A MOBILE HEALTH FRAMEWORK FOR PUBLIC PRIVATE MIX IN TUBERCULOSIS PREVENTION AND CARE IN SOUTHWESTERN UGANDA

WILSON TUMUHIMBISE

2018/PhD/030/PS

A THESIS SUBMITTED TO THE FACULTY OF COMPUTING AND INFORMATICS IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN COMPUTING OF MBARARA UNIVERSITY OF SCIENCE AND TECHNOLOGY

DECEMBER 2022

DECLARATION

I hereby declare that this thesis is my original work and has never been submitted to any other institution of higher learning for any academic award to the best of my knowledge.

Signature: .....

DATE: 12/12/2022

i

APPROVAL

I, Dr. Angella Musiimenta, do hereby certify that this PhD research has been presented for the award of Doctor of Philosophy with my approval as the Mbarara University of Science and Technology Supervisor.

Signature ..... DATE 12/12/2022.....

I, Dr. Fred Kaggwa, do hereby certify that this PhD research has been presented for the award of Doctor of Philosophy with my approval as the Mbarara University of Science and Technology Supervisor.

Signature ..... DATE 12/12/2022.....

I, Dr. Daniel Atwine, do hereby certify that this PhD research has been presented for the award of Doctor of Philosophy with my approval as the Mbarara University of Science and Technology Supervisor.

Signature ..... DATE 12/12/2022.....

ii

DEDICATION

To my dear wife, Doreen Babirye, you have loved me unconditionally, thank you for praying for me always.

To my dear son, Mwine Eliel Isaac and all the Wilsonites, you are our perfect gift from the Lord and when time is full and you come across this writing, may you be encouraged that you can only stand out only if you allow the Lord Jesus to be on the steering wheel of your life. May this work propel you to do even more to manifest his glory in your own paths that you choose. Always know that the Lord who made and called you is faithful and will preserve you till the day of perfection for no weapon formed against you shall ever prosper and every tongue that shall rise against you in judgement, you shall condemn (Isa 54: 17). May you always see far in life and not to be short-sighted and never settle for less. May you be relentless in your pursuit for Christ Jesus and always remember that "You would rather dine with a thief who believes that God Almighty exists than a saint who doesn't. For the latter is ungrateful, but Grace, there is for the former".

To my beloved mother Busingye Edith, you have walked with me from the day I was born and never gave up on me, thank you for not giving up on me.

To my mentor Dr. Angella Musiimenta, you have believed in me, supported, and prayed for me always. Thank you for giving me "entandikwa", you are indeed my destiny helper

To my Pastor Apostle Willy Tumwine, you have been my greatest encouragement in life and it's your faith that this work has manifested.

ACKNOWLEDGEMENT

I would like to thank the Almighty God for His grace and love towards me and for the courage he gave me to start on this journey. I would like to thank specifically my mentor and main supervisor Dr. Angella Musiimenta, who has been always there for me throughout the entire period of the study, gave me a scholarship from her Eunice Kennedy Shriver National Institute of Child Health & Human Development of the National Institutes of Health funded Project (R21HD107985) and a job since October 2016.

I would like to acknowledge Associate Professor Luke Davis (Yale School of Medicine) for the support in conceptualizing the research idea. I would like on a special note to appreciate Dr.Fred Kaggwa, Dr. Daniel Atwine (my supervisors), Dr. William Wasswa and Dr. Evarist Nabaasa (members of the Doctoral Committee) for the guidance and your time offered to me during my doctoral studies. I honestly wouldn't have reached this far without you.

I would also like to thank my colleagues at work (Mr. Aaron Mugaba, Ms. Kobutungi Phionah, Mr. Derrick Tumusiime) and FCI at large for all the support during this period, Mr. Amos Baryashaba, Owen Muhangi and Lasto Mubiru for the opportunity you gave me to volunteer in the Computing Unit Department in 2015, that opportunity made me reach this far.

I would also like all my dear friends and my church for the prayers and encouragement. I thank you all.

In a special way, I would to thank every individual in your respective capacities who held my hand in any way possible (financially, morally and spiritually) since birth. I would not have reached this far without that act of kindness. Thank you so much and may God grant you your heart's desires.

TABLE OF CONTENTS

DECLARATION i

APPROVAL ii

DEDICATION iii

ACKNOWLEDGEMENT iv

List of Figures xii

List of Tables xiii

ABSTRACT xiv

Abbreviations xvi

CHAPTER ONE: INTRODUCTION 1

1.1 Background to the subject area under investigation 1

1.1.1. Public Private Mix 3

1.1.2. Private Hospitals Involvement in TB care 4

1.1.3. Potentials of mobile health technologies 8

1.1.4. Mobile Health frameworks and the research gap 10

1.2 Problem statement 11

1.3 Research goal, objectives and questions 12

1.3.1 Research objectives 12

1.3.2 Research questions 13

1.4. Structure of the Thesis 15

1.5. Rationale for this Thesis 16

CHAPTER TWO: LITERATURE REVIEW 20

2.1 Introduction 20

2.2 MHealth for Tuberculosis care 20

2.3 MHealth for Tuberculosis care in developing countries 23

2.4 Mobile Health for Tuberculosis care in Uganda 25

2.5 Mobile Health for Public Private Mix in TB care 26

2.6 Overview of frameworks for guiding the implementation of PPM 27

2.6.1 WHO's Emerging Policy Framework for Public Private Mix 27

2.6.2 PPIA MODEL (Private Provider Interface Agency Model) 29

2.6.3 SPARK TB MODEL 31

2.7 Frameworks guiding the design of mHealth interventions 33

2.7.1. The mHealthDroid Framework 34

2.7.2. Multiple stakeholders and data analytics framework (MUCODAF) 36

2.7.3. The University of Limerick Tool for Ecological Momentary Assessment and intervention Triggering (ULTEMAT) Framework 37

2.8. Acceptability and feasibility of mHealth Technologies for TB care 40

2.8 Overview of models for behavioural change and technology adoption 40

2.8.1 The Consolidated Framework for Implementation Research (CFIR) 41

2.8.2 The Unified Theory of Acceptance and Usage of Technology (UTAUT) 43

2.9 Synthesis of Literature and Research gap Identified.....45

CHAPTER THREE: RESEARCH METHODOLOGY 46

1.1. Introduction.....46

1.2. Research philosophy adopted in this research.....48

1.3. User Centered Approach.....49

1.4. Research Investigations.....50

1.4.1.1. Identification of Studies.....51

1.4.1.2. Search strategy.....52

1.4.1.3. Study selection criteria.....52

1.4.1.4. Exclusion criteria.....54

1.4.1.5. Data extraction and analysis.....54

1.4.1.6. Quality Assessment.....54

1.4.2. Research methods for objective two: A formative qualitative investigation.....56

1.4.2.1. Ethical Approval.....56

1.4.2.2. Study Design and Setting.....57

1.4.2.3. Selection of Study Participants.....58

1.4.2.4. Data Collection.....59

1.4.2.5. Data Analysis.....59

1.4.3. Research methods for objective three: A framework design investigation.....61

1.4.3.1. Overview.....61

1.4.4. Research methods for objective four: A mixed methods investigation 62

1.4.4.1. Overview 62

1.4.4.2. Data Collection 62

1.4.4.3. Data analysis 63

CHAPTER FOUR: PRESENTATION OF RESULTS 65

4.1. Introduction 65

4.2. Results for research objective one 65

4.2.1. Search results 65

4.2.2. Quality of studies 73

4.2.3. The application of mHealth for PPM in TB care 75

4.3. Results for research objective two 80

4.3.1. Introduction 80

4.3.2. Barriers and motivators to private Hospitals' Engagement in TB care 82

4.3.3. Potentials of mHealth technologies for enhancing PPM 90

4.4. Requirements for MOHE framework 96

CHAPTER FIVE: FRAMEWORK DEVELOPMENT 99

5.1. Introduction 99

5.2. Description of the MOHE framework 99

5.3. MOHE Framework Modules 100

5.4. The MOHE Framework 101

5.4.1. Typical use case and application of MOHE Framework 104

5.4.2. MOHE Framework Response to the Use case 104

CHAPTER SIX: INITIAL FEASIBILITY AND ACCEPTABILITY OF THE DEVELOPED INTERVENTION BASED ON THE FRAMEWORK 107

6.1. Chapter overview 107

6.2. **Tuuka Mobile Application Development to test MOHE Framework** 107

6.2.1. Tuuka Application implementation 110

6.3. Tuuka Application use case diagram 114

6.4. Quantitative findings 115

6.4.1. Social-Demographic Details of Participants 115

6.4.2. Tuuka usability findings based on the SUS 117

6.4.3. Technology adoption findings 119

6.5. Qualitative findings 121

6.5.1. Performance Expectancy or perceived ease of use 121

6.5.2. Effort Expectancy or perceived ease of use 123

6.5.3. Social influence 124

6.5.4. Facilitating conditions 124

CHAPTER SEVEN: DISCUSSION 126

7.1. Chapter overview 126

7.2. Discussion for research objective one 126

7.3. Discussion for research objective two 131

7.4. Discussion for research objective three 140

7.5. Discussion for research objective four 143

7.6. Train, Restructure, Incentivize, Legalize, and Integrate (TRILI) Policy framework for the implementation of Tuuka Mobile application 146

7.6.1. Domain 1: Train 147

7.6.2. Domain 2: Restructure 147

7.6.3. Domain 3: Incentivize 148

7.6.4. Domain 4: Legalize 149

7.6.5. Domain 5: Integrate 150

CHAPTER EIGHT: CONCLUSION AND RECOMMENDATIONS 151

8.1. Chapter overview 151

8.2. Research Objectives Achievement 151

8.3. Research Contribution 155

8.3.1. Knowledge contribution 155

8.3.2. Technological Contribution 156

8.3.3. Theoretical contribution 156

8.4. Strengths of the Study 156

8.5. Limitations of the Study 157

8.6. Implications for Practice and Research 159

8.7. Future Research 161

8.8. Conclusion 162

BIBLIOGRAPHY 166

Appendix 1: Health Care workers Engagement survey (Key Informant survey). 198

Appendix 2: Interview Guide for Private healthcare workers (Key Informant). 203

Appendix 3: INTERVIEW GUIDE for assessing acceptability 206

Appendix 4: MUST REC approval 209

Appendix 5: UNCST Approval 211

List of Figures

Figure 2.1: PPM in Implementation (Source: WHO PPM fact sheet 2017) 28

Figure 2.2: Private Provider Interface Agency (PPIA) Model (Source: (Nandi, 2015) 30

Figure 2.3: SPARK TB Model- Source: (USTB, 2014). 32

Figure 2.4: showing the mHealth Droid Framework 35

Figure 2.5: MUCODAF framework 37

Figure 2.6: illustration of the ULTEMAT Framework 38

Figure 2.7: CFIR domains 42

Figure 2.8: UTAUT Model. (Source: Venkatesh et al 2003) 43

Figure 5.9: MOHE Framework Architecture 101

Figure 10: Illustration of the MOHE Framework 105

Figure 6.11: Overview of Tuuka mobile app features 110

Figure 6.12 screenshots from Tuuka mobile application 113

Figure 13: showing the Use case of Tuuka 114

Figure 14.1: Train, Restructure, Incentivize, Legalize, and Integrate (TRILI) Policy framework 146

List of Tables

Table 2.1 Summary of existing frameworks.....39

Table 4.2 Participant's demographics.....81

Table 4.3 Facility Level Demographics.....81

Table 4.4 CFIR Constructs and their Related Barriers or Motivators for the Engagement of Private Hospitals in TB Care.....83

Table 6.5: Perceived usefulness, ease of use and social norms of Tuuka Mobile application.....119

Table 6.6: Facilitating conditions for Tuuka Mobile application.....120

ABSTRACT

Ensuring that presumptive tuberculosis patients referred from private hospitals have reached their points of referral is key to achieving better tuberculosis control efforts. Although mobile health technologies have been recommended by the World Health Organization as emerging opportunities for closing gaps through enhancing public private mix, there is a lack of frameworks to guide the development of these interventions.

The user-centered design approach was adopted in this research to develop a mobile health framework for designing a mobile application to support the follow-up of presumptive TB patients referred from private to public hospitals in southwestern Uganda. The research employed mixed qualitative and quantitative methods to achieve its objectives. The research involved 35 in-depth interviews with healthcare workers purposively selected from both private and public facilities and 35 interviewer-administered surveys with the same respondents.

Mobile health may offer low-cost alternative approaches for supplementing and enhancing private hospitals' tuberculosis care efforts. A mobile health framework for guiding the design of a mobile health application to support the following up of presumptive TB patients referred from private to public hospitals was developed. Subsequently, a mobile health app (known as Tuuka) was developed to demonstrate the potential of the developed framework and to validate it. A policy framework emerged from lessons learned and suggestions for implementation of the developed mobile application in Uganda.

This thesis identifies mobile health interventions utilized for public private mix, demonstrates how a mobile health framework can be developed and presents how a policy framework for implementing the developed mHealth intervention.

Keywords: mobile health, public private mix, implementation science, CFIR, barriers, motivators, referral

Abbreviations

CDC	Center for Disease Control
CFIR	Consolidated Framework for Implementation Research
COM-B	Capability, Opportunity, Motivation, Behaviour
DOTS	Directly Observed Treatment short course
DS-TB	Drug Sensitive TB
DTU	Diagnostic TB Units
HCW	Healthcare workers
HIV	Human Immunodeficiency Virus
ICT	Information and Communication Technologies
ITU	International Telecommunication Union
MDR TB	Multi Drug Resistant TB
MOH	Ministry of Health
MOHE	Mobile Health framework
MRRH	Mbarara Regional Referral Hospital
MUST REC	Mbarara University of Science and Technology Research Ethics committee
NTLP	National Tuberculosis and leprosy programme
NTP	National Tuberculosis Programme
PDA	Personal Digital Assistants
PNFP	Private not for profit
PPIA	Private Provider Interface Agency Model
PPM	Public Private Mix
SPARK	Slum Partnerships to Actively Respond to Tuberculosis in Kampala District
SUS	System Usability Scale

TAM	Technology Acceptance Model
TB	Tuberculosis
TRILI	Train, Restructure, Incentivize, Legalize, and Integrate
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UML	Unified Modelling Language
UNCST	Uganda National Council of Science and Technology
UNDP	United Nations Development Programme
UNHS	Uganda National Household Survey
USAID	United States Agency for International Development
UTAUT	Unified Theory of Acceptance and Use of Technology
VHT	Village Health Teams
WHO	World Health Organization

CHAPTER ONE: INTRODUCTION

1.1 Background to the subject area under investigation

Tuberculosis (TB) is ranked 13th leading cause of death globally and the second leading infectious disease after coronavirus disease (COVID-19) (WHO, 2021b), despite its being curable and preventable. TB is also a leading killer of people infected with human immunodeficiency viruses (HIV) (CDC, 2016). A total of 10 million people fell ill with TB globally in 2020 with the majority (98%) of these reported cases in low and middle-income countries. In addition, a total of 1.5 million TB deaths were registered in 2020 including 214,000 people living with HIV (WHO, 2021b) up from 1.4 million including 209,000 patients living with HIV) deaths in 2019.

The African region remains with the highest TB incidence: 220 (195-245) per 100,000 compared to the rest of the regions globally like southeast Asia Region: 211 (169-258) per 100,000; Eastern Mediterranean region: 112 (89-138) per 100,000; Western Pacific region: 93 (76-110) per 100,000; PAHO region of the Americas: 29 (26-31) and Europe: 25 (22-28) per 100,000 (WHO, 2021a). TB illness is associated with catastrophic costs for both the patients and their households which greatly limits their ability to access TB care services like diagnosis, treatment, and successful treatment completion.

Uganda is among the 30 high TB burden countries and 30 high TB/HIV burden countries, with a TB incidence of 196 (117-296) per 100,000 and 65 (39-98) per 100,000 people living with HIV. According to the recent Global TB report 2022, these high burden TB countries have contributed to the total of 87% of all global TB cases (WHO, 2022). These countries include, Philippines (650), Lesotho (614), Central African Republic (540), Gabon (514), South Africa (513), Democratic People's Republic of Korea (513), Namibia (457), Mongolia (428), Papua New Guinea (424), Congo (370), Mozambique (361), Myanmar

(360), Indonesia (354), Angola (325), Democratic Republic of Congo (318), Liberia (308), Zambia (307), Sierra Leone (289), Pakistan (264), Kenya (251), Bangladesh (221), Nigeria (219), United Republic of Tanzania (208), India (210), Uganda (199), Vietnam (173) Thailand (143), Ethiopia (119), Brazil (48) China (55).

The majority (98%) of TB deaths occur in developing countries affecting mostly the young adults, thus negatively affecting their productive years and these countries continue to struggle towards achieving the 2035 global targets of the End-TB strategy. These include achieving a 95% decline in deaths due to tuberculosis compared with 2015, reaching an equivalent 90% reduction in tuberculosis incidence rate from a projected 110 cases/100 000 in 2015 to 10 cases/100 000 or less by 2035 and that by 2020, no tuberculosis-affected person or family should face costs that are catastrophic because of tuberculosis care (WHO, 2015a). On average, Drug Sensitive TB (DS-TB) patients and Multi-Drug Resistant TB (MDR TB) patients spend $369 and $3722 respectively on TB-related care in Uganda (MOH, 2019).

The lack of mechanisms for following the referred patients results in delays in drug initiation which hinder successful treatment and prevention efforts. The median total delay among pulmonary TB patients seeking healthcare at a regional referral hospital in Uganda is 13 weeks (Muttamba et al., 2019). This delay increases the probability of disease transmission at a family and community level due to the number of patients who are lost to follow-up (30 to 60%) (Alizadeh et al., 2019). The probability of community transmission in Uganda is 0.21 to 0.69 depending on the household contact and HIV status of the index case (McIntosh et al., 2019) with children being at a risk of being infected compared to adults. This has increased the severity of TB in Uganda as shown by the TB incidence rate of 196 (117-296) per 100,000 and 65 (39-98) per 100,000 people living with HIV and being included among the high TB burden countries (WHO, 2021b). Delay in presentation, diagnosis, and treatment of TB increases the morbidity

and mortality of the disease and increased transmission rates of TB in the community (Muttamba et al., 2019, Kiwuwa et al., 2005), and increases catastrophic costs on the side of the patient.

Intensified research and innovation is one of the pillars for achieving these targets, under which research to optimize implementation and impact, and promote innovations is a major action. It has been reported that indeed most innovations cannot be translated into effective local action without careful planning and adaptation, and partnership with stakeholders (WHO, 2014).

1.1.1. Public Private Mix

Originally, the private health sector was excluded from providing public health initiatives like TB programs since the government was perceived to be a better place to offer promotive, preventive, curative components of healthcare (WHO, 2001). However, due to the increase in the global TB burden, which overwhelmed the National Tuberculosis Programs, a need to shift and involve all healthcare workers in TB care including private providers arose. This was a strategic action in response to high estimate of TB prevalence globally, for the provision of TB services and to supplement and expand the Directly Observed Treatment Short-course (DOTS) (WHO, 2001). The consideration to involve private healthcare providers was due to their being among the key stakeholders that "treat a large portion of TB patients who may be distant from the national TB programme" (WHO, 2017b). In 2003, the WHO introduced Public Private Mix (PPM) in 2003 (Uplekar, 2003).

Public private mix (PPM) is defined as various strategies and approaches that link all healthcare entities from both private and public sectors to national tuberculosis programs for the expansion of Directly Observed Treatment Short-course (DOTS) activities and TB care services provision (WHO, 2004).

Empirical evidence from the implementation of PPM yielded improved case detection and holding in Nigeria (Asuquo et al., 2015), Myanmar (Nwe et al., 2017), and India (Dewan et al., 2006).

Public private mix has proved to be a cost-effective approach for TB care by reducing the financial burden from patients receiving TB care (cost of drugs) in the private sector (Anand et al., 2017). Although global progress has been registered in the involvement of private providers and the implementation of PPM, a large number of healthcare providers remain minimal (Uplekar, 2016) despite meeting a quite large number of patients.

1.1.2. Private Hospitals Involvement in TB care

Private health facilities include all non-state-owned enterprises and individuals in the provision of healthcare services. They range from mobile drug dealers/suppliers and individual clinic operators to corporate private hospitals (Mackintosh et al., 2016) and private-not-for-profit (PNFPs) which are usually subsidized by the government (Buregyeya et al., 2017).

Globally, TB control and care efforts have majorly been focused on the public sector even when over 49% and 81% of patients in sub-Saharan Africa and Asia respectively present TB symptoms initially to private/non-qualified (informal sector) (Wells et al., 2015). And in the process, these multiple visits from different providers result in excessive out-of-pocket expenditure on the patient's side (Tanimura et al., 2014) and substantially delayed diagnosis. Collaborating with different providers has the potential to improve and expand the implementation of PPM (Uplekar, 2016), therefore bringing private providers on board as early as possible is key to ensuring better health outcomes (Bennett et al., 2017).

The provision of TB care services in the private healthcare settings in low and middle-income countries is characterized by limited institutional capacity and weak integration of the TB control into general health services as seen in Nigeria (Ogbuabor and Onwujekwe, 2019), as well as patchy participation of the private providers and distrust from the public sector in India (Anand et al., 2017). In addition, the private sector is also coupled with a frequent loss to follow up among the TB patients being treated as seen in Myanmar (Nwe et al., 2017), and varying diagnostic, referral, and treatment services with the potential of amplifying the risk of drug resistance (Anand et al., 2017, Hudson et al., 2018).

In 2018, an estimate of one-third of the total individuals who developed TB was not detected and notified by the National Tuberculosis Programs (WHO, 2019) and this was more noticeable in settings with the large private sector in high TB burden countries (Stallworthy et al., 2020). Given the significant role played by the private sector in the provision of TB services, the WHO highly recommends the engagement of private healthcare providers as a strategic action in response to a high estimate of TB prevalence globally, for the provision of TB services (WHO, 2001). The deliberate and systemic engagement of private healthcare workers can potentially enable better TB management outcomes and is crucial in enhancing the reduction of unnecessary deaths and sufferings due to substandard diagnosis, inappropriate treatment, and care that characterize the private sector, which in the long run, leads to the reduction in catastrophic costs (WHO, 2018c).

In Uganda, 48% of the population prefer seeking healthcare services in private hospitals compared to 34% who prefer government hospital facilities and 17.6% who prefer, privately owned pharmacies, village health teams, and traditional practitioners (UBOS, 2018). This wide client base makes private providers key players in the healthcare service delivery in Uganda (USAID, 2017). However, most private health facilities in Uganda are incapacitated to provide TB treatment and care (Wynne et al.,

2014) they screen patients for symptoms and refer them for better management in public health facilities. Only public hospitals and a handful of private hospitals offer TB treatment (Sendagire et al., 2010, Buregyeya et al., 2014). According to the NTLP (2017), Out of 1336 diagnostic TB units (DTU), only nine private hospitals and 56 Private not-for-profits (PNFP) health facilities have laboratories providing TB Microscopy in Uganda. In addition, of the 111 installed Xpert MTB machines, Only 15 are found in private facilities (13 PNFP and 2 private clinics). The rest are in the public facilities. Most private hospitals lack capacity in terms of laboratory facilities to diagnose TB in case of suspicion—these end up being referred to government-owned health centers where TB diagnostic facilities and treatment services are found (Wynne et al., 2014). When patients are suspected of TB from a private health facility, they are issued referral notes from the healthcare workers which they present in high-level facilities (public) for better management and care (Mugisha, 2018).

Despite the referrals, patients often delay going to the referral units mainly due to the reluctance to transfer from private facility to public facility. Most patients from private healthcare providers end up getting lost to contact (30 to 60%) on referral since it is usually difficult to know whether the referred patients reached the referral health units and were initiated on TB treatment (Choun et al., 2017a) and (O'hanlon et al., 2017). This lack of patient follow-up mechanisms has led to increased delayed diagnosis and treatment initiation and lost follow-up and contact after referral. This has consequently resulted in increased disease severity, prolonged duration of infectivity and transmission at the household level, increased household expenditure in managing TB, increases the risk of drug resistance (Law et al., 2017), worsens the patients' health conditions, and eventually leads to death in the long run (Wood et al., 2010). There is a need for combined efforts for strengthening and establishing mechanisms (Buregyeya et al., 2014) for enhancing the tracking of patients to ensure that they reach the referral unit (Choun et al., 2017a).

The limited involvement of the private sector in TB care (MOH, 2017b) has resulted in increased prevalence and incidence of TB cases due to delayed case detection, lack of follow-up, and non-medication adherence. Consequently, catastrophic costs (spending at least 20% of household income on TB care) (MOH, 2019) in terms of managing Drug Sensitive TB (DS-TB) patients and Multi-Drug Resistant TB (MDR TB) to patients and their families (WHO, 2018b), increased risk of both untreated and undertreated infections and drug resistance (Cohen et al., 2016) among patients become inevitable.

Several approaches have been identified and put in place for ensuring systemic and scalable effort for engaging the private hospitals in TB control and care like contracting which involves the utilization of public funds to engage the private entities to deliver services (Bennett et al., 2017). This requires the definition of who does what in regards to implementation (Wells et al., 2015). However, the inability to design and manage these contracts by both the public and the private facilities hampers the process of implementation. On the other hand, regulation as another method of engagement that involves the establishment of standards and policies to ensure appropriate case management (Bennett et al., 2017) suffers inadequate enforcement due to the weak health systems capacity in high TB burden countries, most of these regulations are not followed. Funding which constitutes the major pillar of enhancing the PPM is still inadequate for ensuring proper implementation of the approach.

To address the current gap in PPM for TB care, guidelines for enabling the standardization of PPM for TB were developed in 2018 by Uganda stop TB partnership and the Ugandan Ministry of Health/NTLP. According to this report, the implementation of PPM in Uganda is conducted via a phased approach to enable the engagement of private facilities in TB service provision through training and mentorship, to build the capacity of the participating private health facilities. Progress indicates that a handful of private health practitioners including doctors, nurses, and laboratory personnel from six districts (Mbale, Tororo,

Jinja, Iganga, Gulu, and Kitgum) in eastern and northern Uganda were trained in the implementation of PPM activities. In addition to this capacity building, the MOH in partnership with United States Agency for International Development (USAID) Defeat TB project trained 20 private health practitioners to improve quality TB care to enable private health facilities to improve TB case notification, detection, and treatment in Kampala, Wakiso and Mukono Districts in Central region, Uganda. Although this continuous mentorship and coaching resulted in the engagement of over 150 health facilities in the country (MOH, 2018), facilities and healthcare workers from the southwestern part of the country have not yet had an opportunity to be involved which affects TB care efforts in the region.

Literature about barriers and motivators of private hospitals' engagement in TB care in Uganda is lacking. These barriers and motivators can be holistically identified through the Consolidated Framework for Implementation Research (CFIR) which is rich in providing a realistic structure for approaching multilevel constructs in the real world (Damschroder et al., 2009). It largely remains unclear how to translate the understanding of barriers and motivators into private hospitals' engagement in TB care. The application of CFIR to understand the barriers and motivators associated with private hospitals' engagement in TB care is crucial in guiding the identification of a potential behavioral technique to enable the involvement of private hospitals in active TB care. details about CFIR framework have are discussed in chapter two section 2.8.1.

1.1.3. Potentials of mobile health technologies

Mobile health (mHealth) refers to the use of portable devices with software applications to provide services and manage patient information (Källander et al., 2013). These technologies include mobile phones, tablets, and personal digital assistants. The use of mHealth technologies (e.g. smartphone apps, text messages, wearable devices) in supporting TB care is highly recommended by the WHO as an

emerging opportunity that can close the gaps in TB care (WHO, 2019). mHealth technologies are low-cost applications that can be sensitive to both the private sector ways of working and the expectations of the NTPs (Uplekar, 2016) with the ability to produce promising results in facilitating the engagement of the private hospitals.

The proliferation of mobile phones globally offers an open opportunity for exploration and use especially in low resource settings like Uganda where there are over 28.9 million mobile phone subscriptions (UCC, 2021a). mHealth interventions are less expensive, with the potential to reach a wide client base and the hard-to-reach groups (Evans et al., 2016). The utilization of mobile technologies has the potential to reduce the amount of time spent at health facilities, (Tumuhimbise et al., 2020) and enhance medication adherence among patients (Musiimenta et al., 2019, Musiimenta et al., 2018a). The adoption of mHealth has risen among healthcare workers for learning and informative purposes (Pande et al., 2017a), data collection (Ali et al., 2016b), and case notification (Lestari et al., 2017). However, their adoption and integration in the routine operations of the health sector have been slow compared to other sectors like banking, airline, and insurance (Bhattacharya et al., 2018). There is a dearth of research about their application in fostering PPM in Uganda. This knowledge would practically inform the future development of mHealth interventions for engaging private health facilities in TB care. Yet the use of such technologies can potentially address the current weak patient referral systems highlighted by Khan and colleagues (Khan et al., 2017), the lack of appropriate patient tracking and support systems, and the lack of the ability to cross-link and identify patients who move between private and public sectors, which continue to cripple the performance of TB control programs.

Although mHealth technologies can potentially enhance the involvement of the private sector, their utilization in Africa remains limited (Tumuhimbise and Musiimenta, 2021a). The development of

mHealth interventions should follow good software practices by outlining the frameworks on which they are developed, this is because they guide the process of translating effective interventions into practice (Moullin et al., 2020). Several frameworks have been implemented (Banos et al., 2015), (Van De Ven et al., 2017, Daramola and Nyasulu, 2020), however, little is known about those guiding the design of mHealth interventions for enhancing PPM for TB care which makes translation into practice difficult. Thus a need for new frameworks aimed at bridging this gap.

