adopted rapidly in physician offices and healthcare systems serves as another example of how eHealth can be beneficial during an infectious disease outbreak (Chowdhury et al., 2021).

Moreover, Community Health Workers (CHWs) that contribute to mHealth programs and strengthen national health systems by enabling healthcare access in hard-to-reach areas in LMICs, also experienced the effects of the COVID-19 pandemic (O'Donovan et al., 2020). The same paper highlighted how existing initiatives of CHWs relying on mHealth applications (e.g., SMS texting) can be adapted for contact tracing and recording COVID-19 cases in communities CHWs serve, and for disseminating accurate information regarding this novel virus. Hence, relying on eHealth technology especially at times of crises can have life-saving benefits.

2.3 Adoption of eHealth

In recent years, there have been steady adoption of eHealth interventions and strategies in LMICs (Kiberu et al., 2017; Omotosho et al., 2019). When implementing eHealth projects in LMICs, it is considered that accessible Internet connectivity, mobile network and infrastructure; national government support; and training support for professionals and workers act as enablers to succeed with project implementation (Kiberu et al., 2017; Noreña et al., 2020). Despite facilitators, there are barriers to implementing eHealth projects in LMICs, and this includes lack of adequate funding, expensive telecommunication services, poor government support and will, and poor infrastructure

(Kiberu et al., 2017; Noreña et al., 2020). Further, specifically for adopting EHR systems in resource poor settings, lack of appropriate infrastructure in relation to Internet connectivity, and the availability of reliable power act as key barriers (Allen et al., 2007; Chaplin et al., 2015; Manders et al., 2010; Oza et al., 2017).

Considering the role of paper in health systems in LMICs, a study focusing on an mHealth program used by CHWs, highlighted that using paper records can result in loss of data, and can be a time-intensive process with being an inefficient system to handle data (Neupane et al., 2014). However, a commonly observed practice in health interventions and systems is using a combination of electronic and paper records, including hybrid medical records (using different mediums to store patient information) (Chavis, 2011). Using a combination of EHR and paper records is a common practice especially in developing nations and in infectious disease outbreak settings (Allen et al., 2007; Chaplin et al., 2015; Manders et al., 2010; Oza et al., 2017).

Despite the inefficiencies associated with paper-based systems, hybrid records can be viewed as an inevitable situation due to lack of interoperability of existing eHealth systems and because not all relevant documents (e.g. laboratory reports) have been integrated into the electronic record system (Chavis, 2011). However, a major drawback of using both paper and electronic records in healthcare settings is the duplication of work effort when maintaining both types of records. A study reviewing EHR adoption in Saudi Arabia, a developing country, shows that the challenge of duplication of work efforts can be directly due to the fragmentation of national and local healthcare systems, lack of interoperability in implemented electronic records systems (EHR, EMR), and lack of

nationwide adoption of technological standards for EHR/EMR systems (Al-Aswad et al., 2013).

The transition from paper to electronic records is challenged by various factors based on the implementation scale and setting. For example, in resource-limited settings, infrastructural challenges are the main concern; however in more developed nations that have adopted EHR systems on a large scale, the main concern is ensuring interoperability among adopted EHR systems to increase the efficiency of data sharing among various hospitals or clinics (Aldosari, 2014). It is important to note that the adoption of eHealth and EHR systems and transition to national scale is a time-consuming and expensive process that requires both short-term achievable goals/resources and long-term stable plans/policy guidelines, which is often lacking due to mixed public-private healthcare systems in most nations worldwide.

2.4 After eHealth project implementations

There are many examples of implementations of eHealth systems in the developing world at the pilot-level or isolated small-scale levels (Luna et al., 2014). However, nationwide level or large-scale implementations of sustainable eHealth programs are limited due to several challenges. Some of the challenges are lack of appropriate and reliable infrastructure (including variations in available electricity and Internet communications), insufficient financial resources to support long-term programs, lack of interoperability standards, and lack of appropriate legal and ethical frameworks to address privacy issues and ethics surrounding implementations of digital technologies (Luna et al., 2014).

The sustainability of implementations after pilot projects is a growing concern with eHealth implementations. The term ‘pilotitis’ is used to describe how eHealth implementations cannot transition to scale from the pilot stage especially in LMICs (Fanta & Pretorius, 2018). More specifically, pilotitis can also refer to how successful results are exemplified in small-scale interventions but cannot be replicated in large-scale interventions due to concerns such as interoperability, long-term sustainability, economic concerns, and political barriers (Fanta & Pretorius, 2018; Huang et al., 2017).

Moreover, Fanta & Pretorius (2018) note that the success of eHealth implementations is based on the sustainability of technology, end-users willing to accept the technology, and considering the expectations of stakeholders. According to the theory of sustainable eHealth, eHealth programs should consider the economic (i.e., financial resources), social (i.e., society or individuals relevant to the project) and environmental (i.e., organization or institution where the program is implemented) implications of the project and the non-linear relationships between these three factors (Fanta & Pretorius, 2018). With such concerns it should be acknowledged that prior to implementing DH technologies, the needs and perceptions of stakeholders should be factored into the design, and the interoperability of DH systems should also be considered (Huang et al., 2017).

Furthermore, to avoid a case of pilotitis, beginning from the planning stages to the scale-up stage, eHealth project developers and implementors should consider interoperability of the technology, partnerships between stakeholders, the trust and acceptance of end-users, and whether project goals align with participant needs (Shuvo et al., 2015). Kiberu et al. (2017) describe how even though there are many eHealth

implementations in Uganda, these systems work independently, and most of them lack sustainability – hence they strongly encourage the need to plan and create strategies for implementation and conduct need readiness assessments prior to implementing eHealth projects. Furthermore, Omotosho et al. (2019) emphasize that to avoid sustainability issues after implementation of eHealth programs, several factors (such as availability of funding, existing infrastructure, availability of eHealth personnel, and national health policies) should be considered prior to implementation. Avoiding pilotitis and ensuring an eHealth program is sustainable with capacity to transition to scale can be more beneficial than only implementing at a small scale and realizing later that the project is not fit to scale-up, or it has to be abandoned due to the termination of funding.

2.5 Attempts at transition to scale

As aforementioned, scaling-up of eHealth projects is a significant challenge in LMICs. However, despite barriers to scaling-up resulting in countless pilots, few projects have attempted or achieved successful scale-up in LMICs (Shuvo et al., 2015). It is recognized that there is a need to transition to scale for eHealth projects because the benefits of these innovations can only be reaped significantly when they are regularly and widely used (Wilson et al., 2014). However, when there is no shared goal (such as achieving institutionalization), fragmentation of health systems can occur, which can and has resulted in a plethora of small-scale eHealth implementations that cannot contribute to the achievement of the broader impact of eHealth programs (Wilson et al., 2014).

Despite the few projects that scale-up, literature identifies enablers for successfully scaling-up LMIC eHealth projects. One such study identified five key factors for

succeeding scale-up, which are: needs of end-users should be met and their input should be considered; stakeholder engagement during all stages of the process should occur; the project should be interoperable and flexible; the project should align with existing policy and long-term sustainable funding should be made available; and existing infrastructure and other extrinsic support should be considered (Labrique et al., 2018). Moreover, Wilson et al. (2014) emphasize the importance of creating realistic long-term funding plans for eHealth implementations and ensuring long-term commitment to achieving results from these programs. Even though enabling factors are described in the literature, it is important to note that in many LMICs there is no adequate public funding for project scale-up, or there could be heavy dependence on donor-funding without institutionalization or integration with national healthcare systems (Hampshire et al., 2021; Labrique et al., 2018).

In recent years, there have been few successfully scaled-up eHealth projects in LMICs. These projects help in identifying key barriers and facilitators to scaling-up and sustaining LMIC eHealth projects. One such example is the mTrac eHealth system in Uganda that collect and analyse health information at community and health facility levels (Fanta & Pretorius, 2018). In this project a key success factor for scale-up is considered to be how the system was designed to be interoperable with the other electronic (e.g., DHIS2) and paper systems in Uganda (Fanta & Pretorius, 2018). As there are examples of successful LMIC eHealth projects, it is possible to derive lessons and improve existing and future eHealth projects. With perseverance, eHealth programs can contribute significantly to providing equitable healthcare for all populations, and this could begin to happen more frequently in the near future.

Similar to the successful scale-up of the mTrac eHealth project mentioned above, cStock eHealth application in Malawi is recognized as a successful scale-up in an LMIC (Dimagi Inc, n.d.). cStock is considered as an eHealth tool as it is a SMS-based mobile technology that is used by Health Surveillance Assistants (HSAs) for stock management. Further, cStock is recognized for its long-term sustainability as a Supply Chain Management (SCM) tool since it is being used by more than 3900 HSAs to save the lives of children under five in Malawi (Dimagi Inc, n.d.). In a broader perspective, cStock is viewed as a SCM tool that supports health system strengthening in Malawi. The cStock electronic system is based on the CommCare data collection platform product developed by Dimagi, Inc. which is used in more than 80 countries across the world as a rapidly adoptable digital innovation, especially in LMICs. Hence, the cStock project was selected for further study for this thesis as it is a rare example in sub-Saharan Africa of a successful eHealth program that has achieved national scale-up across Malawi. It is my view that analysing the cStock project in detail for this exploratory study will help identify core lessons to help existing and future large-scale eHealth projects in low-resource settings. Hence, in the next section, I provide the context of health in Malawi and an overview of its cStock project to facilitate the in-depth study of the project in later Chapters.

2.6 Case study

2.6.1 Malawi context

eHealth implementations in sub-Saharan Africa are increasing at a rapid pace to strengthen health systems (Njoroge et al., 2017). Malawi is a developing country in

Southeast Africa with a 20.8 million population in 2021(International Monetary Fund, 2021a). Health disparities are common in Malawi and 84% of the population live in rural areas (Makwero, 2018). Also, Malawi is one of the poorest countries in sub-Saharan Africa. The International Monetary Fund (IMF) reported that in 2020 the annual real GDP growth of Malawi was 0.6% and in 2019 it was 4.5% (International Monetary Fund, 2021b). The World Bank defines the poverty gap at $3.20 a day as "the mean shortfall in income or consumption from the poverty line $3.20 a day (counting the nonpoor as having zero shortfall)", and reported the poverty gap at $3.20 a day as a percentage was 50.1% in Malawi population in 2016 (most recent data available), which compares with the significantly lower poverty gap of 32.3% for sub-Saharan Africa as a whole in 2016 (The World Bank, 2021). The specific healthcare challenges in Malawi include access to timely and quality healthcare, child malnutrition, high rates of maternal mortality, and high prevalence of HIV/AIDS (Malanga & Chigona, 2018).

Mobile telephone ownership in Malawi is relatively low when compared to other countries in sub-Saharan Africa, at a 45% mobile penetration rate (Malanga & Chigona, 2018). However, mHealth initiatives and implementations are beginning to grow rapidly in Malawi. Malanga & Chigona (2018) identified 14 mHealth implementations in Malawi since 2010 and Hampshire et al. (2021) states that there are 30 active mHealth programs at different implementation scales in Malawi. For most mHealth programs the target population of users are CHWs (Community Health Workers, also called Health Surveillance Assistants in Malawi) and the areas of focus have been Maternal, Neonatal and Child Health (Malanga & Chigona, 2018). Also, since 2014 there have been national

eHealth/mHealth implementation strategies in place in Malawi, including eHealth implementations such as the Antiretroviral Therapy EMR (ART EMR) system by the Malawi Ministry of Health and BaoBab Health Trust (Hampshire et al., 2021; Landis-Lewis et al., 2015). The ART EMR achieved successful scale-up by implementing the system in 66 facilities (facilities with more than 2000 patients for HIV treatment) across Malawi in 2015 (Landis-Lewis et al., 2015). Few scale-ups of eHealth projects have occurred in Malawi, and Hampshire et al. (2021) state that problems with sustainability and transitions to scale are a common occurrence.

2.6.2 Case Study Description

There is a diverse range of eHealth applications that are being adopted in LMICs and which aim to address different areas of health. Applications can include tools used for case management, stock management, communicating with clients via texts, and data collection tools, especially in areas of maternal, reproductive and child health (Hampshire et al., 2021; Wallis et al., 2017). There are also many examples of mHealth implementations including 'MomConnect' (text based tool), 'Diabetes phone' project (mHealth tool to monitor and record blood sugar levels of patients), and using apps such as 'WhatsApp' for clinical communication in LMICs (Wallis et al., 2017). Further, there are eHealth systems that can and has been implemented at larger scales (national, global) such as the widely adopted District Health Information Software 2 (DHIS2) in LMICs, which aids data collection, reporting and dissemination (Noreña et al., 2020).

After substantive review of the literature on successful eHealth projects in sub-Saharan Africa, I determined that studying CommCare-based eHealth applications might provide valuable insight into successful eHealth project implementations and scale-ups in LMICs, especially considering the community impact and global recognition of CommCare by Dimagi, Inc. in over 80 countries (Dimagi, 2021). It was determined that analysing the CommCare-based cStock system in Malawi through this exploratory study might help determine facilitators and barriers experienced by implementors and system-users while achieving a successful nationwide level eHealth project. Further, the U.N. SDG target 3.2 directly aims to end "preventable deaths of newborns and children under 5 years of age" by 2030 (UNSDG, 2015). Hence, it was recognized that the important focus on improving child health via cStock in Malawi will help determine generalizable lessons that will help other eHealth projects focused especially on the common issue of high mortality and morbidity of children under five in LMICs.

CommCare

CommCare is a mobile data collection platform that can be modified to suit specific needs such as EHRs for clinical trials (Dimagi, 2016; Wacksman & Sampat, 2018). CommCare was developed by Dimagi Inc. and is targeted for frontline workers in resource limited communities to aid with tracking clients, facilities and any other measures during a time period (Wacksman & Sampat, 2018). CommCare also acts as a software tool to implement mobile applications in resource limited settings. It has two components. CommCare Mobile is the component that is used for data collection through a mobile application and is used in the field by CHWs, Field Workers, etc. (Wacksman & Sampat,

2018). The CommCare HQ is a website that supports data management, data monitoring and managing mobile workers, and is used by project managers, supervisors, data analysts, etc. (Wacksman & Sampat, 2018). CommCare can be used as a mobile application on Android smartphones or on basic phones like Nokia. CommCare has many benefits including data collection to digitize information, decision support to guide users to ask suitable questions and provide advice, and aids for worker supervision.

There have been several implementations of CommCare health applications in LMICs. These include several large-scale, successfully scaled-up projects, including the cStock project in Malawi. Other examples include the Integrated e-Diagnostic Approach (IeDA) project in Burkina Faso that is a nationwide scale-up to improve the diagnosis of ill children using the Integrated Management of Childhood Illnesses; a digital health program in Guatemala introduced by TulaSalud which focuses on maternal, newborn and child health benefiting nearly 3.4 million individuals; and the Reducing Maternal and Newborn Deaths (ReMiND) project in India focused on delivering pre- and post-natal care at community level and uses a mHealth application that is being used by more than 300,000 CHWs (Dimagi, n.d.; Terre des Hommes, 2019; TulaHealth, 2021). Through afore-mentioned scaled-up projects that are similar to the cStock Malawi case study, the significant community health impact of CommCare is evident.

Malawi Case Study

The ability to have timely access to medicines for patients, especially in hard-to-reach areas, is related to having efficient medicine supply chains (Pisa & McCurdy, 2019).

In the context of LMICs, many essential medicines supply chains may not be efficiently functioning which leads to unavailability of medicines (i.e., stockouts) when treatments are needed the most (Pisa & McCurdy, 2019). Relying on paper-based supply chains is perceived to be ineffective due to the inability to maintain rapid communication, and it being a time-intensive process (Minior et al., 2017; Pisa & McCurdy, 2019). Hence, using digital technology for supply chain management is perceived to be a solution to this global health challenge of inefficient supply chains in LMICs (Pisa & McCurdy, 2019).

The Malawi case study focuses on providing healthcare and treatment for children under five in a timely manner, removing the burden of travel needed to reach health facilities, and strengthening disease prevention systems in a low-resource setting by adopting an eHealth tool for Supply Chain Management (SCM) (Dimagi Inc, n.d.). In Malawi, the CHWs are known as Health Surveillance Assistants (HSAs). The HSAs treat children under five with medicines (antimalarials, antibiotics, etc.) in areas where health facilities are hard to reach due to distance from healthcare facilities. In order to track supplies and quantities of medicines used by HSAs, prior to cStock, a paper-based supply chain system was used (Dimagi Inc, n.d.). However, lack of data visibility resulted in frequent stockouts of medicines and delays in reporting by HSAs, which negatively impacted the health of children under five in the region (Dimagi Inc, n.d.). CommCare-based cStock was seen as the solution to this issue through its SCM system for efficiently tracking the availability of medicine stocks by improving data visibility and reducing reporting time by HSAs (Dimagi Inc, n.d.).

cStock is an eHealth (more specifically an mHealth tool) application that calculates the medicine and product supply needs of individual HSAs. *Figure 1* provides an overview of the Malawi cStock system and shows how it is used by multiple users in the supply chain. Using a basic phone, HSAs text (SMS) the stocks of medicines they have on hand to the cStock system (JSI Research & Training Institute, n.d.-b). cStock system then automatically calculates supply quantities for Health Centers (resupply points) that pre-pack medicine orders, and informs HSAs when their order is ready via text (SMS) (Dimagi Inc, n.d.; JSI Research & Training Institute, n.d.-b). This process contributes to the efficiency of resupplying medicines to HSAs as it saves time and avoids unnecessary trips to the re-supply point (Dimagi Inc, n.d.). Further, cStock allows higher-level staff to receive notifications if re-supply points cannot fulfill orders, or if an HSA continues to have low stock levels despite being resupplied (Dimagi Inc, n.d.). The web-based component of the cStock electronic system enables real-time problem identification and monitoring of supply chain performance, hence improving visibility of the medicine supply chain (Dimagi Inc, n.d.). District and Central level Ministry of Health and Population (MoHP) administration can access data from this system's web-based dashboard.

The cStock Malawi project began as part of the Supply Chains 4 Community Case Management (SC4CCM), implemented by John Snow Inc (JSI) Research & Training Institute, Inc. (JSI Research & Training Institute, n.d.-a). The SC4CCM project was carried out in three sub-Saharan African countries namely, Malawi, Ethiopia, and Rwanda, from 2009 to 2015 in order to improve the efficiency of supply chains associated with child health and solve the challenges faced by CHWs in the three nations. JSI worked closely

with the governments of the three countries and implemented the SC4CCM project based on the government (MoH) Integrated Community Case Management (ICCM) programs unique to the three nations. cStock eHealth application was only implemented in Malawi as there was a recognized need to improve data visibility of the medicine supply chain at the time. In Rwanda, the SC4CCM project implemented strategies and procedures such as standard resupply procedures, supply chain indicator, and quality improvement teams to improve the existing supply chain used by CHWs (SC4CCM Project Team, 2014b). In Ethiopia, an existing initiative called the Integrated Pharmaceutical Logistics System (IPLS) was introduced to health posts to be used for SCM (SC4CCM Project Team, 2014a). Among the three nations, in this thesis I focused on the cStock project in Malawi as it involved the development, implementation, and then scale-up of a novel eHealth application in an LMIC context.

The success of the cStock project was achieved by multiple implementation partners. In the project implementation phase carried out by JSI during the period of 2009 to 2014, JSI subcontracted Dimagi, Inc. to develop the cStock software (JSI Research & Training Institue Inc. & Ministry of Health, 2012). During the 2009 to 2014 period, the SC4CCM project was funded by the Bill & Melinda Gates Foundation, and the project was implemented by JSI Research & Training Institute, Inc. (JSI Research & Training Institue Inc. & Ministry of Health, 2014). The SC4CCM project ended in November 2014. This resulted in handing over the Malawi cStock project to the Malawi MoHP in order to ensure that the project would be able to continue (Dimagi Inc, n.d.). Even though the project was handed over to the Malawi MoHP in 2014, the implementation and scale-up of the cStock

project continued (Dimagi Inc, n.d.). Currently the project is maintained through the leadership of the Malawi MoHP, funded by the Global Fund, and managed by World Vision Malawi (Dimagi Inc, n.d.).

The Malawi case study portrays ICCM using community-level data collection via an electronic application. In 2014, over 3900 HSAs were using the app from across Malawi (Dimagi Inc, n.d.). HSA reporting rates have increased above 80% for all districts with the implementation of cStock and can be compared to the low rate of 43% prior to the project (Dimagi Inc, n.d.). The positive impact of a mobile application for ICCM is evident as 99% of HSAs reported that cStock was efficient and helped to reduce the time required for managing supply stocks (Dimagi Inc, n.d.). The Malawi case study is an example of a successful nationwide implementation of an eHealth application in the context of ICCM.