1.1.4. Mobile Health frameworks and the research gap

Despite the implementation and adoption of mHealth interventions for enhancing public-private linkage for TB care globally, there is a lack of application frameworks guiding the design of these interventions (Tumuhimbise and Musiimenta, 2021d). The usability of most mobile applications has been mostly affected by user interface functionalities and limited processing power challenges (Laakko et al., 2008). Researchers and software developers should ensure that the developed apps are effective in ensuring better health outcomes, thus a need for tools and frameworks for supporting the development and validation of mHealth applications (Banos et al., 2015) for TB care. Application frameworks have been marked to speed up the development process and keep the development costs of the tailored software relatively low (Laakko et al., 2008). For purposes of this research, a framework is an abstraction in which the software providing generic functionality can be selectively changed by additional user-written code thus providing application-specific software. In a scoping review that was carried out by the investigators (Tumuhimbise and Musiimenta, 2021d), only one out of nine studies utilizing mHealth applications for enhancing PPM documented the software framework on which the implemented mobile app was developed. This restricts software architecture replication and implementation for applications with

similar features and provision of support for large-scale reuse of the interventions (Fayad, 2001, Fontoura et al., 2000).

In this thesis, a framework for guiding the design of an mHealth application for linking and following up presumptive TB patients referred from private hospitals to public hospitals called Mobile Health Framework (MOHE) is discussed. The thesis introduces the MOHE framework and its use and describes a practical example of using the MOHE framework in a mobile application called Tuuka app used in tracking the referred presumptive TB patients from private hospitals to ensure that they reach the public hospitals (the place of referral). The framework was tested using Tuuka mobile app in the context of a private to public hospital referral environment for initial feasibility and acceptability. To concretize the implementation of the developed mHealth intervention, a policy framework called TRILI that emerged from the lessons learned and recommendations from the study findings is also introduced.

1.2 Problem statement

Lack of mechanisms for following up TB patients from private clinics who are referred to public hospitals (Sulis and Pai, 2017, Khan et al., 2017) has led to increased delayed diagnosis (Getnet et al., 2017) and treatment initiation (Okethwangu et al., 2019, Muttamba et al., 2019, Buregyeya et al., 2014), and lost follow-up/contact after referral. This has consequently resulted into increased disease severity, prolonged duration of infectivity (Jurcev-Savicevic et al., 2013) and transmission at household level, increased household expenditure in managing the disease, increases the risk of drug resistance (Law et al., 2017), worsens the patients' health conditions and eventually leads to death in the Long run (Wood et al., 2010).

Although the use of mHealth technologies in TB case identification and management, and patient support is highly recommended by the WHO (WHO, 2017a) due to their ease of use, broad reach and wide global

acceptance (WHO, 2018c), their utilization in enhancing PPM for TB care in Uganda is limited. Although, there has been modest application of mobile health interventions for Public Private Mix in Tuberculosis care (Choun et al 2017), literature regarding frameworks guiding the development of these mHealth interventions for PPM intervention design (Mummah et al., 2016) which makes replication and usability challenging. To the best of the researcher's knowledge, the existing frameworks for PPM in TB prevention and care (such as WHO's Emerging Policy Framework (WHO, 2001), and SPARK model (USTB, 2014) utilize face-to-face approaches which are restricted by geographical boundaries, and are time consuming. Specifically, the application, feasibility, acceptability of utilizing affordable mHealth tools in PPM for TB prevention and care remains unknown, which necessitates efforts to develop a new framework, assess its application, acceptability, and feasibility in enhancing TB prevention and care.

1.3 Research goal, objectives and questions

The overall goal of this research is to enhance the following up of TB patients referred from private to public hospitals through an mHealth framework in southwestern Uganda. To achieve this goal and address the identified research problem, the following specific research objectives were formulated.

1.3.1 Research objectives

In the light of the identified research gaps, this study addresses the following objectives

1) To analyze the existing mHealth interventions for public private mix to identify their strengths and weaknesses.
2) To explore the barriers to and motivators of private hospitals' engagement in TB care and the potentials of mHealth technologies to inform the design of a potential mHealth intervention using the CFIR framework.

3) To develop a framework for designing a mobile health application for following up presumptive TB patients referred from private to public hospitals.
4) To assess the initial feasibility and acceptability of the developed mobile health intervention for following up presumptive TB patients referred from private to public hospitals using the UTAUT model.

1.3.2 Research questions

In the light of the identified research gaps, this study addresses the following questions

1) What are the strengths and weaknesses of existing mHealth interventions for PPM in TB care?
2) What are the barriers and motivators to private hospital engagement in TB care and the potentials of mHealth technologies in enhancing PPM among private healthcare workers?
3) How can a framework for designing a mobile health application for following up presumptive TB patients referred from private to public hospitals be developed?
4) What is the initial acceptability and feasibility of a mobile health intervention for following up presumptive TB patients referred from private to public hospitals?

Addressing these research questions, involved four investigations each of which contributes to the achievement of the research objectives. The investigations include:

- Research investigation one: A scoping review study
- Research investigation two: A formative qualitative study
- Research investigation three: A framework design study
- Research investigation four: A mixed-methods study

The objective of research investigation one (a scoping review study) was to synthesize the evidence of the existing mHealth interventions for PPM in Tuberculosis care and their effectiveness from the existing literature. This investigation involved searching peer-reviewed literature from Google scholar, PUBMED, IEEE Xplore, and ScienceDirect databases from 1st January 2003 to 31st December 2020 for studies about the mHealth interventions for PPM in TB care. The review was guided by the scoping review methodology proposed by Arksey and O′ Malley (Arksey and O'Malley, 2005). Studies that discussed the utilization of mHealth interventions for implementing PPM in TB care were included and only nine studies met the inclusion criteria and were analyzed for review.

The objective of research investigation two (a formative qualitative study) was to explore the barriers to and motivators of private hospitals' engagement in Tuberculosis care and the potential of mHealth technologies to inform the design of a potential mHealth intervention using the CFIR framework. The study utilized in-depth interviews with 13 private healthcare workers purposively selected in June 2020 due to their active involvement in Tuberculosis care from four urban private hospitals in Mbarara City. An inductive, content analytic approach framed by the Consolidated Framework for Implementation Research, was used for analysis.

The objective of research investigation three (a framework design study) was to develop an mHealth framework for the design of an android mobile application for following up presumptive TB patients referred from private to public hospitals. A mobile application called Tuuka was developed based on the MOHE Framework.

The objective of research investigation four (a qualitative and quantitative study) was to assess the feasibility and acceptability of the developed mHealth intervention for linking presumptive Tuberculosis patients referred from private to public hospitals. The study utilized in-depth interviews and

questionnaires based on the UTAUT model among 18 private healthcare workers involved in TB care from three r urban private hospitals in Mbarara City, and four public healthcare workers at MRRH TB clinic who were trained and used the application for a period of one month February 2022.

1.4. Structure of the Thesis

This thesis is structured as follows: following this introductory chapter where the subject under investigation is presented, chapter two positions this research within the mHealth field. The review briefly discusses the PPM, an overview of different theories for behavioral change in technology adoption. Chapter three presents the research methodology approach adopted for this research. In this chapter, the mixed methods, the user-centered design approaches, data collection and analysis techniques for all the study objectives, and ethical considerations for the study are discussed.

Chapter four presents major findings of the existing mHealth interventions for PPM, the strengths and weaknesses and also the barriers and motivators to private hospitals' engagement in TB care, and the potential of mHealth as an enabler for healthcare workers' engagement.

Chapter five presents the framework development process where the description of the MOHE framework, its requirements, and modules, are discussed. The chapter also presents the Tuuka smartphone mobile application that was developed based on the modules of the MOHE framework. Chapter six presents the major findings of the initial feasibility and acceptability of the intervention developed among the Healthcare workers based on the UTAUT model.

Chapter seven presents the discussion of the thesis and chapter eight is the last chapter of the thesis which presents the research contributions (Knowledge, theoretical, technological), strengths, limitations, and

implications for future research, the general conclusion, and final remarks about the implication for research and practice and future research.

1.5.Rationale for this Thesis

TB is a serious global public health problem. Globally, nearly 10 million people develop TB and 1.5 million people die due to TB annually. About 98% of these cases and deaths occur in low and middle-income countries. Uganda is faced with a high burden of TB and is ranked among the WHO's high TB burden countries with an incident rate of 196 (117-296) per 100,000 and 65 (39-98) per 100,000 people living with HIV. TB is also a leading cause of death among people living with HIV/AIDS in Uganda (MOH, 2017b).

Most TB patients initially seek care from private clinics, which are often incapacitated to provide care (Anand et al., 2017). Private health facilities provide the majority of healthcare services in Africa and Asia (Montagu et al., 2016). In Uganda, 48.4% of the patients seek health services first in private hospitals, 13.6% in privately owned pharmacies compared to 34% who seek healthcare first from public hospitals (UBOS, 2018). Private health facilities are often the first point of contact for most TB patients before reaching the NTPs. In Uganda, the involvement of private health facilities in TB care has been minimal with only a handful providing TB services (Buregyeya et al., 2014). This has increased delayed case detection and treatment initiation, and non-medication adherence which can potentially explain the increased prevalence and incidence of TB in Uganda.

Mobile health technologies have shown promise for improving TB care, but there is a lack of studies utilizing these technologies to enhance PPM for TB prevention and care. The existing WHO Emerging Policy Framework through which the PPM is implemented (WHO, 2001) is mainly focused on policies

and recommendations and lacks the incorporation of mHealth technologies in the involvement of all healthcare providers in TB care. There is a need for a centralized referral tracking system that can reduce the number of delayed and missed referrals (Spahr et al., 2018), which ensures that patients referred from the private hospitals have been linked to the public facility where the TB management services are. To the best of the researcher's knowledge, the existing frameworks for PPM for TB prevention and care (such as WHO's Emerging Policy Framework (WHO, 2001), and SPARK model (USTB, 2014) lack mHealth components.

This study presents a mobile health (MOHE) framework to guide the design of an mHealth intervention for following up presumptive TB patients referred from private to public hospitals. The framework has the potential to reduce the missed/delays in diagnosis and treatment initiation and can result in better patient care and management. The framework is aligned with the WHO End TB strategy of reducing the number of TB deaths by 95% by 2035 (WHO, 2015b) and Uganda's health sector vision which is "to have a healthy and productive population that contributes to economic growth and economic development". MOHE framework is also in line with the sustainable development goal (SDG) number three which emphasizes ensuring "good health and wellbeing" to put an end to the epidemics of AIDS and Tuberculosis among others by 2030 (UNDP, 2015).

To the best of the researcher's knowledge, this is the first study to utilize mHealth technologies to follow up the referred presumptive TB patients from private to public hospitals. Thus, the study generates new knowledge about the application, feasibility, and acceptability of the developed mHealth intervention for enhancing PPM for TB prevention and care. This can be used as a basis for the Ugandan MOH to improve the involvement of private hospitals in the fight against TB, thus reducing missed referrals, as well as reducing delays in TB diagnosis and treatment initiation.

Based on the research gaps highlighted in the above existing literature, this research is necessary for the following four main reasons:

1. Due to the lack of clarity about which interventions that have been utilized for PPM in TB care, conducting a scoping review of published evidence on the utilization and effectiveness of mHealth interventions for PPM in TB care from literature, may help identify areas of improvement.
2. Given the lack of literature about the barriers and motivators to private hospitals' engagement in Tuberculosis care and the potentials of mHealth technologies in enhancing PPM in Uganda, it is important to explore the barriers to and motivators of private hospitals' engagement in Tuberculosis care and mHealth potentials in addressing the identified barriers to enhance PPM in Uganda to inform the design of a future mobile intervention.
3. There is lack of frameworks for guiding the design of mobile applications (Mummah et al., 2016a) for following up presumptive TB patients referred from private to public hospitals.
4. Given the current global efforts to engage the private sector in TB care efforts, understanding the feasibility and acceptability of the developed mHealth application can generate important insights for guiding practice and research.

The research presented in this thesis documents a review of published evidence on the utilization of mHealth interventions for PPM in Tuberculosis care, presents an exploratory analysis guided by the CFIR framework that explored context-specific barriers and motivators to private hospitals' engagement in TB care in Uganda. In addition the potentials of mHealth technologies for enhancing TB care were also explored to better inform the design of behavioural interventions that are aimed at enhancing the involvement of private hospitals in TB care. The thesis presents an implementation framework called

MOHE Framework for guiding the design of Tuuka mobile application for following up presumptive TB patients referred from private to public hospitals in southwestern Uganda. And lastly assesses the initial feasibility and acceptability of the developed mobile application.

This chapter (chapter 1) outlined a general introduction to the study by highlighting the background of the subject area under investigation, the research problem, the research objectives, and questions to guide the research investigation. The general literature about mHealth for TB care is discussed in the next chapter (chapter 2).

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter analyses literature in relation to this study, the researcher provides an overview of mHealth for TB care on a global scale, in developing countries, and in Uganda. The section gives an overview of the utilization of mHealth for enhancing PPM in TB care, offers an overview of frameworks for guiding the implementation of PPM and those guiding the design of mHealth interventions, discusses the feasibility and acceptability of mHealth technologies for TB care and discusses theories in which this work has been based on and synthesis of literature and research gap identification.

2.2 MHealth for Tuberculosis care

MHealth is an "emerging mobile communication and network technology for healthcare" (Istepanian et al., 2006). Källander and colleagues define it as the use of portable devices with software applications to provide services and manage patient information (Källander et al., 2013). Global Observatory for eHealth (GOe) defines mHealth as a medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, and personal digital assistants (PDAs) (Kay et al., 2011). Jeffrey Sachs, the director of Earth Institute cited in (Charles et al., 2014) stated that "Mobile phones and wireless internet end isolation and will therefore prove to be the most transformative technology of economic development of our time" (Sachs, 2008). The use of mHealth to support the achievement of health objectives is a growing area of e-health due to the increase in the coverage of mobile cellular networks and its ability to provide consistency in the delivery of interventions across a wide population at a low cost (Cooper et al., 2017).

MHealth has evolved to cover a variety of ranges which include wearable sensors in form of headbands, skin patches, earphones, clothing, watches, and bracelets which allow unobtrusive, passive monitoring, tracking, and transferring of biometric data with the healthcare workers, researchers and family members (Steinhubl et al., 2015), lab on a chip which offers diagnostic capabilities, imaging from afar that involves the usage of high-resolution cameras lense of smartphones to host several medical applications.

Smartphone applications have been identified among business-friendly approaches sensitive to both the private sector ways of working and the expectations of the NTPs (Uplekar, 2016, Buregyeya et al., 2014) with the ability to produce tremendous results in facilitating the engagement of the private hospitals. However, the utilization of such technologies in developing countries is still limited. Khan and colleagues document that lack of information and communication technologies (ICT) usage, weak patient referral systems, lack of appropriate patient tracking and support systems, and the lack of the ability to cross-link and identify patients who move between private and public sectors cripple the performance of TB control programs (Khan et al., 2017).

The application domains of mHealth include education, point of care diagnostics, registries and event tracking, collecting data and reporting, provider to provider communication and peer to peer consultation, scheduling, financial transactions, and incentives (Labrique et al., 2013, Charles et al., 2014). This helps in eliminating geographical barriers in ensuring the enhanced coverage, and quality of health services (Nhavoto and Grönlund, 2014, Varshney, 2014, Miah et al., 2016).

In addition to revolutionizing how populations interact with national services, mHealth has proved to advance the quality and coverage of healthcare, and increase health information services and skills thus improving health behaviors to prevent diseases (WHO, 2018a). MHealth interventions are less expensive,

with the potential to reach a wide client base and the hard-to-reach groups (Evans et al., 2016, Déglise et al., 2012).

Literature has shown that mHealth has been utilized in TB care. A scoping review by Lee and colleagues documents the utilization of mHealth interventions in medication adherence via SMS and video observed therapy via smartphone apps in the United States of America, China, and India (Lee et al., 2020). In addition, three systematic reviews by (Ngwatu et al., 2018, Subbaraman et al., 2018, and Alipanah et al., 2018) also document how SMS and video observed therapy has been utilized to support TB medication adherence (Ngwatu et al., 2018). A descriptive review by Keutzer and colleagues identified 55 mobile apps that were utilized in supporting TB treatment by supporting patient adherence, adjusting medication dosages, supporting e-learning, and diagnosis of TB (Keutzer et al., 2020). Deep learning based on deeper neural networks has also been piloted in Peru and has shown promise in improving TB diagnosis (Alcantara et al., 2017).

An mHealth application that aimed at supporting the provision of home-based Directly Observed Treatment (DOTS) among 394 providers was implemented in Bangladesh to manage 435 MDR (Multidrug-resistant) TB patients, improved TB treatment adherence, treatment compliance, and reduced missed DOT (Kak et al., 2016). This facilitated case management of the MDR patients and reduced the human resource burden for supervision through central monitoring thus enhancing patient care. The utilization and adoption may be attributed to the increased number of mobile subscribers globally (Pew_Research_Center, 2019) and internet access (Rodríguez-Castelán et al., 2021). However several barriers that might limit the adoption of mobile internet adoption were highlighted by GSMA and these are (i) affordability of data services, (ii) limited awareness about the benefits of mobile data usage, (iii) lack of products that meet the users' needs, (iv) the negative aspects and risks associated with the internet,

(v) and lack of access to the internet (GSMA, 2021). Therefore the deployment of interventions that require the internet to function should put into consideration of the noted factors.

Despite its utilization in supporting TB care, with the potential to reach a wide client base, literature about the utilization of mHealth in following up presumptive patients referred from private to public hospitals as a key factor for PPM is limited despite its ability to enable the participation of the private health facilities (non-state-owned hospitals, clinics, pharmacies) in identifying cases and following them up till they reach the referral unit.

2.3 MHealth for Tuberculosis care in developing countries

mHealth technologies have been utilized in developing countries and actually, their usability is on the rise because of the increase in the number of mobile phone subscribers. Most of these phones are feature phones which limit the compatibility with modern smartphone technologies for supporting TB care (Ngwatu et al., 2018). According to the International Telecommunication Union (ITU) report, it is projected that in Africa, there will be a 90% mobile phone penetration rate as of 2025 (ITU, 2020). This presents an opportunity for utilization in achieving health outcomes. A formative study carried out in Uganda noted that mHealth technologies may be acceptable tools for reminding patients to take their medication, demonstrate their commitment to adherence, and also help in the provision of instrumental, emotional, and informational support among TB patients (Musiimenta et al., 2019, Musiimenta et al., 2020a). A systematic review by (Betjeman et al., 2013) highlighted the potential of mHealth in supporting medication adherence, enhancing communication between healthcare workers, and standardizing the storage, analysis, and sharing of patients' data. In Tanzania, a TB self-screening and patient treatment mobile application were launched in 2018 among the general population by the NTLP to increase symptomatic TB patients identification and to offer TB treatment information for patients

who were initiated on TB. The intervention saw the TB self-screening of over 164,018 patients and 7,657 individuals who used the messaging service (CDC, 2019). In Lesotho, an SMS intervention enhanced communication between patients, treatment supporters, and providers (Hirsch-Moverman et al., 2017).

A pilot study in South Africa that developed a mobile application for case notification and treatment initiation was implemented and resulted in reduced delays in treatment initiation (Maraba et al., 2018). Another study carried out among six countries in Africa (Senegal, Algeria, Democratic Republic of Congo, Niger, South Africa, and Cameroon) showed that countries with high mobile phones rate showed higher rates of TB treatment completion compared to those with lower mobile phone rates (Ibeneme et al., 2021). There are also several challenges associated with the deployment and implementation of mHealth interventions in developing countries like Africa which may hinder their utilization. The challenges include the availability of the necessary infrastructure, operational costs, and knowledge of using the developed intervention and policies within the organization or countries about using mHealth interventions (Betjeman et al., 2013).

Although mHealth has been utilized in developing countries, it is majorly implemented within the public health facilities, this excludes the private sector engagement in TB care even when it is recommended as part of efforts to avert TB disease. Factors that facilitate the adoption of mHealth technologies in TB care remain unknown despite being the key players in the provision of health services in Africa. This calls for an investigation to understand the barriers to and motivators for private hospitals' engagement in TB care and the potential of mHealth technologies in enhancing PPM.

2.4 Mobile Health for Tuberculosis care in Uganda

Currently in Uganda, the number of mobile phone subscribers stands at 29.1 million (UCC, 2021b). The increase in the number of mobile phone subscriptions comes with the potential for exploration as far as the adoption of health-related services is concerned. Several mHealth interventions have been utilized including SMS for contact tracing (Meyer et al., 2018, Meyer et al., 2020), supporting medication adherence (Musiimenta et al., 2019), and enhancing the linkage of presumptive TB patients (Buregyeya, 2020). SMS messages have shown promise in decreasing TB treatment attrition among TBHIV patients in Uganda (Hermans et al., 2017) and in delivering test results (Babirye et al., 2019). DOT selfie, an mHealth intervention supplemented with a social bundle incentive is being studied to understand its effectiveness in increasing adherence to medication adherence (Sekandi et al., 2021). A mobile intervention that utilizes mobile money to incentive medication adherence and access to TB care among patients is currently being piloted in southwestern Uganda (Musiimenta, 2021). A mobile phone-based interactive voice response software for remote TB symptom reporting is being implemented in Kisenyi Kampala (Byonanebye et al., 2021).

All these interventions have shown promise in ensuring better TB health outcomes however their implementation in Uganda must be done with attention issues of status disclosure, and not seeing the SMS messages on time (Musiimenta et al., 2019) which might affect adherence or use of the intervention. In addition majority of these interventions have been implemented in public hospital settings thus leaving their effectiveness, usability, and feasibility in private hospitals limited, since factors that facilitate public settings might differ from those in private settings hence a need for investigation.

2.5 Mobile Health for Public Private Mix in TB care

Although mHealth has been recommended by the WHO as an emerging opportunity to close the gaps in TB treatment and care (WHO, 2017a), literature documenting the utilization of these mHealth technologies for enhancing PPM is limited. Several mHealth interventions have gradually been integrated into TB care to enhance the PPM in India (Velayutham et al., 2015a, Pande et al., 2017b, Chadha et al., 2017a), Vietnam (Thu et al., 2020b), Indonesia (Lestari et al., 2017), Cambodia (Choun et al., 2017a, Choun et al., 2017b), Pakistan (Khan et al., 2012b, Mohammed et al., 2016a, Ali et al., 2016a) through, case notification, screening, following up patients. This thesis conducted a scoping review study (investigation one) to analyze the existing mHealth interventions for PPM to identify their potentials, strengths, and weaknesses, and a detailed account of the results is presented under chapter four section 4.2. The review was carried out to inform the appropriate design of a potential mHealth intervention in Uganda and replication of successful interventions and identify areas of improvement like feasibility, acceptability, and efficacy of the implemented interventions in TB care.

Although this scoping review highlights the several mHealth technologies that have been utilized in enhancing PPM in TB care, its utilization is still limited in African settings. No Africa-based study was identified by this review. Future studies should focus on assessing the utilization of mHealth for PPM in Africa.

2.6 Overview of frameworks for guiding the implementation of PPM

2.6.1 WHO's Emerging Policy Framework for Public Private Mix

In a bid to involve all the healthcare workers in the provision of services, the WHO introduced the PPM in 2001 and was implemented on an emerging policy framework (WHO, 2001) composed of five key contours of implementation as explained below.

Encouragement of action-oriented communication with and information gathering on the private health sector at all levels. This contour calls upon the NTP managers to assess the extent and nature of the involvement of the private health facilities in TB care, by analyzing the possible threats and opportunities posed by their involvement.

Collaboration with the private health sector within the DOTS framework. This contour highlights the need for maintaining accountability when engaging the private health facilities and should ensure autonomy when devising PPM delivery models.

Evaluation of PPM pilot projects and scaling up those found to be successful. The contour highlights the need for setting up pilot projects for enhancing PPM which should be evaluated in terms of their outcomes and scaled up if successful.

Availability of public funding for provision of TB care by private providers. This contour highlights the need for funding to run TB services from the NTP.

Emphasis on the public health aspects of the control of TB and other communicable diseases in the medical curricula. This contour highlights the need for medical students to spend more time working with the NTP to enhance their training.

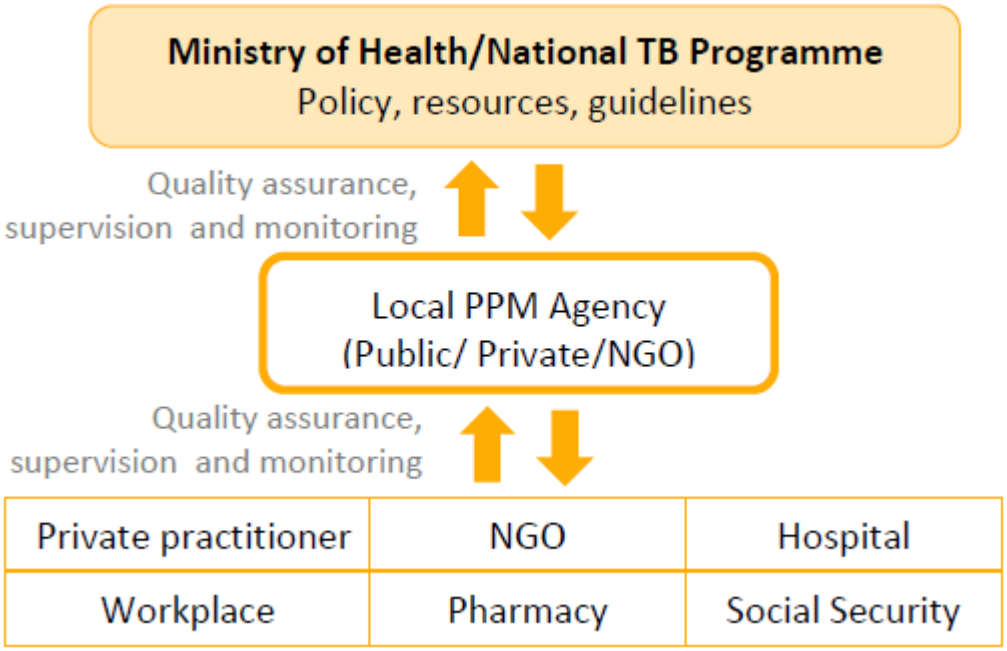


Figure 2.1: PPM in Implementation (Source: WHO PPM fact sheet 2017)

The above contours are the key pillars of the WHO's Framework for implementing the PPM. The framework majorly focuses on the considerations that should be in place to ensure a successful PPM implementation, for example, the availability of funding contour which many developing countries grapple with may not be realized due to limited budgets to finance both the private and the NTP TB care. The communication by the NTP with private health facilities is not sufficient and this is evidenced by the majority of the private health facilities in Uganda who are unaware of the existing public-private partnership (MOH, 2017a) which leaves the private hospitals out in the provision of TB services. This calls for a need for innovative strategies for developing low-cost for all sectors technologies that will be utilized by the private health facilities to ensure that successful outcomes are ensured.

2.6.2 PPIA MODEL (Private Provider Interface Agency Model)

The Private Provider Interface Agency model was developed and implemented by PATH in 2013 in Mumbai India as a systematic and innovative to enhance the engagement of the private sector in TB disease management (PATH, 2019, Nandi, 2015). The model utilizes the hub and spoke model as a one-stop-shop for all the services that a patient would get in-house at the same point through an electronic voucher system to handle patient subsidies by establishing PPIA one-stop-shop centers. It is an innovative approach to networking the private providers for timely disease diagnosis and treatment.

In this model, when a patient is suspected of TB by X-ray, he or she is referred to a hub hospital where the chest physician/ consultant provides specialized care for enhanced early diagnosis and if diagnosed with TB, they receive free first-line anti TB drugs from the private chemist and if they are resistant to rifampicin he or she is referred to the public sector for treatment. The patients are then monitored by tracking their drug refill dates and sending them daily text message reminders and phone calls to ensure that they comply with their medication-taking behavior.

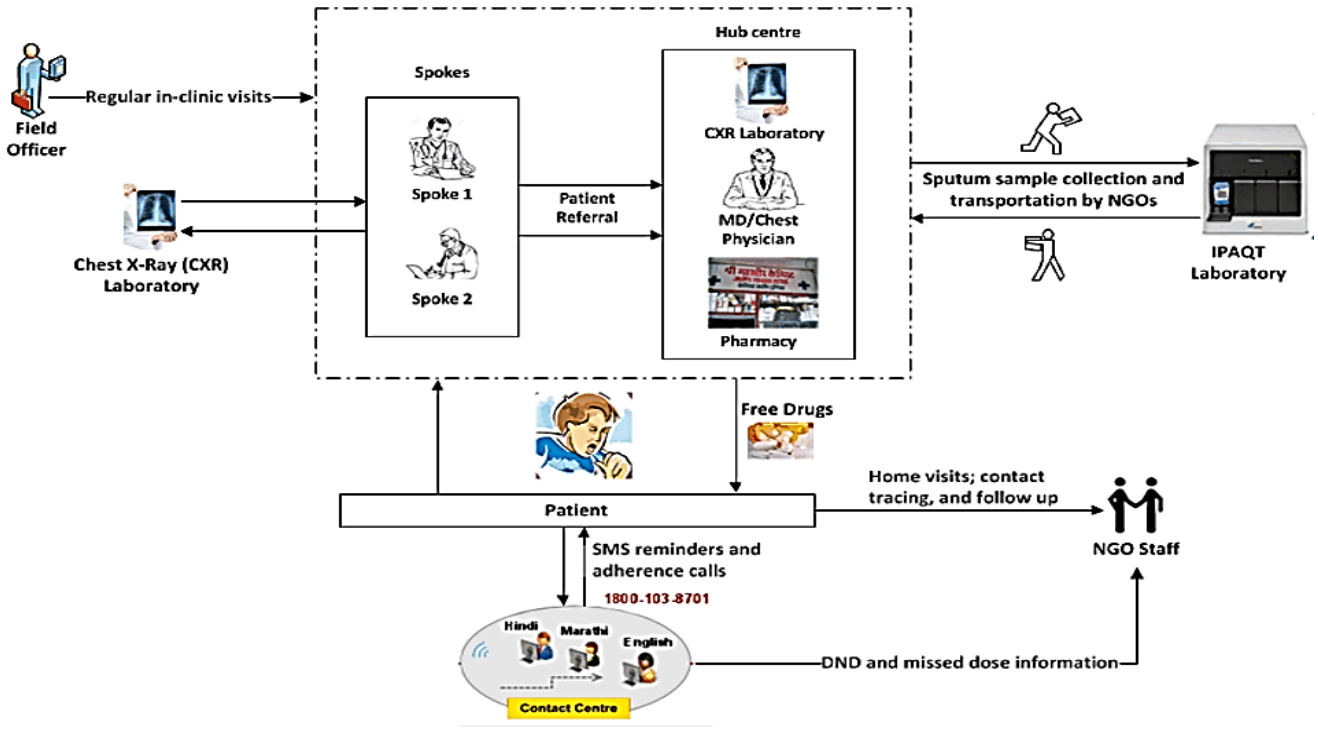


Figure 2.2: Private Provider Interface Agency (PPIA) Model (Source: (Nandi, 2015)

2.6.2.1 Strength and Weaknesses

The strength of this method is that healthcare providers can retain the patients and can offer value-added services (Wells et al., 2015), and enhances quick patient referral and early initiation of anti TBs by the patients. The implementation of this framework focuses on establishing a network amongst private providers and empowers the private hospitals to manage TB patients. However, in its establishment, the PPIA model doesn't spell out the involvement of public health facilities, to ascertain concrete evidence of PPM.

2.6.3 SPARK TB MODEL

Slum Partnerships to Actively Respond to Tuberculosis in Kampala District (SPARK TB), a public-private partnership model was implemented between October 2011 and April 2014 for improving access to quality TB diagnosis and treatment for the urban poor in Kampala slums by The Union (USTB, 2014). By combining the public, private, and community efforts and skills to increase TB services. The model is composed of nine main components: Selecting the private providers, training the public sector on how to engage the private health facilities, meeting the directors of the private hospitals for buy-in and signing the memorandum of understanding, and training the private healthcare providers in TB care, Branding the Private sector, supporting the private hospitals in receiving medicines from the public sector (Linking Private facilities to public facilities for medication, Directly supplying the private hospitals or linking the private facility to another private facility for medication), Linking the community volunteers to private facilities for patient follow up, improve community education on TB and monitoring of service delivery.

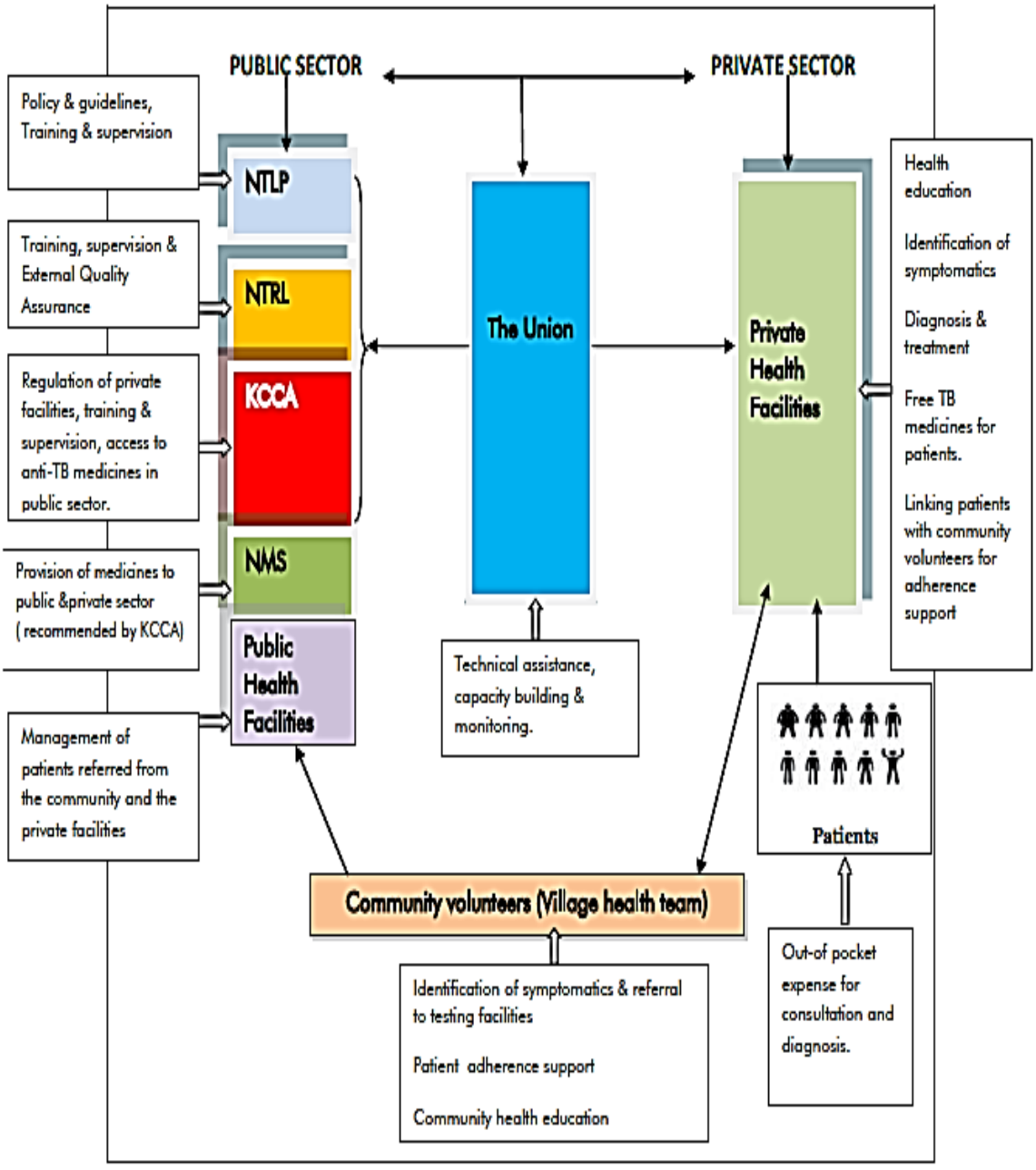


Figure 2.3: SPARK TB Model- Source: (USTB, 2014).

Strength and weaknesses of SPARK TB Model

The model resulted in increased case identification due to the private health facilities' involvement and the community VHTs (Village Health Teams), increased case diagnosis in the private health facilities, and improved treatment success rate to 80% (USTB, 2014). However the model doesn't cater to modern digital health interventions, it only relies on the Village Health Teams (VHTs) for patient follow up which is expensive in the long run to sustain their efforts and inherits the challenges of DOTs (Directly observed Treatment, Short-course). Thus a need for the implementation of an mHealth framework for following up with patients to ensure that they adhere to the hospital appointments. Frameworks that guide the implementation of interventions that utilize mHealth technologies are needed for exploiting the benefits of mHealth in enhancing PPM.

2.7 Frameworks guiding the design of mHealth interventions

The development of mHealth interventions is a complex process since it involves key stakeholders engagement, working with the developers to come up with the a final working mobile solution (Sporrel et al., 2021). As a way of improving the development process of mHealth interventions, frameworks have been proposed for example the Integrate Design, Assess and share (IDEAS) framework (Mummah et al., 2016b). Frameworks for guiding the development of mHealth interventions informed by the perspectives from user results in high rates of usability and changes in health behaviours (Phillips et al., 2019).

Several frameworks have been developed to guide the development of mHealth interventions and these include the mHealthDroid Framework (Banos et al., 2015), Multiple stakeholders and data analytics framework (MUCODAF) (Daramola and Nyasulu, 2020), Digital collaborative framework (DCF) (Daramola and Nysaulu, 2019) and the University of Limerick Tool for Ecological Momentary

Assessment and intervention Triggering (ULTEMAT) Framework (Van De Ven et al., 2017) as explained below.

2.7.1. The mHealthDroid Framework

The mHealthDroid Framework is an open-source mHealth framework for android developed to enhance the easy and rapid development of both mobile and biomedical apps (Banos et al., 2014, Banos et al., 2015). The framework was developed to accommodate several mobile devices including tablets, wearable sensors, and other biomedical systems specifically for monitoring and enhancing personal healthcare and wellbeing.

MDroid offers a generic structure for designing and integrating biomedical android systems and enables the collection and extraction of biomedical data from several interconnected mobile devices for both ambulation and biomedical signals, enabling alerts and guidelines for multiple interventions. The framework supports diverse modes and enables extensibility across various platforms and environments to facilitate the implementation of new systems. The framework is composed of six key modules namely; (i) system manager for managing mobile device resources including wireless connections like WiFi, and Bluetooth; (ii) communication manager for providing abstraction for different applications to function independently, (iii) storage manager for storing raw data locally and remotely; (iv) visualization manager for graphically representing the processed data and offers diverse ways of displaying data; (v) data processing manager for processing raw health data for signal processing, data mining and machine learning and (vi) service enablers including triggering alerts, notifications, guidelines, and

reports.

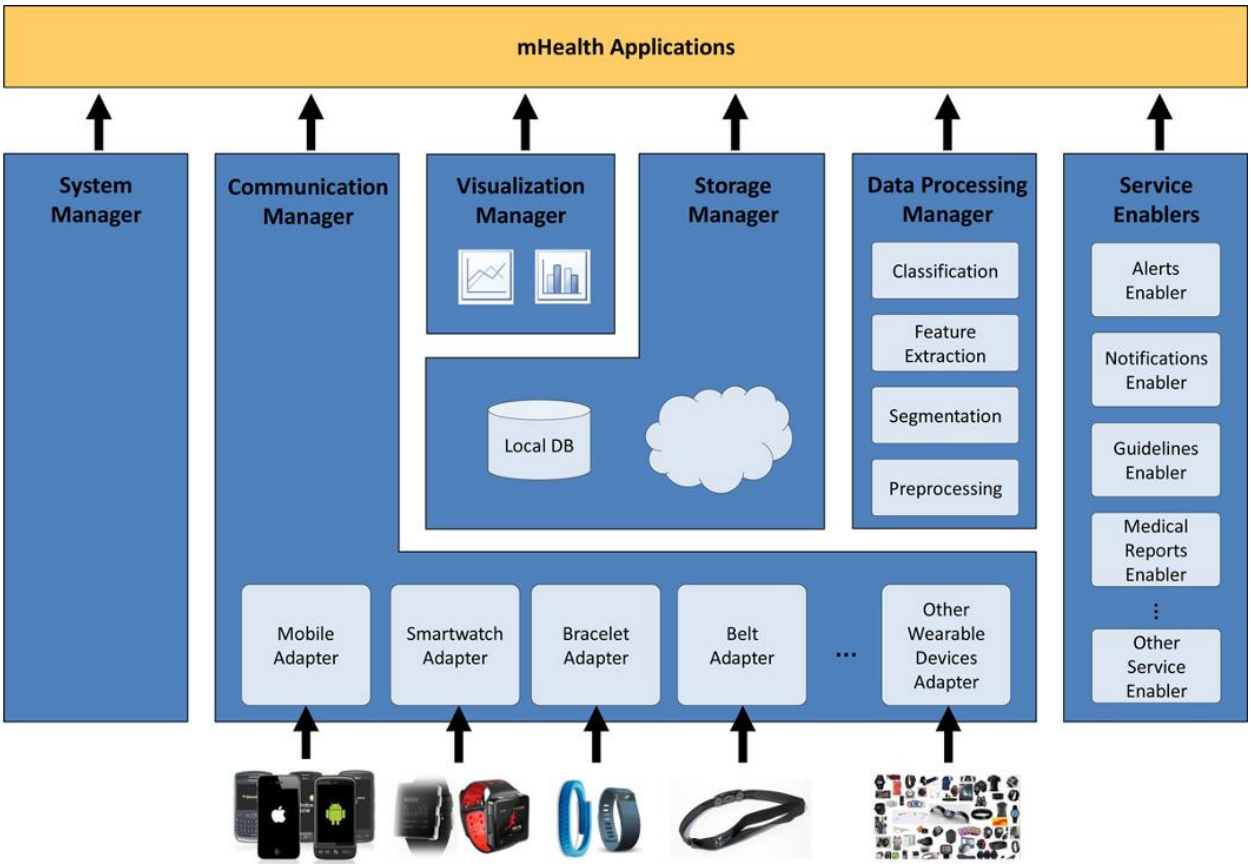


Figure 2.4: showing the mHealth Droid Framework

Strength and weaknesses of mHealth Droid framework

The framework enables the collection and extraction of biomedical data through external wearable devices from several interconnected mobile devices. In addition, mHealthDroid implements enablers that offer interfaces for triggering phone calls and text messages. The framework through the data processing manager encompasses modern data science techniques like data mining and machine learning.

However, the framework is only limited to android platforms leaving out other platforms like IOS, thus a need for frameworks that run across all platforms to enhance and increase service usability.

2.7.2. Multiple stakeholders and data analytics framework (MUCODAF)

MUCODAF framework is a conceptual governance framework for improving medication adherence among relevant stakeholders involved in TB patients' care like healthcare workers, family members, and friends to collaborate to offer support to the TB patient (Daramola and Nyasulu, 2020). The framework proposes the integration of cloud computing, wearable sensors, artificial intelligence, machine learning, and data analytics techniques to enhance TB patient care. The main purpose of the framework is to improve TB patients' medication adherence and enhance better treatment outcomes. The framework is majorly focused on five main use cases;

- Digital collaboration of multiple stakeholders for enhancing information exchange between stakeholders using a mobile application.
- Medication adherence monitoring through data acquisition about the patients' medication behaviors, involving the usage of water proof smartwatch worn by the patient which is paired with the patient's smartphone via Bluetooth.
- The data-Driven decision-making use case for supporting healthcare workers' decision making based on the medication adherence data received and can be able to make an informed decision about the patients' treatment
- The personalized treatment strategy for patients via intelligence recommendations from the received data. These recommendations include counseling for non-adherent patients, this is meant to support healthcare workers to make best-informed decisions
- Data archiving and curation through automated processing for data categorization and reuse.

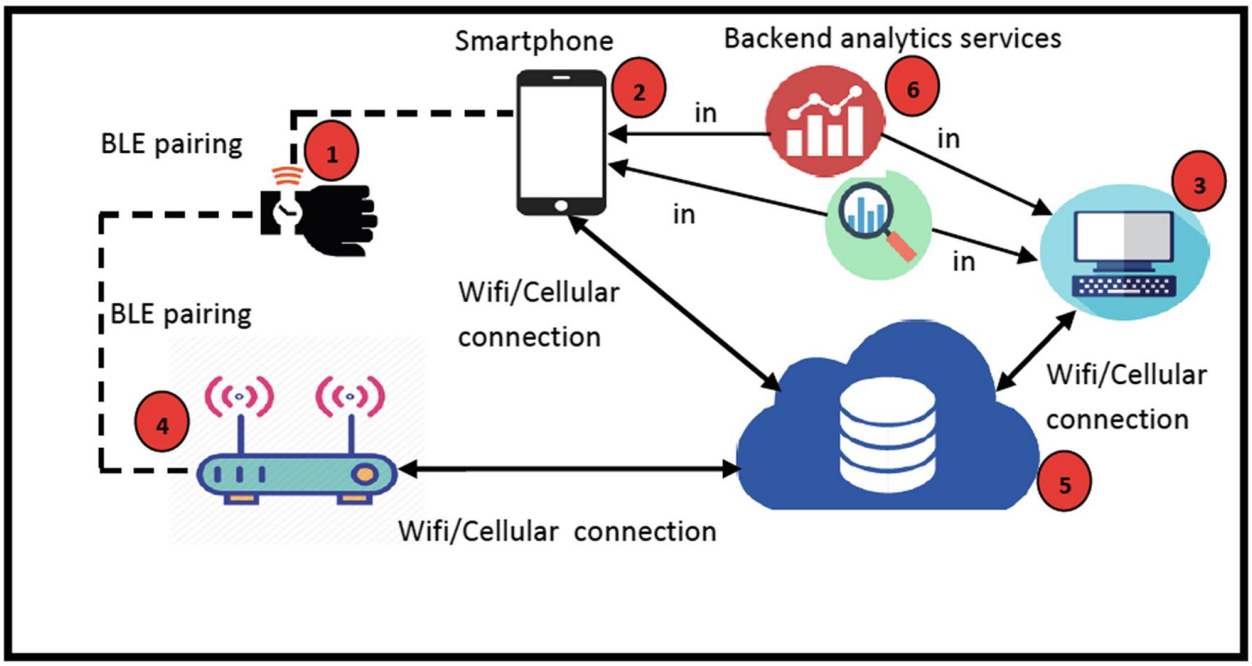


Figure 2.5: MUCODAF framework

Strength and weaknesses of MUCODAF

The framework has the potential to integrate cloud computing, wearable sensors, artificial intelligence, machine learning, and data analytics techniques in enhancing TB medication adherence among patients. However, being at a conceptual level, its practical guidance in developing an intervention becomes difficult to ascertain.

2.7.3. The University of Limerick Tool for Ecological Momentary Assessment and intervention Triggering (ULTEMAT) Framework

This framework was developed to enhance the scheduling and delivery of ecological momentary assessments (EMAs) to the users' mobile devices (Van De Ven et al., 2017). The framework enhances

the triggering of time-based ecological momentary assessments. The framework was implemented in the investigation of the cost-effectiveness of blended cognitive behavioral therapy depression treatment. The framework uses a flexible and extendible architecture for allowing the addition of new triggers and EMAs to the existing codebase. ULTEMAT is an android based framework and was implemented in a smartphone application called the mood booster app which presents the users with an option of rating different aspects of their physical and mental health, provides motivational feedback to the users to improve their treatment adherence, and presents the graphical interpretation of mood levels to the users and allows therapists to communicate with their patients.

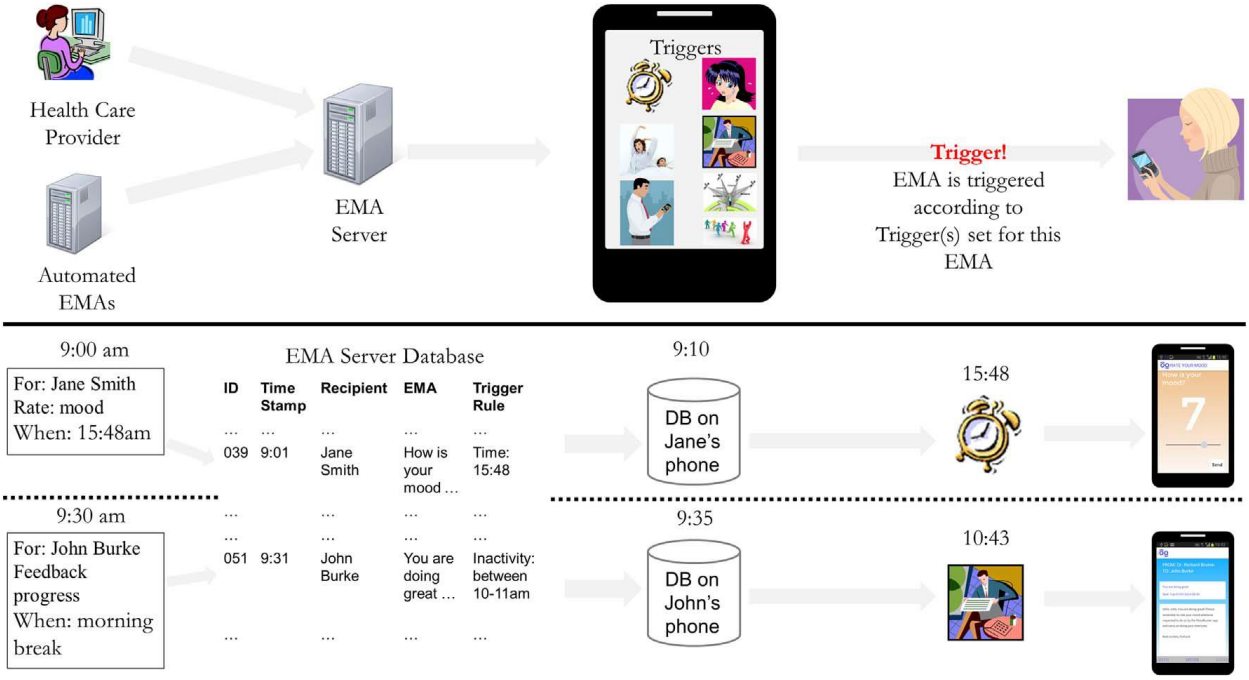


Figure 2.6: illustration of the ULTEMAT Framework

Strengths and weaknesses of ULTEMAT framework

The framework enhances the scheduling based on time, the usage of the application, physical activity, location, and responses which are aimed at enhancing patient-based care. The framework enhances

feedback from clinicians and automated feedback to patients. The framework is validated by a smartphone mobile application. However, the framework is also limited to android platforms leaving out other platforms like IOS, thus leaving its implication and usability across other platforms unknown.

Table 2.1 Summary of existing frameworks

Framework	Strength	Weakness
WHO's Emerging Policy Framework for Public Private Mix (WHO, 2001)	Focuses on the considerations that should be in place to ensure a successful PPM implementation	• Doesn't cater for modern mHealth interventions
Private Provider Interface Agency (PPIA) Model (Nandi, 2015)	Enhances quick patient referral and early initiation of anti TBs by the patients.	• Doesn't clearly spell out the involvement of public health facilities, to ascertain a concrete evidence of PPM • Doesn't cater for modern digital health interventions
SPARK TB Model (USTB, 2014)	• Increased case identification • increased case diagnosis in the private health facilities	• Doesn't cater for modern digital health interventions • Relies on the Village health Teams (VHTs) for patient follow up which is expensive
mHealthDroid Framework (Banos et al., 2015)	• Collection of biomedical data from interconnected mobile devices • Triggers phone calls and text messages	• Not customized to TB care
ULTEMAT Framework (Van De Ven et al., 2017)	• Enhances the triggering of time based ecological momentary assessments	• Not customized to TB care
(MUCODAF) (Daramola and Nyasulu, 2020)	• Integrates AI, machine learning techniques for TB medication adherence.	• Conceptual level • Focused on TB medication adherence

The literature documented above and in table 2.1 above indicates that several frameworks have been developed to guide the development of several mHealth interventions however there is limited

information about frameworks that have been developed for following up the referred presumptive TB patients from private to public hospitals.

2.8. Acceptability and feasibility of mHealth Technologies for TB care

Understanding the acceptability and feasibility of mHealth technologies is important in laying the foundation for the usability, adoption, and utilization of the developed technologies. However, literature regarding the acceptability and feasibility of mHealth technologies for TB care in enhancing PPM is limited. Given the promise of mHealth interventions in supporting TB care, studies about how acceptable and feasible these technologies are especially in enhancing PPM are needed. A study was carried out in Indonesia by Lestari and colleagues to explore the feasibility of a referral and reporting back mobile smartphone application (Lestari et al., 2017) and found the application feasible. A pilot intervention study for determining the technical feasibility of the Weltel intervention utilizing Automated SMS messages from a computer system at a clinic in British Columbia was feasible (van der Kop et al., 2013). The feasibility and acceptability of mHealth interventions for following up the referred presumptive TB patients from private to public health facilities in Uganda are lacking. This thesis addresses this gap by exploring the acceptability and feasibility of an mHealth intervention for following up presumptive TB patients referred from private to public hospitals in southwestern Uganda.

2.8 Overview of models for behavioural change and technology adoption

Models provide a road map or a summary of what factors to consider when designing, implementing, and evaluating a health promotion program (Raingruber, 2014). They provide a clue as to why people and communities make health-related choices thus providing a potential clear way of understanding situations, examining the relationship, and predicting potential outcomes.

Various models and theories have been developed in the past with several constructs that might help to explain the acceptability, and feasibility of using mHealth for following up presumptive TB patients referred from private to public hospitals, and these are the Unified Theory of Acceptance and Use of Technology (UTAUT) model, and the Consolidated Framework for Implementation Research (CFIR).

2.8.1 The Consolidated Framework for Implementation Research (CFIR)

The Consolidated Framework for Implementation Research (CFIR) was developed to guide researchers to systematically assess multilevel implementation factors which influence intervention, implementation, and effectiveness. This is aimed at enhancing study findings' generalizability and interpretability (Keith et al., 2017). The utilization of a validated theoretical framework like CFIR offers a logical structure for guiding formative evaluations (Damschroder et al., 2009) and understanding the perceptions of stakeholders in evaluating interventions. The CFIR framework was proposed by Damschroder and colleagues and is composed of five main domains namely: (1) Intervention characteristics which involves stakeholders' perceptions about relative advantage of engaging private hospitals in TB care, (2) Outer settings; that involves external features that influence the engagement of private hospitals in TB care (3) Inner setting; features of private hospitals that influence their engagement in TB care (4) Characteristics of individuals involved in private hospitals that might influence the process of engagement in TB care and (5) Implementation process that involves tactics that might influence the engagement of private hospital's in TB care.

The application of CFIR to understand the factors associated with private hospitals' engagement in TB care is important in guiding the identification of a potential behavioral technique to enable the involvement of private hospitals in active TB care. CFIR was chosen for this study because it has a successful track record for providing a comprehensive approach for identifying barriers and facilitators

to the adoption of health behaviors and guiding formative evaluations that can address context-specific barriers that could compromise the viability of the interventions (Damschroder et al., 2009).

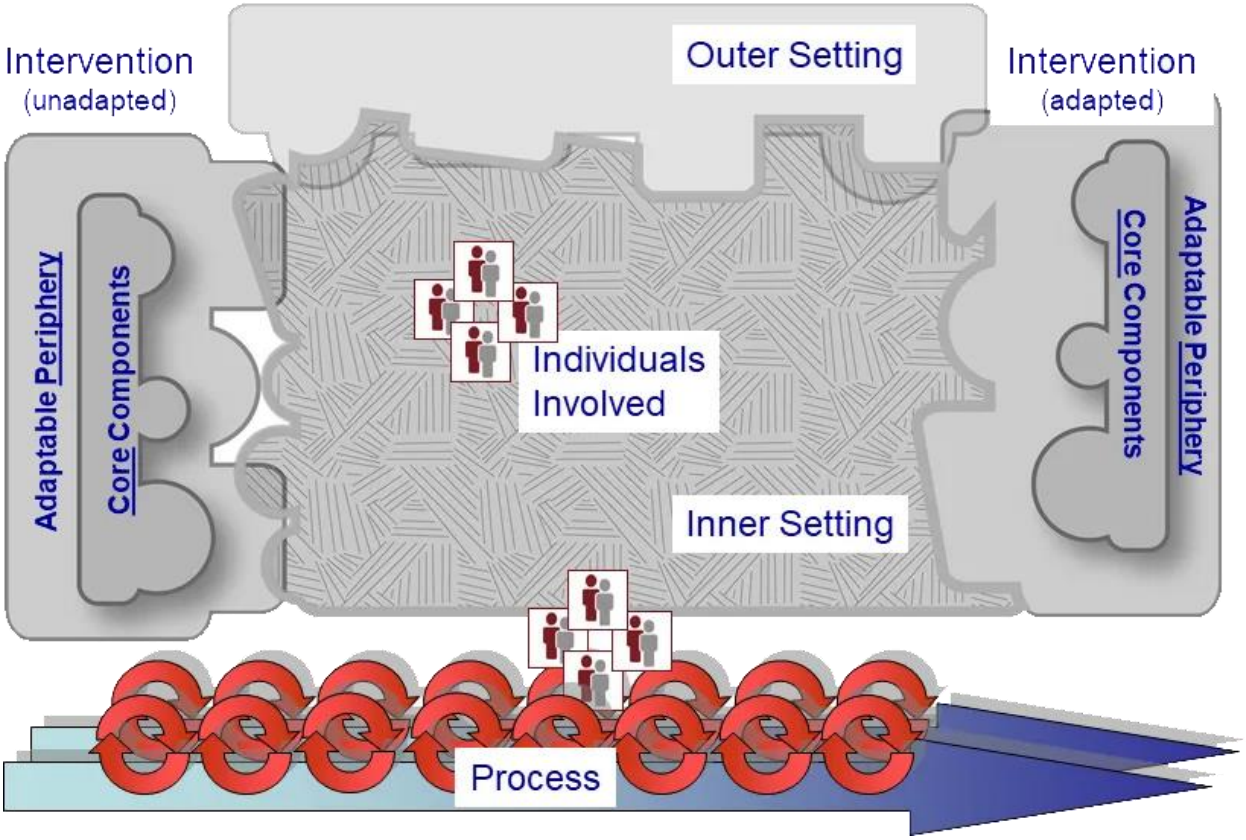


Figure 2.7: CFIR domains

Although the CFIR framework has been utilized in understanding how nurses perceive task-shifting strategies in hypertension (Gyamfi et al., 2020), and not yet utilized in investigating the barriers and motivators associated with the engagement of Private Hospitals in Tuberculosis care and the potentials of mHealth in enhancing PPM in Uganda. It largely remains unclear how to translate the understanding of barriers and motivators into private hospitals' engagement in TB care. Literature about barriers and motivators of private hospitals' engagement in TB care and the potential of mHealth in Uganda is lacking. These barriers and motivators can be holistically identified through the Consolidated Framework for

Implementation Research (CFIR) which is rich in providing a realistic structure for approaching multilevel constructs in the real world (Damschroder et al., 2009).