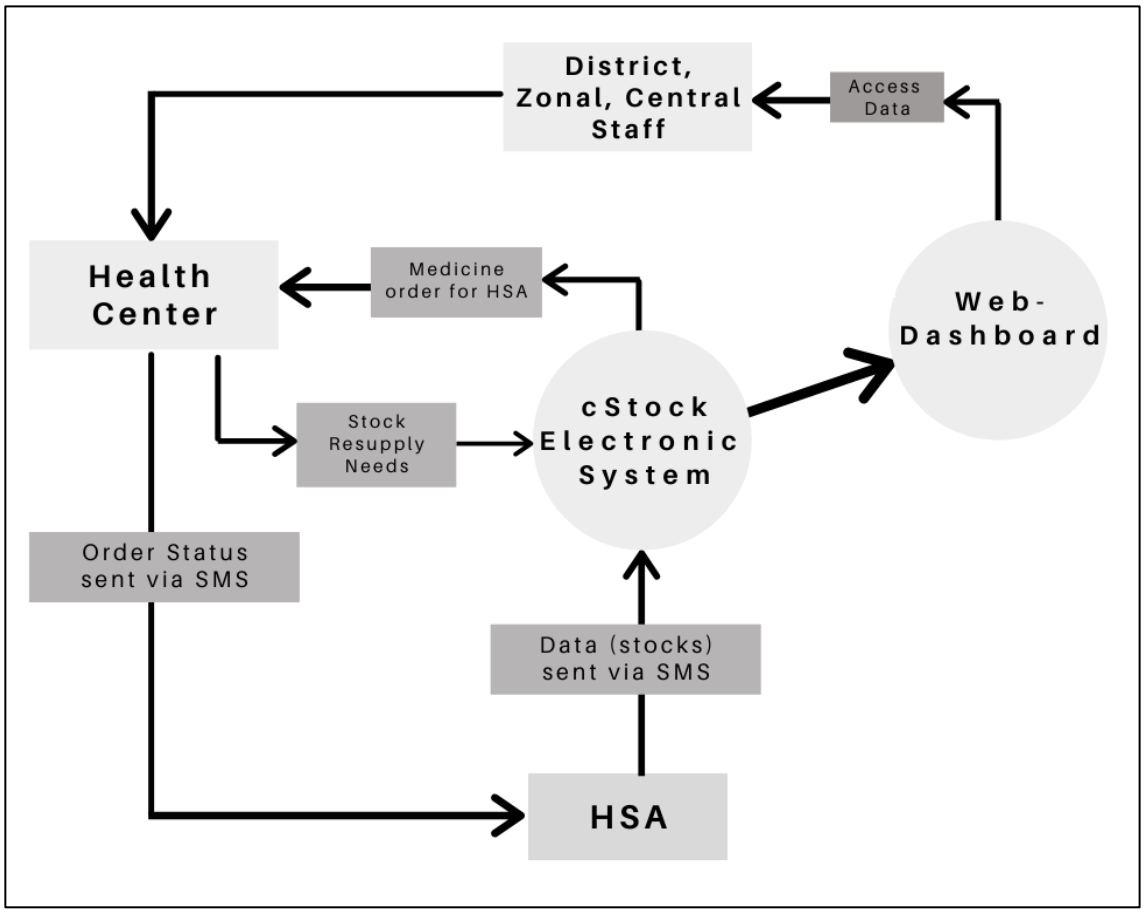

Figure 1. *Overview of the cStock system*

*This diagram is based on an original diagram published by the JSI - SC4CCM project (JSI Research & Training Institute, n.d.-b).

CHAPTER 03 – Literature Review

In Chapter Two, I discussed various aspects related to the adoption, implementation and use of eHealth projects, and provided a contextual background to complement the literature review and the overall thesis. The purpose of this Chapter is to provide the literature review that was conducted as part of the study design. The literature review serves two purposes. First, it aids in understanding existing research and literature surrounding eHealth implementations in LMICs and second, it helps to identify the specific questions addressed in the literature on digital health project implementation and scale-up in the global South that shaped the data collection and analysis in the Malawi case study. In this Chapter, I will first present the methodology of the literature review (3.1). Then, in sub-section (3.2), the search results will be presented with reference to the three questions of the literature review. The first question (3.2.1) presents facilitators and barriers to eHealth project implementations in LMICs, broken down into three categories: eHealth (A), mHealth (B), and EHR/EMR (C) projects. The second question (3.2.2) addresses the barriers to transition to scale for eHealth projects in LMICs. The third question (3.2.3) presents findings on global and regional partnerships in eHealth projects in LMICs.

3.1 Methodology

This literature review was conducted to examine the literature on eHealth project implementations and scale-ups in LMICs. Hence, the questions formulated to guide the literature review are distinct from the research questions of the thesis (Research

Question(s)) which are tailored to the specific cStock Malawi eHealth project. The three questions formed to direct the scope of the literature review are:

1. *What are some common factors affecting (positively and negatively), the implementation of eHealth applications in developing countries?*
2. *What are the perceived barriers to nationwide implementation of eHealth applications in developing countries?*
3. *What is the role of partnerships (regional and global) in eHealth adoption and scale-up in developing countries?*

It was determined that Web of Science, PubMed, and Google Scholar databases should be used for this literature review based on the relatedness of the topic of eHealth to global health, and social and medical research. A grey literature search was used for the third guiding question and databases such as World Health Organization library, The World Bank library, and United Nations Digital library were also searched. Hand searching was used to manually identify any relevant research articles for all three guiding questions. In general, the inclusion criteria of this literature review included literature accessible in the English language; literature focused on eHealth applications (mainly eHealth, mHealth, EHR/EMR, telemedicine); and literature of any publication date.

The search strategy began with an initial keyword search using the Medical Subject Heading (MeSH) thesaurus and database. The search terms used include eHealth, digital health, mHealth, OpenMRS, OpenEMR, EHR, medical record, developing countries, global South, global North, LMIC, resource poor settings, implementation, scale up, nationwide, global connection, and partnership. Initially, I conducted a keyword search

using the Web of Science and PubMed databases. This was followed by a general search using the Google Scholar database. I reviewed all initial search results using the titles from the Web of Science and PubMed databases. For the Google Scholar database results, only the first 50 results from each search were used to review titles. After reviewing the titles of 444 papers, duplications were removed, and 37 papers were selected for abstract review based on the inclusion criteria. Following the abstract review, the literature pool was narrowed, and 22 papers was selected for full review. When conducting full reviews, I tabulated all relevant data from each paper based on the study authors, topic, and case study country. Then, in the data extraction phase, necessary themes, challenges, facilitators, and other relevant information were recorded for each paper. Lastly, I compared the collected information to identify similarities, differences, and other connections in the literature.

3.2 Search Results

The following *Figure (2)* outlines the search results based on the search strategy steps outlined above for each guiding question.

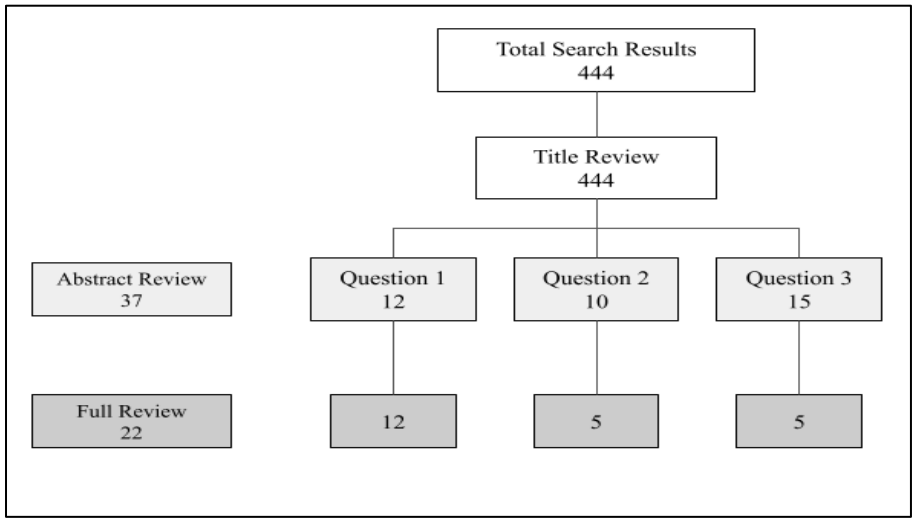

Figure 2. *Summary of literature review search results*

In the following section, I present the search results for the three guiding questions in detail. The first question addresses factors affecting eHealth implementation and adoption in LMICs. In this section, the studies were categorized into studies focused on eHealth, mHealth, and electronic health records (EHR)/ electronic medical records (EMR) (*Tables 3 – Appendix A and Table 4 – Appendix B*). The second question presents factors affecting the scale-up of eHealth projects in LMICs (*Table 5 – Appendix C*). The third question addresses global and regional partnerships in LMIC eHealth projects.

3.2.1 - Question 1: Facilitators and barriers to the implementation of eHealth applications in LMICs

The search results for Question 01 will be presented based on the eHealth project type: (A) eHealth, (B) mHealth, and (C) EHR/EMR project implementations.

(A) - eHealth project implementation

Four studies were categorized as studies focusing on the barriers and facilitators of eHealth implementations in resource-poor settings. Granja et al. (2018) describe a systematic review focused on barriers and facilitators to eHealth project implementations. Kiberu et al. (2017) present a literature review focused on the implementation challenges and facilitators for eHealth programs in Uganda. Muinga et al. (2020) describe a mixed-methods study, conducted using a survey and interviews to gather evidence on adoption of DH systems in public hospitals in Kenya. Alshahrani et al. (2019) present a systematic

review studying acceptance, implementation, and use of eHealth applications in Saudi Arabia.

There are five major barriers identified in the reviewed literature which hinder the implementation of eHealth in LMICs. The first of the major barriers identified in the literature is infrastructural barriers (Alshahrani et al., 2019; Kiberu et al., 2017; Muinga et al., 2020). Kiberu et al. (2017) provide examples such as frequent power outages and Internet issues and Muinga et al. (2020) describe limited availability of hardware (computers, computer peripherals, damaged network equipment), theft of equipment, and unreliable power as infrastructural limitations.

The second major challenge is financial constraints when implementing eHealth projects in resource-poor settings (Alshahrani et al., 2019; Granja et al., 2018; Kiberu et al., 2017; Muinga et al., 2020). The study by Granja et al. (2018) identified financial cost as the primary barrier contributing to the failure of eHealth project implementations. This study also explains how important it is to secure adequate funding, since the availability of funding drives the organizational changes which are necessary to implement eHealth projects. Interestingly, Alshahrani et al. (2019) describe two contrasting viewpoints on the prioritization of funding by eHealth implementers. The first viewpoint identifies financial limitations as the single most important factor in determining the success of a project; and the second viewpoint prioritizes lack of technical knowledge and training over financial barriers (Alshahrani et al., 2019). Furthermore, the impact of underfunded health systems can be seen from severe physician shortages such as the assignment of only eight physicians per 100, 000 people in Uganda (Kiberu et al., 2017). Moreover, the uptake of eHealth in

sub-Saharan African countries is impacted by the high burden of disease, rapidly growing population, combination of low median age and poverty resulting in low tax bases (Kiberu et al., 2017). It is important to note that low tax bases essentially reduce publicly available funds to contribute to the national budget and in turn the health sector (Mars, 2013). Without public financing and the prioritization of eHealth on national agendas by governments, it is difficult to implement and sustain eHealth projects in LMICs, especially with their generally poor existing infrastructure (Mars, 2013).

The third barrier is focused on workflow challenges experienced by healthcare users of eHealth systems. Granja et al. (2018) point out that this includes challenges such as the increased work necessary after the eHealth intervention; the lack of alignment between eHealth tools and clinical processes; and staff turnover when eHealth tools are only available in one or a few departments and the rotation of healthcare workers requires frequent training and learning. Limitations in computer literacy among eHealth users and the usually limited number of ICT personnel can also affect workflows (Kiberu et al., 2017). Further, Muinga et al. (2020) identified the challenge of having poorly documented medical information because healthcare workers find that work schedules are a challenge.

The fourth major challenge relates to the sociocultural context when implementing eHealth projects. These considerations include the political climate of project implementation, civil unrest, and government will which play a key role in whether eHealth initiatives can be implemented successfully (Kiberu et al., 2017). Further, lack of confidence in new technologies, resistance to new services, and limited willingness to use

technology can also negatively impact eHealth implementations (Alshahrani et al., 2019; Muinga et al., 2020).

The fifth barrier to eHealth implementations is related to broader level challenges. This includes: lack of policy surrounding eHealth implementations, lack of implementation frameworks, lack of policy or regulatory guidelines for protecting privacy and security of health information, and interoperability issues associated with eHealth initiatives (Kiberu et al., 2017; Muinga et al., 2020).

There are four major facilitators and positive factors influencing the adoption of eHealth projects in LMICs that were identified in the reviewed literature. Firstly, positive motivations for eHealth projects such as utilization of eHealth technology for the betterment of healthcare for patients is seen as a main facilitator (Granja et al., 2018). Secondly, there are several infrastructural facilitators for eHealth project implementations, including improved Internet bandwidth and increased Internet penetration over communities (Kiberu et al., 2017). Thirdly, the capacity to secure sufficient funds to cover costs of the project also acts as a major facilitator (Alshahrani et al., 2019). Lastly, there are facilitators related to technology such as the ready availability of diverse systems for DH technology; easier system acquisition if healthcare workers have prior experience with using DH systems; and the recognized need to manage clinical data that becomes feasible with eHealth systems (Muinga et al., 2020).

(B) mHealth project implementation

There are also factors affecting the implementation of mobile health (mHealth) projects. Three studies specific to mHealth adoption were included in my review. The study

authored by Bakibinga et al. (2020) assesses the experience of Community Health Volunteers, health workers and others involved in management of a mHealth application implemented in Nairobi, Kenya. The study by Källander et al. (2013) is a review of mHealth implementations in LMICs and details the experiences and practices of these initiatives. The systematic review by Aranda-Jan et al. (2014) describe recorded experiences of mHealth initiatives in Africa including strengths, weaknesses, opportunities and threats related to mHealth projects. There are four main categories of barriers to adoption, implementation, and use of mHealth projects.

Firstly, there are infrastructural and financial barriers to adopting and deploying mHealth projects in resource poor settings. Bakibinga et al. (2020) mention there is unreliable power and lack of basic electric fixtures in Kenya. Several other infrastructural and financial problems such as the need for phone maintenance and charging, inadequate funding to support complex telemedicine in emergency situations in LMICs, and limited network capacity is described by Källander et al. (2013). Further, Aranda-Jan et al. (2014) describe the common issues of inadequate funding and infrastructural issues such as unreliable power, Internet and network. Simultaneously, Aranda-Jan et al. (2014) describe system problems specific to mHealth initiatives and this includes challenges when monitoring content of texts, under-reporting of data, and the potential of receiving biased responses from participants (e.g. participants may be reluctant to convey sensitive information over the phone).

Secondly, it is important to consider various barriers related to health workers. Bakibinga et al. (2020) describe challenges such as how health professionals have

inadequate ICT knowledge and skills which in turn contributes to poor attitudes and behaviours towards mHealth technology. The study by Källander et al. (2013) describe challenges such as health worker resistance to new technology and recommend using monetary incentives, discussing benefits of mHealth, and providing sufficient training to health workers. Further, Aranda-Jan et al. (2014) also describe similar challenges among health workers such as high workloads for health workers, staff shortages, and limited technical knowledge on maintaining mHealth platforms.

Thirdly, there are sociocultural, behavioural, and political challenges related to mHealth implementation and adoption in resource-limited settings. The study by Bakibinga et al. (2020) describe the unique experience of the mHealth app implementation being affected by a presidential election which occurred in the year of implementation. Bakibinga et al. (2020) also indicated that a health worker strike and the presidential election negatively impacted the use of the mHealth app because of the sudden shortage in staff which in turn resulted in increased workloads. Further, another study suggest that even though CHWs benefit from using mHealth technology, they are gradually shifting the perceived image of CHWs from normal human nature to "data collection robots" (Källander et al., 2013, para 24). This highlights the disconnection community members feel towards CHWs' use of mHealth apps.

The fourth category of challenges relate to the health system, policy, and government. Bakibinga et al. (2020) indicate that there is only weak support from the government to strengthen health systems, even though on paper and documents it is stated there is adequate governmental support. Further, Bakibinga et al. (2020) identify lack of

County Governments' commitment as a barrier to implementing mHealth projects in Kenya. The problem with collaborating with national governments is further explained by Källander et al. (2013) as frequently government priorities and aims of application developers working on site do not align well. This in turn connects with how difficult it is to maintain ongoing collaboration among all stakeholders including health ministers, officials, mobile service providers, doctors, technologists and financers (Källander et al., 2013).

Aranda-Jan et al. (2014) also mention that it is imperative to have clearly defined roles and responsibilities and the participation of government to successfully implement a mHealth program. Moreover, Källander et al. (2013) describe how lack of eHealth and mHealth policies affect sustainability of nationwide mHealth programs because they rely on the national health care system. They also mention that lack of policy is connected to limited knowledge available on "what works, how it works, and how much it costs" regarding mHealth and eHealth initiatives (Källander et al., 2013, para 39). The lack of policy guidelines and financial support from national governments appears to be a common challenge in resource-poor settings, as described by Aranda-Jan et al. (2014).

Despite numerous challenges associated with mHealth implementations, there are facilitators or positive factors affecting the adoption of mHealth in LMICs. This section presents three categories of facilitators. Firstly, both Källander et al. (2013) and Aranda-Jan et al. (2014) consider having sufficient funding, and low-cost mHealth technology to be facilitators that promote the success of a mHealth initiative. The second category consists of facilitators related to sociocultural, and behavioural considerations when

implementing mHealth systems. Both Bakibinga et al. (2020) and Aranda-Jan et al. (2014) point out that familiarity of mobile phones or previous experience with DH technology acts as a main facilitator for adopting and accepting mHealth initiatives. Moreover, Källander et al. (2013) say that it is important for a successful progression of a project to consider the social and cultural context of the local project region to develop strategies that can mitigate and overcome language and literacy barriers.

The third category consists of facilitators related to health systems, policies, government, and partnerships. Bakibinga et al. (2020) highlight that creating eHealth policies can aid with promoting opportunities for ICT in the health sector. Also, Aranda-Jan et al. (2014) specifically identified a strong facilitator in government support offered via mHealth/eHealth strategies and the interest and willingness of the government to integrate mHealth projects. It would be then feasible to develop such mHealth/eHealth strategies if true partnerships between users and policymakers occurred throughout all phases of a mHealth project (i.e. planning, design, and implementation) (Källander et al., 2013). Further, considering the particular aspect of collaboration, Aranda-Jan et al. (2014) emphasize that projects implemented by public-private partnerships (e.g. involvement of local private service providers) tend to be more successful. Further, Källander et al. (2013) also mentioned the importance of cooperating with local communities, and the presence of regional and national health information systems to ensure success of an mHealth project.

(C) EHR/EMR project implementations

In this section, five studies are included which specifically focuses on EHR/EMR implementations in resource-poor settings. Studies by Oza et al. (2017), Allen et al. (2007),

Manders et al., (2010) and Muinga et al. (2018) describe the implementation of various open source EMR/EHR systems in Sierra Leone, Rwanda, Mozambique, and Kenya respectively. Also, a study by Chaplin et al. (2015) describe the development and implementation of an 'Electronic Medical Records System' (EMRS) for a large scale HIV/AIDS clinic in Nigeria.

There are four categories of barriers identified as influencing the implementation of EHR/EMRs in LMICs. This includes infrastructural, workflow, sociocultural and behavioural, and management and evaluation challenges. Firstly, the adoption of EHRs in resource poor settings is mainly challenged by lack of appropriate infrastructure in relation to Internet connectivity and reliable power (Allen et al., 2007; Chaplin et al., 2015; Manders et al., 2010; Muinga et al., 2018; Oza et al., 2017). The study by Oza et al. (2017) identify malfunctioning of equipment, delays in fixing bugs, and long delays in acquiring necessary hardware that act as infrastructural barriers to implementation. Another infrastructural challenge identified by Manders et al., (2010) is the limitations in the availability of physical space to accommodate the servers used with EHR systems.

The second category of challenges is related to the workflows of EHR/EMR system users. The study by Oza et al. (2017) recognize workflow challenges directly related to the implementation of EHR systems in health emergency settings. The same study points out that due to the dynamic nature of an emergency setting, there is an added complexity of frequent changes in clinical protocols, workflows, and staff shortage and turnover. This in turn affected the adoption of an EHR/EMR system. Further, this essentially contributes to

the problems that arise when the EHR system does not fully integrate with the clinical workflow (Oza et al., 2017).

Thirdly, the category of sociocultural, behavioural, and human challenges was also explored by several of the studies. The study by Muinga et al. (2018) describe how users of the system felt that the EHR system belonged to outsiders. This portrayed an exclusive image which in turn affected the user acceptance. To avoid depicting EHR systems as exclusive, Muinga et al. (2018) recommend creating a more inclusive design for the EHR system. The study by Chaplin et al. (2015) found that lack of alignment between end-users' and donors' priorities fueled a reluctance to adopt the EMR system after implementation. This conflict arose as donors were interested in collecting clinical data while the end users prioritized using the system for patient-management purposes (Chaplin et al., 2015).

Lastly, challenges related to project management and evaluations was recognized as a barrier for EHR/ EMR project implementations in the reviewed literature. Muinga et al. (2018) describe how poor support from country management, use of external developers, and incorporating a wide project scope acted as additional barriers to the implementation of an EHR system in Kenya. Further, the studies authored by Oza et al. (2017) and Manders et al., (2010) describe how limited availability of "true evaluations", and usage and performance data constraints limit the ability to improve new and existing EHR/EMR project implementations in resource-poor settings (Manders et al., 2010, p. 413). Oza et al. (2017) suggest that this limited availability of evaluation data could be a result of challenges in conducting reliable research projects on site. Further, Manders et al., (2010) mention that it is difficult to understand the independent impact of an EHR/EMR system

as this kind of technology is interconnected with the national or local (e.g. hospital facilities) network grid.

In the literature, there are two positive factors and facilitators influencing the adoption of EHR/EMR systems in resource-limited settings. Firstly, a key positive factor is communication and collaboration among various stakeholders involved in the project. As an example, Allen et al. (2007) explain that collaboration among stakeholders (Partners In Health, Regenstrief Institute, and South African Medical Research Council) has helped in increased accessibility of resources to develop the EHR software (OpenMRS). Also, Manders et al., (2010) pointed out that forming partnerships between the Ministry of Health (national level) and Academics can contribute to conducting more research and inventing solutions. Further, Muinga et al. (2018) described how collaborating and communicating with local stakeholders, improving local software development, and promoting end-user system ownership can help implement an EHR/EMR system successfully. Oza et al. (2017) also mentioned that improved communication between platform developers and project implementers can influence the implementation process in a positive manner.

Secondly, the training provided for end-users is another key positive factor identified in the literature. Oza et al. (2017) describe that consistent and frequent training is necessary for success. Also, it is important to introduce a new technology for smaller groups of users and implement it slowly, starting with an experienced team member on site for a successful project implementation. There are many other facilitators to EHR/EMR project implementations. The study by Chaplin et al. (2015) explain how their EMR system did not require a constant Internet connection, did not require advanced training, and did

not need expert software developers (i.e. relying on an existing and previously tested software) which in turn contributed to the successful project implementation.