In this thesis, an exploratory analysis guided by the CFIR in which the investigator sought to explore the context-specific barriers and motivators affecting the private hospitals' engagement in TB care in Uganda is presented. In addition, the potential of mHealth in enhancing PPM to better inform the design of behavioral interventions for enhancing the involvement of private hospitals in TB care is also presented.

2.8.2 The Unified Theory of Acceptance and Usage of Technology (UTAUT)

The Unified Theory of acceptance and use of technology model was used to assess the acceptability and feasibility of the mHealth intervention developed based on the MOHE framework for enhancing tracking patients referred from private to public hospitals. UTAUT is the unification of several frameworks that help to explain the acceptance and use of technology (Venkatesh et al., 2003). These frameworks include Diffusion of Innovation Theory, Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), Combined Technology Acceptance Model, and Theory of Planned Behaviour, Model of PC utilization and Social Cognitive Theory. UTAUT has been tested in various studies like Salim (2012), Khan *et al* (2015) and has been found to be a useful tool for assessing the likelihood of success for new technology and helps in understanding the factors for acceptance for proper designing of interventions (Venkatesh et al., 2003). Thus making it appropriate during this study. The questions for assessing the acceptability and feasibility of using mHealth based application for enhancing the tracking of patients referred from private to public hospitals were based on

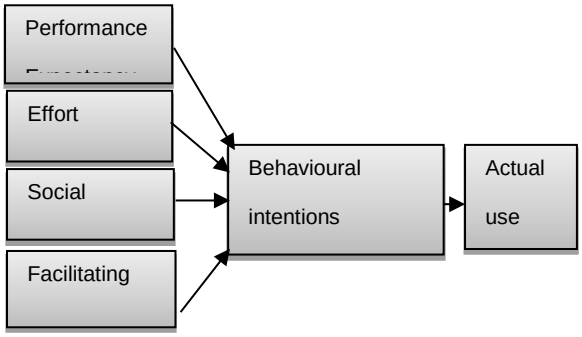


Figure 2.8: UTAUT Model. (Source: Venkatesh et al 2003)

UTAUT model which focuses on four major constructs and these are: performance expectancy, Effort expectancy, Social influence and Facilitating conditions.

Performance expectancy is defined as the extent to which an individual believes that using a system will help him attain his job performance. This construct was used to assess whether the private healthcare workers believe that using a mHealth-based application for following up presumptive TB patients referred from private to public hospitals improves patient follow-up. In this case, performance means that the private healthcare workers get the details about the suspected TB patient on time, and easily use the application to notify the case to the public (NTP) for ensuring that the patient reached the referral point and received further treatment and managed appropriately.

Effort expectancy is defined as the degree of ease associated with the use of the system. This construct shall be used to assess how easy it is for the private healthcare workers to use a mHealth-based application to follow up on patients that have been referred to the public centers.

Social influence is the extent to which an individual perceives how important others believe that they should use the new system. In this, the researcher assessed whether the private healthcare workers expect others such as friends, relatives, and partners, to appreciate their usage of the mHealth application in following up on TB patients on referral.

Facilitating conditions can be defined as the extent to which an individual believes that an organizational and technical infrastructure exists to support the use of the system. This construct aimed at assessing whether the study participants have all that is required to use mHealth for patient follow-up (Organisational support).

2.9 Synthesis of Literature and Research gap Identified

Much as the involvement of the private hospitals is crucial in TB care and is recommended by the WHO towards the End TB strategy, their involvement in TB care in Uganda is limited due to lack of TB diagnostic services, (Wynne et al., 2014) drugs and lack of leadership by the Ugandan MOH in ensuring this engagement. Majority of the private hospitals feel left out in the commitment to address TB due to this isolation. This necessitates mechanisms for bringing on board private hospitals in active TB care.

Literature regarding the use of mHealth for following up presumptive TB patients referred from the private to public hospitals is lacking, yet mHealth tools can be critical mechanisms for scaling up PPM programmes due to their ability to simplify care and delivery. Although mHealth technologies have been recommended by the WHO as emerging opportunities for closing gaps in TB care through enhancing PPM, there is lack of frameworks to guide the development of mHealth interventions for following up presumptive TB patients referred from private to public hospitals especially in settings where most private hospitals are not licensed to manage TB cases. This research therefore presents an investigation into the utilization of mHealth technologies for PPM, the barriers and motivators to private hospitals' engagement in TB care and how feasible and acceptable an mHealth intervention developed based a framework is in southwestern Uganda.

CHAPTER THREE: RESEARCH METHODOLOGY

1.1. Introduction

In the previous chapter (chapter two), the existing literature about mHealth for TB has been presented to give the reader an account of what has been done by other researchers and the research gap that needs to be addressed. This chapter, therefore, documents the methodology and methods for each specific objective and how they were achieved. The aims of the research in this thesis were to: (1) To analyze the existing mHealth interventions for the public private mix to identify their strengths and weaknesses; (2) To explore the barriers to and motivators of private hospitals' engagement in TB care and the potentials of mHealth technologies to inform the design of a potential mHealth intervention using CFIR framework; (3) To develop a framework for designing a mobile health intervention for following up presumptive TB patients referred from private to public hospitals; (4) to assess the initial feasibility and acceptability of the developed mHealth intervention for linking presumptive TB patients referred from private to public hospitals.

The research methodology involved conducting a scoping review, and formative fieldwork for identifying barriers and motivators of private healthcare workers in TB care guided by the CFIR framework as the basis for the development of the framework. Developing the framework and testing it in a practical context through a mobile application called Tuuka for following up the referred presumptive TB from private to public hospitals. Mixed methods approach using both qualitative and quantitative methods for data collection was employed to explore barriers and motivators to private hospitals' engagement in TB care. The same design (mixed methods) was used to assess the initial acceptability, and feasibility guided by the UTAUT model (Venkatesh et al., 2003) of the mHealth intervention for following up presumptive TB patients referred from private to public hospitals. The user-centered design

approach guided the design and implementation of the framework and prototype because of its focus on the system user's involvement in the development phase which facilitates the acceptability of the developed prototype among the end-users of the system (Goold et al., 2006). The main reason for using the qualitative method was to explore an in-depth understanding of barriers, and motivators to private hospitals' engagement in TB care as well as the potentials of mHealth technologies, feasibility, and acceptability of the developed mHealth intervention while the use of quantitative methods was to get information about social demographics, usability, and technology adoption.

1.2. Research philosophy adopted in this research

Research philosophy is concerned with the development of knowledge and the nature of that knowledge (Bajpai, 2011). This involves several assumptions that characterize a specific paradigm that underpins the research strategy and methodology thus offering guidelines on how data is collected, analyzed, and interpreted. Two main philosophical paradigms may be considered namely; positivism and interpretivism paradigm.

Under the positivism paradigm, the reality is believed to be stable and can be observed from an objective point of view (Levin, 2008). This paradigm believes that there is no need to interfere with the phenomena under investigation. Data is obtained via quantitative approaches using surveys, fixed choice questions by looking at predictions, and causal effects for assessing inter relationships and this data can be used for theoretical and hypothetical testing. However, on the other hand, the interpretivism paradigm asserts that there is a need for subjective interpretation of the intervention to fully understand it. The paradigm believes that there is a need to interact with the actors under investigation via qualitative approaches (in-depth interviews, observations, focus groups) to get first-hand information about the phenomena under investigation (Tombs and Pugsley, 2020). Reality is internally experienced and socially constructed based on the interaction and interpretation of the data of the actors involved (Berger, 1991).

This research follows an interpretivism paradigm for understanding the first-hand information among healthcare workers about the barriers to and motivators for private hospitals' engagement in TB care and eliciting the potentials of mHealth technologies for enhancing PPM, exploring the feasibility and acceptability of the developed mHealth intervention. Although several components of the positivism paradigm are included to assess quantitatively the acceptability and adoption of the mHealth intervention, it does not go deeper for theoretical formulation and hypothesis testing. Although there are both

components of positivism and interpretivism, this research is largely based on the interpretivism paradigm since it's mainly aimed at understanding healthcare workers' perceptions, and experiences relevant to mHealth intervention for enhancing PPM.

1.3. User Centered Approach

This study employs a user-centered design approach (Gould and Lewis, 1985) that is based on three main principles as explained below.

1. **Early focus on users and tasks.** This principle asserts that developers should understand the cognitive, behavioral, anthropometric, and attitudinal characteristics of the users. This involves interviews and discussions with the key users of the system to be developed, this is aimed at understanding how the users do their work and what their actual problems are before designing the system to be used. A formative qualitative investigation guided by the CFIR framework involved soliciting potential ideas from healthcare workers about the barriers and motivators of private hospitals' engagement in TB care and the potential of mHealth technologies in enhancing PPM among healthcare workers. This laid the foundation for the development of a framework for designing a mHealth intervention for following up presumptive TB patients referred from private to public hospitals. This was carried out in objective two and the findings are discussed in chapter four of the thesis.
2. **Empirical measurement.** This is the second principle that asserts that users should be involved in using the developed prototypes and their performance observed, recorded, and analyzed. This is key in understanding the learnability and usability of the system among the key users (Gould and Lewis, 1985) and giving proof of how easily the users will use and react to a system. This study employs both the qualitative and quantitative approaches guided by the UTAUT model

(Venkatesh et al., 2003) and the system usability scale (SUS) (Brooke, 1996b) to empirically measure the usability, acceptability, and feasibility of the developed mHealth intervention. This was carried out in objective four and the findings are discussed in chapter six of the thesis.

3. **Iterative design.** This is the last principle of the user-centered design that proposes fixing problems in the system in case they emerge thus making the design process iterative. The system must be tested, measured, and redesigned until all problems are resolved. In research objective three, the developed mobile application was rolled out to healthcare workers for assessing the usability and feasibility.

This research is therefore based on the above user-centered design principles

1.4. Research Investigations

Four separate research investigations were carried out

1.4.1. Research methods for objective one (A scoping review investigation).

Several literature reviews (Lee et al., 2020, Ngwatu et al., 2018, Subbaraman et al., 2018, Alipanah et al., 2018) have documented several mHealth technologies used in TB control. However, those documenting the utilization and effectiveness of these mHealth technologies for enhancing PPM are lacking. Although some mHealth interventions are gradually being integrated into TB care to enhance the PPM, to the best of the researcher's knowledge, there has not been a scoping review of mHealth interventions for PPM in TB care. Thus, it remains unclear which interventions have been utilized for PPM in TB care. This review aimed to synthesize the evidence of the existing mHealth interventions for PPM in TB care and their strength and weaknesses from the existing literature, which can inform the

replication of successful interventions and identify areas of improvement, which could potentially inform the development of an effective mHealth intervention to enhance PPM in TB care and management.

This investigation consisted of a scoping review of mHealth interventions for PPM whose aim was to summarize the published evidence on the utilization and effectiveness of mHealth interventions for PPM in TB care from literature. The scoping review methodology approach by Arksey and O'Malley comprised of six key steps i) identifying the research question, ii) identifying relevant studies; iii) study selection iv) charting data v) collating, summarizing, and reporting results and vi) consultation guided this review (Arksey and O'Malley, 2005). The methodology was adopted for this review because it enables researchers to obtain a quick overview of the existing literature on the research topic (Lentferink et al., 2017) and allows the inclusion of various types of studies other than randomized trials (Arksey and O'Malley, 2005).

1.4.1.1. Identification of Studies

This review was conducted using a highly sensitive search strategy to identify, screen, and analyze all studies that discussed mHealth interventions for PPM in TB care. Articles published between 2003 and 2020 were reviewed. This was because the PPM was officially recommended by WHO in 2003 to involve all relevant healthcare workers in TB control (Uplekar, 2003). An initial database search yielded 347 hits (without duplicates), of which nine articles met the inclusion criteria. Details of these nine studies, including details of the interventions evaluated, are listed in Table 4.1.

The search for the review aimed at addressing the following research questions 1) what are the mHealth interventions for PPM in TB care?" 2) which mHealth interventions worked in the implementation of

PPM for TB care?, and why did they work as well as which interventions didn't work and why didn't they work?

1.4.1.2. Search strategy

Google Scholar, PUBMED, IEEE Xplore, and ScienceDirect databases were searched in June 2020 and May 2021 because of their highly indexing and integration capacity. The search aimed at identifying research articles that contained information about interventions that utilized any form of mHealth like mobile applications, SMS, and telephone calls for enhancing PPM in Tuberculosis. The following terms were used to determine the eligibility of the studies: Articles that were related to the following three key terms were searched from the aforementioned databases. 'mobile health', 'public private mix', and 'Tuberculosis'. Each word was entered as a keyword in Google scholar, ScienceDirect, IEEE Xplore, and PubMed databases to identify relevant articles relevant to the investigation. The Boolean search was used to capture articles related to every single main concept using union ('OR') and the intersection ('AND') of the key concepts to focus on the main objective of this review. The bibliography/ reference lists of the included studies were also screened to get more studies for inclusion in the study. The results from the search query from the four databases (Google Scholar, Pubmed, IEEE Xplore, and ScienceDirect) were uploaded to the EndNote X7 Reference manager (Thomson Reuters, Philadelphia, PA, USA) and were independently assessed for inclusion based on title, abstract and full text. Divergent opinions about the inclusion and exclusion of studies were discussed among the authors until a consensus was reached.

1.4.1.3. Study selection criteria

Studies were included in the review if they met the following criteria.

i. Peer reviewed
ii. Full research papers
iii. Empirical research (qualitative and quantitative)
iv. Clearly explained research methods
v. Explicitly described mHealth technologies for enhancing PPM in TB care or the mHealth interventions were discussed in the methods section.
vi. The effectiveness in terms of preliminary impact
vii. Explicitly described outcomes on TB care
viii. Published between 1st January 2003 and 31th December 2020
ix. Study available in English language.

Criteria 1-4 were considered to ensure the reporting of original research and high-quality work. Criteria 5 was included to ensure that the paper reported on mHealth interventions for enhancing the PPM mix in TB care. This investigation defines mHealth as the utilization of basic functionalities of mobile phones for health-related purposes. This includes functionalities such as SMS reminders that can run on basic phones, which, compared to smartphones have a wider adoption in TB burdened countries.

This review defines "mHealth" as any medical or public health practice which capitalizes on a mobile phone's core utility of voice and short messaging services (SMS) as well as more complex functionalities and applications including Global Positioning Systems (GPS), General packet radio service (GPRS) and Bluetooth technology (WHO 2011). Interventions that were delivered using any form of mHealth like mobile applications, SMS, telephone calls, and GPS were included in this review. Criteria 3, 4, and 6 were considered to enable the quality of evidence assessment. Criteria 6&7 was considered to assess the reported TB management outcomes. Criteria 8 was considered because the PPM was recommended by

WHO in 2003 (Uplekar, 2003), therefore the inclusion of articles before 2003 would not report the actual experiences.

1.4.1.4. Exclusion criteria

The studies were excluded if they did not focus on mHealth interventions for PPM in TB care, carried out before 2003. Included studies were examined to ensure that they reported the outcomes of the mHealth intervention, thus protocols, reviews, formative/exploratory studies, editorials; letters, position papers were not included. All the studies were included irrespective of the study design and geographical location in order to expand the search.

1.4.1.5. Data extraction and analysis

The following characteristics were extracted from the included studies: study setting, study design, mHealth intervention used, and the study duration as shown in Table 4.1, and the description of the identified mHealth interventions' strengths and weaknesses are listed in Table 4.2.

Of the nine studies included, three were conducted in India, three in Pakistan, one in Vietnam, one in Indonesia, and one in Cambodia. No study reported the usability of mHealth intervention for PPM in TB was identified from Africa. The differences in the studies for inclusion were reviewed and checked to ascertain compliance to the inclusion criteria.

1.4.1.6. Quality Assessment

mHealth evidence reporting and assessment (mERA) checklist (Agarwal et al., 2016) was used to assess the quality of the identified mHealth interventions. This checklist consists of 16 key items for reporting the evidence of mHealth interventions by addressing their content, context, and several implementation

features. The checklist was used because it offers guidance on the development of complete and transparent reports on studies that evaluate the usability, feasibility, and effectiveness of mHealth interventions (Hesam et al., 2020).

In addition, a validated checklist for evaluating studies with diverse designs by Sirriyeh and colleagues was used to assess the quality of the included studies. Each paper was assessed against 14 points on the checklist if the study was either qualitative or quantitative and 16 points on the checklist if it used mixed methods (Sirriyeh et al., 2012). A percentage score to measure quality was calculated for each paper, studies that scored less than 50% were considered poor quality, those that scored 50% to 70% were considered Moderate and those greater than 70% were considered high quality.

1.4.2. Research methods for objective two: A formative qualitative investigation

In this research investigation, the main aim was to explore the barriers to and motivators of private hospitals' engagement in TB care guided by the CFIR framework which offers a rightful analytic approach for understanding barriers and motivators to private hospitals' engagement in TB care. The themes were categorized per the domains of the CFIR framework to better understand multilevel barriers and motivators associated with private hospitals' engagement in TB care. The framework can be applied at any stage of implementation (before, during and after) which may help in the planning and development of interventions that may be testable based on specific CFIR constructs. The framework was chosen for this study because it offers an opportunity for baseline intervention assessment which would lay a foundation for understanding whether or not the intervention will be effective or not if implemented. Thus, offering a rightful analytic approach for understanding the barriers, motivators for private hospitals engagement in TB care and the perceptions of healthcare workers about the potentials of mHealth technologies for PPM TB care.

1.4.2.1. Ethical Approval

Official permission was sought and obtained from the participating hospitals where the study was conducted. Ethical approval was obtained from Mbarara University Research Ethics Committee—MUREC (Protocol number: 32/03-20) and the Uganda National Council of Science and Technology—UNCST (Registration number: HS963ES). All participants provided written consent before participating in the study.

1.4.2.2. Study Design and Setting

This study employed a qualitative approach which involved conducting in-depth semi-structured interviews. Healthcare workers (medical doctors and nurses) were recruited from three private for-profit hospitals and one private not-for-profit faith-based hospital. These were purposively selected due to their current involvement in TB care, for having relatively large medical establishments, a large number of healthcare workers (Mathee 2017), and being at the center of handling a large number of outpatients in Mbarara city in Southwestern Uganda. A large number of patients received in private health facilities increases the likelihood of detection of presumptive TB cases presented at the outpatients' department. In addition to a large number of patients, the hospitals refer the suspected TB patients to Mbarara Regional Referral hospital which is the only NTP facility that manages Tuberculosis in Western Uganda.

1. Divine Mercy Hospital: a private for-profit hospital that provides general medical consultation services to over 2,600 patients that attend the out-patients department (OPD) annually (MOH, 2017a). (Number/cadre of healthcare workers involved in TB-related care: four medical doctors and six nursing officers).
2. Mayanja Memorial Hospital: a private for-profit hospital providing general medical consultation services to over 13,835 patients in the OPD annually (MOH, 2017a) and has an ART clinic where HIV patients receive their treatment and care. (Number/cadre of healthcare workers involved in TB-related care: five medical doctors and 10 nursing officers).
3. Homely Medical Center: a private for-profit hospital providing general medical consultation services to over 1,500 patients annually. (Number/cadre of healthcare workers involved in TB-related care: four medical doctors and six nursing officers).

4. Ruharo Mission Hospital: a private not-for-profit faith-based hospital with an OPD that serves over 27,764 patients annually (MOH, 2017a) and offers general medical treatment and ART services. (Number/cadre of healthcare workers involved in TB-related care: four medical doctors and eight nursing officers). However, this hospital was not considered for inclusion in investigation four for assessing initial acceptability and feasibility because presumptive TB patients are not referred to MRRH. After diagnosis, patients are started on anti-TBs.

1.4.2.3. Selection of Study Participants

The study participants were purposively selected to participate in the study based on their direct involvement in TB care and willingness to provide relevant information about TB care practices in private hospitals. The purposive sampling technique was employed by the investigator in the selection of the participants to achieve a relatively well-balanced representation by gender, and TB disease management expertise to elicit diverse opinions. Defined as the selection of participants to be recruited in the study due to the qualities the informant possesses (Tongco, 2007), the purposive sampling technique's ability to allow the selection of information-rich participants that are well versed in the phenomenon of interest (Etikan et al., 2016) made it suitable for selecting the targeted participants. A total of 13 healthcare workers (11 doctors and two nurses) were recruited to identify the barriers encountered and motivators for TB care. The inclusion criteria for study participants were as follows:

a) employed medical doctor/nurse in a private hospital setting,

b) have experience in TB care practices,

c) willing and able to give informed consent.

The main purpose of this objective was to gather in-depth information about the barriers motivators to private hospitals' engagement in TB care to inform the design of a potential mHealth intervention to address the identified barriers.

1.4.2.4. Data Collection

Between June and July 2020, a semi-structured interview guide was developed in English, pretested to ascertain the reliability and validity of data to ensure an accurate data collection process. Semi-structured in-depth interviews with the medical doctors and nurses from the study sites were conducted by the investigator who has experience and training in qualitative research and research ethics. Interviews were carried out until thematic saturation was reached at the 13th participant and no new themes were coming out from the data except repetition. Each interview lasted between 30 and 40 minutes in a private convenient place depending on the respondents' preference. Interviews were digitally recorded and later transcribed. The information about the barriers and motivators to TB care was elicited from the participants. Following each interview that was carried out, the transcripts were reviewed for quality assurance, clarity, and detail. A short survey was also administered to gather their social demographic details.

1.4.2.5. Data Analysis

A coding scheme through an initial review of transcripts was developed and an inductive content analysis approach (Hsieh and Shannon, 2005) was used to generate themes and subthemes from the codebook. Qualitative categories from several sections of the texts from the transcripts about the barriers and motivators to private hospitals' engagement in TB care were extracted. The codebook was reviewed for content relevant to the barriers to and motivators for private hospitals engagement in TB care. The

investigator assembled the codebook following an iterative approach that included category construction of codes to represent the content, writing the operational definitions, and elaborations. Differences in the coding were harmonized by the investigator to come up with a final codebook. Intercooled STATA (Statacorp 2013 Stata Statistical Software Release 13; StataCorp, College Station, TX, USA) was used to describe study participants' characteristics.

1.4.3. Research methods for objective three: A framework design investigation

1.4.3.1. Overview

The aim of this investigation to develop an mobile health application framework for the design of an android mobile application for following up presumptive TB patients referred from private to public hospitals. In this investigation, the investigator developed an application software framework for the design of an mHealth application for linking and following up presumptive TB patients referred from private hospitals to public hospitals called MOHE Framework. The design of the framework was guided by Unified Modelling Language (UML) a multipurpose language with many notational constructs (Fontoura et al., 2000). The adoption of UML for the design of the framework because it uses notations to explicitly represent the variation points in the structure of the framework thus allowing partial automation of the development and implementation and also provides extension mechanisms that allow to define appropriate labels and makings of the UML model elements. This work introduces the MOHE framework and its use and describes a practical example of use of the MOHE framework in a mobile application called Tuuka app used in following up the referred presumptive TB patients from private hospitals to ensure that they reach the public hospitals (the place of referral). The framework was simulated in a context of private to public hospital referral environment.

1.4.4. Research methods for objective four: A mixed methods investigation

1.4.4.1. Overview

In this investigation, the main aim was to assess the initial feasibility and acceptability of the developed mHealth intervention (Tuuka application). The investigation involved in-depth interviews with purposefully selected healthcare workers from the three private hospitals and Mbarara Regional Referral Hospital to understand how feasible and acceptable the intervention was. Participants were trained and given two weeks to test the developed intervention and then were asked to participate in phone-based interviews. The investigator also administered demographic and social-behavioral questionnaires to the healthcare workers at enrolment to capture age, gender, education level, residence, and the number of years in practice. A technology adoption survey was administered at the study exit to elicit the experiences of healthcare workers and challenges encountered utilizing the intervention.

1.4.4.2. Data Collection

The intervention would be considered acceptable if 80% of the participants reported acceptability (Bangor et al., 2009). Acceptability was determined quantitatively with the System Usability Scale (SUS) (Brooke 1996) after use. The SUS is a 10-item Likert scale that assesses domains including desired frequency of use, complexity, needs for support, functionality, irregularities, ease of learning/use, the time required for use, confidence, and training needed. The intervention would be considered acceptable if 90% of Healthcare workers rate 70% (7/10) items on the SUS scale as “very good” or higher. Qualitatively, the investigator assessed the acceptability of the intervention following the Unified Theory of Acceptance and Use of Technology (UTAUT) model (Venkatesh et al., 2003) (see UTAUT model). UTAUT was used for it has been found a useful tool for assessing the likelihood of success for new technology and helps in understanding the factors for acceptance for proper designing of interventions

(Venkatesh et al., 2003). Semi-structured interviews (based on the UTAUT model) were carried out with 18 private healthcare providers and 4 public healthcare providers. The study participants' experiences of using the mHealth intervention were assessed to document the acceptability and feasibility of the intervention through qualitative in-depth interviews. The data captured the perceived usefulness (Performance expectancy) of the intervention, perceived ease of use (Effort expectancy), Social influence, and the facilitating conditions.

1.4.4.3. Data analysis

Feasibility and acceptability. Feasibility metrics and the quantitative assessment of acceptability were analyzed descriptively using STATA 13. The investigator used summary statistics to analyze the socio-demographic data. Data about the desired frequency of use, complexity, need for support, functionality, irregularities, ease of learning/use, the time required for use, confidence, and training needed to ascertain the acceptability and feasibility of the framework-based prototype.

Qualitative data analysis

Interviews were recorded, transcribed, and analyzed using an inductive analysis approach based on the UTAUT model. In this approach, themes tailored to Performance expectancy, effort expectancy, social influence, and Facilitating conditions (Venkatesh et al., 2003) were developed from the collected data and a codebook was developed and reviewed for meaningful data extraction through an inductive and content analysis (Neuendorf, 2017) strategy, a systematic process for interpreting textual data content through coding and category construction. Themes and subthemes were generated to describe different data patterns and category construction about the initial acceptability and feasibility of the developed framework-based Tuuka mobile application in TB care using Nvivo Version 11 software. The review of

transcripts guided the development of a coding scheme composed of various text sections that addressed the concepts of interest for example the perceived ease of use, influence from friends, workmates and the requirements to use the prototype by the private healthcare workers in following up TB patients on referral, were assigned descriptive codes. The elaboration and definitions for those illustrative codes and were categorized based on particular themes.

In conclusion, this chapter has described the general research methodology that was utilized to achieve the research objectives. The results section in the next chapter (chapter 4) discusses how the results for the study objectives one and two were achieved.

CHAPTER FOUR: PRESENTATION OF RESULTS

4.1. Introduction

In the previous chapter (chapter 3), the research methodology for achieving the research objectives was presented. This chapter therefore, presents key research findings from the scoping review investigation (objective 1) and the formative qualitative investigation (objective 2).

4.2. Results for research objective one

This section presents key findings from research objective one which sought to analyze the existing mHealth interventions for public private mix to identify their strengths and weaknesses. The objective aimed to answer the following research question "What are the strengths and weaknesses of the existing mHealth interventions for PPM in TB care?"

4.2.1. Search results

Figure 4.1 below shows the database search results, screening, exclusion, and final inclusion in the study. The studies described and identified different mHealth interventions implemented in five countries where the studies were carried out (India, Vietnam, Indonesia, Cambodia, and Pakistan).

Flow diagram for the selected studies

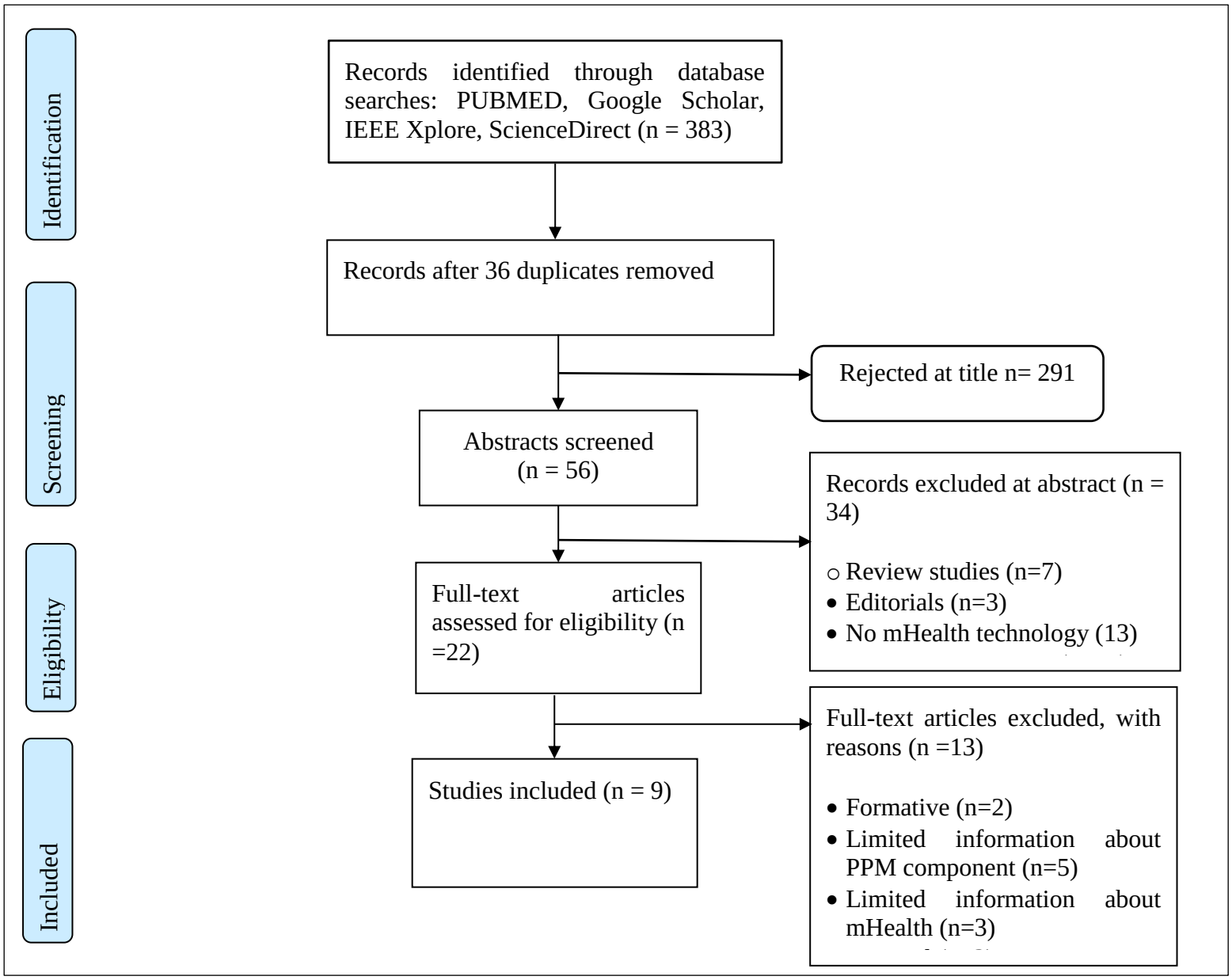


Figure 4.1: Flow diagram for the selected studies

Table 4.1 Characteristics of the included studies

Author and Year	Study design/ Method/ location	mHealth Intervention	Objective	Primary outcome	Effect	Key Findings
(Velayutham et al., 2015b)	A Pilot Study that involved private practitioners from three TB units in India who were given a demo of using the app to notify TB cases for a period of 6 months. *Study duration:* 1 year *Participants:* 184	• A TB notification Voice based application (MITUN-Mobile interface TB Notification). Private medical practitioners registered in the system and were provided with a designated number where they would call and give the details of the TB cases following the voice prompts	To determine the usefulness and feasibility of Mobile Interface in TB notification (MITUN)voice based system for the notification of TB cases by private medical Practitioners	Utilization and Feasibility	• Of the 184 private medical doctors who participated in the study, only 11 (6%) practitioners used the application. • Of the 155 TB cases that were diagnosed, only 15(10%) were notified through MITUN.	Suboptimal performance with 6% utilization • Lack of time to use the system • Technical/ operational challenges • Busy phone line/ call interruptions
(Thu et al., 2020a)	A cohort study that involved the analysis of routine surveillance data of patients aged 15 and above attending the OPD for a period of six months in Vietnam *Study duration:* 6 months *Participants:* 110 TB cases	• A mobile application was used to reduce dropout in the care cascade and to enhance follow up care by community health workers	To evaluate the performance of an innovative Private sector engagement model by tracking the cascade of TB care among individuals attending Haiphong International General Hospital (HIGH)	Utilization	• Of the 299 patients who had suggestive TB symptoms, 110 total cases were notified through the application. Of the diagnosed cases, 105 (95%) were initiated on treatment and 97 (93%) had a successful treatment outcome	• The Mobile app enabled the notification of every TB case diagnosed by alerting the healthcare system to provide follow up care to patients thus reducing the initiation and completion

(Lestari et al., 2017)	A Pilot study among private practitioners in Bandung city, Indonesia *Study duration:* 6 months *Participants:* 12 private practitioners and 36 TB symptomatic patients	• A mobile app for the notification of TB cases that enabled referral and report back system that utilized simplified versions of the NTP forms	To evaluate the feasibility of the intervention package to increase TB case detection and notification rates among private practitioners in Indonesia	Feasibility and Acceptability	• Of the 12 Private practitioners who successfully installed the app, only five (41.6%) registered patients with TB symptoms and cases into the app. • 36 patients with TB symptoms were identified and 17 were confirmed TB positive.	• Application was acceptable and feasible to enable notification of cases.
(Choun et al., 2017a)	A Descriptive study involving following up of TB patients referred to peripheral health facilities in Cambodia *Study duration:* 10 months *Participants:* 109 referred TB patients	• Telephone calls were made to contact patients three days after having been referred to ensure that they reached the peripheral health facility	To assess if tracking of TB patients referred to peripheral health facilities using mobile phone technology can reduce Lost to Contact after referral (LTCR)	Feasibility	• Out of 109 TB patients referred to the peripheral unit, 107 (98%) had access to a phone of which 103(97%) were contacted directly and placed on continued TB support. • All participants could be traced compared to previous years where 16-69% of the referred patients were missed	• High retention of the referred patients from the tertiary hospital settings
(Khan et al., 2012a)	An Impact evaluation study of mass communication strategy to encourage people with 2 weeks or more productive cough to seek care at private facilities in Pakistan *Study duration:* 10 months	• A mobile phone app linked to conditional cash transfers were used by screeners to collect, submit and retrieve data • Screeners utilized telephone calls to follow up the identified TB patients who never initiated TB treatment.	To measure the effect of a multifaceted TB case detection strategy in Pakistan	Usability	• Of the 388196 individuals screened, 2416 cases were detected and notified via the NTP reporting center. This implies a 2.21 times increase in case notification (95% CI 1.93-2.53) compared to the control	• Increase in TB case notification in the intervention group compared to the control area.

	Participants: 2416 TB cases notified				area where the number reduced by 9%.	
(Mohammed et al., 2016b)	A randomized Control Trial at TB treatment Facilities in Karachi Pakistan *Study duration:* 3 years *Participants:* 2207 newly diagnosed TB patients	• A two way scheduled SMS reminders (Zindagi SMS), patient responds back through an SMS or an unbilled phone call to indicate that a patient has taken medication	To measure the impact of *Zindagi SMS*, a two-way SMS reminder system, on treatment success of people with drug-sensitive TB.	Clinically recorded treatment success	• No significant difference between the *Zindagi SMS group and the* control group for clinically recorded treatment success (719 or 83% vs. 903 or 83%, respectively, p = 0.782).	• No significant difference between the SMS group and the control group
(Chadha et al., 2017b)	A pilot study among the rural healthcare providers (RHCPs) in India *Study duration:* 3 months *Participants:* 30 healthcare providers and 127 TB cases	• A ComCare Mobile application for rural healthcare providers to refer presumptive TB cases to the nearest microscopy center	To determine the feasibility and yield of presumptive TB case referrals by RHCPs using mHealth technology.	Feasibility	• 1578 presumptive TB referrals of which 1056 were referred using the mobile app compared to 522 cases referred by those who never had the app. • Of the total 194 cases that were diagnosed, the number of mRHCP referrals was 127(65.5%, four TB cases per RHCP) compared 64 cases (34.5%, 0.5 TB cases per RHCP) referred by their counter parts who never used the app.	• The Rural Healthcare Practitioners using mobile technology referred nearly nine times more presumptive TB cases than those without the technology • Reduced the amount of time taken for diagnosis and treatment initiation.
(Pande et al., 2017a)	A pilot study among clinicians at a private hospital in Manipal India *Study duration:* 1 month	• Learn TB Mobile app among private sector academic clinicians in Kasturba hospital, India	To understand the user experience and acceptability of a smart phone application *LearnTB* amongst	Experiences and acceptability	• 101 clinicians received the mobile app on iPads for use. • High user experience of the learnTB application with the mean score =	• High user experience among the clinicians • There was a significant correlation between perceived ease of use (PEU)

	Participants: 101 clinicians		private sector academic clinicians.		94.4 (92.07-96.76) with a significantly correlated perceived ease of use (PEU) to perceived usefulness (PU) (r=0.466, P<0.0001). • The app was perceived to have potential to promote good clinical practices (QR=5.23 (1.35-20.29); P=0.016).	and perceived usefulness (PU)
(Ali et al., 2016b)	A pilot study aimed at utilizing digital scanning among the District field workers in Pakistan *Study duration:* 3 months *Participants:* 4 field workers and 122 patients records retrieved and analyzed	• ODK (Open data Kit) scan for data collection and management	To reduce the time and resources spent on TB data collection by improving data collection and digitization process and reducing on manual data entry	Experiences	• Significant time reduction in data aggregation, & transfer activities with the 99.2% of multiple choice fill in bubble responses & 79.4% of numerical digit responses recognized accurately.	Despite the ability to reduce significant time reduction in data aggregation and transfer activities, form filling and verification consumed more time

Table 4.3: Description of the identified mHealth interventions' strength and weaknesses

Author	Intervention	Strength	Weakness
Voice based system for TB case notification			
(Velayutham et al., 2015b)	A mobile interface in Tuberculosis notification (MITUN) voice based system for notifying TB cases among the private healthcare providers.	Based on the VoiceNet architecture that allows the usability on low-end mobile phones	• System complexity resulted into non usability • Long period of time for case notification • Poor system configuration that resulted into delays in notifying cases due to busy phone lines
Mobile applications			
(Thu et al., 2020a)	A mobile application for enhancing patient follow up by community health workers	• Notification of every diagnosed case by alerting the healthcare system and community health workers to proactively track and follow up patients	• The operation of the app are not discussed (how case notification was done, how the alerts for follow up were done) • Doesn't describe the software framework on which the app was developed
(Lestari et al., 2017)	A referral and reporting back system mobile phone app for case notification	• Utilized simplified version of NTP forms for case notification • Secure centralized server for inputted information • User registration and account creation	• Doesn't describe the software framework on which the app was developed • Not standalone (requires internet to access) • No reminder system to alert the private provider if the patient doesn't complete their treatment follow-up
(Chadha et al., 2017b)	ComCare mobile application for assisting rural healthcare providers (RHCPs) to identify and refer presumptive TB patients to the nearest microscopy Centre	• Generates SMS reminders for patients to adhere to referral • Assists healthcare providers in providing guidance and counselling to patients • Uses multimedia educational messages for RHCPs	• Not standalone (requires internet to access) • Doesn't describe the software framework on which the app was developed
(Khan et al., 2012a)	A mobile phone based interactive application for community lay people to screen patients for TB in private clinics.	• The app allowed scheduling for sputum collection, initiation of treatment, clinic visits and drug dispersal • Allows data entry and retrieval • Secure centralized server for inputted information	• Doesn't describe the software framework on which the app was developed
(Pande et al., 2017a)	The LearnTB mobile app for educating the private sector clinicians about definition, diagnosis,	• Educate private sector clinicians in TB care	• Not standalone (requires internet to access)

	treatment, management and counselling practices for TB		• Doesn't describe the software framework on which the app was developed
(Ali et al., 2016b)	An android based smartphone application that utilizes an inbuilt camera to capture an image of a scan compatible paper form that is processed through image processing algorithms to map the captured image to its corresponding template	• Significant time reduction in data aggregation and transfer activities	• Decreased digital data quality • Long period of time for data entry and verification
Telephone calls			
(Choun et al., 2017a)	Mobile phone tracking of the referred patients' through telephone calls. Health staff made telephone calls to the referred patients to ascertain whether they had reached the designated peripheral health facility where they were referred	Utilized simple phone calls to follow up the referred patients	• Unavailability of telephones numbers (Calls not reached) • Possibility of wrong telephone numbers • Poor connectivity
SMS			
(Mohammed et al., 2016b)	Zindagi SMS reminders among the newly diagnosed patients. This used two-way reminders for encouraging patients to engage with the reminders. Patients were expected to reply by sending either a text message or an unbilled phone call as a proof that they have taken medication.	Utilizes SMS technology for reminding patients to adhere to medication.	• Doesn't favor those unable to read • Poor connectivity

4.2.2. Quality of studies

All the papers that were included in this review were of moderate or high quality ranging from 62.5% (Ali et al., 2016b) to 83.3% (Pande et al., 2017a).

4.2.2.1. mHealth essential Quality Assessment

The mERA criteria (Agarwal et al., 2016) guided the assessment of the quality of mHealth interventions included in this review where all the included studies met between 56.25% -93.75% of the mERA criteria. All the included studies documented the availability of infrastructure to support the technology, the technology platform on which the mHealth intervention would run, were compliant with the national guidelines, and were delivered as planned (fidelity) as shown in figures 4.2 and 4.3 below.

All the studies reported mHealth interventions that:

i) Were integrated within the existing health information systems
ii) Clearly documented the mode of intervention delivery and the adoption inputs necessary to implement the mHealth solution.
iii) Clearly described how the intervention was adopted (contextual adoptability),

Four studies (Chadha et al., 2017b, Khan et al., 2012a, Lestari et al., 2017, Pande et al., 2017a) described data security protocols. Five studies (Ali et al., 2016b, Chadha et al., 2017b, Choun et al., 2017a, Khan et al., 2012a, Velayutham et al., 2015b) described support for replicability. Five studies documented limitations to scale (Ali et al., 2016b, Chadha et al., 2017b, Choun et al., 2017a, Lestari et al., 2017, Velayutham et al., 2015b). Five studies reported feedback from users (Ali et al., 2016b, Choun et al., 2017a, Lestari et al., 2017, Thu et al., 2020a, Velayutham et al., 2015b). Six studies (Ali et al., 2016b, Chadha et al., 2017b, Khan et al., 2012a, Lestari et al., 2017, Pande et al., 2017a,

Velayutham et al., 2015b) reported details about the content of the intervention (Intervention Content). Four studies (Khan et al., 2012a, Lestari et al., 2017, Thu et al., 2020a, Velayutham et al., 2015b) documented the usability/ content testing with the participants. Only two studies reported the cost assessment of the intervention (Choun et al., 2017a, Lestari et al., 2017), and only one study does not report the access of individual participants (Thu et al., 2020a).

The percentage of studies meeting the mERA criteria

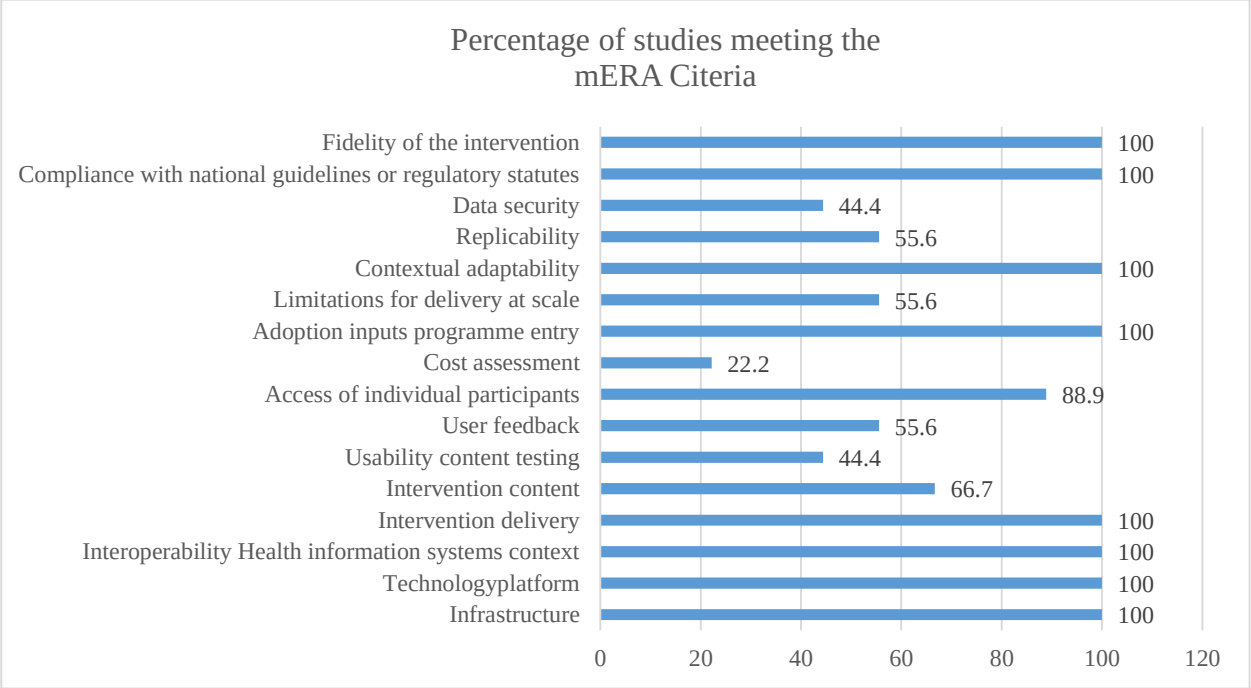


Figure 4.2*: *showing the percentage of studies meeting the mERA criteria

Percentage of studies meeting the mERA criteria

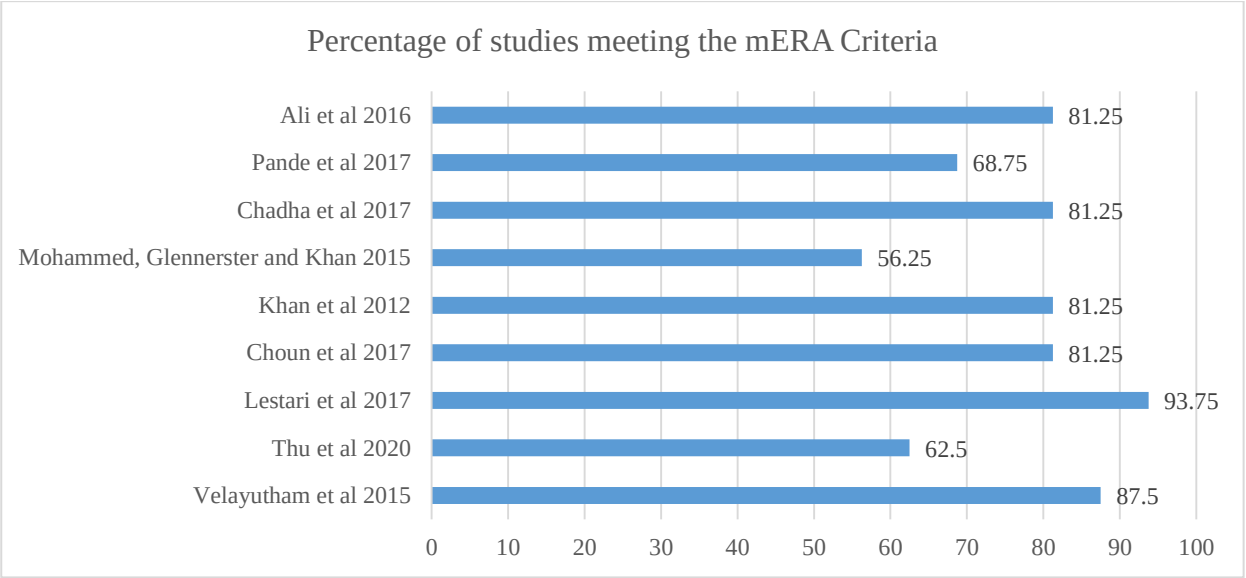


Figure 4.3: *showing the studies meeting the mERA criteria*

4.2.3. The application of mHealth for PPM in TB care

Details of all the studies are indicated in table 4.1 above

TB screening

An impact evaluation study that involved 54 private family medical clinics was carried out in Karachi Pakistan by Khan and colleagues (Khan et al., 2012a), who reported the incentivization and training of community lay people to screen patients in the private clinics. This was done using a mobile phone-based interactive algorithm that utilized electronic forms that were linked to a conditional cash transfer for assessing patients and visitors in the clinic waiting for areas and the outpatients' departments. The software operated on any Java-enabled phone with General Packet Radio Service (GPRS) and allowed the entry and retrieval of data to a centralized database. The app also allowed scheduling for sputum collection, initiation of treatment, clinic visits, and drug dispersal..

TB case Notification

Five studies (Chadha et al., 2017b, Khan et al., 2012a, Lestari et al., 2017, Thu et al., 2020a, Velayutham et al., 2015b) reported the utilization of mobile apps for TB case notification.

Thu and colleagues implemented an innovative PPM model in Vietnam by utilizing a mobile phone-based case notification application to reduce the dropout in the TB care cascade and enhance patient follow-up by community health workers (Thu et al., 2020a). The study reported the utilization of the mobile application for notification of every diagnosed case, which enabled the healthcare system and providers to proactively track and provide follow-up care to the patients thus reducing the gaps in treatment initiation and completion.

A pilot study (Velayutham et al., 2015b) that was conducted in Chennai India reported the utilization of a voice-based notification system (Mobile Interface in TB notification (MITUN)) for notifying TB cases among the private healthcare providers. Designated telephone lines through which the private healthcare workers would call on to interact with the interactive voice response system (IVRS) to notify a case were established. The study reported failure to use MITUN due to technical problems such as busy telephone phone lines and call interruption, and lack of time to hold on to the call.

Treatment adherence

One randomized control trial (Mohammed et al., 2016b) that was conducted in Karachi Pakistan utilized Zindagi SMS reminders among the newly diagnosed TB patients. This used two-way reminders to encourage patients to engage with the reminders. Daily SMS reminders were sent to enrolled patients to take their medication and they were expected to reply by sending either a text message or an unbilled phone call as proof that they have taken medication. The study reported no significant difference in treatment outcomes between the SMS intervention and the control group.

Data collection and management

A pilot study was carried out in Pakistan by Ali and colleagues to implement a mobile phone-based application that was aimed at reducing the amount of time and resources spent on TB data collection by digitizing the data collection process and reducing reliance on manual data entry in the public-private mix model of the TB control program of Pakistan. The app utilizes the device's inbuilt camera to capture an image of a scan-compatible paper form that is processed by the app to map the captured image to its corresponding template (Ali et al., 2016b).

Patient referral and followup

In another study that was conducted in Khunti district, Jharkhand state, India by Chadha and colleagues, the ComCare mobile application was developed to assist rural healthcare providers (RHCPs) to identify and refer presumptive TB patients to the nearest microscopy center. The app had different interfaces for the RHCPs, laboratory technicians, and supervisors who were trained to use the application. When a presumptive case was identified by the RHCPs, they would be referred to a TB microscopy center where patients' details were entered using the available options in the mobile app. The supervisors would view this information on their mobile phones and then the lab technicians would transmit results to the presumptive cases/ patients on their mobile phones via inbuilt text messages in the Comcare application. In case the patient fails to visit the TB microscopy center after getting the results, the application automatically sends SMS reminders to the patient about visiting the microscopy center. The app also has multimedia content for RHCPs for counseling and guiding patients. The app operated on android mobile phones and was installed on the RHCPs' mobile phones (Chadha et al., 2017b).

A descriptive study was carried out in Cambodia by Choun and colleagues to assess if tracking TB patients referred to peripheral health facilities using mobile phone technology can reduce Lost to Contact after Referral (LTCR) (Choun et al., 2017a). The study implemented mobile phone tracking of the referred patients' through telephone calls. Health staff made telephone calls to the referred patients to ascertain whether they had reached the designated peripheral health facility where they were referred.

In another study carried out by Lestari and colleagues in Bandung City, Indonesia, a referral and reporting back system mobile phone application was developed (Lestari et al., 2017). The app was composed of simplified NTP forms where patients' identity, symptoms, diagnostic examinations, type of TB, and treatment were inputted. The app had a centralized server where the inputted data was sent and monitored by the research staff.

Khan and colleagues also reported utilizing telephone calls by screeners to follow up on identified TB patients who never initiated TB treatment in Pakistan. Screeners were required to attempt at least three phone calls to the identified TB cases that never initiated treatment (those intending to default) in addition to two home visits to follow up with these patients(Khan et al., 2012a). However, the study doesn't report the efficacy of these phone calls on the health outcomes of the identified TB patients that were being followed up.

Education

Pande and colleagues implemented the LearnTB mobile app for educating private-sector clinicians in India (Pande et al., 2017a). The app was developed to educate Indian clinicians about the available definition, diagnosis, treatment, and management practices of TB. The app was made of sections for clinicians to click to read and get more information. One hundred one (101) clinicians received the

mobile app on iPads for use and were assessed to understand their experiences and the feasibility and acceptability of the application.

4.3. Results for research objective two

This section presents key findings from research objective two which sought to explore the barriers to and motivators of private hospitals' engagement in TB care and the potential of mHealth technologies to inform the design of a potential mHealth intervention using the CFIR framework. The objective aimed to answer the following research question "What are the barriers and motivators to private hospital engagement in TB care and the potentials of mHealth technologies in enhancing PPM among private healthcare workers?"

4.3.1. Introduction

Thirteen healthcare workers including 11 medical doctors and two nurses from four private hospitals participated in this study. Participants were recruited because they were actively involved in screening and diagnosing presumptive TB patients to gain deeper insights and identify the behavioral diagnosis for the identified barriers to enable active TB care in private hospitals. As shown in table 4.2 below, the majority of the participants were male (n=8) and came from private for-profit private hospitals (n=11). The median age of participants was 29 years of age. . Of the four private hospital facilities that were part of this study, only two were accredited to provide TB services as shown in the facility level demographics table 4.2 below.

Table 4.2 Participant's demographics

Baseline characteristic	Participants
	n
Median Age (IQR)	29 (28-31)
Gender	
Female	5
Male	8
Marital status	
Single	5
Married/partnered	8
Highest educational level	
Certificate	1
Diploma	1
Degree	7
Masters	3
PhD	1
Designation	
Nurse	2
Doctor	11
Number of years in general medical practice	
1-3	7
4-5	2
>5	4
TB services provided by healthcare workers	
Screen and manage [a]	5
Screen and refer [b]	8

Note. IQR – interquartile range.

[a] Participants able to both screen and manage TB cases

[b] Participants able to both screen and refer presumptive case

Table 4.3 Facility Level Demographics

Facility	Accredited for TB service delivery	
	n	(Yes/No)
Private Hospital 1	4	No
Private Hospital 2	3	Yes
Private Hospital 3	4	No
Private Hospital 4	2	Yes

N represents the number of healthcare providers from each facility

4.3.2. Barriers and motivators to private Hospitals' Engagement in TB care

The following section highlights the barriers to and motivators of private hospitals in TB care which are categorized under the five domains of the CFIR framework, namely: the intervention characteristics, outer setting, inner setting, characteristics of the individuals, and the process of implementation. Of the 39 CFIR constructs assessed, eight were relevant to the context of this study to assess barriers and motivators to private hospitals' engagement in TB care as shown in Table 4.4 below.

Table 4.4 CFIR Constructs and their Related Barriers or Motivators for the Engagement of Private Hospitals in TB Care

CFIR Domain	CFIR construct	Barrier or motivator	Explanation for motivators and barriers
Intervention Characteristics	Relative advantage	Motivator	Private hospitals were perceived to have a relative advantage of providing high-quality healthcare services and for enabling privacy and confidentiality for patients
	Cost	Barrier	Healthcare providers perceived high costs in terms of payment for care by patients. In addition, they also noted that TB care is an indirect income generating service which makes it unattractive to venture in since most private hospitals are for-profit
Outer setting	Patients' needs and resources	Motivator	Private hospitals are nearer to patients thus saving them from costs involved in traveling to public health centers that are far
	External policy and incentives	Barrier	Lack of drugs, registers, and diagnostic tools and lack of accreditation from the Ugandan MOH hinder the engagement
Inner setting	Structure characteristics	Barrier	Limited space for keeping TB patients
	Networks and communications	Barrier	Lack of proper follow-up mechanism for the referred patients
Characteristics of individuals	Knowledge and beliefs about the intervention	Barrier	Lack of training and qualified human resources to manage TB disease and delayed seeking of healthcare by the patients
The process of implementation	Engaging	Motivator	Formalization of partnerships between private hospitals and the government

Barriers to private hospitals' engagement arose from the following five constructs: cost, external policies and incentives, structure characteristics, networks and communications, and knowledge and beliefs about the intervention. The barriers include concerns regarding the payment of care by patients; the indirect income-generating nature of TB management; lack of drugs, registers, and diagnostic tools; lack of accreditation from the Ugandan MOH; limited space for keeping TB patients; lack of proper follow-up mechanism; lack of training/ qualified human resources; and delayed seeking of healthcare by the patients. Motivators to private hospitals' engagement arose from the following constructs: relative advantage, patient needs and resources, and engaging. The motivators include perceived high quality of care in the private hospitals; privacy and confidentiality concerns; long distances to the public healthcare centers; and formalization of partnerships between private hospitals and the government.

CFIR Domain one: Intervention Characteristics

Private hospitals were perceived to have a relative advantage of providing high-quality healthcare services to patients compared to public hospitals. They (participants) highlighted patients' perception of being cared for in terms of prompt services and attention provided in private hospitals which motivates them to seek healthcare in private hospitals. A medical doctor from Hospital 2 reported that *"Some patients may come because they were previously treated well in that hospital or the attendant liked the services offered, in case of any illness, they are more likely to come back".(Medical Doctor, Male, 28 years*).