3.2.2 - Question 2: Barriers to transition to scale for eHealth projects in LMICs

In this section, five studies are included that focus on eHealth project scale-up in LMICs. These studies present several important challenges to transitioning to scale for eHealth projects. In general, literature demonstrates that there is limited knowledge, research and evaluation of eHealth projects available in the LMIC context (Shuvo et al., 2015). As a result, project implementers may not be aware of the start-up costs or cost-effectiveness due to lack of evidence and the rarity of projects that have been successfully scaled-up (Aranda-Jan et al., 2014). There are theories about scaling-up, but not enough practical knowledge or experience that is shared – which might be preventing eHealth projects from scaling up effectively. Schweitzer & Synowiec (2012) mention that without sufficient research or data, it is difficult to establish general conclusions regarding eHealth investment decisions. Further, they suggest a challenge to scaling up is the failure to show and acknowledge the value of eHealth. However, in the context of an ongoing global pandemic, it is conceivable that the potential of eHealth technology is demonstrated in the literature based on implemented projects.

There are four main barriers to transition to scale for eHealth projects in developing countries. It is important to note that these barriers are not independent categories, but rather that they are interconnected and influence each other.

The first major category regards financial constraints. Kwao et al. (2019) and Sundin et al. (2016) both identify economic limitations as a major barrier to scaling-up and ensuring sustainability of eHealth projects. In the realm of finance and economics for eHealth, Schweitzer & Synowiec (2012) point out that it is important to consider the upfront investment needed to establish eHealth infrastructure, the operating cost, costs for non-health services (e.g. hardware and telecommunication cost to healthcare users), and the demand for eHealth technologies that can increase demand, possibly decreasing vendor prices. Sensitive factors such as inappropriate distribution of funds among project components, the sources of funds, lack of knowledge on estimated return of investments (ROI), and the national budget allotment to the healthcare sector act as barriers in the financial category (Kwao et al., 2019; Shuvo et al., 2015).

Further, the literature suggests that in African Union countries, the actual budget allocated for the health sector is lower than the Abuja Declaration's target allocation of 15% of a budget (e.g. only 7.1% budgeted in 2018 in Ghana) (Kwao et al., 2019, p. 819). This limited funding by national governments contributes to the slow progress and establishment of an unsupportive environment to improve eHealth in the healthcare sector of developing countries (Kwao et al., 2019). Moreover, failure to consider and establish an appropriate business and revenue model impacts the ability to sustain and scale-up an eHealth program. Sustainable financing is not currently a practiced measure in most eHealth programs. This was discussed in the Transform Africa Summit in 2018, where leaders of African countries and other stakeholders determined that 72% of financial investments for eHealth are from external donors, which directly reflects on the poor

financial sustainability of such eHealth projects (Tran Ngoc et al., 2018). Further, since the cost of maintaining eHealth systems increase as the user base grows, and these projects continue to rely on donor funds, this can further aggravate any possibility of achieving financial sustainability of these projects in LMICs (Kwao et al., 2019; Sundin et al., 2016).

Due to the collaborative nature of eHealth projects, the second challenge category is developing and maintaining partnerships (e.g., global, public-private), and the role of national government when transitioning to scale for eHealth projects. Shuvo et al. (2015) describe how partnerships connects all other challenge categories such as infrastructural requirements and local governance needed for successful eHealth project implementations and scale-up. Another aspect of partnership and collaboration is the interconnectedness of the local community and project implementers. Shuvo et al. (2015) point out that it is imperative for an eHealth program to meet the needs and priorities of the local population to form a sustainable project. Moreover, private-public partnerships are central to eHealth projects because of the significant role of donor funding, and the involvement of non-governmental and non-profit organizations that can be both local and international when executing an eHealth initiative (Shuvo et al., 2015; Sundin et al., 2016; Tran Ngoc et al., 2018). Especially, public-private partnerships between with private telecommunication service providers are found to be a key relationship in eHealth projects (Shuvo et al., 2015; Tran Ngoc et al., 2018). The role of such partnerships with telecoms can be described in terms of persuading private telecom companies to support eHealth initiatives, and considering effective cost schemes for mHealth (i.e., SMS cost) programs (Sundin et al., 2016; Tran Ngoc et al., 2018).

Another important aspect of collaboration is the involvement of the national government in eHealth initiatives. The country leaders at the Transform Africa Summit in 2018 recognized that political will and commitment, and South-South collaboration is essential for scaling up because eHealth systems cannot be maintained in isolation (Tran Ngoc et al., 2018). Further, Shuvo et al. (2015) describe how local ownership is important for achieving sustainability and scale-up of eHealth projects. If there is no government ownership or involvement and the project is implemented by non-government actors, then there is a risk the project will not be sustainable after the initial project timeline.

Concurrently, "insufficient and inadequate capacity for DH [digital health] governance and leadership" acts as a major challenge because eHealth programs should align with national strategies in order to transition to scale in a fragmented national health system (Tran Ngoc et al., 2018, p. 4). However, even if there is government ownership and involvement of an eHealth project, there should also be measures to secure ongoing investments in order to maintain these eHealth projects (Shuvo et al., 2015). Further, the importance of partnerships in financing eHealth projects and unanswered questions such as "what incentives can the public sector put in place to drive down costs?" are highlighted in the reviewed literature (Schweitzer & Synowiec, 2012, p. 75). Hence, the political will, involvement of public representatives, and sufficient funding clearly plays a central role in ensuring sustainability of an eHealth project.

The third category of barriers to eHealth project scale-up is regarding infrastructural problems. Shuvo et al. (2015) identify several problems such as inaccessible roads, lack of suitable transportation, and unreliable electricity which hinders the ability to maintain

eHealth systems in developing countries. There are specific technological barriers as well. This includes the lack of familiarity of technology or technological illiteracy among healthcare workers, cellphone limitations such as phone theft, and limited memory capacity; and Internet limitations such as insufficient, expensive, and narrow Internet bandwidth in developing countries (Sundin et al., 2016). Another aspect related to infrastructural, or system barriers involves concerns regarding employee management. This includes challenges such as lack of oversight of business decisions, and business setbacks such as using excess profits for personal needs or reporting lower sales to decrease the amount of owed commissions (Sundin et al., 2016). Lastly, there are information security issues which can be viewed as a significant barrier to scale-up of eHealth projects. This includes concerns among stakeholders of eHealth systems about hacking, inappropriate disclosure of patient health information, and the legality of donating an eHealth system to a physician (Kwao et al., 2019, p. 820).

The fourth and final category of barriers to eHealth project scale-up is contextual factors. Sundin et al. (2016) describes how gender dynamics, stereotyping and stigma has a negative impact on eHealth project sustainability. It is important to consider gender dynamics because, as an example, women may not have access to relevant education or to Internet and technology applications depending on the local sociocultural context of the project region (Sundin et al., 2016). Also, stereotyping and social stigma around illnesses such as HIV or psychological illnesses can also have an impact on the eHealth project (Sundin et al., 2016). Moreover, Kwao et al. (2019) mentions the presence of resistance to

change because there is resistance by physicians and other providers to implementation, and the challenge of possible disruptions in clinical care when implementing a project.

3.3.3 - Question 3: The central role of global and regional connections of eHealth projects in LMICs

eHealth applications implemented in developing countries are clearly related to the study of global health. This relation highlights the importance of understanding the collaborative nature and local, regional, and global connections that underpin eHealth projects. In this section, five studies are included that focus on global and regional partnerships in eHealth. Two key aspects were identified from the literature as a result: the impact of dynamics between global North and South in eHealth projects, and the necessity for partnerships in eHealth projects in LMICs.

Global North and Global South in eHealth

In global health the term global South generally applies to countries in Africa, Asia and Latin America, and the term global North refers to North America and Western Europe (Curioso & Mechael, 2010). There is an asymmetrical power dynamic between global North and global South countries which is a "well-recognized socioeconomic phenomenon of globalization" (Kim et al., 2017, p. 401). Further, this unbalanced power dynamic is a component of the divide between the global North and South and is fueled by decades of colonialism, neocolonialism in the present day, and the dominance of the global North (Kim et al., 2017). Hence, it is important to recognize the social context and cultural differences

between these regions and determine "the ease of access to health resources, the dominant health culture and how health knowledge is sought and shared between the peoples" when there are global North-South partnerships in eHealth projects (Kim et al., 2017, p. 406).

The majority of the eHealth projects implemented in developing or least-developed countries are international projects executed with global partnerships and specifically with a global North partner since the bulk of eHealth implementations are donor-funded by a global North partner (Shuvo et al., 2015; Sundin et al., 2016; Tran Ngoc et al., 2018). Iluyemi & Briggs (2009) describe how developed countries use eHealth as an international development measure or as an initiative to portray their commitment to addressing global health challenges. This worldwide political practice leverages the development of eHealth innovations by private sectors and this in turn is used to benefit developing countries. Noticeably, the private industry members also benefit from the return on their investment by investing in the development of eHealth technology in LMICs (Iluyemi & Briggs, 2009).

Furthermore, according to Iluyemi & Briggs (2009), eHealth projects in developing countries are divided into the stakeholders providing funds and the stakeholders delivering the health service. This division in stakeholders tends to be a public-private partnership. This partnership could potentially be based on how the public sector in the developing country maintains the health service delivery while the funding and technology is provided by the private or industry stakeholders in high income countries (Iluyemi & Briggs, 2009). This global North-South transfer of technology and resources results in an intricate relationship influenced by contextual differences – and the failure to understand these global North-South inter-relationships can easily result in eHealth project failures.

Due to the prime role contextual factors play in determining the success of eHealth projects, it is important to consider the role of global South-South or regional partnerships. South-South partnerships can be between the private sector, government, non-governmental organizations, and academic institutions (Curioso & Mechael, 2010). An exemplar of regional collaboration is economic partnerships between countries in sub-Saharan Africa as seen from unions such as the Economic Community of West African States (ECOWAS) and the Economic Community of Central African States (ECCAS) (Lee et al., 2017). The advantages of these South-South partnerships are that knowledge, lessons, and experience can be easily shared and will be applicable to similar sociocultural and socioeconomic contexts (Curioso & Mechael, 2010; Lee et al., 2017). Further, regional collaboration in mHealth can specifically aid with efficient monitoring, surveillance, and control of communicable and non-communicable diseases that is specific to geographic regions (e.g., sub-Saharan African countries) (Lee et al., 2017). Hence, utilizing these regional and global partnerships effectively can help with knowledge sharing and resource management, and ultimately contribute to collectively improving healthcare access and quality of health service delivery.

A recognized need for partnerships in eHealth projects

One of the emerging challenges the literature presents is ensuring effective knowledge translation in the health sector in general and in global health in particular. There appears to be a "chasm between what is known and what we do in health, the so-called "know-do gap"' (Kwankam, 2004, p. 800). This lack of translation of scientific or

experiential knowledge to practical applications essentially dooms the effectiveness and benefits of academic research and project evaluations. It is important to recognize that with advanced and widely accessible technology like eHealth it is possible to rapidly disseminate health information to community members or frontline healthcare workers to aid with effective and efficient health decision-making (Kwankam, 2004). Global and regional partnerships can play a significant role in filling the knowledge translation gap in health via technology. Kwankam (2004) provides an example of how the World Health Organization started an initiative called the *Health Internetwork Access to Research Initiative* to enable health professionals in developing countries to access scientific journals with no or limited cost. eHealth technology is particularly useful in filling the know-do gap because of the flexibility and the lack of limitations in geographic location or time.

Another aspect of this knowledge translation challenge is gathering evaluations and lessons from eHealth projects that have been deployed in developing countries. This is because, without gathering this knowledge, there will be a duplication of effort and wasting of resources which further hinders achieving progress in eHealth systems with global and national standings (Lee et al., 2017). Hence, despite numerous benefits of eHealth, it is imperative to establish a global observatory to monitor progress and developments of eHealth systems so that the practical knowledge and experience of utilizing eHealth applications can be recorded and effectively shared among neighbouring countries (i.e., regional partners) (Kwankam, 2004). This will collectively achieve success, instead of repeating similar projects and wasting both time and resources.

Moreover, there has been a recent sharp increase in mHealth implementations in Sub-Saharan Africa. This suggests that there is more knowledge and experience about mHealth in Africa, especially in hotspots where nations have the highest number of mHealth implementations, such as Kenya, Tanzania, Malawi, and Uganda (Lee et al., 2017). Hence, it is important to establish regional collaboration among countries in the continent to contribute to and experience positive synergistic benefits. Lee et al. (2017) recommend that these hotspot countries should lead regional collaboration initiatives and effectively share and utilize knowledge on mHealth that is applicable for similar economic and sociocultural contexts. This will lead to investments in scaling-up successful eHealth projects instead of engaging in a futile cycle of repeating similar mHealth projects. A more in-depth and specific collaborative approach to eHealth among global North and global South, and between global South and South partners could ultimately help move forward and beyond the all-to-frequent eHealth failures and pilotitis.

The search results of the literature review presented in this chapter identify key challenges and facilitators for both implementation and scale-up of eHealth projects in LMICs. The literature review also highlights the importance of global and regional partnerships in eHealth projects. Lastly, in my view, financial limitations experienced during implementation and scale-up of eHealth projects can be considered as the most significant barrier in LMICs. This highlights especially the issues of, and the influence of donations from International Financial Institutions or foreign aid agencies on the recipient LMIC national governments, and heavy aid dependency of health sectors in many LMICs. These two issues will further be discussed in Chapters Five and Six. Hence, considering

sustainable financing from the beginning and always planning to achieve the end goal of co-financing or domestic investments to strengthen health infrastructure in LMICs should be a priority of all stakeholders. It is envisioned that the search results of the literature review will also contribute to the cStock case study in Malawi which will be presented in Chapter Five.

CHAPTER 04 – Methodology

In Chapter Three, I presented the methodology and search results of the literature review conducted as the first component of this thesis. In this Chapter, I will explore in more detail how, despite all the barriers and challenges in Chapter Three, one mHealth project in Malawi was able to move beyond the proof of concept to become a national platform and an example of the promise inherent in eHealth initiatives in the global South. As I mentioned in Chapter Two, the cStock initiative in Malawi had many of the elements that have failed so regularly in other projects. My intention in this thesis was to interview participants in the design and implementation of this project to compare their experiences with the barriers and opportunities identified in previous chapters. Hence, in this Chapter, I will present the methodology of the qualitative primary research conducted based on Key Informant interviews for the cStock case study in Malawi. This Chapter will first present the methodological approach (4.1), followed by sampling and recruitment (4.2). Next, the data collection methods will be presented (4.3). Lastly, the methodology of the data analysis process (4.4) and any limitations of the study methods (4.5) will be presented.

4.1 Methodological approach

This research study utilized a qualitative study design with a case study format. A qualitative design was chosen because data collection was set to occur in a natural setting (i.e., no external interventions); the researcher is considered to play a central role in the research as they create data collection instruments, and collect data on their own; the research is undertaken in the context of Malawi; the research focuses on participants'

perspectives and meanings about an experience or phenomenon; and the study design evolves throughout the research timeline (Creswell & Poth, 2018, p. 81-82). In this research, the cStock case-study in Malawi will be analyzed with support from Key Informant interviews. A case study format is appropriate for this research because the study aims to understand the case in-depth, analyzing the cStock case supports in answering the primary and secondary research questions, and this is a unique case that is real-life and time bound (Creswell & Poth, 2018).

4.2 Sampling and recruitment

The sampling strategies used in this study to find potential participants are purposive and utilize snowball sampling. Both sampling techniques used are non-probability strategies. I used purposive sampling because participants were not interchangeable, and each Key Informant was selected based on their ability to provide rich information in their own expert area in the case study. Also, purposefully selecting participants enabled the collection of diverse perspectives on the same project. Snowball sampling was used to identify potential participants. Using a snowball strategy leveraged the existence of networks and connections among participants and work-colleagues in this study (Baltar & Brunet, 2012). Furthermore, the snowball strategy was useful because this research was conducted in an online setting which imposed constraints on identifying and initiating contact with potential participants. Baltar & Brunet (2012) also suggest that the snowball method can be useful for small-scale studies with very few participants, or in studies that have participants in hard-to-reach areas.

In this study five participants who were involved with the project implementation and scale-up, or had used cStock were included. The study participants included three participants who work at the central management level, and two participants who work at the district level. Participants at the central level are involved with national and international matters, while district level participants are involved with national and community level matters pertaining to cStock. All participants in this study were based in Malawi and had significant long-term experience with the project. This ensured that the contributions of each participant consisted of rich information and valuable insight.

The recruitment process involved the following inclusion criteria: Participants must be above the age of 19, can communicate in the English language, can provide informed consent in written or verbal formats, and have used cStock or be involved with the project design, implementation, or scale-up processes. There was no discrimination or selection criteria based on the gender of participants. Lastly, no direct incentives or monetary incentives were provided for participants.

4.3 Data collection

In this study, the primary instrument of data collection was the virtual Key Informant interview. As the data collection method involved a minimal risk study with human participants, it was determined that ethics review from the Hamilton Integrated Research Ethics Board (HiREB) was necessary prior to any data collection. After review, ethics approval was granted by HiREB in May 2021.

Initially, I contacted the participants after an introduction to potential participants by a third person not in the research team. I used e-mail and WhatsApp to contact and

maintain communications with participants. All participants were provided a digital copy of the Letter of Information/Informed Consent Form (ICF), attached in Appendix D. All participants provided written or verbal consent prior to the start of the interview. For written consent, the ICF was signed, and for verbal consent, I signed a verbal consent record and provided it to the participant as a reference.

Key Informant interviews were conducted using a semi-structured interview format with a time duration ranging from 30 to 60 minutes. All interviews occurred virtually using Zoom and/or WhatsApp platforms in the English language. All participants were asked for their gender and work position in order to understand their demographics and for data analysis purposes. Three general interview guides were used to suit work positions of each Key Informant, attached in Appendix E. The questions in these three guides were chosen from the initially created five interview guides based on work positions such as CHWs, Supervisors of CHWs, Project Implementors, Data Users, and Platform Developers and were also submitted to HiREB for ethics review process. However, due to the diverse work positions of participants, and the inability to find participants based on initially proposed work positions, the interview questions asked were different in minor ways. Also, due to the qualitative and semi-structured nature of the Key Informant interviews, some of the questions asked from participants were not based on the interview guides. The interview questions were regarding challenges and facilitators with project design, implementation and scale-up. Also, questions related to project sustainability, the impact of the COVID-19 pandemic, and any connections between paper and electronic records were included. The conceptual framework on sustainable eHealth by Fanta & Pretorius (2018) and the eHealth

project evaluation framework by Khoja et al. (2013) were used when developing interview questions. All interviews were audio-recorded with the permission of the participant, and digital files were saved using an alphanumeric study ID assigned for each participant.

Transcription of audio-recorded interviews was conducted using an automated transcription software called *Sonix* (Sonix, 2021). After the initial transcription using *Sonix*, I manually edited the transcripts to ensure all words were accurate. Also, during the manual editing I removed any personal information of the participant or others mentioned by the participant (i.e., deidentification process) and replaced these sections with square brackets to show altered material. The transcripts were saved using the study ID assigned to each participant.

4.4 Data analysis

Thematic content analysis as described in the *Framework Method* was followed to analyse the data from transcriptions. The *Framework Method* for social science research was first developed by Ritchie et al. (2003). However, the application of the *Framework Method* described by Gale et al. (2013) was used to guide the data analysis of this study. Gale et al. (2013) described seven steps to follow for a thematic content analysis. According to Gale et al. (2013), the first step is transcription, and the second step is becoming familiar with the content of the interview. The third step is coding, which involves open coding in inductive studies, and coding using pre-identified codes in deductive studies. This step helps in identifying codes, hence initial coding was conducted only on a few transcripts. The fourth step was to create a working analytic framework, where initial codes were assigned to categories. The fifth step involved the application of

the analytic framework for all transcripts, known as indexing. Step six involves summarizing the transcript data based on categories and codes, using a matrix format in a spreadsheet. The final step was interpreting and mapping the data by identifying similarities, differences, comparisons with literature, and looking for relationships or causalities to determine the findings of the study.

To facilitate the coding process, *Dedoose* data analysis software was used (Dedoose, 2021). Initial codes were formed using the two conceptual frameworks by Fanta & Pretorius (2018) and Khoja et al. (2013), and with personal insight. Due to the inductive nature of this study, open coding was also used. After coding the first two transcripts, all codes had been categorized. Next, the large categories of codes and small-level codes were organized and used as a working analytic framework to code the remaining three transcripts. It is important to note that, during the coding process, new codes were added as new information was present in latter transcripts. Also, a separate code was used to highlight any important quotes that could be useful in the later stages. After the coding process concluded, all data and codes were exported from *Dedoose* to an *Excel* spreadsheet to facilitate the process of summarizing data based on categories. I summarized all coded excerpts while ensuring that the meaning of the raw data was retained. Lastly, from the summarized data I drew connections, similarities, and differences among different code categories, participant responses, and existing literature. Drawing connections from code categories and summarized data helped in forming six major themes related to the research questions of the thesis, which will be presented in Chapters Five and Six.

4.5 Limitations

There are two key limitations to the study methodology. Firstly, by conducting interviews virtually due to travel restrictions imposed by the COVID-19 pandemic, it limited my ability to gather knowledge on the social and cultural contexts in Malawi for the cStock case study. Limited knowledge on the local context may have had a negative effect on the interpretation and analysis of collected data. Secondly, conducting Key Informant interviews virtually also hindered my ability to gain first-hand experience and insight on the reality of the cStock system, which may have limited my ability to interpret data and draw conclusions accurately.

CHAPTER 05 – Findings

In Chapter Four, I presented the study design and methodology used to analyze the cStock case study in Malawi. In this chapter, I will describe relevant findings of the literature review and findings of the Key Informant interviews of the cStock study. I will start with the relevant findings from the literature review in section 5.1. Then, I will present the findings from the thematic content analysis of cStock Key Informant interviews in section 5.2.

5.1 Findings of the literature review

In Chapter Three, the search results of the literature review were presented as three questions, which focused on: barriers and facilitators to eHealth project implementations in LMICs, barriers to scaling-up their eHealth projects, and the role of regional and global partnerships in eHealth projects in LMICs. In this section, only the relevant findings to the cStock case study will be presented.

Firstly, the most relevant barriers to eHealth project implementations were found to be financial limitations such as issues with securing funding for eHealth project implementations; infrastructural constraints such as unreliable electricity, poor Internet connections and issues with mobile phone charging; and sociocultural challenges such as resistance to new services by staff involved in eHealth projects (Alshahrani et al., 2019; Granja et al., 2018; Källander et al., 2013; Kiberu et al., 2017; Muinga et al., 2020). The literature review also identified enablers for eHealth project implementations in LMICs.

The most relevant enabling factors for implementation are Government interest and support for mHealth projects; providing regular training for project staff; and collaboration through partnerships at local and international levels (Aranda-Jan et al., 2014; Muinga et al., 2018; Oza et al., 2017).

Secondly, three key barriers to scaling-up eHealth projects were identified to be the most relevant for the cStock case study. The search results identified financial constraints such as limitations of national budget allocations to the health sector; lack of Government ownership and involvement in the eHealth project; and technology barriers such as scarce and expensive Internet connections, and narrow Internet bandwidth in LMICs (Kwao et al., 2019; Shuvo et al., 2015; Sundin et al., 2016; Tran Ngoc et al., 2018).

Thirdly, with reference to the role of regional and global partnerships in eHealth project implementations and scale-ups presented in the literature review, two key aspects were identified to be relevant for the cStock case study. Firstly, the asymmetric power relations between the global North and South partners in an eHealth project that tends to result from financial contributions, and directly impacts decision-making related to project design and implementation (Kim et al., 2017). Secondly, it was found that international partnerships are necessary to carry out eHealth projects in LMICs due to the immense need for financial resources by global South nations, and the financial donor-role assumed by global North partners (Iluyemi & Briggs, 2009).

The above-mentioned challenges and facilitators to eHealth project implementations and scale-ups, and the role of global partnerships observed in the cStock case study will be discussed further in the following section.

5.2 Findings of the cStock case study

In this section, I will first provide an overview of the cStock case study based on publicly available documents and other material on Malawi cStock system, and from findings of the Key Informant interviews conducted. Secondly, I will present six major themes identified from the thematic content analysis of Key Informant interviews as (1) facilitators and barriers to cStock implementation, (2) facilitators and barriers related to scale-up and sustainability of the cStock project, (3) the impact of the COVID-19 pandemic, (4) the role of paper records in the cStock project, (5) transitioning to full electronic SCM and health (eHealth) systems in Malawi, and (6) recommendations for improving cStock and future eHealth projects in LMICs. Each theme includes sub-categories. The direct quotations in this section are from Key Informant interviews I have conducted. To protect the privacy of study participants, quotes are marked with a Key Informant number assigned to each participant (e.g., Key Informant #2).

5.2.1 - Overview of cStock

The SCM cStock project in Malawi started in 2010 as part of a project called Supply Chains for Community Case Management (SC4CCM). This project was led by JSI and was a three-country project encompassing similar SCM initiatives implemented in Ethiopia, Rwanda, and Malawi. In 2014, SC4CCM concluded, and to continue the successful SCM project – cStock in Malawi, full control and leadership was transferred to the Malawi Ministry of Health and Population (MoHP). After 2014, the cStock project was scaled-up to all 29 districts in Malawi. The cStock project is still in-use in Malawi.

The key implementation partners of the project are the Malawi MoHP as a project lead since 2010, and JSI as the project lead from 2010 to 2014. The key funding organization during the 2010 to 2014 period was the Bill and Melinda Gates Foundation (JSI Research & Training Institue Inc. & Ministry of Health, 2014). During this time, JSI subcontracted Dimagi, Inc. as the technology partner to develop and design the cStock program for Malawi. After the conclusion of the SC4CCM project in 2014, Malawi MoHP (or MoH) assumed responsibility for the project with financial support from the Global Fund and management support from World Vision International (Dimagi Inc, n.d.). Based on Key Informant information and the End Line report published by JSI (2014), throughout the cStock project at different time periods since 2010, UNICEF, USAID, WHO, Service Delivery Integration-Services (SSDI-Services) project, and Save the Children have also been partners in the cStock project (JSI Research & Training Institue Inc. & Ministry of Health, 2014). Lastly, Key Informants stated that the two key network service providers are TNM and Airtel.

The internal organizational structure of the cStock project in Malawi consists of several actors. There are three levels of management – the central MoHP level, district level, and community level. In the central MoHP level, there are MoHP project coordinators, who interact with external (international) partners described above. At the district level, there are logistics officers, district pharmacy technicians, master trainers, and environmental health officers, among other individuals. At the community level, there are individuals such as Health Surveillance Assistants (HSAs) and HSA Supervisors. Aside from these individuals, there are several teams with key roles in the project. Key Informant

#2 described, a Technical Working Group at the central level with members from the MoHP and external partners, and this group has been acting since 2010 to resolve supply chain issues at the national or central level. Also, Key Informant #5 described three key teams at the district level. Firstly, the District Product Availability Teams (DPAT) address product stockouts experienced by HSAs at the community level. DPATs are chaired by district level pharmacy technicians and includes other district level staff such as the family planning coordinator and HSA supervisors (JSI Research & Training Institue Inc. & Ministry of Health, 2014). Secondly, there is a District Health Management Team (DHMT) which supports DPAT activities such as facilitating meetings, responding to financial needs of Health Facilities, etc. Thirdly, there is a Drugs Therapeutic Committee (DTC) which is responsible for managing drug supply and distribution. Further, at the community level, there are Health Facility Product Availability Teams (HPAT), who are responsible for addressing supply chain issues at the Health Facility level, and coordinating with district staff (JSI Research & Training Institue Inc. & Ministry of Health, 2014).

The beginning of the cStock project is well-described through the SC4CCM project End Line report (2014). Key Informants #2 and #3 also described two models tested for SCM in Malawi during the 2010-2014 period. The first model is known as the Enhanced Management (EM) approach, which comprises the cStock electronic component and DPATs. The second model is known as the Efficient Product Transportation (EPT) which is focused on improving the transportation system used by HSAs to pick up and distribute medicines to patients (i.e., increasing availability of repair parts for bicycles) (JSI Research & Training Institue Inc. & Ministry of Health, 2014). According to the Key Informants,

both models focused on improving data visibility in the supply chain. However, due to the significant success of the first model – EM approach – the MoHP only scaled-up this model to all 29 districts in Malawi.

This SCM project focuses on reducing mortality and morbidity for children under the age of five in Malawi by using the Integrated Community Case Management approach (ICCM). The HSAs run village clinics in hard-to-reach areas where they provide drugs for malaria, pneumonia, and diarrhea, and family planning products. The cStock system is a tool to track and maintain the supplies of such products used by HSAs to ensure that medicine and product stockouts do not occur. Each HSA is associated with a Health Facility which is linked to a district hospital. The HSAs receive resupplies from their associated Health Facility. In a case of a stockout at a Health Facility, the Health Facility can receive stocks from their affiliated district hospital.

The electronic cStock system uses SMS messages for communications and it is used as a stock reporting tool. Key Informants #3, #4, and #5 provided explanations of how cStock was used for SCM. To begin, the HSA sends stock on hand information at the beginning of every month via SMS messages to the cStock system, which is then used by the system to automatically calculate necessary resupply quantities. These calculated resupply quantities are sent to the HSA supervisor and the Health Facility staff. Once the resupply order is packaged and ready, the HSA receives an SMS message to pick up the order. The web-dashboard component of cStock is used by district and central level staff to monitor the supply chain and ensure availability of product stocks. Alongside the electronic cStock system, paper-based reports are also used. Some of these reports include resupply

worksheets (used by HSA Supervisors to record resupply quantities), and transaction reporting forms (used by district or central level staff to maintain a record of drug orders).

Further, Key Informants stated that training is a significant component of the cStock project. During the implementation phase in 2010, approximately eight trainers were trained for the first time, and eventually they became master trainers. The master trainers are currently responsible for training other trainers and HSAs, and supervising training and refresher training sessions. Some of the specific training components provided to HSAs include information on scenario challenges, and reporting methods.

Another important aspect is the payment system of cStock. The SMS text messages used by HSAs, Supervisors of HSAs, and Health Facility staff to communicate stock quantities and deliver feedback are free of charge to the individuals. However, a reverse-billing system is used to pay the telecommunication service providers such as TNM and Airtel by central level staff and external funding partners. It is recognized that maintenance and sustainability of the cStock project is depended on securing funds to essentially pay for "telephone service and message fees, server, software and maintenance costs, as well as system administration and other costs. … staff training and supervision" (JSI Research & Training Institue Inc. & Ministry of Health, 2014, p. 68). The 2014 End Line Report identified cStock as a system that relies on funding and how important it is to secure long-term funding as this system cannot function or sustain without funding support (JSI Research & Training Institue Inc. & Ministry of Health, 2014).

The MoHP has been maintaining the cStock project since 2014. The Key Informants mentioned that since 2018 there have been ongoing discussions, plans, and preparations

such as transferring technical knowledge and skills of Dimagi, U.S. to Malawi, to facilitate local hosting of the cStock server in Malawi. Local hosting of cStock is perceived to be a positive step towards sustaining cStock. However, it appears that cStock is currently cloud-based and hosted by Dimagi, Inc. in the U.S.

5.2.2 - Themes

Theme 1: ***Facilitators and barriers to cStock implementation***

In the cStock case study, Key Informants described facilitators that propelled the project from design to implementation in Malawi. Four key facilitators related to the cStock project development and implementation process were identified. They are, (1) Local and Global partnerships, (2) Government commitment, (3) Technology aspects that act as facilitators, and (4) Performance enhancement of HSAs and other staff.

(1) <u>Local and Global partnerships</u>

It was found that the role of partnerships can be described as strong partnerships at a local, international, or global level. Partnerships that drove the implementation process were maintained due to local level support offered by the Technical Working Group led by the Malawi MoH. Key Informant #1 said that "coordination meetings" among members of Malawi MoH and other implementation partners facilitated this process, and that this experience is, "you know these [coordination meetings] are the ones that fuel implementation and partnership operations between the Ministry of Health and also the stakeholders. This is where you frame, strategize, but also you perfect implementation".

Further, it was found that partnerships at local and global level were necessary for the cStock project implementation. This strong necessity for successful partnerships was described by Key Informant #1 as, "you need to reinforce implementation in terms of optics, where you engage in managing the partnership approach with within [*sic*] government sectors, but also with the partners that are supporting health issues on the supply chain".

Moreover, the international support provided by external partners such as WHO, UNICEF, and USAID were identified by participants as a key facilitator to cStock implementation. Key Informant #2 said that the overall goal of cStock to improve child health aligned with the visions of these external partners. Key Informant #2 stated in support, "we had very strong partnerships. We had the UN, you know, agencies that have a vested interest in supporting, you know, child health".

It was also found that, when cStock first piloted in 2010, and as the project continued through 2014, there had been high interest from international partners to achieve the Millennium Development Goals (MDG) by 2015. Considering that cStock was a SCM system focused on improving child health especially for children under five, cStock had received generous support from international donors to implement the project. Key Informant #2 described this situation as follows:

> "One of the focus areas of the MDGs was actually a reduction in child, you know, mortality rates or general improvement in child health outcomes. And everybody else was committed to be able to contribute towards, you know, attaining desirable outcomes."

Furthermore, it was found that global South-South partnerships were helpful when implementing eHealth projects. The SC4CCM project carried out by JSI was a three-nation program implemented in Ethiopia, Rwanda, and Malawi. JSI had promoted South-South partnerships between the three countries, and it has helped with motivation, as well as other benefits as described by Key Informant #1:

> "So, it was JSI, you know, promoted networking us. We learned a lot. But during that time, the program in Ethiopia was moving faster than Malawi and Rwanda. So, it promoted, you know, and influenced our scaling up efforts to ensure that we move at the same pace and level in terms of learning, but also sharing of experiences across the three countries."

Hence, strong partnerships at a local level, such as within the government, and committed partnerships at an international level helped in driving the implementation of the cStock project.

(2) Government commitment

It was found that the key facilitator which helped in achieving a successful project implementation and eventually scale-up was the national Government commitment. Participants described the high-level of strong leadership and long-term commitment of Malawi MoH as a key driver that fueled the implementation process. Key Informant #1 captured this:

> "I feel when you have a project that is led by MoH leadership, that is fantastic! Because, you know, a project when it is introduced in the country. They should not have parallel stuff. So, for cStock, if you have a government led or Ministry of

> Health led implementation arrangement, where you use the Ministry of Health as your nail. You are assured having a very strong implementation platform. So, an MoH led, you know, arrangement is fantastic."

Further, cStock is maintained under the leadership of the Malawi MoH. This high-level leadership role has allowed for achieving the goals of Malawi MoH. Hence external partners, and stakeholders of the cStock project have played a secondary supportive role. Key Informant #2 described this:

> "The leadership from the government was strong and they knew what they wanted. So, our role as partners was basically to support, achieve what the Ministry was looking for, by actually deploying innovations such as cStock. And we did not implement the project like separately, we were actually implementing together with the Ministry, we would actually co-plan together activities."

Key Informant #2 described how the Government (MoH) provided support for the cStock project by helping with securing funds for the project and prioritizing cStock in the agenda. Key Informant #2 stated:

> "The Ministry actually worked together with a project [cStock] and provided leadership in terms of linking with potential funders. Then we're looking at the Global Fund. We looked at the USAID, through different other projects. And the Ministry actually was the key in terms of negotiating these conversations. The Global Fund actually, you know, said if it [cStock] is a Ministry priority, then we'll consider funding it. And the Ministry actually put cStock as one of the top three priorities."

Strong Government commitment can be defined as support provided at regulatory, administrative, and human resource levels, for instance by prioritizing cStock in the MoH agenda, actively collaborating with partners, securing long-term funding for cStock, and actively leading teams such as the Technical Working Group to manage the project. This strong Government commitment helped arrange the necessary political will to achieve a successful implementation of the cStock project, and eventually the scale-up of the system.

(3) Technology

In this category, it was found that the benefits of using the electronic cStock system acted as a facilitator to project implementation. Firstly, the basic and low-cost nature of the cStock technology acted as a facilitator as it could be used without needing any complex resources. Key Informant #2 described this as, "the cStock is designed to be a very simple, you know, SMS based technology. […] it doesn't necessarily require like a smartphone or a complicated phone". Additionally, Key Informant #3 stated that "this is the only system which was, which was [*sic*] used at low-cost because it was reverse-billing […] there was nothing like using maybe a smartphone or another phone".

Secondly, the visibility of data provided by the cStock technology also has acted as a key facilitator because it helps with identifying supply chain problems at the community level and addressing them. Key Informant #2 said, "For the first time, I think cStock proved that you can have a lot more visibility into community level, you know, data that wasn't there before". Additionally, Key Informant #2 stated the importance of data visibility:

> "When we deployed cStock and we had the online dashboard up and running, we would first look at where are we going for supervision? We would actually look

> into the dashboard and see what are the issues for this district in general, but also for the facilities and the HSAs would actually be supervising. So, as we went, we already knew most of the issues straight from the office. We already knew what is going right, what is going wrong […]. And so, we went there to engage in finding solutions, not to understand the problems. We already knew what was happening straight from the dashboard."

This data visibility especially has helped in ensuring accountability and transparency of the supply chain as described by Key Informant #1 as cStock technology offers "quality of service, in addition to the accountability and transparency it provides".

Thirdly, HSAs has had a positive experience with cStock due its benefits such as reducing the time spent on the resupply process. Key Informant #4 said "the HSA only goes to the facility to pick the products once he or she is notified that products are ready". Also, Key Informant #3 added that before cStock "if you [HSA] use transport money to go to facility to collect products, there's money wasted, and time, money, energy wasted" because prior to cStock there was no resupply pickup notifications accessible for HSAs. Moreover, the adoption of cStock by HSAs without resistance has also helped with project implementation. Key Informant #5 said that "the HSAs as well, they accepted the system, despite of the challenges maybe or maybe have not phone [*sic*], a network problems [*sic*], but they truly love the system, the HSAs".

(4) <u>Performance enhancement</u>

Training, and supervision offered to HSAs and other staff helped in improving and maintaining the performance of HSAs – ultimately leading to the successful

implementation and scale-up of the cStock project. Key Informant #1 described the important role training played in the project implementation as, "and if we had not, you know, we had failed to train all health care workers who are responsible to be supervisors and those that we fail to do to [*sic*] train, they could not support implementation".

Further, Key Informant #2 highlighted the importance of supervision and feedback in the implementation process by stating that "consistent mentorship, consistent supervision, on [*sic*] consistent availability of medicines is key to effective delivery of cStock implementation". Hence, the methods used to improve and maintain the performance of HSAs and other staff such as frequent training, and supervision have helped with achieving successful implementation of cStock.

Barriers to cStock project implementation

In any eHealth project in LMICs, there are barriers that hinder project development and implementation. In the cStock case study, four key barriers were identified. They are, (1) Financial limitations, (2) Partnership maintenance, (3) Resource limitations, and (4) Management and Worker issues.

(1) Financial limitations

A shared concept among participants was that financial constraints act as a key barrier for the cStock project implementation and its continuation. Financial limitations have essentially hindered medicine availability, conducting evaluations, and implementing eHealth or health policies in the context of cStock and in general in Malawi.

It was found that there is a high level of foreign aid dependency due to very limited national health budgets. Key Informant #1 described the low health budget as, "Unfortunately, most of the districts receives a thirty percent allocation for drugs, irrespective of mobility or consumption data and the districts are forced to prioritize what type of commodities they have to make the requisitions for". Further, adding to the lack of availability of medicines due to financial constraints, Key Informant #2 said:

> "There were higher level challenges to do with the general availability of medicines. So essentially, the pipeline was not a 100 percent, you know, financed. And that is a general, I think, future that we are likely to see in most of the developing countries. So, the issue of prioritizing medicines for the lowest level became central."

Reflecting on the issue of lack of funds to implement health policies, Key Informant #1 shared the following information:

> "These all policies are there. But to fulfill what is written down, as has been to order, because most of the strategic plans have not been fully funded. So that has been a very big challenge, in terms of implementing our vision and the basically mission, which still remains a dream."

This grave situation of lack of funds also limits the ability of project implementors and higher-level staff to conduct much needed program evaluations. Key Informant #1 described this, "Unfortunately, as a country, we have not had comprehensive and comprehensive [*sic*] midterm evaluation of our strategic plans because they are basically not fully financed, that's the greatest challenge".

This distressing challenge of financial constraints directly reflects on the poor national economy of Malawi, which ultimately results in the need to depend on foreign or external funds for long periods to develop health infrastructure, implement health policies, and secure commodities such as essential life-saving medicines in Malawi.

(2) Partnership maintenance

Similar to human relationships, partnerships among various stakeholders in an eHealth project also require effort to manage any arising conflicts. It was found that there have been conflicts due to differences in interests when managing partnerships with their telecommunication services providers, TNM and Airtel. Key Informant #2 described the conflicts with telecommunication companies when arranging contracts for service rates "the telecos are in the business. All right. So, whatever they do, it needs to make a, you know, strong or suspected business case to invest their time in that". This describes the challenges experienced when partnering with the private sector for the cStock project due to differences in perspectives.

(3) Resource limitations

In this category, it was found that there are three main resource constraints which hindered the cStock implementation and continuation. These constraints are medicine stockouts, limited availability of mobile phones for HSAs, and infrastructural issues.

Firstly, medicine supplies are sometimes limited and can deplete quickly (i.e., medicine stockouts). This can occur due to limited availability of funds. The medicine stockouts resulted in HSAs not reporting to the cStock system, which ultimately affects the

management of the supply chain. This phenomenon of lack of reporting was described by Key Informant #1:

> "They [HSAs] could not use it [cStock] because there were stockouts, so it was like a zero reporting. So that was a system challenge […] as a low-income country, it is, you know, a real challenge, yeah, in our context."

Secondly, the cStock system relies on HSAs using their own mobile phones. Key Informant #1 said "being a low-income country, availability of those mobile phones was not a guarantee". Further, HSAs who owned or had access to a mobile phone had "issues with battery life". Such resource limitations continue to affect cStock system continuation.

Thirdly, there are infrastructural issues such as unreliable network connectivity or no network in hard-to-reach areas, and limited availability of electricity to charge mobile phones that HSAs use. These infrastructural issues have resulted in late reporting of stock information by HSAs. Key Informant #1 described the effects of unreliable network:

> "Most of the community-based health workers who do experience, you know, loss of network or no network at all, but rather they would only send data when they move out over their look [*sic*], their remote areas, to go to a very urban area you know to send data. And that was delayed communication."

.. and delayed reporting resulting from unreliable electricity for HSAs:

> "You are talking about most of the phones that the community-based health workers had relied using electricity for recharging. […] So, it just says how their phones or for [*sic*] three or four days without sending data and that was and that remains a huge challenge up to now."

Hence, resource limitations such as medicine stockouts, availability of mobile phones, and infrastructural issues act as a key barrier for project implementation and continuation of cStock in Malawi.

(4) Management and worker issues

The final barrier to cStock implementation was found to be management and worker issues. Firstly, there were communication issues among different levels of the hierarchical organization structure of cStock (i.e., community, district, and central levels). Key Informant #1 described issues with managing the distribution of medicine resupplies to HSAs: "there was a lack of coordination between the community-based level on cStock, but also primary health care level facilities. That, you know, created a gap in terms of ensuring availability or consistent availability of commodities".

Secondly, in the beginning of the cStock project implementation, there was resistance from medical assistants. Key Informant #2 said "There was a challenge, as I said, in terms of attitudes set in medical assistants at facility level, that some of them did not initially agree that, and they [HSAs] should actually be given medicines". However, this challenge was addressed by providing training for medical assistants to ensure they understood the important role played by HSAs in the community to improve child health.

In summary the barriers to cStock project implementation mainly surrounded financial limitations, challenges with maintaining partnerships, resource limitations, and management or worker challenges.

Theme 2: Facilitators and barriers related to scale-up and sustainability of the cStock project

There are facilitators which fuel the cStock project scale-up and achievement of sustainability. Four key facilitators were identified. They are, (1) Government leadership, (2) Commitment to health service, (3) Regular feedback, and (4) Teamwork.

(1) Government leadership

It was observed that government ownership of cStock, government leadership, and sustainable strategies helped with project scale-up and achieving sustainability.