In addition, private hospitals also were perceived to have a relative advantage of enabling privacy and confidentiality for patients since they offer an opportunity to patients to have the liberty to get drugs from the hospital privately and also have the freedom to make private arrangements for drug delivery within their homes.

> *So in a private hospital, there is privacy, patients are taken very well, they can go and get their drugs in privacy sometimes, they can arrange taking drugs to their clients at their homes which may not be possible in a public hospital. (Medical doctor, Male, 43 years, Hospital 1).*

However, on the other hand, the cost was reported as a barrier to private hospitals' engagement in TB care. Across the private hospitals, participants highlighted that payment for services involved in the treatment of TB in form of additional costs that come along with the TB disease and the indirect income-generating nature of TB treatment service provision as barriers to TB care efforts in private hospitals. TB is treated for a considerably longer period (six months and more) which makes it difficult for patients to manage the comprehensive private hospitals' care management.

At Hospital 1, a medical doctor said *"I think the challenge is in the length of treatment and the cost that would come with that and so you find that the challenge is in the payment of care". (Medical Doctor, Female, 28 years).*

Another medical doctor at Hospital 4 explained that *"Most of these patients may not afford comprehensive private management in the private hospitals when there is an almost free government facility that would give free drugs to them". (Medical Doctor, Male, 39 years).*

Furthermore, the indirect income-generating nature of TB treatment service provision makes it difficult for private hospitals to engage in due to its infectious nature, thus making it an unattractive venture to venture into since most private hospitals are for profit.

> *TB management is not something that may bring in money quickly, it is not a direct income-generating activity, and therefore the private facility owners have to be convinced about the need to give care to people who may not be able to pay back. (Medical doctor, Male, 39 years, Hospital 4).*

4.3.2.1. CFIR Domain two: Outer Setting

Private hospitals were perceived to meet patients' needs and resources. Participants highlighted that private hospitals are nearer to patients thus saving them from costs involved in traveling to public health centers which are far. This is a key motivator for engaging private hospitals in TB care since some patients feel more comfortable receiving drugs from nearby private health facilities. A medical doctor from Hospital 2 reported that *"Some private hospitals are nearer, and people are more comfortable with having their drugs and medications come from there". (Medical Doctor, Male, 28 years).*

However, the external policy and incentives construct was highlighted to have negatively influenced the engagement of private hospitals in TB care. The lack of basic treatment services like drugs, diagnostic tools, and registers for reporting the identified cases hamper the complete TB care process among the private hospitals thus limiting their capacity to manage the disease effectively and comprehensively.

> *But most times, we refer because we do not even have the basic TB treatment services, we do not even have the supply from the government, we do not stock TB commodities even at times we may not even have the right face masks for protection so we do not prefer to keep in those patients except if they can't go anywhere else. (Medical Doctor, Male, 43 years, Hospital 1).*

Furthermore, the lack of accreditation/ approval from the Ugandan MOH to provide TB services on the other hand leaves out many private hospitals to engage in TB care despite the huge number of patients that seek care from these health centers. Excessive complicated administrative procedures involved in obtaining accreditation from the Ugandan MOH are the main contributors to persistent delays in obtaining full accreditation.

We have qualified staff and space, but we do not have the accreditation from the MOH to be able to offer some of those services and so many times in the training and updates, we are left out simply because we do not have that accreditation. (Medical Doctor, Male, 43 years, Hospital 2).

Another participant from Hospital 4, mentioned that they had initially applied to be accredited to effectively manage TB but had not yet received accreditation "We initially applied to be accredited as a TB management health facility but up to now, we have not yet received accreditation".*(Medical Doctor, Male, 39 years, Hospital 4).*

4.3.2.2. CFIR Domain three: Inner Setting

Structure characteristics construct was highlighted to have negatively influenced the engagement of private hospitals in TB care. Lack of space for accommodating TB patients in private hospital facilities was reported by participants as the main barrier which hinders the process of admission of patients. This is intended to avoid mixing TB patients with other patients which would increase the transmission of the disease. One participant from Hospital 4 pointed: *"We do not have an isolation unit, we use the same rooms for admitting all patients, so basically it wouldn't be proper for us to admit TB patients in these usual rooms". (Medical Doctor, Male, 35 years, Hospital 4)*This results in frequent referrals of patients to public health facilities for better TB management.

However, the networks and communications construct hampered effective engagement due to the lack of proper follow-up mechanisms within private hospitals to ascertain whether patients adhere to their medication and whether they go to the centers where they are referred for better management. Participants reported that most of the patients get lost in the community and are untraced by the healthcare workers. This hampers the patient's follow-up pathway and makes it difficult to ascertain whether the patient received the kind of care or not.

Even when you refer, not all the time that you have someone to accompany the patient to the referral unit, so you write the referral documents for patients to take them to the next clinical units, but you can't be sure whether every patient went or not. (Medical Doctor, Female, 30 years, Hospital 2).

4.3.2.3. CFIR Domain four: Characteristics of Individuals

Knowledge and beliefs about private TB care were a key construct and barrier. Participants highlighted the delay to seek healthcare among the patients who only come to the private hospitals when they are very sick and as a last resort to seek medical attention thus making the treatment process complex since they come in advanced stages of the disease.

So many of them come late to the hospital; the ones I used to see, used to come when they were very sick, so they are difficult to treat because of complications. Even when you give them TB treatment, most of them are very weak to take the medication (Medical Doctor, Male, 31 years, Hospital 3).

Additionally, lack of training in TB disease management practices among healthcare workers in private hospitals limits private healthcare workers' capacity to screen and diagnose the disease and interpret the results for better management. A medical doctor from Hospital 2, mentioned that *"Most of the health workers do not have the necessary training, they may not diagnose TB well, may not have the capacity to interpret the tests". (Medical Doctor, Male, 31 years, Hospital 3).*

4.3.2.4. The Process of Implementation

Engaging both the private and public hospitals through establishing formal partnerships between the private and the government sectors was reported as a key motivator to enable concerted efforts against TB disease. These partnerships would be supplemented by the provision of adequate funding for the

private hospitals involved in TB care, free supplies of TB drugs, educating the healthcare workers in private hospitals, and routine supervision to monitor the progress of implementation. This would enhance the process of TB case identification in private hospital settings which would have been easily missed thus reducing the disease burden within the population.

> *There is a need for establishing official partnerships between the government and private hospitals and also the government should support private hospitals in terms of supplying free drugs, funding specifically for TB care services in the private sector, educating health workers on how to identify the disease in the privacy settings, provide diagnostic tools and monitoring these private hospitals to see how they are progressing to know how many patients come from different parts, see how much support they need and what is not there. (Medical doctor, Male, 28 years, Hospital 4).*

In addition, the participants reported that bringing the private hospitals on board for managing TB disease would help in eliminating cases of patients who are lost along the referral pathway through providing access to services to patients who seek care in private hospitals. This is because some private hospitals are the first primary care centers for patients and are preferred by patients found to be convenient and less congested.

> *The private sector and government need to work together against TB because this is a disease that needs to be treated for a very long time and one sector can't stand alone. Private hospitals receive a large number of patients and before they go to public hospitals. Sometimes patients are lost along the referral pathway and tend to move from one hospital to another which makes the continuity of care hard and makes other patients default. Private hospitals are the first primary healthcare givers to patients. I remember while growing up my mother would first take me to the private clinic, and in case things did not work out, then they would take*

me to the government hospital. Private hospitals are preferred to be easier, less congested, and more convenient for patients to access. I believe when you bring the private sector on board, they will properly manage those patients who seek care in those facilities. (Medical Doctor, Male, 31 years, Hospital 4).

4.3.3. Potentials of mHealth technologies for enhancing PPM

This section highlights several potentials and concerns of mHealth in fostering PPM in TB care that were highlighted by healthcare workers and were also categorized under the five domains of the CFIR framework, namely: the Intervention Characteristics, outer setting, inner setting, characteristics of the individuals, and the process of implementation.

Of the 39 CFIR constructs evaluated, only five were relevant to the context of this study to assess the potential and concerns of mHealth in enhancing PPM for TB care. The remaining 34 constructs could have been relevant but were not assessed because they did not yield themes relevant to the study and these include; intervention source, evidence strength and quality, relative advantage, adaptability, trialability, complexity, cost under the intervention characteristics domain; patient needs and resources, peer pressure, external policy and incentives under the outer setting domain; structural characteristics, culture, implementation climate, tension for change, compatibility, relative priority, organizational incentives and rewards, goals and feedback, learning climate, readiness for implementation, leadership engagement, available resources, access to knowledge and information under the inner setting domain; self-efficacy, individual stage of change, individual identification with organization, other personal attributes under the characteristics of individuals domain, and planning, opinion leaders, formally appointed internal implementation leaders, champions, external change agents, executing, reflecting and evaluating under the process domain.

The potential of mHealth arose from design and quality packaging, relative advantage, cosmopolitanism, networks and communications, knowledge, and beliefs about the intervention and engaging constructs. These include the potential of mobile health to map and link the referred patients to the referral units; support patient care and medication adherence; reduce stigma; improve knowledge and beliefs of healthcare workers and patients, and notify and report tuberculosis cases respectively.. Concerns about mHealth technologies arose from the following constructs: networks and communications; and knowledge and beliefs about the intervention these include: Poor internet connection would limit the usability of internet-based interventions; and lack of knowledge to use several mHealth technologies among healthcare workers.

4.3.3.1. Intervention Characteristics

Mobile health was perceived to be an excellent mechanism for tuberculosis case notification and reporting. Participants highlighted that mobile health can enable timely reporting and notifying of tuberculosis cases to the Ugandan Ministry of Health on what is happening in the private hospitals. The technological enhancement of various mobile health technologies that include modern report generation tools enhances remote uploading of daily, weekly reports about activities to the government. This would help in reducing the time to notify tuberculosis cases between different health centers and updating the national database about the number of cases. One participant from Hospital 3 reported that

> *Mobile health can help in reporting and giving timely reports. You can design an app where we can upload the work we are doing weekly so that we constantly update the government on the work that is going on. If there is a case that I have diagnosed, I can easily upload patients' details in the mobile application, which can quickly update the number of cases at the national level from both the public and private hospitals. (Medical Doctor, Hospital 3).*

Mobile health technologies were perceived to have a relative advantage of reducing stigma among patients referred from private to public hospitals. Participants noted that patients fear going to the places of referral due to fear of being seen in tuberculosis clinics in public hospitals but with mobile health technologies since the healthcare workers at the public facilities will have already been notified about the incoming patient, it gives the patients confidence to go and receive faster care.

> *Mobile health can help in reducing stigma. One of the stumbling blocks in tuberculosis care is the challenges the patients are likely to find on the other side, first of all, some have this notion that tuberculosis is not curable and some are worried that when they reach there they will be tossed up but with mobile health technologies like apps, the patient will reach the facility when he or she is already known by the healthcare worker through notifications. (Medical Doctor, Hospital 3).*

Mobile health was perceived to be an excellent mechanism for TB case notification and reporting. Participants highlighted that mHealth can enable timely reporting and notifying of TB cases to the MOH on what is happening in the private hospitals. The technological enhancement of various mHealth technologies that include modern report generation tools enhances remote uploading of daily, weekly reports about activities to the government. This would help in reducing the time to notify TB cases between different health centers and updating the national database about the number of cases. One participant from Hospital 3 reported that

> *Mobile health can help in reporting and giving timely reports. You can design an app where we can upload the work we are doing weekly so that we constantly update the government on the work that is going on. If there is a case that I have diagnosed, I can easily upload patients' details in the mobile application, which can quickly update the*

number of cases at the national level from both the public and private hospitals, (Medical Doctor, Male, 28 years, Hospital 3).

4.3.3.2. Outer Setting

Mobile health was reported to have the potential to map and link presumptive tuberculosis patients that have been referred from private hospitals to the hospital facilities where they have been referred for tuberculosis services. The ability of mobile health to ensure interconnectedness across different settings, and transcending geographical boundaries puts it at an advantage in establishing linkages between public and private hospital facilities. This involves aiding in the identification of presumptive tuberculosis patients and ensuring that they have been linked or connected to the nearest clinics that provide the required tuberculosis services. One medical doctor from Hospital 1 reported that

Mobile health can help in mapping and linking the patients to the nearest health facility that offers tuberculosis services. (Medical Doctor, Hospital 1).

In addition, mobile health technologies were perceived to be useful in informing the referral centers about the details of an individual patient that needs to be attended to, which could potentially result in faster services. One participant from Hospital 4 described,

If I get a presumptive tuberculosis patient at a private facility, through the mobile app, I can inform the tuberculosis clinic at the public hospital which is licensed to provide tuberculosis services that on a certain day, a patient from a certain hospital is coming, it will result in faster care on the presumptive tuberculosis case. (Medical Doctor, Hospital 4).

4.3.3.3. Inner Setting

Mobile health was perceived to enhance communication between facilities by allowing healthcare workers from both the private and public health facilities to communicate with each other about presumptive patients that were referred from private to public hospitals. One participant from Hospital 2 noted

> *Mobile health provides the easiest way for healthcare workers to communicate with each other about the referred patient. An application that can be used by healthcare workers at private hospitals to notify the healthcare workers at public hospitals about the patient that has been referred through SMS reminders might be helpful. When a patient is received at the facility, healthcare workers can also immediately reply via the application which brings easy communication across facilities. Using mobile health can provide an interface for two-way chatting via SMS or Video between healthcare workers about the progress of the patient. (Medical Doctor, Hospital 2).*

On the other hand, participants raised the concern of poor internet connection (e.g., slow connections or lack of internet) which might affect the usability of mobile health interventions that rely entirely on the internet. If a hospital facility doesn't have a well-set up internet infrastructure for ensuring the running of mobile health interventions that are internet-based, it might hinder the adoption and use of the intervention.

> *If the app uses the internet, in some places, there are poor network connections, which might affect the operation of the intervention. (Medical Doctor, Hospital 3).*

4.3.3.4. Characteristics of Individuals

Mobile health technology was perceived to improve the knowledge and beliefs of healthcare workers and patients by enhancing learning about how to care for tuberculosis among healthcare workers and providing information to patients about the benefits of medication adherence which in long run enhance better health outcome. One participant from Hospital 4 noted,

> *I think mobile health technology can be used as a tool for enhancing learning for healthcare workers, especially about best practices for tuberculosis care like screening, and remotely relay information to patients wherever they are about the side effects of the drugs they are taking and information on benefits of medication adherence. (Medical Doctor, Hospital 4).*

However, on the other hand, some participants expressed concerns about the lack of knowledge among health workers to use the developed mobile applications which might hinder the operation and implementation of the technology due to abandonment by the intended user. One medical doctor from Hospital 2 reported that

> *Some health workers may not know how to use the app and in the long run, may abandon it. (Medical Doctor, Hospital 2).*

4.3.3.5. The Process of Implementation

Healthcare workers perceived mobile health as a tool for enhancing coordinated patient care and monitoring by facilitating communication between patients and healthcare workers across health facilities. One medical doctor from Hospital 1 reported that

I think mobile health would help if someone had an app on their phone installed that would keep the patient and the health care providers in touch, which would ensure better adherence to the drugs among patients, and better follow-up. (Medical Doctor, Hospital 1).

The communication between healthcare workers and patients via short messaging service reminders may enhance medication adherence, and encourage patients to attend their clinical appointments as scheduled. A medical doctor from Hospital 4 reported that

Mobile health can help in monitoring patients to take their medication on time, and also help them know when to refill their drugs and also reminders of when to come back to the clinic. (Medical Doctor, Hospital 4).

4.4. Requirements for MOHE framework

Findings from the scoping review (objective 1) and the formative qualitative investigation (objective 2) offered a basis for the proposition of a potential framework that can guide the development of a potential mHealth intervention. The study findings revealed that the development of a potential framework should consider the several requirements that are important to the realization of a scalable mHealth intervention. The scoping review carried out in this study provided an investigation of the existing mHealth interventions and assessed their strengths and weaknesses which offered key insights in terms of lessons learned from elsewhere. The formative qualitative investigation (objective two) findings explored the barriers and motivators to private hospitals' engagement in TB care and assessed the potential of mHealth technologies in addressing the identified barriers. Understanding the barriers and motivators offered a grounding of barriers that might hinder the implementation of the mHealth technologies. The following are the basic requirements that are critical to the realization of the MOHE framework.

- The research findings from the formative research investigation identified a need for a mobile health mechanism for following up on referred patients. The majority of private hospitals in Uganda are not accredited to provide TB services and refer patients to public hospitals which are accredited to provide TB services. However, the lack of mechanisms to follow up patients referred from these facilities to public facilities hinders the referral pathway since it remains unknown whether referred patients reached the place of the referral or not. Therefore developing an mHealth intervention for following up the referred patients could improve the tracking of these referred patients.

- The scoping review findings revealed that the development of mHealth interventions should be based on frameworks that enable simpler and faster use. Simple and easy-to-use architectures are key in enhancing usability, acceptability, and adoption of the developed mobile interventions. Failure to bear in mind these key factors results in the development of interventions that are difficult to use and yield sub-optimal usability.

- For the sake of the practicability, MOHE Framework facilitates the participation of healthcare workers from both private and public hospitals in tracking and following up the referred patients from private hospitals to ensure that they arrive at the referral unit without getting lost along the referral pathway. The framework offers a practical way of communication among the private hospitals, referred patients, and public hospitals for collaborative efforts to ensure better patient-centered care and management through establishing a streamlined communication link between the parties involved along the referral pathway.

- For the sake of functionality, the framework enables access to the tracking of patients to the Healthcare workers by utilizing mobile internet data connectivity for data transmission to the referral unit by the private facility. Private healthcare workers can effectively communicate

with the public healthcare workers through a centralized mechanism for coordinated efforts to better ensure that the patient reached the referred unit.

- For the sake of privacy and security, the framework ensures that the referral SMS reminders generated by the system to the referred patients and healthcare workers at the public health facility are only interpreted by the patients and healthcare workers themselves. The SMS reminders sent do not reveal the type of disease the patient is suspected to be having to avoid status disclosure and to protect the privacy and confidentiality of the patient. The framework ensures a secure local and remote storage of patients' data by establishing mechanisms for accessing and extracting this data. The framework ensures the availability of aggregated data on tracking patients for analysis to determine the amount of time spent along the referral pathway, and the amount of time taken to start on medication. The framework implements visualization and analytic algorithm that provides access to data in a way that is understood by both the average users and technical specialists.

In summary, this chapter has outlined the research findings from research objectives one and two for the study and general requirements which laid a foundation for the development of the MOHE framework and its subsequent mobile application developed based on the modules of the framework as discussed in the next chapter (chapter 5).

CHAPTER FIVE: FRAMEWORK DEVELOPMENT

5.1.Introduction

In the previous chapter, the key findings from objectives one (a scoping review investigation) and two (a formative qualitative investigation) have been presented. This chapter therefore, presents key findings from research objective three which sought to develop a mobile health framework for following up presumptive TB patients referred from private to public hospitals based on the findings from objectives one and two. The objective aimed to answer the following research question "How can a mobile health framework for following up presumptive TB patients referred from private to public hospitals be developed?"

5.2. Description of the MOHE framework

A framework can be defined as a collection of several fully or partially implemented components with largely predefined cooperation patterns between them. The main purpose of a framework is to implement the software architecture for a family of applications with similar characteristics and provides support for large-scale reuse (Fayad, 2001, Fontoura et al., 2000). MOHE framework enhances the linkage of presumptive TB patients referred from private hospitals to public hospitals for better TB care and offers a centralized approach for integrating human interaction technology for Healthcare workers both at Public and private facilities to ensure that patients are not lost to contact on referral and along the referral pathway.

The framework was used as an experimentation tool for the development of a mobile application for following up and tracking TB patients referred from private to public hospitals to ensure that they adhere to the referral pathway. Successful application of this framework in designing referral applications for tracking TB patients may be applied in tracking patients referred from private to

public hospitals suspected of other diseases for better management. The framework was designed using the Unified Modelling Language (UML). UML is a standardized modeling language made up of an integrated set of diagrams for assisting software developers in specifying, visualizing, constructing, and documenting the artifacts of software systems (Padmanabhan, 2012). UML uses notations to explicitly represent the variation points in the structure of the framework thus allowing partial automation of the development and implementation. To avoid re-inventing the wheel, The MOHE framework followed the reuse concept by customizing the architecture of the mDroid framework focusing on specific modules tailored for following up the referred patients from private to public hospitals. The mDroid framework customization was done by the investigator by aligning modules specific to this study. The framework was adopted because of its ability to enable the collection and extraction of data and triggering of text messages. The modules were customized to fit the TB context and make it simpler for the healthcare workers to use. This work extends the framework to add particular components for following up the referred patients.

5.3. MOHE Framework Modules

MOHE framework is composed of six different modules including the application layer module, network connection module, a storage module, service module, data processing module, and data analytic module, , and When the patient's data is entered via the application layer module (this is enables the mobile app to run on android platform), patients and healthcare workers at the public health facility receive SMS notifications about the place of referral and the incoming referral respectively which is enabled by both the service and the network connection modules. The data entered must be stored under the storage module which is composed of both the local and cloud database and this entered data can be processed by the data processing module and be visualized via the data analytics module which enhances the analysis and report generation.

5.4. The MOHE Framework

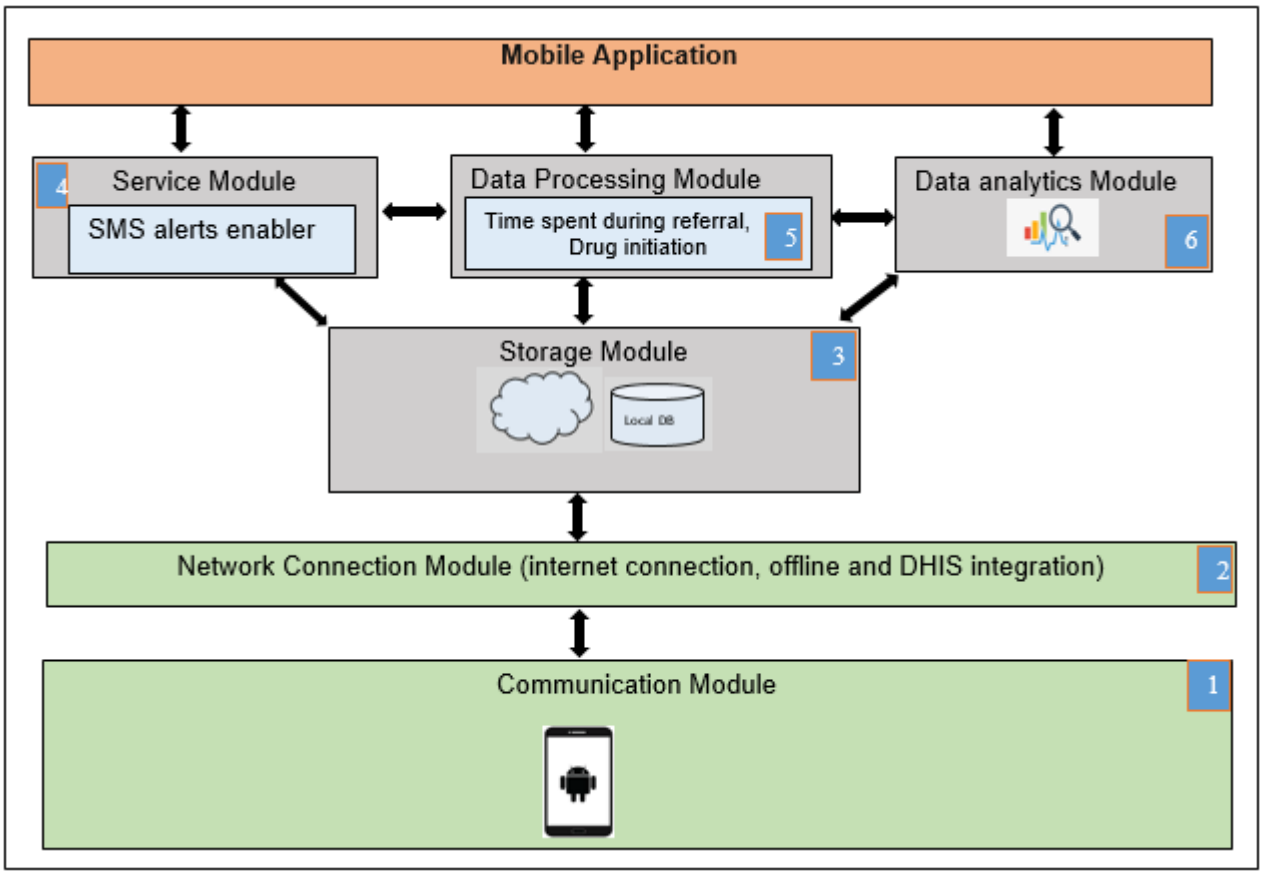


Figure 5.9: MOHE Framework Architecture

The Application layer module

This module offers a platform that enables Tuuka mobile app to function with ease on the android platform. The platform enables the application to function on a smartphone and helps interpret data entered on the device. The module offers an interface where private healthcare workers enter patients' details to notify the presumptive TB cases, and enables the public healthcare workers to verify and acknowledge receipt of the Patients referred. This module offers a backbone for the connection of all other modules of the MOHE framework.

Network connection module

This module is responsible for ensuring the connectivity of the developed application to ensure that it functions. Tuuka app is an internet-based application (requires the internet to operate), this module, therefore, ensures that the application connects to the internet to run efficiently. For standalone applications, the module ensures data synchronization to facilitate data capture. This module also offers an interface for external integration for other systems like the District Health Information System (DHIS) for national case notification.

Storage Module

This module offers storage and access to the patients' data. The module enhances the connection of the app and is responsible for ensuring that data is accessed and retrieved. The module is responsible for the local and cloud database management and a central repository for ensuring that all data regarding patients are stored, this is in addition to storing data regarding the number of SMS reminders sent to the patients, the amount of time spent from the time the patients were referred from private to public health facilities which offers a basis for data analytic module which offers guidance

on the appropriate mechanism for following up the referred patients. This module is responsible for the secure transmission of the data to the local database and the cloud database (Banos et al., 2015).

Service module

This module is responsible for enhancing the sending of SMS reminders to presumptive TB patients referred from private to public hospitals, receiving SMS reminders and managing requests from the users and provides response. The module is based on the network connection module and manages queues and is responsible for system security including the login sessions and authentications.

Data Processing module

This module is responsible for retrieving data stored in the storage module and making it available for viewing and manipulation by the public healthcare workers. The module is responsible for presenting information about the referred patients which is viewed by the public healthcare worker who decides whether to start the patient on TB treatment or not. The module is also responsible for calculating the amount of time spent from referral to diagnosis, amount of time spent from referral to drug initiation

Data Analytic module

This module enables the analysis and generation of reports from data collected on patients tracking data generated weekly, monthly and quarterly which will be helpful in guiding the decision making process by practitioners to guide their operational procedures and policy makers including the Ugandan MOH about the number of cases notified from a particular hospital setting.

5.4.1. Typical use case and application of MOHE Framework

Use case: A patient presents to the private health facility with presumptive TB or symptoms of TB. If the symptoms are negative (not TB), the patient is checked for other disease conditions. If TB is suspected, the private healthcare worker decides on further action. Due to the inability to effectively diagnose and treat TB disease and lack of accreditation to manage TB disease among private hospitals in Uganda (Tumuhimbise and Musiimenta, 2021a), the private healthcare worker refers the patient to a health facility that has the diagnostic facilities in most cases the public health facility is the referral point. The referral process involves a doctor writing a referral note that the patient is expected to present at the referral unit. It's up to the patient to go to the referral unit or not since private healthcare workers only stop at issuing the referral note which is a common virtue with in the Ugandan setting.

5.4.2. MOHE Framework Response to the Use case

MOHE framework is built on a centralized patient management scenario to provide patient-centered TB care that involves bringing together the parties involved in the patient's pathway to effectively manage the patient where the private hospitals notify the public hospital about the referred presumptive TB patient. Figure 5.2 below illustrates how MOHE framework is used during following up of the referred patient.

An illustration of the use of MOHE framework

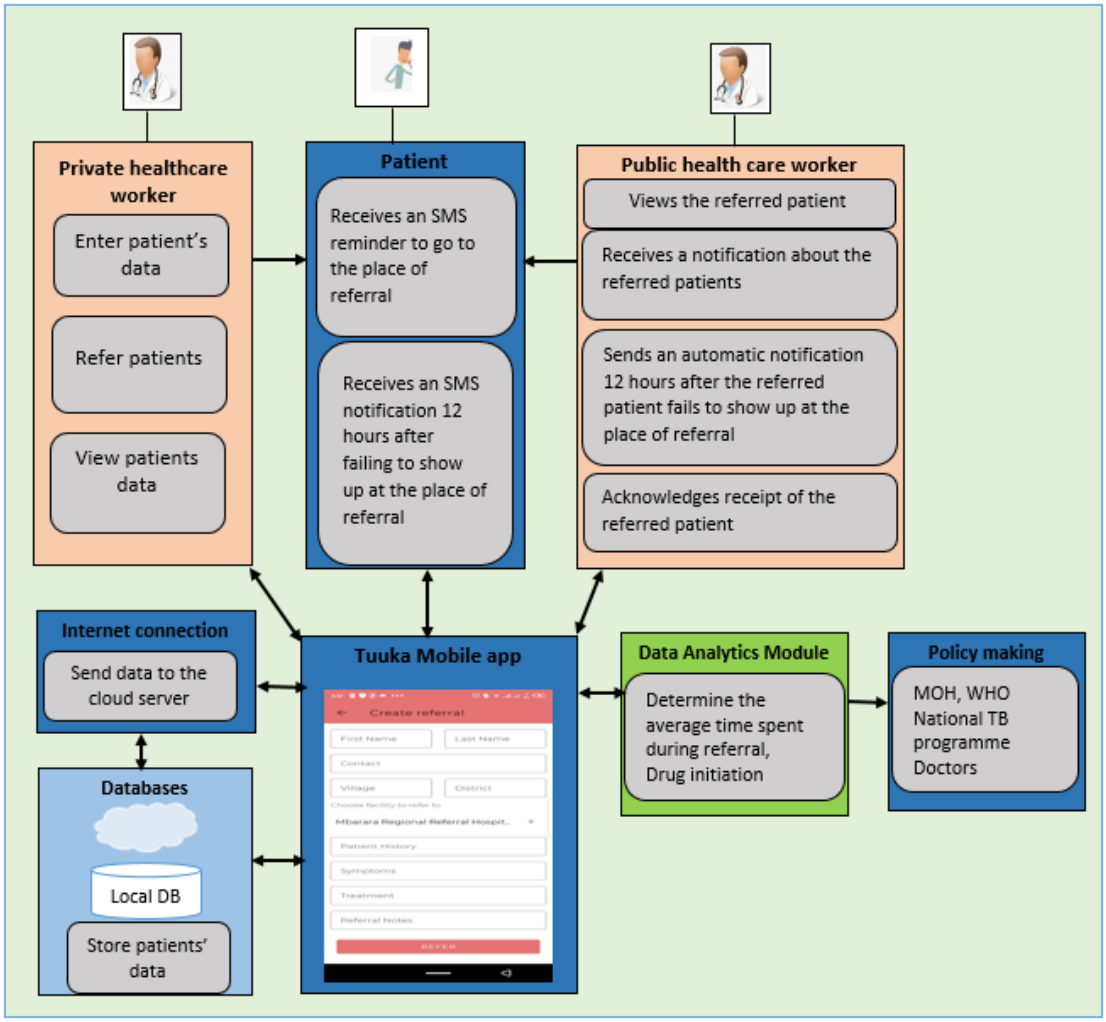


Figure 10: Illustration of the MOHE Framework

a) Upon data entry about the presumptive TB patient at the private facility by the private Healthcare worker in the Tuuka app, the referred patient receives an SMS reminder about the referral unit and the importance of adhering to the referral, and also the Public healthcare worker receives a notification about the referred presumptive TB case.

b) The patient's information about the exact time and date referred from the private hospital and arrival at the referral unit is ascertained by the Tuuka app to understand whether the patient is affirmative or not to the referral process.

c) If the patient is affirmative, he or she goes to the referral unit and if the patient is not affirmative, after 12 hours from the time of referral, the public health worker notifies him or her about going to the referral unit through an automatic SMS message.

d) When the patient arrives at the referral unit, the public healthcare worker acknowledges receipt of the referred patient and verifies by submitting the steps taken to handle the patient in terms of diagnosis, and initiation of treatment.

e) The data analytics module then generates reports about the patients tracking to ascertain the number of patients tracked, their location, and the average number of time taken from the private health facility to a public health facility.

In conclusion, this chapter has outlined the development of the MOHE framework for guiding the design of an mHealth intervention for following up presumptive TB patients referred from private to public hospitals. In addition, a mobile application developed based on the modules of the framework has also been discussed. The next chapter (chapter six) discusses how acceptable and feasible the developed mHealth intervention is among healthcare workers in southwestern Uganda.

CHAPTER SIX: INITIAL FEASIBILITY AND ACCEPTABILITY OF THE DEVELOPED INTERVENTION BASED ON THE FRAMEWORK

6.1. Chapter overview

In the previous chapter, the developed framework has been presented. This section therefore, presents an mHealth intervention called Tuuka mobile application developed based on the framework and key findings from research objective four which sought to assess the initial feasibility and acceptability of the developed mHealth intervention for following up presumptive TB patients referred from private to public hospitals using UTAUT model. The objective aimed to answer the following research question "What is the initial acceptability and feasibility of an mHealth intervention for following up presumptive TB patients referred from private to public hospitals?" Below is the description of the developed intervention.

6.2. Tuuka Mobile Application Development to test MOHE Framework

Tuuka app was developed to illustrate the potential of the MOHE framework, to prove its reliability (internal consistency and stability), validity (construct and concurrency), and accuracy in enhancing the tracking of TB patients. The key features of the MOHE framework have been utilized in the implementation of the Tuuka app. The word Tuuka is a Luganda word meaning reach and was chosen to represent the referral context in which the application was implemented. The app was implemented among private Healthcare workers made up of doctors, and nurses from four private hospital facilities who referred patients to a public hospital (Mbarara Regional referral Hospital TB clinic).

Tuuka app was deployed on healthcare workers' compatible low-cost smartphones both at the private health facilities and the TB clinic at the public facility (Mbarara Regional Referral Hospital) to enable private healthcare workers to notify the public healthcare workers about presumptive TB cases

referred. The referred patients receive system-generated SMS reminders on their mobile phones about the details of the referral unit and educational content about how important it is to adhere to the referral. In case of failure to adhere to go to the clinic after 12 hours, the app also sends a reminder to the patient to go to the place of referral. Healthcare workers at the public facilities also receive system-generated SMS notifications about the details of referred presumptive TB patient. Whereas the automating SMS message is good and ideal to remove the burden from the healthcare workers, there are chances that patients may be referred by the private hospitals to a public hospital and upon reaching the facility, a public healthcare worker may receive him or her but because of the busy schedule, he or she might not have the time to verify in the app in real time, which he or she may do when she gets free time. Therefore to avoid sending unnecessary messages that might come with the automation, it is important to let the healthcare workers at the public facility decide whether they have received the patient and notify or send the message in case the patient hasn't been received.

The application was developed based on all the six modules of the MOHE framework and its acceptability, and feasibility in linking and following up TB patients referred from private to public hospitals are currently being studied in a pilot study. Following a user-centered design approach that involved input from the users (healthcare workers) during the development phase, the Tuuka app was developed. This was aimed at understanding the end user's perspectives about the use of the Tuuka app. Subsequent feedback was obtained from healthcare workers and refinements and redesigning of the app were carried out until the desired prototype was reached.

The app enables healthcare workers at the private hospital to notify a presumptive TB patient by enabling data input about the patient's details and then sends him/her an SMS reminder about the importance of adhering to the referral and also the notification to the Health worker at the public Hospital about the presumptive TB patient that has been referred to the facility and in case the patient

fails to turn up at the referral, the system automatically sends a reminder to the patient to comply to the referral.

Overview of Tuuka Mobile app features

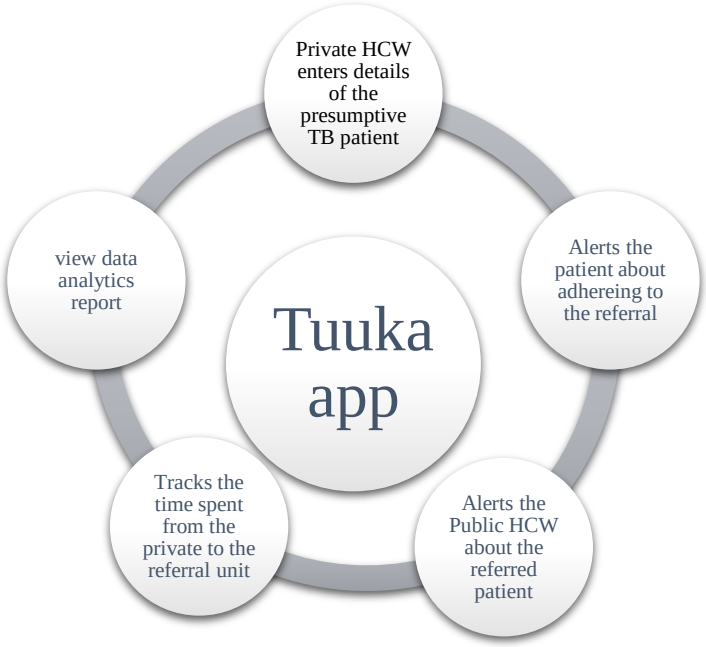


Figure 6.11: Overview of Tuuka mobile app features

6.2.1. Tuuka Application implementation

The main operators of the Tuuka app are healthcare workers from both the private and the public hospitals and its main functionality is capturing the referred patients' data using built-in digital referral forms/ notes. Private healthcare workers who log in the app can enter the presumptive TB patient's details and then refer the patient who receives an SMS reminder about the place where he or she has been referred and also the Healthcare worker at the public hospital receives an SMS reminder about the patient who has been referred.

The forms are designed to capture the following patient's details; the first name; the last name; the telephone contact; village; district; patient history; symptoms; treatment; and referral notes. The forms are designed to collect the same information collected through standard paper-based referral notes currently used by healthcare workers at private health facilities. Upon data entry by the private

healthcare worker, the record indicates a blue circled arrow showing that the patient has not been received at the public hospital and upon receipt of the patients by the healthcare worker at the public facility, the record indicates two green ticks upon refreshing or reloading the page.

Tuuka is made up of two main components, the application server which is responsible for providing services to the users (Aldosery et al., 2021), and the client-side which provides an interface between the services provided by the system and the users. The application server is the back end of the developed application which responds to the requests and processes the received data and user authentications. The server is hosted by Linode with a secure cloud-based database for the storage of data at monthly fee of $5. Linode was choosen because of being a secure cloud computing service provider which grants a two-factor authentication feature for data protection. In addition, Linode is enabled by IPv6 support which provides safe traffic for the application.

The Application Client is the front end that allows users to interact with the system. The users in this context are both the private and public healthcare workers and the system administrators. This side communicates with the server-side through the API and has two main forms of access, the web interface, and the application interface. The web interface is specifically for the system managers for accounts creation and report generation. This manager web application has been built with the Kotlin language. The web application can be accessed through the following link: https://tuuka.tech/ through a web browser on any device (desktop, laptop mobile phone) regardless of the operating system.
The Mobile application was developed in android using the Kotlin language that follows the Model View Model architectural pattern that breaks down the code into pieces which enables separation of the logic from the user interface thus encouraging code reuse and scalability. This pattern provides extra security and efficiency in code expansion. The Tuuka web application and mobile application communicate through a restful application programming interface (API) to allow interaction between the platforms.

Tuuka is developed in laravel which is a PHP framework with a MySQL database that is fully encrypted and running on an Nginx server. Because of the object-relational mapping utilized by laravel, the MySQL database and other relational databases are supported by the Tuuka backend as long as the database type is specified in the .env file of the Laravel file. Laravel comes with inbuilt connectors and drivers that can convert the models into the relevant SQL queries of the natively supported databases by Laravel. Tuuka app is available on the google play store https://play.google.com/store/apps/details?id=ug.global.mohe.

Authentication and security

The app performs full encryption of databases. Then authentication and authorization are performed on both the mobile apps and web applications. The application requires users to authenticate themselves to ensure that they only access the information specific to them. Accounts are only created by the system administrator. The domain or connection to the server is through HTTPS which ensures that all communications are encrypted and TLS enforced at all times.

Screenshots from Tuuka Mobile application

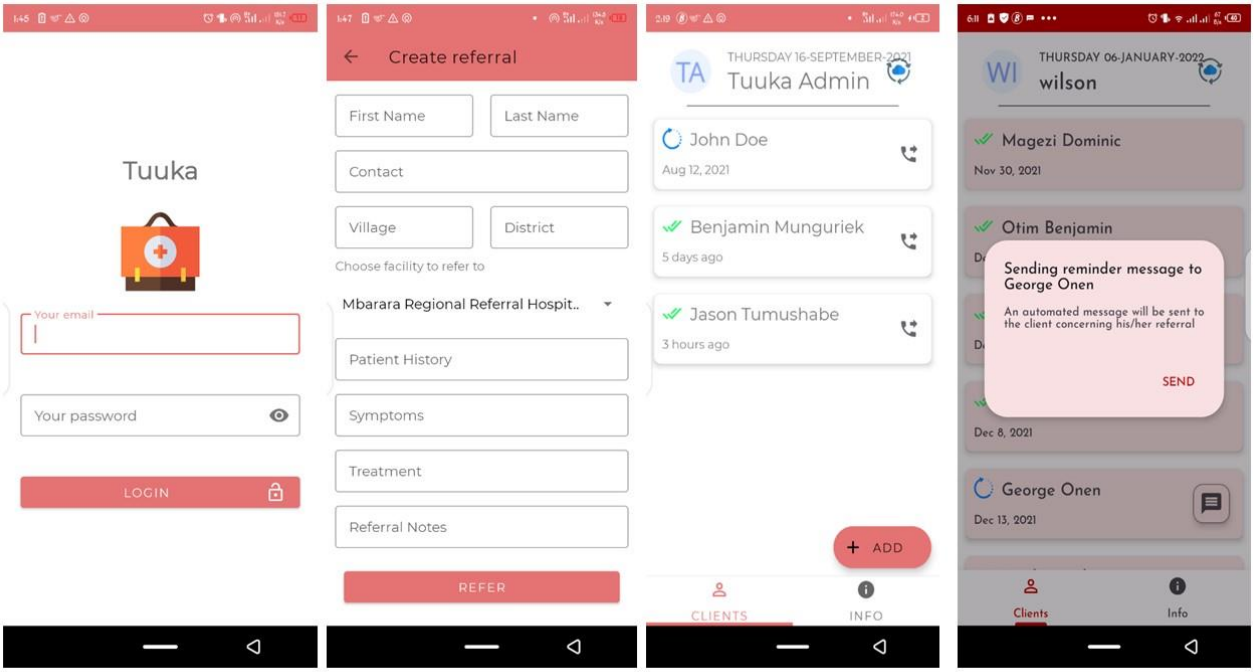


Figure 6.12 screenshots from Tuuka mobile application

6.3. Tuuka Application use case diagram

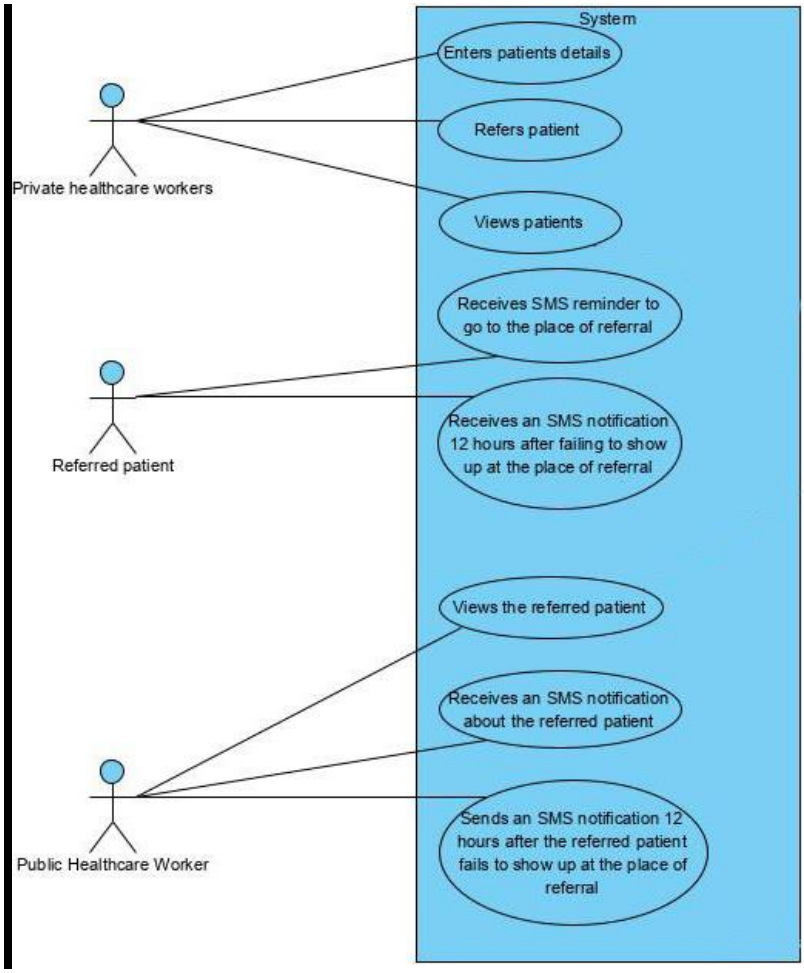


Figure 13: showing the Use case of Tuuka

All study participants received the final version of the Tuuka mobile application by following the link on the google play store (https://play.google.com/store/apps/details?id=ug.global.mohe) and were trained on how to use the application (eg, adding the referral in the app). Of the 24 participants who received the application, two reported failure to download the application from the shared link. After one week of receiving the application, downloading, and installing the app, participants were contacted for a phone interview, and the interviewer-administered questionnaire to assess their overall experience with using the intervention.

6.4. Quantitative findings

This section discusses the quantitative results about the demographics of the participants, findings from the System Usability Scale, and the technology adoption survey based on the UTAUT model for assessing the acceptability

6.4.1. Social-Demographic Details of Participants

Demographic details of the healthcare workers collected to assess the initial acceptability and feasibility were analyzed using descriptive statistics and details are shown in table 6.1 below. Twenty-two healthcare workers including three medical doctors and fifteen nurses, three laboratory technicians and one pharmacist from three private hospitals and Mbarara Regional Referral Hospital participated in assessing the initial feasibility and acceptability of the developed mobile intervention. Participants were recruited because they were actively involved in screening and diagnosing presumptive TB patients to gain deeper insights into the initial feasibility and acceptability of the developed intervention. As shown in Table 6.1 below the majority of the participants were female (n=16) and were nurses (n=15). Their median age was 28 years of age. All the three private hospital facilities that were part of this study refer presumptive TB cases to Mbarara Regional Referral Hospital.

Table 6.1: Showing demographics of participants who participated in Tuuka evaluation

Baseline characteristic	Participants
	N (%)
Median Age (IQR)	28 (25-29)
Gender	
Female	16 (73)
Male	6 (27)
Marital status	
Single	12 (54.5)
Married/partnered	10 (45.5)
Facility	
Public Hospital	4 (18)
Private Hospital 1	8 (36)
Private Hospital 2	5 (23)
Private Hospital 3	5 (23)
Highest educational level	
Certificate	7 (32)
Diploma	10 (45)
Degree	5 (23)
Designation	
Nurse	15 (68)
Doctor	3 (14)
Lab Technician	3 (14)
Pharmacist	1 (4)
Number of years in general medical practice	
1-5	12 (54)
>5	10 (46)

Table 6.2: The potentials of Tuuka mobile application among private healthcare workers

Characteristic (N=18)	Agree	Strongly Agree
Helping me make quicker medical decisions	2	16
Help me communicate with other healthcare workers about the referred patient	1	17
Enhance patient follow up	1	17
Facilitate partnership with other health institutions	0	18
Quick TB case notification	1	17
Quick and efficient referral system	2	16

The majority of the participants reported that Tuuka mobile application would help them make quicker medical decisions regarding the referred presumptive patient, enhance communication with other healthcare workers about the referred patients, enhance patient follow up and quick TB case notification, facilitate partnership between private and public hospital facilities and was perceived to be a quick and efficient referral system as shown in tables 6.2 and 6.3.

Table 6.3: The potentials of Tuuka mobile application among private healthcare workers

Characteristic, N=4	Strongly Agree
Helping me make quicker medical decisions	4
Help me communicate with other healthcare workers about the referred patient	4
Enhance patient follow up	4
Facilitate partnership with other health institutions	4
Quick TB case notification	4
Quick and efficient referral system	4

6.4.2. Tuuka usability findings based on the SUS

The system usability scale (SUS) (Brooke, 1996a) was used to explore how the healthcare workers perceived the usability of the Tuuka mobile application. The SUS is a 5 Likert scale for subjective

assessment of system usability.The total mean for all respondents to the SUS was 98 (SD 1.97) intervention. The descriptive scores of responses to the 10 questions of the SUS are presented in Table 6.4 below.

Table 6.4: Results of the System Usability Scale items for all participants (N=22)

Characteristic (N=22)	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**
I think that I would like to use Tuuka app frequently	0	0	5	17
I found the Tuuka app unnecessarily complex	22	0	0	0
I thought the Tuuka app was easy to use	0	0	3	19
I think that I would need the support of a technical person to be able to use this app	18	4	0	0
I found the various functions in this app were well integrated	0	0	0	22
I thought there was too much inconsistency in this app	19	3	0	0
I would imagine that most people would learn to use this app very quickly	0	0	4	18
I found the app very cumbersome to use	21	1	0	0
felt very confident using the app	0	0	7	15
I needed to learn a lot of things before I could get going with this app	22	0	0	0

The total mean for all respondents to the SUS was 98 (SD 1.97) intervention which according to (Bangor et al., 2008) would be in the fourth quartile range in the acceptability range.

6.4.3. Technology adoption findings

UTAUT model guided the quantitative exploration of how the healthcare workers perceived the acceptability of the Tuuka mobile application. Questions were structured according to the four main constructs of the UTAUT model namely; performance expectancy, effort expectancy, social norms, and facilitating conditions. The intervention was found acceptable and the descriptive scores of responses are presented in Table, 6.5 below.

Table 6.5: Perceived usefulness, ease of use and social norms of Tuuka Mobile application

Characteristic (N=22)	**Neither**	**Agree**	**Strongly Agree**
Tuuka mobile app is useful in following up the referred presumptive TB patients	0	7	15
Tuuka mobile app is more useful than the current referral procedures	0	6	16
Tuuka mobile app positively affected the way I feel about referring presumptive TB patients	0	5	17
Tuuka mobile app would help me in following up the referred patients in time	0	5	17
Tuuka mobile app makes it easier to follow up referred patients	2	5	16
Perceived ease of Use of Tuuka mobile app			
It would be easy for me to use Tuuka mobile app to refer patients	0	4	18
It would easy for me to remember to use Tuuka mobile app	0	4	18
It was easy for me to install Tuuka mobile app	0	5	17
Social norms about using Tuuka			
People think I should use Tuuka mobile app to refer patients	0	6	16
My friends, workmates think I should use Tuuka mobile app to refer patients	0	0	22

All participants reported that Tuuka mobile app is useful in following up the referred presumptive TB patients, more useful than the current referral procedures, positively affected the way I feel about referring presumptive TB patients, would help healthcare workers in following up the referred patients in time. They also noted that the app is easy to use

Facilitating Conditions for Tuuka mobile app

All participants had smartphones for Tuuka to be installed had electricity and cellular network as facilitating factors to the usage of Tuuka as shown in table 6.6.

Table 6.6: Facilitating conditions for Tuuka Mobile application

Characteristic	**Strongly Agree**
Have a personal smartphone	22
My smartphone allows Tuuka mobile app to successfully operate	22
Have electricity	22
Have mobile telephone network	22

6.5.Qualitative findings

This section highlights findings from in-depth interviews with 22 healthcare workers. The results are presented following the UTAUT model and detail the performance, effort expectancy, social norms, and facilitating conditions associated with the mobile intervention.

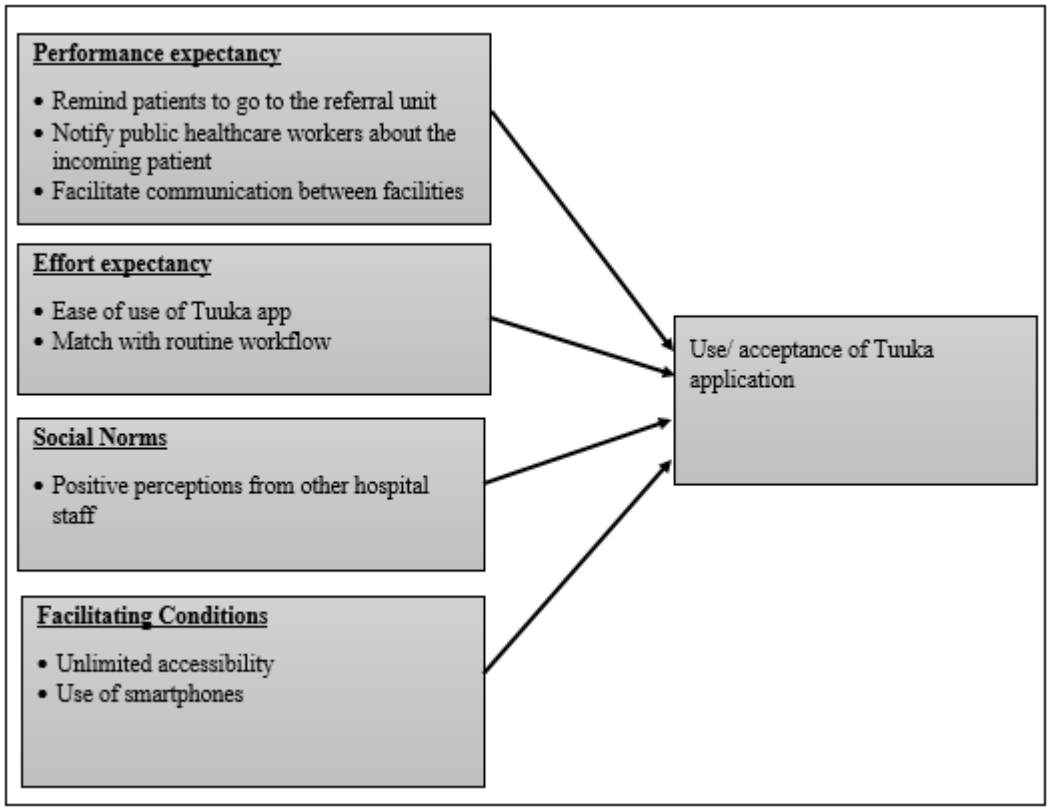


Figure 6.3: Organization of qualitative data on acceptability following the UTAUT model.

6.5.1. Performance Expectancy or perceived ease of use

The study participants found Tuuka mobile application useful in notifying both patients to go to the place of referral and the public healthcare workers about the referred patients. They described that the SMS notifications triggered by the Tuuka mobile app at the private health facility remind and force patients to go the place of referral and also enables the healthcare worker at the public health facility to prepare to receive the referred patient.

But what I liked about the app is that it notifies the healthcare worker at the public facility that a certain patient has been referred from a private hospital and is on the way coming and also notifies the patient to go to the place of referral. So if the patient receives this message, he or she will be forced and reminded to go to the hospital where he has been referred. This prepares the healthcare worker to be alert knowing that a patient is coming from the private hospital and also enables the healthcare worker to get more information about the history of the incoming patient which enables the healthcare worker to prepare enough and to know what to do when the patient comes to the facility and it forces the healthcare worker to follow up the patient and know whether this patient reached the hospital. (Female, Nurse, 38 years, Public Hospital)

Tuuka mobile application was reported to enhance communication between facilities. The application was reported to allow healthcare workers at both the private and public health facilities to communicate with each other about the referred patient after receiving an SMS notification which would help to ascertain whether the patient reached the place of the referral or not.

If every facility can have that application so that when they refer the patient and notify cases through the application it becomes an easiest way to communicate with other facilities to follow up. Because when the person at the private hospital refers a patient, you receive a message that a patient has been referred, so when you receive that patient, you also immediately reply in the application which brings that easy communication across facilities. (Male, Lab technician, 46 years, Private Hospital)

The mobile app was reported to enhance patient-centered care through coordinated patient follow up efforts in both the private and public health facilities and through ensuring the privacy and

confidentiality of patients where they can easily be worked on without lining up since the healthcare workers are made aware in advance about the referred patient.

> *Usually patients from private hospital always require privacy and confidentiality, they don't want to be in those long lines, so this app helps in connecting them by alerting the public health facility about their coming and they can be worked on faster by the healthcare workers upon reaching the facility. This makes a patient feel good knowing that he or she is being cared for. (Female, Nurse, 25 years, Private Hospital).*

6.5.2. Effort Expectancy or perceived ease of use

Following the healthcare workers' initial orientation to use the application, they found it easy to use for referring the presumptive TB cases. The application has an SMS functionality that would notify the healthcare worker at the public facility about the referred patient which would prompt them to do the needful and the application irrespective of where they are.

> *I think the app does not need a lot of time to operate, it's just a matter of adding the patients' details and the public hospital gets notified about the referred patient. The interfaces were fast and easy, it is user friendly, you just put it details and it is simple it directs you to the next stage. Most people don't like a lot of data entry, so when it has few data entries, it makes the process simpler. (Female, Nurse, 25 years, Private Hospital).*

The participants at the referral unit noted that the app functioned well as evidenced by receiving SMS notifications about an incoming patient as soon as the private healthcare worker referred the patient.

> *The application was working very well because immediately when a patient was referred from the private hospital, I would receive the message on my phone about the incoming patient. (Female, Nurse, 38 years, Public Hospital)*

6.5.3. Social influence

Participants noted that the SMS messages received by patients might result in unintended status disclosure which might cause issues, especially among patients whose spouses might not be aware that they were sick

> *The message could result in unintended disclosure partly for example couples get access to each other's phones, one might not know that his or her spouse went to the facility and then all of a sudden sees the message about the referral*
>
> *(Female, Medical Doctor, 26 years, Public Hospital)*

6.5.4. Facilitating conditions

Participants noted that the app does not require a lot of space for installation and the internet to be downloaded which was perceived to enhance its acceptability. They reported being repulsive to downloading apps that require a lot of space and internet in terms of MBs as it would be expensive in the long run.