Firstly, government ownership of cStock is viewed as a facilitator or a step towards achieving sustainability. Local ownership and hosting are perceived to be an act of gaining independence from international or external partners' control. Key Informant #1:

> "Dimagi were the developers of the system and they were locally hosting the system in the US, it is a cloud server and that is U.S. based and U.S. controlled. So administratively, we did not have control. [..] until three years ago when we as a country, we said we have now matured, and we have entered into a period where we needed to locally manage and host [cStock]."

Secondly, it was determined that strong government leadership from Malawi MoH facilitated the scale-up process. Key Informant #2 said "the leadership from the Ministry was very clear and strong" and this "very strong leadership" moved "everybody in that [scale-up] direction".

Thirdly, the development of a sustainable strategy and a roadmap is seen as a facilitator to the project scale-up and shows the long-term commitment of Malawi MoH.

Key Informant #1 described the importance of having a sustainable strategy and the commitment of the MoH as:

> "… [the sustainability plan] is one of the tools that we are using as Malawi in terms of trying to bring into focus, what we want to do as a country, but also how we want to do it, in terms of making sure that we do not just talk about MoH led, you know, cStock system implementation, but we need to be talking about MoH leadership with supporting systems at implementation level where community health workers are deployed."

Further, a roadmap to achieve sustainability was also developed, which is useful to execute the sustainability plan (Key Informant #1). The development of the roadmap also shows the MoH commitment to the cStock project, which makes government commitment, leadership, and prioritization of cStock a key facilitator to the successful scale-up and maintenance of the project.

(2) Commitment to health service

The strong sense of health service promoted by the cStock SCM tool was viewed as a key facilitator to project scale-up because of the support received by partners due to the good will it promoted. Key Informant #1 stated "because cStock system and the application itself is a health system strengthening component. So, Global Fund recognized that". Further, Key Informant #2 outlined the true health service-orientated nature and impact of the cStock system:

> "It's like so in the very rural areas, HSAs are considered as doctors. And they are respected because they are really helping out a lot in terms of timely responding to

> under five, you know, conditions in the rural areas where some of them actually because of distance issues, were not able to make it to the facilities. So having somebody deep in the rural area and responding to their needs pretty quick is something the communities really value."

Key Informant #1 described how positive motivation and "goodwill" helps with continuing the cStock project: "So, we have a lot of goodwill. We have a lot of good support in terms of looking forward".

Hence, these findings show that ultimately, humanity is valued, and positive motivations help to fuel large-scale eHealth projects such as cStock.

(3) Regular feedback

It was found that regular feedback provided to HSAs was a key facilitator that contributed to enhancing and maintaining the performance of HSAs throughout the long-term cStock project. Regular feedback provided to HSAs and other staff of cStock helped in acting as a strong motivator to staff members. Key Informant #3:

> "So, the system was able to give feedback to the HSAs, by giving feedback to the HSAs, it proved to be to be [*sic*] like, a motivation, a motivation [*sic*] to themselves. Because they were able to know where they're doing nice, and where they were doing badly and where they needed to improve."

Also, Key Informant #3 described how alongside of feedback, HSAs were recognized for their performance:

> "…, they [HSAs] were as well being able to be recognized by maybe congratulating them. […]. There is [*sic*] more rewards, we could give the rewards, but not in

> monetary form. So, this motivated the the [*sic*] all the members from the HSAs up to the management level, at all the, at all the, [*sic*] in all the districts in Malawi."

(4) Teamwork

It was found that teamwork played a central role in managing the cStock system. Participants described the contributions of several teams such as DPAT, HPAT, DTC, DHMT, and the Technical Working group. Each of these teams collaborate and work together on solving supply chain issues to maintain the cStock system. Further, Key Informant #4 described how the cStock electronic system has promoted teamwork:

> "What is making it very successful for HSAs is that we are still, in terms of product availability and collection there is teamwork among members. The health centres at times before when the system was not in place, the the [*sic*] health centre teams could work in isolation. Now we're coming in with the cStock system. It has brought them together."

To summarize, the key facilitators which contribute to the cStock project scale-up and sustainability are government leadership and commitment to achieving sustainability, commitment of the project to health service and goodwill, providing regular feedback to staff which also helps with boosting motivation, and strong teamwork among different management levels of the cStock project.

Barriers to cStock project scale-up and sustainability

Despite the facilitators, there are barriers hindering scale-up and achieving sustainability for eHealth projects in LMICs. Three key barriers were identified for the

cStock project. They are, (1) Financial affordability, (2) Infrastructure limitations, and (3) Resource constraints.

(1) Financial affordability

It was found that the cStock project is not financially sustainable in the long-term due to the dependence on donor funds. This directly reflects on the financial affordability of cStock for Malawi. Key Informant #5 said "cStock is a paying system, the country needs to pay for it to use it". Further, Key Informant #2 described how it is important to note that financial sustainability is a common issue among LMICs:

> "And so, this [financial sustainability] is I think it needs to be looked at within the broad perspective that in most of the developing economies like Malawi for example, a [*sic*] resource constraints are one of the big issues. So, prioritizing becomes very critical."

The cStock project was carried out in a resource limited setting with major financial support from international donors such as Bill and Melinda Gates Foundation, the Global Fund, UNICEF, and USAID. Key Informant #2 described how the lack of financial input from Malawi MoH is ultimately filled by international financial partners:

> "But what we've seen is much as the Ministry was not able to put in, you know, financial resources immediately to take over that from, for example, the Gates or from the Global Fund. The Ministry actually worked together with a project and provided leadership in terms of linking with potential funders."

It was found that financial support from international partners cannot be perceived as 'free' funds because of power and control that is attributed to money. Hence, aid

dependency is not only an unsustainable financial measure, but also a controlling measure that can be leveraged to make important decisions in project designs, project implementation aspects, etc. Key Informant #1 described this phenomenon as "You know, resources from partners, they make you dance to their tune. That is a problem. So, they're not flexible".

Further, when relying on financial aid from international partners, there is a possibility the project design may not meet local community needs – which inherently deems the innovation or tool unfitting and unsustainable. Key Informant #1:

> "…, sometimes most of the partners that support government supplying services, they have made those plans and, you know, not with the Government agencies […], who know our needs, so the plan is done in Toronto and you come and they want to implement in your own way, and then I would say, no, no, no we have twenty community based health workers and then you say we only budgeted for 15."

This high-level of aid dependency portrays the cStock project as lacking financial sustainability, and hence it lacks the ability to be sustained without foreign aid.

(2) Infrastructure limitations

Participants also described challenges imposed by poor infrastructure as a key barrier to maintaining the cStock project. The two key infrastructure limitations are the lack of appropriate shelter structures for HSAs, and poor mobile network and Internet connections.

Firstly, Key Informant #1 described how HSAs need housing and this challenge was considered as part of the sustainability issues of the cStock project "they [HSAs] need to be always in the community. They need to be housed. They need to provide [*sic*] shelter".

Secondly, Internet connections and mobile networks are poor or unavailable at times. This challenge was described by Key Informant #4:

> "Sometimes it might a problem could be, maybe network or the Internet problem connectivities. It's a big, sorry, a big challenge. You want to see maybe the Internet connection is very poor when you are not sit [*sic*] around and login log into [*sic*] the system and see how the HSAs really [*sic*] all the facilities collect without performing."

Further, Key Informant #4 described the problems with mobile networks for HSAs:

> "Now, the big problem that I have noted is the community connectivity is very very poor in most of the remote areas, so much that every time when there [*sic*], for example, an HSA wants to send a stock on hand report, and there's no connectivity in the area, some of the HSAs have to travel three, four, five, six kilometers to get a good network so that they can send whatever report they have."

These infrastructural challenges continue to hinder the maintenance of the cStock project in Malawi.

(3) <u>Resource constraints</u>

This category of resource constraints includes two key challenges. Firstly, there have been unequal distributions of resources such as essential medicines due to the assignment of specific districts to be managed by specific international finance partners

such as UNICEF. Key Informant #5 described the resource constraints caused by this situation:

> "…, the availability of commodities in some districts. Because the districts in Malawi, we are funded by different organizations. […]. It was a UNICEF district whereby commodities were as available compared to other districts which are funded by other organization as well. So, we are looking at the commodities like for malaria commodities. So, in UNICEF, in UNICEF [*sic*] districts, we gets [*sic*] access commodities. […] there were other districts which did not have any organizations supporting them. So, there'll be misadjustment of commodities. So, it was not a level playing field for all the districts."

Secondly, there are human resource challenges. Key Informant #5 described how the number of master trainers have been reduced to three trainers over the years, and how this has imposed challenges on conducting trainings for HSAs and for other trainers who train HSAs. Also, Key Informant #4 mentioned the unavailability of members of DPAT sometimes, due to other work commitments. Key Informant #4 said "so the availability of members at times is a problem because of the engagement", reflecting on the fact that assigned duties can be overlooked due to unavailability.

Hence, the key barriers to cStock project scale-up and achieving sustainability include the lack of financial affordability and high aid dependency in Malawi; infrastructural problems such as mobile network and Internet connection problems; resource constraints such as unequal distribution of commodities in districts; and human resource challenges.

Theme 3: The impact of the COVID-19 pandemic on the cStock project

In some capacity, all participants expressed the effects they have experienced due to the COVID-19 pandemic during their employment with the cStock project. In this theme there are two key categories: (1) positive perceptions regarding cStock during the pandemic, and (2) challenges imposed by COVID-19 on program maintenance.

(1) Positive perceptions of cStock

Among most participants, the central theme of viewing cStock system in a positive light was clear. It was a shared perception that cStock is the most suitable solution for overcoming challenges imposed by the COVID-19 pandemic. Key Informant #1 described how cStock is a powerful and befitting solution during the pandemic:

> "Despite the COVID pandemic, when you have systems like cStock, you know, and then you are using the mobile application, to get commodities. That is the solution to COVID. You know, on it of us [*sic*], it is something that we are looking at it in direct, but the effects and its strength. It's fantastic. Because cStock, is one of the solutions, in terms of strengthening Supply-Chain for community-based health workers."

Amidst viewing cStock with optimism, participants also mentioned three key benefits of cStock during the COVD-19 pandemic. Firstly, Key Informant #2 mentioned that a national level scaled-up electronic tool such as cStock is particularly useful for rapid dissemination of COVID-19 related information for mass populations in resource-poor settings:

> "cStock, provides an opportunity or in a digital, you know, system such as cStock, provides an opportunity to facilitate information flow from the central level who are basically planning, you know, how to respond to the crisis, to the implementers who are down on the ground. Yeah, and working with limited resources. With cStock, we can actually send standardized messages in that [*sic*] all the HSAs. […] So, they [HSAs] can use it as part of their outreach to disseminate the messages to the community."

Secondly, Key Informant #3 described how an electronic system like cStock helps with reducing human interactions, which is useful during the COVID-19 pandemic, by effectively creating a system so that HSAs can collect their resupply medicines from Health Facilities after sending and receiving pick-up notifications. Key Informant #3:

> "…, we avoid a lot of interactions with the community. It was a [*sic*] once you send your message, you can go there privately as long as it on the first and second day to collect your medicines, but the, that's the benefit."

Thirdly, Key Informant #3 also indicated that relying on the electronic cStock system helps with reducing COVID transmittance from paper-based records. The infection transmittance when using paper records was described as "they'll [*sic*] be more interactions in on the papers, where someone touches the paper and then we without good precaution measures can get the COVID-19 back on" (Key Informant #3). Whereas it was described that with electronic records "you don't touch anything, you just communicate. So, to me, it's like cStock has got an impact opposed the one, because electronics has proved to every

[*sic*] prevent further infection on COVID-19 pandemic" (Key Informant #3). Hence, it was generally considered that cStock offers benefits as an electronic tool at times of crisis.

(2) Challenges with COVID-19

Participants also mentioned several different challenges experienced across various work positions in the cStock project. Four key challenges were identified from the interviews.

Firstly, participants said that training and refresher training programs offered to HSAs, both new and employed, have not been maintained due to social distancing and travel restrictions imposed by the COVID-19 pandemic. Key Informant #4 said "the HSAs, they have not been able to [*sic*] not been able to refresh them, conduct refresher course" and Key Informant #5 stated "So you need to train new HSAs, we needed to train or to refresh the already existing HSAs, but we still with these COVID-19 pandemic, we are unable to conduct training".

Secondly, it was found that limitations associated with working from home due to the pandemic have resulted in network connectivity and mobile network maintenance issues. Key Informant #1 described this challenge:

> "The supply side being the telecommunications companies who are operating from homes. When there are technical connection issues, you know it takes long to support and the, to reconnect. That is where we have [*sic*] we have challenges because of COVID. Connectivity is a very big problem right now."

Thirdly, Key Informant #1 said that lack of appropriate physical spaces for conducting village clinics run by HSAs has posed a challenge because "community-based

health workers used to operate under their homes" which threatens the safety of community members and HSAs because of the infectious nature of COVID-19.

Lastly, at a broader level, there have been resource constraints due to the pandemic. Key Informant #2 said that, in general, there has been a need to reallocate resources and budgets as follows, "what we've seen is a reprogramming of available resources away from some of the activities, let's say, cutting off, you know, some of the budgets here in order to make room to respond to, COVID, as an emergency". Key Informant #1 also mentioned that due to the global nature of the pandemic, there have been supply maintenance problems in Malawi, and described this situation:

> "Because the telecom companies, they cannot maintain their equipment, you know, they buy engineering equipment from India, most of them. Our suppliers are also from India and India is the hardest hit now and everything else is not moving. So it is, it bad, and it has affected us huge."

The resource constraints described above highlight the impact of globalization and the true global nature of the COVID-19 pandemic. The findings of this study clearly show that electronic tools such as cStock offers benefits, despite the challenges at times of crisis.

Theme 4: The role of paper records in the cStock project

The cStock system is an electronic technology that is used in a resource-limited setting to help with SCM in Malawi. Even though the cStock system was available, it was found that paper-based records still played a central role in this SCM project. In this theme

there are three key categories: (1) Paper as a backup system, (2) Paper and human trust, and (3) Disadvantages of using paper records.

(1) Paper as a backup system

Throughout Key Informant interviews, when posed the question 'why continue to use paper records with the cStock electronic system?' – the popular answer was that paper records act as a backup system. It was found that cStock was considered to be unreliable due to network challenges, and to ensure information is recorded and the supply chain system can be maintained, paper records were used. Key Informant #3 expressed this grave concern of unreliability of cStock and why paper records are viewed as the solution to maintaining accurate supply records:

> "We believe that there are some advantages that the paper-based has, especially when the system is maybe about that already or maybe it has some problems: where do we get the back-up from? information to seeing into the same system? So, we are still using the paper-based, not as the [*sic*] our main reporting tool, but still is [*sic*] as a backup tool."

Also, to highlight the role of paper records as a backup system, Key Informant #4 described the immense reliability of paper records as, "Sometimes network is a very big problem. This has led to other people, not sending the report on time, sending late report, and others were still not reporting at all, but lived depending on paper-based reporting form".

Further, Key Informant #4 described how using paper records are strongly promoted and encouraged by HSAs to be used alongside of cStock to maintain an accurate

supply record. Key Informant #4 stated "Those the other forms, besides using cStock, we also train them [HSAs] that they should not stop using paper-based reporting form".

Lastly, Key Informant #3 captured the role of paper records as a backup system and secondary reporting tool with the captivating analogy of:

> "We do use the paper-based, like something that is a back-up or is historical background or whatever is happening on the cStock, or something that we keep like, there is a New Testament, if you, if you [*sic*] in your Bible and the Old Testament. So cStock is like a New Testament of the way we do things."

(2) Paper and human trust

When the role of paper records within the cStock project was examined further, it was observed that human trust is inherently associated with paper records. It was found that users of cStock viewed electronic systems with slight mistrust because of the unreliable nature of digital systems, especially in resource limited settings due to poor network connectivity. Key Informant #5 described this situation:

> "Whereby people, were saying maybe cStock system, cannot be trusted wholly, if maybe we are to use one system, and then the cStock system as any electronic system maybe, is [*sic*] maybe compromised in an event where maybe there's an issue, maybe like what we, we are experiencing in Malawi."

Further, it was found that cStock users resorted to paper records at times when cStock was not available, which suggests that paper records are perceived as the familiar and comfortable form of reporting tool, which is inherently associated with long-term trust

placed on paper records. Key Informant #5 provided insight on the familiarity of paper records:

> "So, paper-based reporting initially it was like, the lifeline, if cStock may be, gets, if cStock is not functioning, people then go back to and look for the paper-based reporting. So, the paper-based reporting, was there to support the cStock system, in case of eventualities like what happened? [*sic*] We are not using the cStock system, but still, we are using the paper-based reporting."

Moreover, this high-level of human trust placed on paper records could also be connected to the tangible nature of paper records which is not offered through electronic records. It was observed that cStock users have placed paper records on a higher pedestal compared to the unreliable cStock system. Key Informant #3 described how cStock users could rely on paper records anytime without any challenges to continue their workflow because of their readily available nature. The views of Key Informant #3 are:

> "But the paper-based now is like, that keeping some records that if, even if your phone maybe is broken or the system is, has got some problems now we can as well, count a check on how the system is working. Like is the system resupplying the right quantities? [*sic*] Now, now, it's like the paper based was there just to check on how the system is resupplying, the resupplying medicines and even the cStock system was was [*sic*] working, the paper based was like a referee to the system. So, paper based was used like a back-up."

Hence, due to the familiar and readily available nature of paper records, it can be inferred that paper records are a trustworthy form of a backup system for the electronic cStock system.

(3) Disadvantages of paper records

Despite the deep connection and trust associated with paper records, it was a shared view that there are major disadvantages of using paper records in an SCM setting. Key Informant #3 stated: "it [paper record] is very slow, it needs a lot of resources, time, with a lot of inadequacies, like in calculating how much to be resupplied". Further, Key Informant #3 compared the possibility of making errors in calculations on paper records to the accurate and minimal-error nature of cStock:

> "…, as this cStock system is automated. So, in order to mention with the cStock system, we learned out some errors like adding two plus two to say six is always false, because its automated. So, it's like in, the paper based has got a lot of errors."

Lastly, it is important to note that despite these disadvantages of paper records, paper is still used as the back-up system due to human trust and reliability of paper records, in the context of the cStock SCM project in Malawi.

Theme 5: Transitioning to full electronic SCM and health (eHealth) systems in Malawi

The current cStock SCM project in Malawi relies on both electronic and paper records. Hence, the possibility of transitioning to full electronic SCM and health systems in Malawi was examined in this research. There are two key categories in this theme: (1) views on achieving full electronic systems in Malawi, and (2) challenges to transitioning to full electronic systems in Malawi.

(1) Views on full electronic systems in Malawi

It was found to be a shared perception that achieving full electronic SCM and health systems in Malawi was viewed in a positive light filled with optimism. Key Informant #1 described with excitement the possibility of achieving full electronic systems: “in general, we want to go the digital way, full through auto”; and Key Informant #2 also stated: “So transitioning the paper based, you know, systems to electronic is a great opportunity that needs to be explored”. This optimism shows the motivation for achieving full electronic systems in the future in Malawi.

(2) Challenges to transitioning to full electronic systems in Malawi

Despite the optimistic views on achieving full electronic systems in Malawi, participants also shared two potential challenges that could hinder the transition to full electronic systems. Firstly, Key Informant #1 described that interoperability issues can arise when there are compatibility issues among different digital systems, describing the issue of interoperability as: “Looking at the strengthening or indeed making digitization only for cStock and the other systems, when the other systems, you know, are not supportive, it has always posed a challenge”.

Secondly, Key Informant #2 said that locally hosting the server of digital systems in resource limited settings can be a significant challenge when transitioning to full electronic systems. Key Informant #2 expressed this: “I think one area we will need to critically look at is the issue of hosting. I think different countries are at different levels in terms of capacity to host and the technical ability to manage the service”.

Lastly, Key Informant #2 emphasized that it is important to "thinking through and planning for it" before transitioning to full electronic systems in Malawi. This directly resonates with the importance of long-term planning in large-scale eHealth projects.

Theme 6: Recommendations

During Key Informant interviews, participants mentioned three key recommendations to help improve cStock and potentially future SCM and eHealth systems in resource-limited settings.

(1) Ensuring the continuity of cStock

It was observed that participants highly valued the life-saving benefits of the cStock system. Key Informant #4 said "if only the system, cStock was up and running beneficial, this is going to be very good" and highlighted reasons such as the large-scale nature of cStock, "we're talking about close to 5000 individual players within the system, they are practicing this", and the benefits of cStock such as "monitor the availability of drugs. […] inform the HSA when to get to the go to the facility, when and not to go to the facility to collect the products". Further, Key Informant #5 emphasized the frustration of discontinuing or not maintaining a system that has been in use for a long time, as follows:

> "So, we need to see, if we, there's continuity no matter what. Because if you started, if we started a program, when you get to use it up to the ink. But now, it seems it's like people just tested it, but the [*sic*] they're not using it. So, we should look at the long-term plan."

The concerns regarding long-term continuity of cStock highlights the challenges associated with lack of self-sustainable eHealth programs, and how discontinuation of long-

term projects can cause distress and frustration for users. This is after all; their time and energy were spent on learning a new tool and experiencing life-saving benefits. Hence, the key recommendation is to ensure the long-term sustainability of a project.

(2) Equal distribution of resources in all districts

The second recommendation was offered by Key Informant #4, with regards to the assignment of individual districts to specific international partners to maintain only the assigned districts. Resembling theme two study findings, this situation has resulted in unequal distribution of resources among districts. Key Informant #4 stated:

> "Had it been, all districts supported by one, or there was the one group of, um ser [*sic*], a group of suppliers, there's one basket supplying to all these facilities that we [*sic*] we should be feeding from one place. Maybe the issue of having stockouts could be an issue of the past."

Considering the above recommendation, it could be worthwhile to consider the assignment of specific international or external partners to specific commodities such as mobile devices, or stock supplies, instead of assigning specific districts to partners.

(3) Developing digital Mobile Apps

The final recommendation provided by participants was regarding the development of digital tools such as a mobile app to help facilitate data transfer even when there is mobile network congestion. This solution is in response to the existing network congestions when HSAs use SMS to send information to the cStock system. Key Informant #5 shared the following recommendation:

> "… if the developers then maybe develop an application in [*sic*] now. […] a mobile app so that people might be using it. Maybe it could minimize issues of having two mobile operators getting hold of the system. Because one mobile operators [*sic*] were saying of congestion when the HSAs are sending messages."

This recommendation is of importance because it also shows the willingness of members to adopt eHealth tools. As the target users of eHealth tools become more willing and open to adopting new digital tools, it may reduce any sociocultural barriers or resistance to implementing and sustaining eHealth projects in the long-term.

In summary, there is an overlap and commonality between the relevant search results of the literature review and the findings presented, especially in themes one and two of the cStock case study. Six themes were presented as findings for the cStock case study in this chapter. Theme one identified key facilitators to implementation such as strong government commitment, and strong local and global partnerships. Also, it was found that financial limitations, partnership maintenance, resource limitations, and management and worker issues acted as the key barriers to implementation of cStock. Theme two identified key facilitators to project scale-up and sustainability as strong government leadership, portraying a commitment to improving health service via cStock, providing regular feedback to staff, and strong teamwork. It was also found that poor financial affordability of cStock, infrastructure limitations, and resource constraints act as the major barriers hindering cStock project scale-up and sustainability. Theme three focused on the impact of the COVID-19 pandemic. It was found that cStock was perceived with optimism during the pandemic especially due to benefits of cStock technology. Additionally, there were

challenges imposed by the pandemic such as limitations with shelter or physical spaces for HSAs to run village clinics by HSAs, and discontinuation of training and refresher courses provided to HSAs and other staff.

Theme four presented findings on the role of paper records in the cStock project. It was found that paper is used as a back-up system and there is strong human trust associated with paper. Theme five focused on the possibility of transitioning to full electronic SCM and health systems in Malawi. It was found that there were positive perceptions and optimism associated with achieving full electronic systems, and several challenges hindering the process such as interoperability and local hosting of server. Lastly, theme six identified three key recommendations to improve cStock and future eHealth applications in Malawi and other resource limited settings. The recommendations were: ensuring the continuity of cStock, ensuring equal distribution of resources in all districts, and developing digital mobile apps. In the next Chapter, a discussion of the findings will be presented with support from findings of the literature review and other literature.

CHAPTER 06 – Discussion

In Chapter Five, I presented the relevant findings of the literature review for the cStock case study, and the findings from the thematic content analysis of cStock Key Informant interviews. In this Chapter, I will discuss and interpret the findings of the cStock case study in relation to the findings from the literature review and other existing literature. In the section that follows, I will formulate my interpretation in terms of the six major themes of the cStock case findings.

Theme 1: **Facilitators and barriers to cStock implementation**

In any eHealth project, the implementation phase is particularly challenging. In the conceptual framework for evaluating eHealth projects by Khoja et al. (2013), the project implementation phase is viewed as the foundation for sustaining an eHealth project where projects can be evaluated and alterations can be accommodated to sustain projects in the long-run. Multiple facilitators and barriers related to cStock implementation were identified, which are summarized in *Table 1* with support from the literature review findings.

Table 1. *Summary of cStock case findings for Theme 1*

Facilitator (F)/ Barrier (B)	cStock Case Findings	Support from the Literature Review
Local and global partnerships (F)	- Global North-South partnerships are necessary to financially support eHealth projects. - Global goals like MDGs helped in developing partnerships with financial and technical partners.	- 72% of DH projects are donor-funded (Tran Ngoc et al., 2018). - South-South partnerships in mHealth projects helps in knowledge sharing, similar experience sharing, and engaging local developers for

Facilitator (F)/ Barrier (B)	cStock Case Findings	Support from the Literature Review
	- South-South partnerships are a motivator and useful for sharing knowledge.	project development (Curioso & Mechael, 2010).
Government commitment (F)	- National government commitment in terms of administrative, policy, technical, and human resources supported project implementation.	- Conveyed government support through mHealth/eHealth strategies, and the will of the government to integrate mHealth projects. (Aranda-Jan et al., 2014).
Benefits of Technology (F)	- Low-cost of the cStock system. - Simplicity of cStock as it uses only SMS texting. - Improved data visibility when using cStock.	- DH systems can be fast-acting, with easier workflows, and ease of use by users in public hospitals of Kenya (Muinga et al., 2020).
Performance enhancement (F)	- Frequent training and supervision.	- Frequent training programs for project staff and ensuring the availability of a more experienced member on site for support (Oza et al., 2017). - Not needing advanced training for eHealth projects is a facilitator (Chaplin et al., 2015).
Financial limitations (B)	- Financial limitations were a barrier to implementing cStock. - Lack of funding hindered the execution of eHealth policies, strategies, and evaluations.	- Financial limitations as a barrier to project implementation (Alshahrani et al., 2019; Aranda-Jan et al., 2014; Granja et al., 2018; Källander et al., 2013; Kiberu et al., 2017; Muinga et al., 2020).
Partnership maintenance (B)	- Difficulties with maintaining public-private sector partnerships with telecommunication service providers due to differing interests.	- Difficulties with partnership maintenance due to challenges such as distinct priorities between the government and on-site application developers, and difficulty in collaborating with multiple stakeholders (Källander et al., 2013).
Resource limitations (B)	- Resource limitations such as medicine stockouts, availability of mobile phones for HSAs, and infrastructure issues.	- Infrastructural problems - unreliable electricity and Internet connectivity (Allen et al., 2007; Alshahrani et al., 2019; Aranda-Jan et al., 2014;

Facilitator (F)/ Barrier (B)	cStock Case Findings	Support from the Literature Review
		Bakibinga et al., 2020; Chaplin et al., 2015; Källander et al., 2013; Kiberu et al., 2017; Manders et al., 2010; Muinga et al., 2018, 2020; Oza et al., 2017).
Management and Worker issues (B)	- Lack of coordination and communication among management levels within the project. - Negative attitudes or resistance to the cStock SCM project in the early days by medical assistants.	- Project staff resistance to adopting new systems and poor willingness to use technology in LMICs (Alshahrani et al., 2019; Muinga et al., 2020).

Local and global partnerships were found to play an important role in fueling the implementation of the cStock project in Malawi. According to the *National Digital Health* (DH) *Strategy* of Malawi, it appears that the collaborations and partnerships within government departments have been especially helpful for implementing DH projects in Malawi (Ministry of Health, 2020). Further, Olu et al. (2019) describes how private sector partnerships, especially with telecommunication companies, are important for maintaining DH projects by showcasing the example of how the African Regional Office of WHO partnered with the International Telecommunication Union in order to improve partnerships between the national Ministries of Health and telecom companies.

Moreover, global North-South partnerships, as cStock participants also highlighted, are a key driver in eHealth projects. eHealth projects in the global South can mostly only be implemented with financial and technical support (foreign aid) from global North partners. Malawi MoH describes how the majority of DH initiatives are donor funded in

Malawi (Ministry of Health, 2020). Also, in African countries 72% of DH projects are donor funded (Tran Ngoc et al., 2018). This suggests that foreign financial investments play a significant role in implementing and sustaining DH projects, hence the need for funds in the global South may reinforce the need for global North-South partnerships in LMIC eHealth projects.

Further, the cStock participants highlighted how the MDGs promoted the cStock project and helped with developing donor partnerships. This suggests that similar interests and high-level global goals (e.g., MDGs) promotes global North-South partnerships. It is important to note that cStock has been sustained for nearly 10 years and even after the MDGs transitioned to SDGs, which shows that cStock is a rare example of an eHealth project in the sub-Saharan Africa context that was able to realistically achieve initially projected outcomes. This is not always the case, as it can be difficult to achieve expected outcomes in LMIC eHealth projects. An example of this situation is the health sector and DH in Nigeria. Nigeria was motivated to achieve the MDG targets in the beginning by assigning government funds, office space, and personnel; however in 2015, Nigeria was still responsible for the majority of the world's extremely poor population and was not able to achieve its MDG targets (Oleribe & Taylor-Robinson, 2016). Some of the key reasons cited for this failure were lack of evaluations, relying on incorrect assumptions about the initial country status, and violence and insurgency (Oleribe & Taylor-Robinson, 2016).

Another aspect of partnerships in eHealth projects arise from South-South partnerships. *Table 1* highlights benefits of such partnerships including sharing knowledge and experience (Curioso & Mechael, 2010). Amid the benefits, it is important to consider

the nature of these partnerships. In contrast to global North-South partnerships, South-South partnerships tend to be based on principles of equality in terms of power and authority distributions (Buss & Faid, 2013; Cheru, 2016). Also, these partnerships tend to have disadvantages and may be intricate. An example in the context of South-South partnerships between Africa and China were issues that included export market competition, substandard labour practices, and competitions in regional and local markets for product availability and imports (Cheru, 2016). Further, Buss & Faid (2013) describe how South-South partnerships began forming in the 1950s in an effort to collaborate and move against colonialism imposed by the global North. This suggests that these partnerships may not have formed due to natural phenomena or closeness in geography – rather, these South-South partnerships were influenced by global North power relations.

Similar to views expressed by cStock participants, the *National DH Strategy* of the Malawi MoH also highlights the strong government commitment provided for DH projects, such as establishing a Technical Working Group to collaborate with and support stakeholders, and human resource support for program implementations (Ministry of Health, 2020). Further, Pisa & McCurdy (2019) highlighted how national government support for establishing and maintaining positive relations with funding organizations shows government commitment for eHealth projects in LMICs. Further, Olu et al. (2019) provide support for how eHealth policies developed by national governments show commitment and national interest in such projects (Ministry of Health, 2020). Olu et al. (2019) also indicate that eHealth benefits are only experienced in the long-term when projects align with national interests.

Benefits of eHealth technology acted as a facilitator in the cStock project (*Table 1*). The simplicity of the cStock platform, which uses SMS texting by frontline health workers, as expressed by cStock participants is a shared view among other SMS-based mHealth users in LMICs (Drake et al., 2020). The same study also describes other advantages of SMS mHealth technology which includes low-cost of data collection, increased usability since SMS texting requires less time to respond compared to phone calls, more privacy, and increased accessibility of SMS texts for communication. Another aspect of eHealth technology is improved data visibility which results in more accountability in these projects. Describing the impact of the cStock project in Malawi, Shieshia et al. (2014) highlighted improved data visibility after cStock implementation, which aligns well with views of the cStock participants. It can be inferred that improved data visibility and accountability achieved through eHealth technology can act as a motivator for system users and frontline workers to continue to rely on technology and continue eHealth projects in LMICs.

Despite the optimistic facilitators for the cStock implementation, there are four key barriers to project implementation. Firstly, financial limitations are a significant barrier to eHealth project implementations, and this is a common concern in LMICs (*Table 1*). Similar to views of cStock participants, Olu et al. (2019) also described how lack of funding can hinder the execution of existing eHealth or DH policies and strategies in LMICs. These key problems associated with financial limitations and the prevailing nature of financial constraints in LMICs can be recognized as a key implementation challenge.

Secondly, cStock participants described the challenging nature of maintaining public-private sector partnerships in Malawi due to differences in interests, which is also supported by literature review findings (Källander et al., 2013). Despite the key role of public-private sector partnerships in eHealth projects, there can be challenges to reap benefits from these partnerships. A study regarding public-private partnerships in the context of health policy in Kenya and Ghana describes how challenges of public-private partnerships include "lack of information sharing; weaknesses in management capacity; funding insecurity; mismatched organizational styles and differing priorities; and corruption" (Suchman et al., 2018, p. 779). Despite differing views among partners, collaboration, effective communication, and similar goals can help with maintaining strong private-public partnerships in health projects in LMICs (Suchman et al., 2018).

Thirdly, resource limitations such as medicine stockouts and infrastructure issues were mentioned by cStock participants, which were also supported by the literature review findings (*Table 1*). Looking more closely at the problem of medicine stockouts, literature suggests it is a common occurrence in LMICs. The Center for Global Development mentions that, in 35 countries, 36% of antiretroviral therapy clinics reported a minimum of one stockout in a period of one year (Pisa & McCurdy, 2019). The same paper also highlighted how 29% of health facilities had an ACT (malaria drug) stockout during a 15-month period. In a study about HIV-related supply chains in LMICs, Minior et al. (2017) described how medicine stockouts are frequent in LMICs, and problems such as financial and infrastructural limitations contribute to medicine stockouts. These challenges reflect

the lack of health system and health infrastructure strengthening measures in LMICs, which can also be connected to the long-term need for major funds from donors.

Lastly, management and worker issues, such as poor project coordination and resistance to change (i.e., resistance from medical assistants to provide HSAs the responsibility to provide medications to communities), were identified as a barrier for the cStock project implementation in Malawi, which is also supported by the literature review findings (*Table 1*). Similar situations have been cited in other literature such as Feroz et al. (2020) describing the failure of an mHealth initiative in rural Nepal due to challenges such as poor project management, data operationalization being unclear and inconsistent, and changes in leadership.

It is important to recognize that these facilitators and barriers are dependent on each other. It can be inferred that the two key factors determining the success of an eHealth project implementation in an LMIC will be project finances and funds, and local and global partnerships. Without adequate funding it appears to be impossible to execute an eHealth project; and without strong partnerships (within a nation, global North-South, global South-South) it would be difficult to secure funds and other resources (e.g., technical capacity, knowledge sharing) and spearhead the implementation of the project. Hence, as a final note, eHealth project development and implementation in LMICs is fueled by global collaboration.

Theme 2: Facilitators and barriers related to scale-up and sustainability of the cStock project

From the long-term successful maintenance of the cStock project it is possible to distill lessons related to facilitators and barriers for the cStock project during scale-up and achieving sustainability. Several facilitators and barriers were identified, which are summarized in *Table 2* with support from the findings of the literature review.

Table 2. *Summary of cStock case findings for Theme 2*

Facilitator (F)/ Barrier (B)	**cStock Case Findings**	**Support from the Literature Review Findings**
Government (MoH) leadership (F)	- Government commitment, and willingness has helped sustain the cStock project. - Without commitment from stakeholders that possess the problem (national government), it is difficult for external stakeholders to sustain a foreign project.	- A recognized need for political will and commitment to scale and sustain eHealth projects (Tran Ngoc et al., 2018). - Recognized need for government ownership and involvement to scale and sustain eHealth projects (Shuvo et al., 2015).
Commitment to health service (F)	- Service-oriented goal of cStock to improve child health in Malawi. - Positive cStock project vision aligned with donors' visions allow project sustainability.	- N/A
Regular feedback (F) and Teamwork (F)	- Regular feedback and teamwork identified as facilitators. - Providing feedback to HSAs regularly acts as a motivator.	- N/A
Financial affordability (B)	- Financial limitations identified as a key challenge. - Financial limitations often lead to foreign aid dependence. This ultimately allows donors to influence the project designs and implementations, where local community needs may not meet.	- Financial constraints are recognized as a key challenge (Kwao et al., 2019; Sundin et al., 2016). - The need for funds results from increase in financial cost as number of system users increases (Kwao et al., 2019). - Sustainable eHealth projects should aim to meet local community needs (Shuvo et al., 2015).

Facilitator (F)/ Barrier (B)	cStock Case Findings	Support from the Literature Review Findings
Infrastructure limitations (B)	- Poor network connections. - Lack of appropriate physical space for village clinics run by HSAs.	- Inaccessible roads, poor transportation systems, unreliable electricity, and narrow Internet bandwidth (Shuvo et al., 2015; Sundin et al., 2016). - Phone theft and poor memory capacity (Sundin et al., 2016).
Resource constraints (B)	- Unequal distribution of resources such as medicines. - Limited human resources – reduced number of master trainers.	- N/A

One of the most important facilitators for the cStock project continuation and scale-up has been government (MoH) leadership; this is also supported by the literature review findings (Shuvo et al., 2015; Tran Ngoc et al., 2018) (*Table 2*). The *National DH Strategy 2020-25* by the Malawi MoH also highlights the importance of government ownership of DH projects to sustain them, especially since the successful end goal of donor-funded pilots is considered to be the transfer of the project to the government (Ministry of Health, 2020). On the other hand, having no government support and commitment for an eHealth project can result in project failure with no possibility of scale-up and sustaining the project. This is conveyed in the DH strategy as the MoH highlights "lack of centralized coordination" in projects has birthed multiple small-scale projects which in turn have limited government ownership of these eHealth projects in Malawi – hence no possibility of sustaining them (Ministry of Health, 2020, p. 28).

Another key facilitator is the project commitment to health service. It is important and refreshing to recognize the humanity promoted through this project – the life-saving impact of the cStock project (*Table 2*). The work of HSAs is highly valued in hard-to-reach

areas in Malawi where otherwise basic healthcare is inaccessible – resulting in high child mortality rates (Shieshia et al., 2014). This valuable aim of making healthcare more accessible may also have helped with achieving scale-up and sustainability for cStock. Feroz et al. (2020) also highlighted the value of the healthcare service provided by CHWs in LMICs and how CHWs are important for the communities in hard-to reach areas where the only healthcare available is through CHWs. Hence, it is key for an eHealth project to have a positive service orientation which can be impactful for communities in need.

In the spirit of communication and collaboration, regular feedback and teamwork were also identified as facilitators in the cStock project context. HSAs are considered to be the core of the cStock project. Hence, providing regular feedback and motivating them helps in creating a positive experience for the end users, which in turn helps with user-retention and sustaining the project. Shieshia et al. (2014) also described how the feedback component of the cStock system has helped in motivating HSAs. Similar to the cStock project, teamwork also plays a central role in executing the *National DH Strategy* of Malawi (Ministry of Health, 2020). An outline of the coordination framework is highlighted in this strategy, and coordination among various departments within the government is promoted. Hence, in eHealth projects collaboration plays a key role in achieving success.

Amid the facilitators, cStock participants also identified key challenges in the scale-up of the cStock project. The main challenge for scaling-up and then sustaining the cStock project and other LMIC eHealth projects is financial limitations (Kwao et al., 2019; Sundin et al., 2016). The great majority of eHealth projects, including cStock, are not profitable

projects or businesses. Hence, the increase in usage of the project (e.g., system users increase) accrues financial cost without any financial gains – which leads to the need for additional investments to sustain the project (Kwao et al., 2019). Yet, domestic investments in eHealth projects tend to be limited. The 2019-20 Health Budget Brief of Malawi by UNICEF stated that the health sector is the third priority and 9.4% of the national budget is allocated to the health sector by the government (UNICEF Malawi, 2020). The same brief also highlights that from 2012-13 to present time, the health budget in Malawi has been below the Abuja declaration of allocating 15% minimum of total national budgets to health (UNICEF Malawi, 2020). Hence, low domestic investments in public health results in relying on external funds or foreign aid for health projects. According to the Health Budget Brief, 85% of the total health budget of Malawi is expected to be donor-funded in the 2019-20 fiscal year (UNICEF Malawi, 2020). One key downside to foreign investments is that this results in eHealth projects lacking financial sustainability. In the *National DH Strategy* for 2020-25, Malawi MoH indicated that it expected the majority of DH projects will only be maintained for five years, during the funding period determined by donors. This is because the MoH cannot continue to maintain many of the DH projects after donor funds end (Ministry of Health, 2020). This unfortunate situation in Malawi directly reflects on the sustainability of the cStock project and of similar financial situations in other LMICs.

The lack of financial affordability and heavy reliance on foreign aid may lead to asymmetric power distributions between the global South recipient MoH and global North donors. The literature demonstrates that donor funding has underlying interests and can often influence national decision-making, policymaking, and policy implementation to

align with global North donor interests. Related to health policy in LMICs, it appears that when large funds are provided to global South recipients, global North donors may influence recipient decision-making related to national health policies (Khan et al., 2018). This can also occur through imposing conditions when providing funds and monitoring activities. Further, influencing recipient nations' health policies can have issues such as "overshadowing of recipient countries' existing programs and priorities, overlooking strengths and absorptive capacities of national health systems, and their ability to sustain gains once donor funding ends" (Khan et al., 2018, p. 216). Another study about donor influence on malaria control programs in LMICs highlighted that having multiple donors to fund a project can help strengthen and promote negotiations that benefit both parties; and having guidance and support from international experts can help promote or contribute to higher level global agendas (e.g., universal health coverage) but this can also hinder the realities of local nations hence the project may not be feasible for resource-poor settings (Parkhurst et al., 2021).

This also suggests that global digital development strategies and frameworks created by international organizations such as WHO, USAID, and the Global Fund, ultimately can influence the project design, leadership, and implementation of eHealth initiatives in LMICs – by promoting views, values, and interests of these international organizations. For example, the *National DH Strategy* of Malawi indicates that the strategy had been created with guidance from the *Principles for Digital Development*, which were created with contributions from key international organizations such as the UNICEF, WHO, USAID, and the Bill and Melinda Gates Foundation (Ministry of Health, 2020;

Principles for Digital Development, n.d.). Also, it can be seen from the DH strategy of USAID that these international organizations in fact have some influence on the decision-making related to DH projects in recipient nations (USAID, 2020). The USAID DH strategy suggests that USAID is able to improve technical capacity to inform decision-making in partners, and also to leverage the private sector and the general public to improve accountability of governments (USAID, 2020).

Global North donor influence on policies in LMICs extends to eHealth projects implemented in LMICs, as projects are often developed and designed by global North members who could be unaware of local community needs and operations in the country of project implementation. Similar views were expressed by cStock participants. Also, the literature review findings suggest that a sustainable eHealth project should meet local community needs; funds and investments should be used to "respond to real needs and priorities"; and that these projects should be considered as a collaboration among partners (Shuvo et al., 2015, p. 98). This highlights the importance of understanding community needs and ensuring that all partners have a collaborative approach to partnerships rather than fostering unequal power distributions between 'partners' in an eHealth project.

Other challenges for the cStock project scale-up and sustainability include infrastructural limitations and resource constraints, and these challenges coincide with findings of the literature review (*Table 2*). It is important to recognize that these infrastructural and resource constraints are directly associated with lack of funds available to develop key health infrastructure and improve the health of populations in LMICs. This ties into heavy aid dependency in LMICs and especially in countries in sub-Saharan Africa,

reinforcing the point that foreign aid may not be viewed as a temporary assistance provided to boost development projects in a nation (Moss et al., 2006). If it is understood that the financial aid is temporary, then it may act as a motivator for LMIC national governments to move towards self-reliance. Hence, Moss et al., (2006) explain that when developing countries rely on foreign aid for a long time period (e.g. three to four decades and more) then foreign aid is not used for capacity building, rather it is used for daily spending or daily survival. This hinders any possibility of improving the domestic economy to achieve sustainability and self-reliance. Hence, considering the ambiguous role of funds in eHealth projects, it can be inferred that the key driving factor which determines scale-up and sustainability of an eHealth project in LMICs is the financial affordability of projects by national governments.

Theme 3: The impact of the COVID-19 pandemic on the cStock project

The COVID-19 pandemic has affected our society at institutional and individual levels. Participants viewed cStock in a positive light in the context of COVID-19 due to benefits offered from using the electronic cStock system (1). These benefits align well with views present in existing literature. Firstly, similar to the cStock Key Informants, in a study focusing on DH technologies in Africa, it was described that rapid health information dissemination can be supported through digital technologies such as when disseminating public health information (Olu et al., 2019). Secondly, Al-Ruzzieh et al. (2020) also pointed out that eHealth tools facilitate social distancing measures imposed by the COVID-19 pandemic by reducing physical interactions, which aligns with the views of cStock participants. Thirdly, the same study also demonstrated that paper records act as a disease

carrier, hence using electronic tools or eHealth applications help with mitigating infection transmission, similar to the descriptions of cStock participants.

Aside from the benefits described by cStock participants, O'Donovan et al. (2020) described other benefits of using mHealth during the COVID-19 pandemic, using views of CHWs in Mexico, Uganda, Ghana and Liberia. Some of these benefits include helping contact tracing and recording of COVID-19 cases using simple SMS technology; and improving communication among CHWs by using mobile apps such as WhatsApp (examples in Uganda and Ghana) to provide peer support and motivation during crises.

Despite viewing cStock in a positive light, participants also highlighted challenges imposed by the COVID-19 pandemic that have disrupted the maintenance of the cStock project in Malawi (2). The literature also presents similar challenges in LMIC eHealth projects during the COVID-19 pandemic. O'Donovan et al. (2020) indicate that, due to the physical distancing necessary to overcome the pandemic, training and supervision provided to CHWs could be hindered. The same article recommends the use of mHealth tools to provide virtual training and supervision for CHWs. For example, the Liberian MoH is in the process of adding COVID-19 material to an existing online learning system used by more than 3500 CHWs through their smartphones (O'Donovan et al., 2020).

Another key challenge supported by literature is the global level supply chain problem imposed by the COVID-19 pandemic. In a study providing recommendations for the pandemic response in LMICs, Ballard et al. (2020) identified the global problem of limited supplies of personal protective equipment and lack of supply chain maintenance due to the pandemic. The same study also indicated the importance of prioritizing health

workers and CHWs and ensuring that health services are continued during the pandemic in LMICs. This relates particularly to the challenge of maintaining village clinics by cStock HSAs in Malawi due to lack of physical space to facilitate social distancing. Further, Ballard et al. (2020) recommend investing in supply chains to ensure that essential products and medicines can be made available at community level in LMICs. Hence, in my view, it is imperative that HSAs in Malawi be well-supported and the cStock system is maintained during the pandemic to ensure health services are continuously available.

Moreover, it is my view that eHealth tools are beneficial during crises. However, it is also important to recognize that the pandemic scenario experienced in the global South is different from the global North. Ballard et al. (2020) highlight how particularly LMICs may not have the necessary resources to withstand and overcome the economic impact of the COVID-19 pandemic. In contrast, a recent report by the World Bank promotes the adoption of digital technologies in all sectors to improve the economy in sub-Saharan Africa (World Bank Group, 2021). This involves creating more employment opportunities to strengthen the economy, and using digital technology as a solution for averting financial limitations that entrepreneurs experience by adopting innovations like digital loans (World Bank Group, 2021). Hence, it is my view that eHealth tools or other digital technologies like cStock should continue to be promoted, advocated for, and used despite the challenges imposed by the COVID-19 pandemic in Malawi and other LMICs.

Theme 4: The role of paper records in the cStock project

In the context of cStock as a SCM tool in Malawi, paper records play a central role in large scale operations by assuming the role of a backup system to maintain accurate records and communication among management levels. To understand the role of paper records in the cStock project, participants described their role as a backup system and trusting paper records while using the electronic cStock system, despite the disadvantages of using them.

Literature also supports and provides examples of using paper systems as a backup in LMICs and placing a high level of trust in paper records. A study describing the implementation of an EMR system in Ghana pointed out that power, Internet connectivity, and the EMR system are unreliable at times and required an automatic data backup to prevent any loss of data in the EMR system (Gyamfi et al., 2017). This relates to the views of cStock participants on how paper records are useful as a backup system. Also, the ubiquitous and tangible nature of paper records contributes to the usability of paper as a backup system for eHealth applications in LMICs. Weeks (2013) postulates that a main barrier to adopting EMR systems is the clinic work culture associated and promoted by paper record systems. Hence, familiarity and comfort associated with paper records probably resulted from building trust in the use of paper medical records in clinics. This can be deduced for the cStock case study as a feeling of trust that participants have built up over time through familiarity with paper records.

The motivation for transitioning to and adopting eHealth or other electronic tools in resource limited settings can be attributed to the disadvantages of using paper records. Oza et al. (2017) described the time intensive nature of paper records compared to an EHR

system; and both Oza et al. (2017) and Feroz et al. (2020) described the high rate of errors when using paper records. These findings support the cStock case findings. Other disadvantages mentioned in the literature include issues with tracking paper records, difficulties with providing supervision for CHWs, and hardships with carrying paper records during household visitations by CHWs (Neupane et al., 2014). Also, literature on the Malawi cStock project highlighted the low rate of 29% of available HSA paper logistics data from Health Facilities prior to the cStock system implementation, compared to the ability to access data from more than 80% of HSAs post-cStock (Shieshia et al., 2014). This aligns well with cStock participant views on improved data visibility after cStock implementation. Furthermore, Feroz et al. (2020) also described how in Kenya, an mHealth tool implemented for CHWs helped with improving the CHW data reporting rate and accountability compared to CHWs who only used the paper-based tool.

It also appears that the disadvantages of using paper-based supply chains acted as one of the motivations for adopting and maintaining the electronic cStock system as an SCM tool. A study focusing on antiretroviral (HIV/AIDS medication) supply chains in LMICs highlighted the difficulty of adapting when problems arise due to poor communication when paper-based information systems are used in supply chains (Minior et al., 2017). Additionally, a scoping review on vaccine supply chains found that using digital SCM tools instead of paper-based systems helped to improve data visibility on vaccine stocks, communications in the supply chain, and allowed for easy availability and access to stock information (Iwu et al., 2019). In contrast to the limitations of using paper records for SCM, the findings of the cStock case study also showed that using electronic

forms for data entry beginning from the community level to higher-level District or National level management allowed for more data visibility and accountability in the supply chain. Hence, it can be discerned that the cStock system has been a suitable and successful SCM tool in Malawi due to the ease of use, reliability, transparency, and data visibility promoted by the cStock system.

It is also important to recognize that paper record systems can promote corruption or misuse of resources, especially in LMIC settings, even though the findings from cStock participants did not reveal any matters related to corruption or inappropriate use of resources. The Center for Global Development found that the large-scale and intricate nature of health supply chains, especially for medicines, tend to carry the risk of corruption (Pisa & McCurdy, 2019). This is because medicines go through many actors in a supply chain before reaching the community health facility, which tends to promote medicine theft and reduced accountability (Pisa & McCurdy, 2019). Although this kind of activity was not observed in the cStock project, it is still important to recognize the role of paper records in facilitating corruption in the SCM context in LMICs. Another study examining the practice of corruption in supply chains highlighted how corruption hinders achieving SCM project sustainability, reduces trust among stakeholders and at management levels, and negatively impacts finance and business aspects of the project (Silvestre et al., 2020).

In the context of corruption, there are two specific concepts of importance: traceability of products and transparency of the project. In a study about sustainable supply chains, Saberi et al. (2019) describe how traceability and accountability are important and necessary when managing supply chains because of the risk of corruption. The same study

also explains how using paper records which can be altered or misplaced in the context of SCM can facilitate corruption and hinder accountability. Further, Neupane et al. (2014) found that mHealth tools help in improving data visibility which in turn helps with tracking referrals between health workers and clients, hence improving accountability. Highlighting the importance of transparency, Lopez (2017) described how increased transparency in national budgets can lower corruption within systems, but found simultaneously that reinforced government transparency can reinforce corruption practices among stakeholders in a system. In the context of the cStock project, it can be inferred that using an electronic data reporting tool for SCM at the community level (the point of service or point of care) which is then accessible by higher level staff for real-time monitoring, actually helps in improving data visibility, accountability, and transparency.

Theme 5: Transitioning to full electronic SCM and health systems (eHealth) in Malawi

Achieving complete electronic SCM and health systems in Malawi is still in process. In this section, I define complete (full) electronic SCM or health systems to be digital systems such as eHealth (or Digital Health), mHealth, and Health Information Systems, at the national scale that can contribute to achieving universal health coverage.

Similar to the optimistic views of cStock participants, it appears that the Malawi Government supports DH adoption to achieve universal health coverage, as seen from the existence of strategies like the *National DH Strategy 2020-25* (Ministry of Health, 2020). However, it is important to recognize that many of the health systems in place in Malawi depend on paper-based systems (Ministry of Health, 2020). The *National DH Strategy*

2020-25 recognizes there are challenges to hybrid (electronic and paper) systems such as work duplication (i.e., need to enter same patient data multiple times), and inefficiencies in the health service system, which highlight the recognized need for full electronic systems in Malawi.

Despite the optimism and the fertile policy environment for DH in Malawi, it is important to address the feasibility of achieving full electronic SCM and health (eHealth) systems. There are two key challenges described as seen from the findings of the literature review, and in the *National DH Strategy* 2020-2025 (Ministry of Health, 2020). Firstly, interoperability is a key challenge. Interoperability can be attributed to having multiple eHealth systems and software in one nation, and sometimes in one health facility, that cannot interoperate properly since each hinders accessibility to information by another (Kiberu et al., 2017; Muinga et al., 2020). In the *National DH Strategy*, interoperability is also identified as a challenge in Malawi to achieving full electronic systems (Ministry of Health, 2020). The MoH described how there are multiple EMR systems in place that do not interoperate well with each other, thus hindering information accessibility and communication among healthcare staff (Ministry of Health, 2020). These issues related to interoperability also support the views of cStock participants.

The second challenge is ensuring sustainability of eHealth systems in Malawi. Theme 2 of this Chapter addressed this issue in detail. It is important to note that the Malawi MoH identified lack of sustainability of DH programs as a key challenge for achieving full electronic systems (Ministry of Health, 2020). The MoH also highlighted the key issue of lack of financial sustainability of projects as discussed in Theme 2. The MoH also described

how lack of sustainability can stem from: not having government ownership and support for all DH projects implemented in Malawi; lack of transition of DH systems to government-owned systems; and poor accounting for local technical and skill capacity to support DH programs after transitioning projects to government ownership (Ministry of Health, 2020). These views align with the views of cStock participants as they described how it is important to account for technical capacity when considering local hosting of DH systems.

Considering the optimism for achieving full electronic health systems in Malawi, and the challenges associated with feasibility – it can be inferred that a considerable amount of time and resources (financial, human, technical) are necessary to achieve full electronic systems in Malawi, hence hybrid paper-digital systems will be in-use for the foreseeable future.

Theme 6: Recommendations

Since the cStock project is a rare example of a long-term eHealth project in a LMIC, it is important to highlight participant recommendations to improve existing and future eHealth systems in LMICs. The three key recommendations proposed are: ensuring the continuity of the cStock system as it is a proven successful system; equally distributing resources in all districts in proportion to demonstrated need; and developing mobile healthcare apps which shows the willingness to adopt eHealth tools and technology in Malawi. Apart from these recommendations, existing literature also suggests recommendations to improve eHealth in LMICs. Olu et al. (2019) present several recommendations for improving DH adoption and sustainability which includes: improving

coordination and governance systems in DH projects, creating policies and strategies at the national level; establishing DH system standards to tackle interoperability issues; executing legal frameworks to promote appropriate ownership of DH data; addressing security concerns; and adopting sustainable finance measures for projects. Further, during the 2018 Transform Africa Summit, country leaders recommended and urged Governments to lead DH projects, with the private sector (ICT Operators) assisting national Governments to scale-up DH projects (Tran Ngoc et al., 2018).

It is important to note there are a plethora of recommendations to improve eHealth use and strengthen health systems in LMICs available in literature, but national leaders and key stakeholders must act and implement the existing wealth of knowledge and strive to achieve progress and the betterment of community health in LMICs.

CHAPTER 07 – Conclusions

This research study has enabled an opportunity to understand the importance of eHealth tools used in general and in supply chain management (SCM) in LMICs as an example within a broad range of differing DH interventions that have been tried in LMICs. It provides an overview of existing literature on eHealth project implementations and scale-ups in LMICs and looked in depth at the successful cStock SCM scale-up in Malawi. The cStock case study is important since the long-term scale-up of successful eHealth projects has not been well documented, and cStock is a rare example of such a project in an LMIC (Olu et al., 2019). The lessons learned from this study will contribute to the knowledge on eHealth project implementations and scale-ups in LMICs, aid with improving existing eHealth projects such as cStock, and provide advice for carrying out future eHealth projects. In Chapter Six, I discussed the key findings from the literature review and the cStock case study as six major themes. In this Chapter, I will present the conclusions drawn from the literature review findings and the cStock case study.

In this study, the primary research question aimed to identify lessons learned from the implementation and use of cStock in Malawi. From the cStock case study, and with support from existing literature, three key lessons can be identified. The first is that financial limitations such as securing long-term funding and lack of affordability of a non-profit (public) eHealth system like cStock results in poor financial sustainability, which in turn leads to heavy foreign aid dependence (UNICEF Malawi, 2020). As seen from the literature this also applies to the bulk of eHealth projects in LMICs where domestic

investments in health infrastructure and development are usually not feasible (Kwao et al., 2019).

The second key lesson identified is that both local and global partnerships played a central role in all stages of the cStock project from project planning and development to implementation and finally to scale-up and sustaining, and this applies to majority of other LMIC eHealth projects (Ministry of Health, 2020; Olu et al., 2019; Tran Ngoc et al., 2018). Regarding global partnerships (global North-South), it is important to realize that global North donors can influence health policymaking and project or national decision-making aspects of global South recipient nations (Khan et al., 2018; Parkhurst et al., 2021). Hence, it is important to view partnerships as collaborations to ensure that the partners work together to meet local community needs (Shuvo et al., 2015). The third key lesson identified is that strong national government commitment and leadership (in terms of policy, regulatory, human resource, and administrative levels as well as prioritizing cStock in the Government agenda) from day one acted as a strong facilitator for project implementation, scale-up, and sustaining cStock, and this is the case in other LMIC eHealth projects (Ministry of Health, 2020; Shuvo et al., 2015; Tran Ngoc et al., 2018).

There are also lessons learned related from the four secondary research questions which focused on: the factors that contribute to achieving sustainability and transition to scale for eHealth applications in LMICs; the perceived benefits of using eHealth applications in the context of COVID-19; the potential benefits and challenges of transitioning fully to electronic record systems, and the feasibility of this in Malawi; and the role of paper records in the hierarchical communication chain in eHealth projects in

LMICs. Firstly, it was determined that long-term funding, strong government leadership and commitment to the project (e.g., via policy/strategy development, prioritizing projects), health service orientation of the project, and the state of infrastructure (e.g., electricity, Internet) act as key factors affecting eHealth project scale-up and sustainability (Feroz et al., 2020; Ministry of Health, 2020; Shieshia et al., 2014; Shuvo et al., 2015; Sundin et al., 2016). Secondly, in the context of cStock and COVID-19, cStock was viewed in a positive light; some of the benefits of using cStock during a crisis include the ability to rapidly disseminate health information, decreased physical interactions, and reduced infection transmission as compared to using paper records.

Thirdly, cStock participants and the MoH of Malawi (as indicated in the *National DH Strategy* 2020-25) views transitioning to full electronic systems in a positive light, but also identified concerns associated with transitioning fully to electronic systems, which include: resolving interoperability issues, moving away from heavily used paper records, and achieving sustainability of eHealth projects (Ministry of Health, 2020). Due to the strong need for financial, technical, and other resources for implementing, scaling-up, and sustaining eHealth systems, it can be inferred that for the foreseeable future there will be hybrid systems of electronic and paper-based systems in Malawi. Lastly, it seems that paper records are considered to be beneficial when used as a backup system throughout the hierarchical communication chain in the cStock project and often in other LMIC eHealth projects due to the ubiquitous and tangible natures of paper records, and the familiarity associated with them (Gyamfi et al., 2017). However, in the context of supply chains in LMICs, it is important to note that the use of paper records may encourage corruption and

promote poor accountability and transparency, since data visibility is limited when paper records are used (Pisa & McCurdy, 2019; Saberi et al., 2019; Shieshia et al., 2014; Silvestre et al., 2020).

Considering the key lessons learned and the findings of the secondary questions, my key recommendation to achieving success for an LMIC eHealth project is to adopt a sustainable financial model that can either directly generate revenue to self-sustain the eHealth system, implement a fee-for-service model where the fee is covered by a national healthcare insurance scheme, or to leverage domestic investments and co-financing options to fund a non-profit eHealth system (Kwao et al., 2019; Schweitzer & Synowiec, 2012; Sundin et al., 2016). As financial limitations are viewed as the key barrier and monetary funds are viewed as a powerful driver of eHealth projects in LMICs, it is important to use temporary foreign aid as a booster to develop a strong foundation of health infrastructure and to develop the national economy (Moss et al., 2006). Once this is in place, it will then be possible to domestically fund and invest in eHealth projects with capacity to sustain them for a long period of time. Further, it is important that the national government develop an organized system to identify existing and future eHealth pilots in the country and invest in a select number of these. This will ensure that limited resources are not wasted on countless pilots which cannot be sustained even after successful implementation. These recommendations seem inconceivable in the short-term but developing an actionable strategy clearly identifying feasible short-term steps to reach the long-term goals will be helpful to formulate to begin with. It is important that governments and key stakeholders

act on achieving financial sustainability since it will act as a key driver for the betterment of community and population health throughout the country, in the long-term.

Study strengths, limitations, and recommendations

This research study has two key study strengths that helped in investigating LMIC eHealth projects and specifically the cStock project in Malawi. Firstly, the qualitative study design helped with improving adaptability of this research and enabled examining the cStock project in detail in a short period of time. Secondly, the inclusion of Key Informants with different work positions and associated levels of management in the cStock project significantly helped with gathering diverse perspectives on the same project. This resulted in gathering rich information details about the project in a short time, even with just a few participants. These study strengths highlight the importance of collaboration in research as this study would not have been possible without the many contributions of multiple actors.

Amid the strengths of this study, there are three key study limitations. Firstly, considering this a qualitative study, the study findings and interpretations are biased towards and influenced by my sociocultural views, values, and beliefs of the study context. Also, the interpretations during the Key Informant interviews could have been influenced by global North - South sociocultural dynamics. Secondly, the travel restrictions imposed by the COVID-19 pandemic limited my ability to travel to Malawi and it also hindered the participant recruitment process. Limiting myself to conducting this study virtually has negatively impacted my ability to gain personal insight on the local context of Malawi, which may have influenced any findings of this research. Thirdly, due to the short duration of this thesis and the virtual study nature, the number of study participants is very small

(five). Hence, data saturation was not possible to achieve. These study limitations may have hindered the accuracy of the study interpretations.

Considering the small-scale of this research study, these study findings depend extensively on existing literature. Future research in the areas of eHealth project scalability and sustainability in LMICs is of utmost importance. More specifically, it will be important to conduct research on the role of partnerships (global North and South) in eHealth projects. For example, this includes examining the possible continuing influence of practices like colonialism, and the importance of feasible sustainable financing models that can improve the long-term outlook for LMIC eHealth projects.

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APPENDICES

APPENDIX A

Table 3. *Barriers to eHealth project implementations in LMICs*

Application	Barriers	References
eHealth	1. Infrastructure - Unreliable electricity and Internet - Limited hardware available - Equipment theft	(Alshahrani et al., 2019; Kiberu et al., 2017; Muinga et al., 2020)
	2. Finance - Limited capacity to secure funding - Limited funding affects needed organizational changes - Limited availability of public funds to support eHealth projects, lack of prioritization of projects by governments.	(Alshahrani et al., 2019; Granja et al., 2018; Kiberu et al., 2017; Muinga et al., 2020)
	3. Workflow - Increased workload - No alignment between system and workflow - Need frequent training - Limited computer literacy - Limited number of ICT personnel - Poor medical documentation due to high workloads	(Granja et al., 2018; Kiberu et al., 2017; Muinga et al., 2020)
	4. Sociocultural challenges - Politics – civil unrest, government will - Lack of confidence in technology - Resistance to new services - Limited willingness to use technology	(Alshahrani et al., 2019; Kiberu et al., 2017; Muinga et al., 2020)
	5. Policy and Government - Lack of policy for eHealth - Lack of eHealth implementation frameworks	(Kiberu et al., 2017; Muinga et al., 2020)

Application	Barriers	References
	- No or limited policy and regulatory guidelines to protect privacy and security of health information	
mHealth	1. Infrastructure and Finance - Unreliable power - Lack of basic electric fixtures - Problems with phone maintenance and charging - Limited network capacity - Challenges with monitoring text content - Under-reporting of data when using mHealth - Biased responses from participants - Insufficient funding for telemedicine in emergency situations	(Aranda-Jan et al., 2014; Bakibinga et al., 2020; Källander et al., 2013)
	2. Health worker challenges - Inadequate ICT knowledge - Poor attitudes and behaviours towards mHealth - Health worker resistance to new technology - High workloads - Staff shortages	(Aranda-Jan et al., 2014; Bakibinga et al., 2020; Källander et al., 2013)
	3. Sociocultural, behavioural, political challenges - Presidential election and health worker strike hindered implementation - Community members may feel disconnected from Community Health Workers' when mHealth apps are used	(Bakibinga et al., 2020; Källander et al., 2013)
	4. Health systems, policy, government challenges - Weak support from governments to strengthen health systems - Lack of County Government commitment - Lack of alignment between priorities of government and app developers - Difficulties with collaboration among all stakeholders - Lack of eHealth and mHealth policies	(Aranda-Jan et al., 2014; Bakibinga et al., 2020; Källander et al., 2013)

Application	Barriers	References
EHR/ EMR	1. Infrastructure - Unreliable Internet and power - Malfunctioning of equipment - Delays in fixing bugs - Delays in acquiring hardware - Limited physical space to accommodate EHR system servers	(Allen et al., 2007; Chaplin et al., 2015; Manders et al., 2010; Muinga et al., 2018; Oza et al., 2017)
	2. Workflow - Frequent changes in workflows in emergency settings affects the acceptance of EHR/ EMR systems - Lack of full integration of EHR/EMR system with clinical workflows	(Oza et al., 2017)
	3. Sociocultural and behavioural challenges - Users felt the EHR system belonged to outsiders which limited user acceptance of the EHR system - Lack of alignment between end-users' and donors' priorities	(Chaplin et al., 2015; Muinga et al., 2018)
	4. Management and evaluations - Poor support from County management - Using external developers - Incorporating a wide project scope - Limited availability of true evaluations, and usage and performance data of EHR/EMR projects	(Manders et al., 2010; Muinga et al., 2018; Oza et al., 2017)

APPENDIX B

Table 4. *Facilitators to eHealth implementation in LMICs.*

Application	Facilitators	References
eHealth	1. Positive motivations - Using eHealth technology to improve healthcare service delivery	(Granja et al., 2018)
	2. Infrastructure - Improved Internet bandwidth - Increased Internet penetration in communities	(Kiberu et al., 2017)
	3. Finance - Capacity to secure sufficient funding to cover cost and operations of the project	(Alshahrani et al., 2019)
	4. Technology - Availability of diverse systems of DH technology - Easier planning and system acquisition with prior experience of using eHealth systems - Recognized need to manage clinical data	(Muinga et al., 2020)
mHealth	1. Finance - Sufficient funding for mHealth projects - Low-cost mHealth technology	(Aranda-Jan et al., 2014; Källander et al., 2013)
	2. Sociocultural and behavioural facilitators - Familiarity with mobile phones - Experience with DH technology - Strategies to overcome language and literacy barriers	(Aranda-Jan et al., 2014; Bakibinga et al., 2020; Källander et al., 2013)
	3. Health systems, policy, government, partnerships - eHealth policies to promote ICT in health sector - Government support via mHealth/eHealth strategies	(Aranda-Jan et al., 2014; Bakibinga et al., 2020; Källander et al., 2013)

Application	Facilitators	References
	- Interest and willingness of the government to integrate mHealth projects - Establishing public-private partnerships - Collaboration with local communities - mHealth/eHealth system alignment with regional and national health information systems	
EHR/EMR	1. Communication and collaboration - Partnerships between the Ministry of Health and Academics to promote research and solutions - Collaboration and communication with local stakeholders - Communication between platform developers and project implementers - Improve local software development - Promote local ownership and end user buy-in	(Allen et al., 2007; Manders et al., 2010; Muinga et al., 2018; Oza et al., 2017)
	2. Training - Providing consistent and frequent training - Introducing new technology to smaller groups - Having an experienced team member on site - Implementing an EHR/EMR system that does not require advance training or expert software developers	(Chaplin et al., 2015; Oza et al., 2017)

APPENDIX C

Table 5. *Barriers to transitions to scale for eHealth implementations in LMICs*

Barriers	References
1. Financial constraints - Inappropriate fund distribution within project - Lack of knowledge on Return On Investment (ROI) - Poor national budget allocation to health sector - Failure to establish suitable business and revenue models	(Kwao et al., 2019; Schweitzer & Synowiec, 2012; Shuvo et al., 2015; Sundin et al., 2016; Tran Ngoc et al., 2018)
2. Partnerships and role of government - No alignment in priorities of local population and eHealth system - Maintaining public-private partnerships - Lack of political will and commitment - Lack of Global South-Global South collaboration - Limited or lack of local and government ownership/ involvement - No alignment between eHealth programs and national health strategies	(Schweitzer & Synowiec, 2012; Shuvo et al., 2015; Sundin et al., 2016; Tran Ngoc et al., 2018)
3. Infrastructure - Inaccessible roads and transportation - Unreliable electricity - Technology barriers: No familiarity of technology, limited memory capacity, Internet is insufficient and expensive, narrow Internet bandwidth - Employee management challenges: lack of oversight of business decisions and business setbacks - Information security issues – hacking concerns and inappropriate disclosure of health information	(Kwao et al., 2019; Shuvo et al., 2015; Sundin et al., 2016)
4. Contextual factors - Lack of considerations of gender dynamics in the project region - Stereotyping and social stigma around illnesses for which eHealth projects can provide healthcare - Resistance to change – by healthcare providers	(Kwao et al., 2019; Sundin et al., 2016)

APPENDIX D

HiREB Informed Consent Form

McMaster University

Inspiring Innovation and Discovery

LETTER OF INFORMATION / CONSENT FOR PARTICIPANT

Study Title

Lessons learned from the implementation and use of eHealth applications in resource limited settings: A comparative analysis of the use of CommCare-based mobile applications in Kenya and Malawi.

Investigators: Damsadie Kaluappuwa Hannedige, BSc (Student researcher); Dr. Christy Gombay, PhD (Principal Investigator); Dr. Norm Archer, PhD, (McMaster University).

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Invitation to participate in research

We are inviting you to take part in this study focused on implementation and use of CommCare-based mobile healthcare applications (apps). These mobile apps are projects being carried out in Kenya and Malawi. We want to gather lessons learned from the experiences of people who have used or implemented (process of executing a plan) these mobile apps. You are eligible for this study because you are over 19 years old, speak the English language, and are able to provide informed consent. You are also eligible because you have used or helped execute the specific healthcare mobile app. Participating in this study is voluntary. There will be no consequences if you choose not to participate in this study. This is a student research project, conducted by the student researcher (Damsadie Kaluappuwa Hannedige), and supervised by the principal investigator (Dr. Christy Gombay).

Purpose of the Study

We are doing this research to gather lessons learned from the experiences of people who have used or helped with implementing certain mobile applications. These apps can improve healthcare in settings that have less resources. I am going to interview community health workers, their supervisors, people who use collected data, implementors, and people who created the mobile apps. I want to understand challenges faced by the users and implementors of these mobile apps. This is so that we can avoid similar mistakes in future projects.

Also, we want to know the benefits of using these apps in resource poor settings. I want to gather advantages and disadvantages of using the applications too. I hope to compare these challenges, benefits, advantages/disadvantages between Kenya and Malawi. I also hope to compare them between different work positions. This is to see if there are similar or different trends. Also, I wanted to find out if these projects will last a long time. I want to know how scaling up of these projects were considered. Lastly, I want to find out if the COVID-19 pandemic affected these programs too. I am doing this research for my master's thesis in Global Health.

Procedures involved in the Research

This study has only one-to-one (i.e. individual interviews) interviews. The interviews will be held online (i.e. virtually). This is a small-scale study. There will be approximately five (5) participants from each study country (Kenya or Malawi). The total number of study participants is about ten (10). You will be asked to provide personal information. This includes your name, gender, email address and work position with the project you are involved. Your telephone number will be needed if you do not have an email address, and this will be used only to contact you. You will be asked to answer a series of questions. I will be asking you questions about your experience with using and/or implementing the specific mobile app. The interview will be approximately 40 to 60 minutes in length.

The interview will happen virtually using Zoom, WhatsApp, MS Teams, or Webex, based on your choice. Using these apps have a low risk of a privacy breach and because they are third-party software, I cannot guarantee the interview will be fully secure. With your permission, the interview will be audio recorded and I will take electronic notes during the interview using my computer. Also, with your permission, anything you say might be used as direct quotes. Lastly, if you provide permission, there can be follow-up interviews or contact (e.g. via email or WhatsApp chat) to clarify anything you said during the interview, or to ask a follow-up question that may have been missed during the interview.

Here are some sample questions that might be asked during the interview:

1. Can you describe your experience with using the mobile application?
2. Are there specific challenges to using the mobile app?
3. Have you experienced new challenges or benefits of using the mobile app during the COVID-19 pandemic?

Potential Harms, Risks or Discomforts:

The risks involved in participating in this study are minimal. There is a low risk of privacy breach when using online communication platforms. This study will use Zoom, WhatsApp, MS Teams, and Webex platforms to collect data, which are externally hosted cloud-based services.

- A link to WhatsApp's privacy policy is available here https://www.whatsapp.com/legal/updates/privacy-policy/?lang=en.
- A link to Zoom's privacy policy is available here https://explore.zoom.us/trust/privacy
- A link to MS Teams privacy policy is available here https://privacy.microsoft.com/en-ca/privacystatement.
- A link to Webex privacy policy is available here https://trustportal.cisco.com/c/dam/r/ctp/docs/privacydatasheet/collaborati

on/cisco-webex-meetings-privacy-data-sheet.pdf and here https://www.cisco.com/c/en_ca/about/legal/privacy-full.html.

While the Hamilton Integrated Research Ethics Board has approved using the platform to collect data for this study, there is a small risk of a privacy breach for data collected on external servers. If you are concerned about this, we would be happy to make alternative arrangements for you to participate, perhaps via telephone. Please talk to the student researcher if you have any concerns. Also, in this study we will ask for the gender you identify with. You may feel uncomfortable in sharing your gender. If you are concerned about this, there is an option to not identify your gender.

Lastly, you do not need to answer questions that you do not want to answer or that make you feel uncomfortable. You can also stop to take a break during the interview. You can withdraw (stop taking part) at any time without penalty.

I describe below the steps I am taking to protect your privacy.

- Firstly, all recorded audio files will be saved on an encrypted computer using FileVault encryption software (encryption converts data into a code to prevent unauthorized access). These audio files will be saved using a study code.
- All participants will have a unique study ID which limits the use of your personal information.
- All digital files with your personal information such as name, and gender will be stored as password protected files on an encrypted computer with FileVault encryption software.
- Only the Student researcher and Principal Investigator will have access to the electronic study key.
- The transcripts created from audio recordings of interviews will be manually de-identified before data analysis.

Potential Benefits

We hope to learn more about challenges experienced when using certain mobile applications. More specifically, in areas with less resources. I hope that what is learned as a result of this study will help us to better understand how to consider long-term continuation of similar programs. The findings can help both existing and future eHealth projects. The findings will also help the greater community, to science, and to society at large, even though it might not benefit you directly.

Confidentiality

In this study, the student researcher will have access to your name, gender, email address, telephone number and work position with your permission. To make sure your personal information remains confidential and protected we will assign a study ID for each participant. The study key that is needed to find out your personal information is only accessible by the student researcher and the principal investigator. The audio recordings will be saved using a code and the electronic transcripts created using these audio files will be de-identified before data analysis. Encryption will also be used for devices with personal information. Also, please do not make unauthorized recordings of the interview. These measures ensure that your identity can be protected up to a certain level.

However, due to the small size of the study participants, and the small size of the participants and implementors of the project, others may be able to identify you on the basis of references you make. Also, we are often identifiable through the stories we tell. Please keep this in mind in deciding what to tell me. Hence, confidentiality cannot be fully guaranteed in this study even though steps are taken to maintain confidentiality.

Information kept on a computer and the audio recording device will be protected by a password and encryption software will be used. Once the study has been completed, an archive of the data, without identifying information, will be kept for five years for publication purposes.

You do have the option to be identified and reveal your identifiable information (e.g. name, gender, work position) in this research study.

Participation and Withdrawal

Your participation in this study is voluntary. It is your choice to be part of the study or not. If you decide to be part of the study, you can decide to stop (withdraw), at any time, even after signing the consent form or part-way through the study. If you decide to withdraw, there will be no consequences to you. You also have the option of removing data already collected for a limited time. You can withdraw your data up to one week after the interview. For example, you have the option of removing all your data from the study including information provided up to the point where you withdraw by one week after the interview. Participating in this study does not limit your ability to co-enroll in other studies.

If you do not want to answer some of the questions you do not have to, but you can still be in the study and answer the questions you want to. Your decision whether or not to be part of the study will not affect your continuing access to services and employment associated with the Lwala Mobile App (Kenya) or cStock (Malawi) projects.

To withdraw from this study at any given point, you will have to contact the student researcher (hannedid@mcmaster.ca) and explain your situation. You will have to directly ask to be withdrawn from the study and clearly mention if you would like to withdraw any data collected up to that point of time. There are no consequences to withdrawing from this study.

Information about the Study Results

I expect to have this study completed by approximately September 2021. If you would like a brief summary of the results, please let me know how you would like it sent to you.

Questions about the Study

If you have questions or need more information about the study itself, please contact me at:
hannedid@mcmaster.ca (Damsadie Kaluappuwa Hannedige)

This study has been reviewed by the Hamilton Integrated Research Ethics Board (HiREB). The HiREB is responsible for ensuring that participants are informed of the risks associated with the research, and that participants are free to decide if participation is right for them. If you have any questions about your rights as a research participant, please call the Office of the Chair, HiREB, at 905.521.2100 x 42013.

CONSENT

I have read the information presented in the information letter about a study being conducted by Damsadie Kaluappuwa Hannedige and Dr. Christy Gombay of McMaster University.

By providing consent for this study, I agree to not make unauthorized recordings of the interviews.

I have had the opportunity to ask questions about my involvement in this study and to receive additional details I requested.

I understand that if I agree to participate in this study, I may withdraw from the study at any time.

I would like to be identified (not remain anonymous) in this research study where my identifiable information such as work position and gender is revealed.
Choose: YES / NO

I will be given a signed copy of this form. I agree to participate in the study.

_____	_____	_____
Name of Participant (Printed)	Signature	Date

Consent form explained in person by:

_____	_____	_____
Name and Role (Printed)	Signature	Date

APPENDIX E – Interview Guides

Interview Guide A – Central level – Project Implementor

Research Team: Damsadie Kaluappuwa Hannedige, BSc (Student Researcher); Dr. Christy Gombay, PhD (Principal Investigator); Dr. Norm Archer, PhD.

Preamble:

Thank you for taking the time for this interview. Please feel free to answer or not answer any of the questions. You can let me know if you would like to stop the interview at any point. Also, please do let me know if you wish to withdraw from the study and withdraw any information you have provided. You can withdraw without penalty at any time. With your permission, I will be audio recording this interview and may use anything you say as direct quotes. Lastly, please do not use personal names when referring to yourself or others during the interview to maintain privacy.

I am interested in finding what we can learn from using cStock in Malawi, to see if it is possible to use these lessons to help with future projects. More specifically, about the challenges, benefits, advantages/disadvantages of using cStock in settings with less resources. I will be asking questions about your experience with implementing and/or using cStock. I appreciate your support with this interview.

Questions:

1. Can you describe your role in the cStock project?
2. What were your main responsibilities in the project?
3. Can you describe your overall experience with project implementation and scale-up?
    - What is the progression of the project from pilot to scale-up?
4. Tell me about any challenges you faced during the implementation or scale-up process.
    - Could you tell me about the greatest challenges in your experience?
    - Were there any infrastructural, health worker, technology, policy, stakeholder challenges?
5. How was stakeholder engagement promoted throughout the implementation or scale-up process?

- Are there any factors that helped in maintaining stakeholder commitment?
- How is stakeholder engagement being continued or maintained presently?

6. How did the project ultimately transition to scale?
    - Which factors helped with the scale up or transition to scale?
    - Could you please describe if other organizations were involved with the scale up process?
    - Was long-term or permanent funding for the program considered before scaling-up the project?
7. How did you or the project implementation team consider incorporating sustainability concepts into the project design?
    - What were the barriers to considering sustainability in a setting with limited resources?
    - Was there a sustainable strategy from the early stages of the project?
    - What do you think are the main factors that contribute to ensuring sustainability for projects in resource limited settings?
    - Was there a time when sustainability of the program became most important?
8. How did you consider financial sustainability of the program?
    - Are there specific components of the program related to technology that could not be financially feasible in the long term?
    - How was long-term funding considered?
    - What is your perspective on the impact of long-term funding on the sustainability of an eHealth project, such as this project?
9. What are your thoughts on whether it is possible to transition fully to electronic records or electronic data collection systems in resource limited settings?
    - How feasible do you think this is?

- What factors would potentially help achieve this?
- What would be the barriers to achieving a complete digital system in a healthcare and a resource-limited setting?
- What would you say about the role of paper records in a healthcare and a resource-limited setting?

10. Do you think the COVID-19 pandemic has affected the program continuation?
    - Are there new challenges with program continuation due to the pandemic?
    - Are there new benefits to using a digital technology such as the mobile app/website during a pandemic?
11. What are the strategies used to overcome barriers imposed by the pandemic?
12. In your experience, do you have any recommendations for improving cStock or future eHealth implementation processes?
13. Would you like to further comment on or add anything to any of the questions asked previously?
14. Would you like to mention anything about your experience with the cStock project that I may have missed?

Interview Guide B – Central level – Data User/ Supervisor

Research Team: Damsadie Kaluappuwa Hannedige, BSc (Student Researcher); Dr. Christy Gombay, PhD (Principal Investigator); Dr. Norm Archer, PhD.

Preamble:

Thank you for taking the time for this interview. Please feel free to answer or not answer any of the questions. You can let me know if you would like to stop the interview at any point. Also, please do let me know if you wish to withdraw from the study and withdraw any information you have provided. You can withdraw without penalty at any time. With your permission, I will be audio recording this interview and may use anything you say as direct quotes. Lastly, please do not use personal names when referring to yourself or others during the interview to maintain privacy.

I am interested in finding what we can learn from using cStock in Malawi, to see if it is possible to use these lessons to help with future projects. More specifically, about the challenges, benefits, advantages/disadvantages of using cStock in settings with less resources. I will be asking questions about your experience with using cStock. I appreciate your support with this interview.

Questions:

1. Can you describe your role in the cStock project?
2. What were your main responsibilities in the project?
3. Please tell me about any challenges you faced during the implementation or scale-up process, or in your day-to-day work?
    - Could you tell me about the greatest challenges in your experience?
    - Are there human resource or capacity challenges?
    - Are there any infrastructural, health worker, technology, policy, stakeholder challenges?
4. What strategies were used to overcome these challenges?
5. Were there frequent program evaluations throughout the cStock project development, implementation, and maintenance?
6. How do program managers use cStock to supervise HSAs (e.g., to see if tasks and roles of CHWs are fulfilled in a timely manner and data reporting occurs continuously)?

7. How did the project ultimately transition to scale?
    - What are the three main reasons for the successful scale-up of the cStock project?
    - Which factors (facilitators or barriers) helped with the scale up or transition to scale?
8. Besides the cStock program, do you use other forms of data collection or monitoring tools like paper-based forms?
9. What would you say about the role of paper records in the cStock project?
    - What are the challenges of using paper-based records?
10. What are your thoughts on whether it is possible to transition fully to electronic records or electronic data collection systems in resource limited settings?
    - How feasible do you think this is?
    - What factors would potentially help achieve this?
    - What would be the barriers to achieving a complete digital system in a healthcare and a resource-limited setting?
11. Do you think the COVID-19 pandemic has affected the program continuation?
    - Are there new challenges with program continuation due to the pandemic?
    - Are there new benefits to using a digital technology such as the mobile app/website during a pandemic?
12. What are the strategies used to overcome barriers imposed by the pandemic?
13. In your experience, do you have any recommendations for improving cStock or future eHealth tools?
14. Would you like to further comment on or add anything to any of the questions asked previously?
15. Would you like to mention anything about your experience with the cStock project that I may have missed?

Interview Guide C – District level – Data User/ Supervisor

Research Team: Damsadie Kaluappuwa Hannedige, BSc (Student Researcher); Dr. Christy Gombay, PhD (Principal Investigator); Dr. Norm Archer, PhD.

Preamble:

Thank you for taking the time for this interview. Please feel free to answer or not answer any of the questions. You can let me know if you would like to stop the interview at any point. Also, please do let me know if you wish to withdraw from the study and withdraw any information you have provided. You can withdraw without penalty at any time. With your permission, I will be audio recording this interview and may use anything you say as direct quotes. Lastly, please do not use personal names when referring to yourself or others during the interview to maintain privacy.

I am interested in finding what we can learn from using cStock in Malawi, to see if it is possible to use these lessons to help with future projects. More specifically, about the challenges, benefits, advantages/disadvantages of using cStock in settings with less resources. I will be asking questions about your experience with using cStock. I appreciate your support with this interview.

Questions:

1. Can you describe your role in the cStock project?
2. What are your main responsibilities in the project?
3. Can you describe how you would typically use cStock or the Web-Dashboard in your daily schedule?
    - What do you use it for?
    - What are your responsibilities?
4. What are the challenges you have experienced in your role(s) in the cStock project?
5. What are the challenges or benefits of using cStock, the electronic program, in your experience?
6. I am aware that the District Product Availability Teams (DPAT) help monitor product availability and supply chain performance. Could you please describe any benefits of these teams, or any challenges experienced?

7. Besides the cStock program, do you use other forms of data collection or monitoring tools like paper-based forms?
8. What would you say about the role of paper records in the cStock project?
    - What are the challenges or benefits of using paper-based records?
    - What are the benefits of using paper and electronic records (or multiple tools)?
9. What are your thoughts on whether it is possible to transition fully to electronic records or electronic data collection systems in resource limited settings?
    - How feasible do you think this is?
    - What factors would potentially help achieve this?
    - What would be the barriers to achieving a complete digital system in a healthcare and a resource-limited setting?
10. Do you think the COVID-19 pandemic has affected the program continuation?
    - Are there new challenges with program continuation due to the pandemic?
    - Are there new benefits to using a digital technology such as cStock during a pandemic?
11. What are the strategies used to overcome barriers imposed by the pandemic?
12. In your experience, do you have any recommendations for improving cStock or future eHealth tools?
13. Would you like to further comment on or add anything to any of the questions asked previously?
14. Would you like to mention anything about your experience with the cStock project that I may have missed?