> *The app didn't take a lot of my data in terms of downloading it because not everyone would be willing to spend more data to download an app and on the other hand the app is small enough, it doesn't take a lot of space on my phone. (Male, Medical Doctor, 26 years, Public Hospital)*

However, participants noted that the internet might limit the usability of the app since the application entirely runs on the internet. The SMS notifications sent to healthcare workers were perceived to force the healthcare worker to buy internet and get more information about the patient

Of course you have to have data (internet) so that every time you receive the message on the phone, you will login the app to send the patient a message in case he or she delays to come. But what I liked about it is that in case one doesn't have internet, after receiving the message, you can be forced to buy data and log in the application and see the details about the referred patient. So the lack of internet does not hinder someone from getting notified because the incoming referred patient. (Female, Nurse, 38 years, Public Hospital)

The lack of smartphones among healthcare workers was reported as a major hindrance to using the application. Participants highlighted the need for integrating the application to operate on feature phones.

May be the hindrance may be unavailability of compatible smartphones. If the healthcare worker is deep in the village at a health center II and suspects TB and he has no smartphone, is it able to run of feature phones? The app should be improved to be used on feature phones. (Male, Lab technician, 46 years, Private Hospital).

In summary, this chapter has outlined the research findings from research objective four for the study. This brings us to the discussion section in the next chapter (chapter 7) which discusses the main research findings.

CHAPTER SEVEN: DISCUSSION

7.1. Chapter overview

This chapter presents the main discussion of the thesis, first the main findings from the scoping review investigation are discussed, and then the formative qualitative investigation, followed by the framework development discussion and lastly discusses the findings about the initial acceptability and feasibility of the developed intervention.

7.2. Discussion for research objective one

The scoping review investigation aimed at summarizing the published evidence on the utilization and effectiveness of mHealth interventions for PPM in TB care from literature. This was through an online database search for peer-reviewed literature about mHealth interventions for PPM in TB care. Studies that discussed the utilization of mHealth interventions for implementing PPM in TB care were included in this review. Only nine studies met the inclusion criteria and were analyzed for review. Several mHealth interventions identified by this review include mobile applications used for TB case notification (Chadha et al., 2017b, Khan et al., 2012a, Lestari et al., 2017, Thu et al., 2020a, Velayutham et al., 2015b), educating clinicians about TB (Pande et al., 2017a) and data collection and management (Ali et al., 2016b). Telephone calls for patient follow-up (Choun et al., 2017a) and SMS reminders (Mohammed et al., 2016b) for Medication adherence. This resulted in high user experience (Pande et al., 2017a), significant time reduction in data aggregation (Ali et al., 2016b), increased case notification (Khan et al., 2012a), and referrals (Chadha et al., 2017b) and proactive tracking and provision of follow up care hence reduced treatment and completion gaps (Thu et al., 2020a). Although various mHealth technologies have been utilized in enhancing PPM, technical and operational challenges encountered by the users can hinder the technology usability as evidenced in India (Velayutham et al., 2015b) where system complexity resulted in non-usability.

The latest WHO Roadmap for PPM (WHO 2018) emphasizes harnessing the power of digital technologies to attain 100% systematic engagement of all non-state providers in TB care by 2030-2035. There is a need for additional practical evidence from the pragmatic implementation of several digital interventions to enhance the translation of findings into local practice (Ngwatu et al., 2018). The scoping review identified several mHealth interventions utilized in PPM for TB care, which include mobile apps, SMS messages, telephone calls, and voice-based notification systems. These interventions have the potential to facilitate better patient outcomes compared to the routine standard of care.

None of the identified studies reported the software framework (an abstraction in which the software providing generic functionality can be selectively changed by additional user-written code thus providing application-specific software) on which the implemented mobile apps were developed. This limits replication and implementation of the software architecture for applications with similar characteristics and provision of support for large-scale reuse of the interventions (Fayad, 2001, Fontoura et al., 2000), which could have contributed to suboptimal usability since several factors could have been missed during the intervention development. There is a need for developers and researchers to ensure the implementation of interventions that allow replication and reuse on a larger scale implementation.

None of the reviewed studies document behavioral theoretical frameworks on which these interventions were developed. Interventions based on behavioral theory are efficacious in changing health behaviors (Hesam et al., 2020, Hagger and Weed, 2019), and yield better health outcomes (Vandelanotte et al., 2016). The lack of theoretically founded mHealth interventions has been a major contributor to small effect sizes. The implementation of mHealth interventions based on behavioral theories has been recommended as a key step for mHealth research design (Glanz and Bishop, 2010). There is an urgent need for theory-based mHealth interventions for enhancing PPM.

Although a mobile application was reported to have increased case detection by (Khan et al., 2012a), it is rather hard to attribute treatment success and evaluate the actual contribution of the mHealth app as far as case notification is concerned. This is because the study was combined with other interventions (mass media campaigns that involved billboards, cable television adverts, posters, banners, and flyers) for encouraging patients to seek medical attention at study sites (Denkinger et al., 2013). In addition, although Thu and colleagues also report that the mobile app reduced the dropout rate in the cascade of care (Thu et al., 2020a), the study does not report the design features (software architecture) of the app, which limits comparability. It is pertinent for researchers to state and define the parameters that were used to design the application, and its key functionalities to enhance the clear assessment of the intervention's effectiveness, especially in instances where mobile apps are combined with several other interventions. This will aid in understanding the effectiveness of the implemented mHealth technology.

On the other hand, the utilization of community lay people to screen patients for TB, might result in potential status disclosure. This might result in stigma, discrimination, and discomfort (Mhode and Nyamhanga, 2016) among patients who might not feel comfortable about their status being known especially when the community lay workers come from the same village as the patients (Rachlis et al., 2016). Patients are more likely to confide in trained healthcare workers compared to lay, people, since they are not trained in confidentiality issues (Geldsetzer et al., 2017). Future mHealth intervention implementers must ensure that the confidentiality and privacy of patients are prioritized. Security and privacy are key concerns in mHealth (Whittaker, 2012) and must be carefully addressed for patients to trust it.

The scoping review noted that the utilization of telephone calls enabled the referred patients to reach the peripheral units of referral in Cambodia (Choun et al., 2017a) which resulted in high retention of TB patients. The utilization of telephone follow-up calls has been reported somewhere else (Houser

et al., 2013) and was associated with satisfaction with care among primary care patients after the ambulatory care visit in the USA. Telephone calls were also found to be a cost-effective strategy for the provision of timely comfort or referral where needed among older patients seeking emergency department service after being discharged from the hospital (Lewis et al., 2017). The review, however, noted that voice-based notifications (Velayutham et al., 2015b) on the other hand did not yield significant results due to both technical and operational challenges encountered on the side of the healthcare workers (busy phone line or call interruptions). The system required about five minutes to notify a single TB case, which is rather a very long time especially for healthcare workers to notify a single case. Such technical issues frustrate the usability and acceptability of the system among the users, which results in the abandonment of the intervention. Using such a system in an already overwhelmed health sector with an alarming uneven doctor-patient ratio, especially in low resource settings overburdens the service provision efforts. Successful implementation of voice-based systems for case notification requires hiring specific staff for reporting the cases to lessen the burden on the healthcare workers.

The development of mHealth interventions requires the restructuring of the system architecture to ensure that simpler, faster, and easy to use interventions (Uplekar, 2016) aimed at easing the work of healthcare workers are developed. Interventions that are perceived to be easy to use can result in sustained use (Opoku et al., 2017) thus better health outcomes. The utilization of user-centered approaches that involve studying the user behaviors, requirements, characteristics, needs, and skills at each phase of the design (Wever et al., 2008) is crucial in facilitating the acceptability of the developed prototype among the system end-users (Goold et al., 2006).

The review found no significant impact of SMS messages on TB medication adherence (Mohammed et al., 2016b), which has also been reported in China (Liu et al., 2015). This, however, is in contrast to findings from three meta-analyses (Wald et al., 2015, Mbuagbaw et al., 2013, Finitsis et al., 2014)

and one randomized trial (Musiimenta et al., 2018a), which on the other hand reports improved ART medication adherence. To ensure positive results, designing and implementing SMS interventions for TB medication adherence should consider various factors like literacy levels, and the duration on treatment since SMS messages are associated with supporting self-administered treatment compared to DOTs (Ngwatu et al., 2018).

Although the review indicates that mHealth technologies have been utilized in fostering PPM for TB care, their utilization and implementation in Africa remain unknown, yet most countries in Africa still grapple with a high number of TB cases. Research utilizing mHealth for PPM in TB care in Africa is limited yet Africa still struggles with high TB disease prevalence and incidence. Africa contributes to 25% of the global TB cases (WHO, 2020). Thus leaving a research gap in understanding how mHealth is utilized to engage the private sector in TB care, especially in African settings. This implies that there is a need for investigation to understand the acceptability, feasibility, and efficacy of mHealth technologies for PPM in TB care in Africa since factors that affect/ influence the adoption of interventions in different economic settings might differ. MHealth technology might help identify the referred patients who do not present for treatment (Islam et al., 2015), and help in reducing the time spent at health facilities (Tumuhimbise et al., 2020). In addition, mHealth technologies are acceptable and affordable alternative approaches for health services in settings where face-to-face approaches are difficult (Musiimenta et al., 2020b, Musiimenta et al., 2021)and monitoring TB medication adherence (Musiimenta et al., 2019). The increased penetration of mobile phone technology and internet usage in Africa (GSMA, 2017) and developing countries offers a strong scientific premise for the implementation of mHealth technologies for enhancing PPM in TB care (Uplekar, 2016).

The scoping review highlights the lack of impact efficacy studies documenting how these mHealth technologies have been effective in enhancing PPM for TB care. Of the included studies, seven were

pilot studies (Ali et al., 2016b, Chadha et al., 2017b, Choun et al., 2017a, Lestari et al., 2017, Pande et al., 2017a, Thu et al., 2020a, Velayutham et al., 2015b). Impact efficacy studies aimed at assessing the effectiveness of mHealth technologies for PPM in TB care would help in narrowing the knowledge gap about several mHealth technologies.

7.3. Discussion for research objective two

Using CFIR as a guide, emergent themes were categorized based on relevant constructs of the five CFIR domains. These constructs include cost, external policies and incentives, structure characteristics, networks and communications, and knowledge and beliefs about the intervention where barriers to private hospital's engagement arose from while relative advantage, patient needs and resources, and engaging construct yielded motivators.

The barriers encountered by the private hospitals in TB care included lack of drugs, registers, and diagnostic tools, which hinder active TB control efforts; lack of proper follow-up mechanism; lack of training and qualified human resources; lack of accreditation from the Ugandan MOH; limited space for keeping TB patients; indirect income-generating nature of TB management; delayed seeking of healthcare by the patients; and concerns regarding the payment of care by patients. The identified motivators were perceived high quality of care in the private hospitals, privacy and confidentiality concerns, long distances to the public healthcare centers, and formalization of partnerships between private hospitals and the government.

The lack of access to drugs, registers, and diagnostic tools to fully manage the identified cases in the private hospitals implies that despite the willingness and availability of the private hospitals to offer TB services, patients end up being referred to the already overburdened public sector and sometimes delay initiating treatment. This lack of TB services may be attributed to a lack of financing for TB-related activities in Uganda (MOH, 2018) which limits the successful TB management outcomes. In

Uganda, the overall funding for the TB-related activities in both public and private sector is meager and insufficient which undermines the need to properly support basic health services for TB (Wynne et al., 2014). A review carried out by Lei and Colleagues (Lei et al., 2015) highlights insufficient funding as one of the challenges that affect the implementation and scaling up of the PPM in the long term. Commitment from the government, private sector, and other funding bodies to ensure continued funding for TB care in the private sector is necessary to enhance collaborative efforts and successful outcomes. Commitment is one of the facets of enhancing the organizational readiness for implementing changes (Shea et al., 2014). Lack of commitment hinders efforts to effect the change within an organization, therefore there is a need for unwavering and persistent shared resolve among key stakeholders to have this engagement done.

Limited training and lack of qualified staff in the private health facilities hinder their ability to fully screen, diagnose, and interpret the results for better patient management. Similar findings have been reported previously (Cattamanchi et al., 2015, Nansera et al., 2010), in Uganda where inadequate skills in detecting and managing TB among healthcare workers hinder TB disease control efforts in Uganda. The results indicate that the healthcare workers in the private hospitals acknowledge that lack of training continues to limit their engagement in TB care efforts. To address this, the WHO recommends Tuberculosis infection Control (TBIC) (WHO, 2009) in healthcare facilities which were implemented by training healthcare workers in TBIC by the Ugandan MOH (MOH, 2011). However, there remains a gap among healthcare workers with correct knowledge and attitudes toward TBIC (Buregyeya et al., 2016). The findings emphasize that training healthcare workers are a key component in ensuring the successful fight against TB, for, through training, healthcare workers are not only equipped with the necessary skills in TB care but also are empowered in TB management. There is a need to train private healthcare workers to increase their levels of TB suspicion and TB infection control (Buregyeya et al., 2014) if the full engagement of the private hospitals is to be

ensured. The training — imparting skills has the potential to equip healthcare workers with the necessary skills to handle TB patients and effectively manage the disease, which may influence the attitudes of healthcare workers, and policymakers towards engagement in TB care. The degree to which an intervention is valued heightens the intention to use an intervention (Ajzen, 1991), therefore skills gained during the training are more likely to increase an individual's value attached to the engagement in TB care.

Lack of accreditation for private hospitals by the Ugandan MOH to provide TB services constrains their engagement in TB care despite being the first point of contact of care before TB suspects/patients reach the public hospitals. This is attributed to the excessively complicated administrative procedures involved in obtaining accreditation from the MOH. In addition, since most private hospitals are for-profit, TB disease management is perceived as a non-lucrative business, its direct benefits are not realized, and this leads to a reluctance among the private hospital owners to venture into it. This puts public health at a risk in settings where private health facilities are the main sources of healthcare-seeking. This calls for efforts to ensure that private TB clinics are supported by the MOH through accreditation/licensing to manage TB and adequate funding. However, with the current health financing challenges evidenced by the underfinanced health sector in the low resource settings like Uganda (Gutierrez et al., 2018), this might be difficult to attain. This implies that most patients who prefer seeking healthcare in private hospitals are referred to other facilities which are accredited to provide TB services and, in the process, the possibility of them being lost to follow-up might arise due to the weak referral system (Wynne et al., 2014). Establishing and streamlining patient referral mechanisms to ensure that the patients referred from private hospitals are followed up to reach the place of referral in public hospitals could provide a cost-effective option for ensuring better TB care outcomes.

Generally, TB management requires comprehensive and additional costs for setting up infrastructure like installing diagnostic machines like Gene Xpert, new separate isolation rooms (Granich et al., 1999), and employing new hospital staff specifically designated to work on TB patients which makes it a financial burden to privately owned hospitals. Lack of facilities results in many cases being unhandled at the private hospitals thus frequent referrals of the suspected TB patients (Nshuti et al., 2001) to public hospitals in search of well-equipped and accredited TB services. This is a common practice in Uganda (O'hanlon et al., 2017) where patients are referred to other facilities for diagnostics and treatment. The referral system in Uganda is however constrained by a lack of patient tracking mechanisms (Oliwa et al., 2020) and patients end up getting lost to follow up between facilities (O'hanlon et al., 2017) and along the referral pathway. Besides, in most cases, government hospitals where TB patients are referred are also grappling with a high patient burden, as evidenced by the doctor-patient ratio that is estimated to be 1:11,000 compared to the recommended 1:1000 by WHO (Achan, 2019). The high patient-doctor ratio results in many patients being unattended to even after they had been referred, thus delayed treatment initiation which makes the patients' referral process less effective. All these factors are recognized by private providers in this study and feel that this continues to hinder the successful efforts of TB care.

On the other hand, several motivators were highlighted, healthcare workers reported that patients find private hospitals more confidential as far as patients' confidentiality is concerned. A study in Kenya (Keesara et al., 2015) documents patients' preference for private hospitals due to high levels of privacy and confidentiality compared to public facilities. Another cross-sectional survey reports high patient satisfaction with the quality of care and responsiveness to the patient preference among private hospitals in Uganda compared to public hospitals (Babikako et al., 2011). The study findings reveal that patients' preference for the private hospitals offers an opportunity for engagement in TB care

provided the facilities are well equipped with the necessary services through funding thus contributing to the success of PPM efforts.

To enhance the engagement of private hospitals in TB care in Uganda, there is a need for commitment — a shared resolve of ensuring that the involvement of private hospitals in TB care among key organizational stakeholders such as healthcare workers (doctors, nurses, etc.), and hospital administrators (Shea et al., 2014). This will gear concerted efforts towards inclusive involvement in TB care. This commitment should be supplemented with the organizational shared beliefs towards change (change efficacy) which involves knowledge to effect the required change and the availability of necessary resources (human and financial) that stimulate commitment towards change.

Establishing official partnerships between private and government hospitals is a key metric to ensuring for ensuring systemic and scalable efforts for engaging the private hospitals in TB control and care. This would require the MOH to meet and engage with the directors of the private hospitals for buy-in and signing of the memorandum of understanding which will help define the jurisdictions and clear definition of each party's (private and public) role in TB care. On the other hand, contracting involves the utilization of public funds to engage the private entities to deliver services (Bennett et al., 2017) and requires the definition of who does what regarding implementation (Lönnroth et al., 2006) can also ensure successful engagement efforts. This would necessitate a commitment to designing and managing these contracts by both public and private facilities to enhance successful implementation. These partnerships would involve the provision of adequate funding, free supplies of TB drugs, educating the healthcare workers in private hospitals, and routine supervision to monitor the progress of implementation by the government.

The adoption and utilization of mHealth technologies may offer a low-cost alternative approach for supplementing and enhancing private hospitals' efforts in TB management and help reduce the

identified barriers and the current burden on the public hospitals. A scoping review conducted by Tumuhimbise and Musiimenta highlights how mHealth has been used in fostering PPM through TB screening, case notification, treatment adherence, data collection and management, patient referral, and follow-up (Tumuhimbise and Musiimenta, 2021d). The utilization of mHealth technologies has shown promise in supporting TB medication adherence (Musiimenta et al., 2019) and has been found acceptable and feasible for supporting ART medication adherence in a public hospital setting (Musiimenta et al., 2018a). Capitalizing on mHealth could enable remote access to healthcare services (Tumuhimbise et al., 2020) for patients especially those referred to public hospitals, and could enable the training of healthcare workers following the National Tuberculosis and Leprosy programme guidelines for screening, diagnosis, and care (O'Donovan et al., 2015), and enhance the provision of allowances (incentives) (USAID, 2015) to incentivize healthcare workers for their efforts to draw masses for screening, financial and infrastructural support from the government and other funders.

The potentials of mHealth in fostering PPM identified from the findings included: mapping and linking patients from private hospitals to the referral units; supporting patient care and medication adherence; as well as notifying and reporting TB cases to the Ugandan MOH. The identified concerns were poor internet connections and lack of knowledge to use mHealth interventions.

The potential of mobile health technologies to map and link referred patients to the referral points could eliminate the risk of loss of patients along the pathway of care but could also result in enhanced patient care and monitoring. Through such mobile health interventions, the proportion of patients that reach their expected referral points and who get started on medication on time could increase, with subsequent reductions in diagnostic and drug initiation delays as evidenced in India (Chadha et al., 2017). Most of the private hospitals in Uganda are not accredited to provide tuberculosis services, this limits their efforts and engagement in tuberculosis care despite being at the center of receiving a majority (48%) of the population who seek healthcare compared to the government (public) health

facilities (34%), 14% who preferred to go to privately owned pharmacies, 1% who preferred field workers/ Village health teams and 3% to shops, outreach services, traditional practitioners, markets and private doctors (Uganda Bureau of Statistics, 2017). Therefore, as a common practice, most of these private hospitals refer presumptive tuberculosis patients to public hospitals (O'hanlon et al., 2017). However, the lack of mechanisms for following up on these patients in private hospitals (Tumuhimbise and Musiimenta, 2021b) still stifles tuberculosis control efforts. In this regard, the adoption of the current information communication technologies like smartphones, and mobile apps (Mobile health) as a mechanism for following up on these patients after referral could ensure easier patient tracking and successful referral processes from private to public health facilities. The implementation and utilization of mobile health in fostering the public-private mix in Africa remain unknown, yet most countries in Africa still grapple with a high number of tuberculosis cases (25% of the global tuberculosis cases come from Africa) (World Health Organization, 2020a). Understanding how mobile health is utilized to engage the private sector in tuberculosis care, especially in African settings has the potential to ensure better tuberculosis disease outcomes in Africa (Tumuhimbise and Musiimenta, 2021a).

The potential of mobile health technologies to support patient care and medication adherence among tuberculosis patients could enhance the timely intake of medication and the attendance of hospital appointments for pill refills (Gashu et al., 2019). Particularly in our study, participants reported that mobile health technology would enable healthcare workers to monitor patients thus enabling adherence to medication and attendance of hospital appointments. Mobile health provides quick access to information for both patients and healthcare workers and offers a qualitative and quantitative interaction between the healthcare providers and the patients (Tumuhimbise et al., 2020). Several studies utilizing mobile health technologies for supporting medication adherence among both tuberculosis and human immunodeficiency virus patients have been conducted in Uganda

(Musiimenta et al., 2018, Musiimenta et al., 2019) and were found to be acceptable and feasible. A randomized control trial (Mohammed et al., 2016) that was conducted in Karachi Pakistan utilized two-way short message service reminders to encourage newly diagnosed patients from public and private health facilities to take their medication. However, the utilization of mobile health technologies between the public and private health facilities in Uganda for tuberculosis care is unknown. This leaves a research gap and calls for a special investigation on how mobile health technologies can be utilized for enhancing the public-private mix in tuberculosis care.

Our study findings report that mobile health interventions could also enhance quick and timely notification of tuberculosis cases from private health facilities to national tuberculosis programs to ensure better planning of tuberculosis management services. Notifying cases is key in enhancing the tracking and management of tuberculosis patients. The tuberculosis case notification rate in Uganda is mostly done by public hospitals (86%), while private for-profit facilities notify only 1% (Ministry of Health, 2020). The report shows that most of the cases are still missed where about 30,000 people with tuberculosis symptoms were neither notified nor diagnosed in 2018/19. This implies a need for establishing mechanisms for ensuring that all cases are notified. Mobile health could play a role in improving notification of every diagnosed case as shown in the literature. According to a scoping review by Tumuhimbise and Musiimenta, mobile health interventions like mobile applications have been utilized in the notification of tuberculosis cases in Vietnam India, Indonesia, Pakistan, and Vietnam (Tumuhimbise and Musiimenta, 2021a). A referral and reporting back mobile phone application was found to be acceptable and feasible for notifying tuberculosis cases among private practitioners in Indonesia (Lestari et al., 2017). Although mobile health has been utilized in the notification of tuberculosis cases elsewhere, its experience among healthcare workers in settings like Uganda where healthcare workers might be overwhelmed with a large number of clients (high patient-

doctor ratio) and fail to find time for real-time use of the application to notify cases; this is being explored in our ongoing research investigation.

Our findings show that mobile health technologies have the potential to reduce stigma among patients referred from private to public hospitals. Literature has shown the potential of mobile health to reduce human immunodeficiency virus-related stigma among youths in the United States (Mulawa et al 2021), however, very few interventions aimed at reducing tuberculosis stigma have been utilized (Courtwright and Turner, 2010), thus a need for exploring the potential of mobile health in stigma reduction in tuberculosis care.

In this study, participants raised concerns about the lack of knowledge to use the developed mobile applications. User involvement during intervention development may play a role in acquainting system end-users with the intervention which in the long run could facilitate the acceptability of the developed application among users (Goold et al., 2006). This approach helps the developers to understand user behaviors, requirements, and skills at each phase of the design (Wever, Van Kuijk, and Boks, 2008). Training users on how to use the application before implementation may improve usability and address this concern. Users who are not well trained to use find it hard to use the technology (Gurupur and Wan, 2017). Therefore, system implementers should ensure conducting initial training sessions before rolling out the interventions. In addition, developers should develop interventions that are easy to use (Tumuhimbise and Musiimenta, 2021a) which are intended to ease the work of healthcare workers.

The reported poor internet connectivity or lack of internet access especially for interventions that entirely run on the internet or require the internet to function can hinder the usability of the application and result in the abandonment of the interventions (Katusiime and Pinkwart, 2019). Mobile health interventions that entirely rely on the internet to operate, require stable internet connections to ensure

thorough operability (Chen et al., 2016). The jurisdiction of the cost burden of internet packages for running these internet-based interventions must be clearly defined lest the cost burden on the users can't be sustained in the long run. Mobile health interventions should strive to remove the cost burden from the users if successful implementation is to be ensured (Zhou et al., 2019). Considering the development of standalone interventions or applications that do not require the internet to operate can address this concern.

The general implementation and coverage of the public-private mix for tuberculosis in Uganda require deliberate efforts to ensure that all private health facilities are involved in tuberculosis care if success and better health outcomes are to be realized. Engaging and empowering the private sector in tuberculosis disease management is crucial in enhancing the reduction of unnecessary deaths and sufferings due to substandard diagnosis, inappropriate treatment, and care that occur in the private sector, thus reduction in catastrophic costs (World Health Organization, 2018). Successful tuberculosis control efforts cannot be achieved globally if private providers are not brought on board to tackle tuberculosis disease.

7.4. Discussion for research objective three

In this thesis, the notion of the mHealth framework for following up and linking the referred presumptive TB patients from private to public hospitals has been presented. The framework is composed of six modules responsible for the functionality of the developed application. These include 1) application layer module which offers an interface for the app to run on the android platform; 2) Network connection module responsible for the connectivity of the developed application to ensure that it functions; 3) storage module responsible for storage, access and retrieval of the patients' data; 4) service module responsible for sending and receiving of short message service reminders to presumptive Tuberculosis patients and healthcare workers; 5) data processing module responsible for

retrieving data stored in the storage module and making it available for viewing and manipulation by the healthcare workers; 6) data analytic module which enables the analysis and generation of reports from data collected on patients. The MOHE framework introduces a new perspective on how mHealth interventions can be developed to follow up patients referred from private to public hospitals thus offering a patient-centered type of care to ensure better healthcare outcomes.

In this thesis, a mobile application called Tuuka was developed based on the modules of the MOHE framework to test its validity and reliability and to enhance the linkage of presumptive TB patients referred from private to public hospitals in Uganda. The underlying technological development used to develop the app can be expanded in following up on all patients referred from private to public hospitals. The application enables the automation of the referral process, especially in settings where public-private referrals are common, and offer valuable insights and knowledge necessary for the development of a similar intervention in other settings.

Most mHealth interventions lack sustained use and are later abandoned by the intended users, this is mainly due to a lack of motivation or declining interest (Mustafa et al., 2022), among the users to use the intended intervention. Literature has shown that one in every two apps installed is uninstalled within a month because of failure to meet the user's expectations (Shani and Omer, 2021). Given the busy working nature of healthcare workers, users may be busy using the application and thus may abandon it at a later stage. This makes sustainability of the intervention difficult thus failure to realize the intended health outcomes. Rewards in form of material incentives such as cash or gifts may potentially increase the user's motivation to use an intervention (Wei et al., 2020). In a study carried out in China, monetary incentives were found to promote the secondary distribution of HIV self-testing among men who have sex with men (Zhou et al., 2022). Incorporating a rewards feature during the design of mHealth interventions may enhance user engagement. There is therefore a need for

ensuring that mHealth interventions are embedded with motivational incentives in terms of conditional cash incentives to ensure motivational use of the intervention among healthcare workers.

7.5. Discussion for research objective four

This investigation addressed the question: what is the acceptability and feasibility of a mHealth intervention for following up presumptive Tuberculosis patients referred from private to public hospitals? Drawing from the UTAUT model, the investigator found that a mHealth intervention is acceptable and feasible for following the referred patients from private to public hospitals among healthcare workers. Findings reveal that the main construct to the acceptability of Tuuka application was perceived usefulness. The developed mobile application not only reminds the referred presumptive patients to go to the place of referral but also notifies healthcare workers at the public health facility about the incoming referred patient which facilitates the communication across facilities and enhances patient based care.

The study findings reveal that sending reminders to patients to go to the referral unit and notifying healthcare workers at the place of referral was interpreted as caring for the referred patients which would motivate the patients to be encouraged and forced to go to the place of referral knowing that their healthcare workers are waiting for him or her. SMS reminders' implication for care for patients has been also reported by (Ware et al., 2016) among people living with HIV in rural Southwestern Uganda

The findings are in tandem with several literature reviews that have highlighted how SMS reminders can aid in reducing missed hospital appointments (Opon et al., 2020) and assist patients to adhere to their regimen to reduce the rates of readmission (Perri-Moore et al., 2016). Therefore the utilization of a mobile application that automatically sends reminders to patients may help enhance care among patients.

Although the application runs entirely on the internet, the SMS component as reminders for patients and notifications for healthcare workers about the referred patients triggered at the private hospital

where the patient was referred may enhance timely care offered to the patient thus reducing delays along the referral pathway. However receiving a message to go to the referral unit doesn't guarantee adherence to the referral, there could be other factors that may hinder a patient from reaching the place of referral like lack of transport as noted (Tumuhimbise et al., 2020), being too weak to reach the facility. Therefore the implementers of mHealth interventions that utilize SMS should bear in mind that other factors may affect adherence to the referral even after receiving the intervention.

The application was also reported to enable communication between both private and public hospitals which helps in keeping track of the stage where the referred patient has reached. This ensures concerted efforts from both public and private facilities to ensure that they are engaged in TB care efforts. In a setting where most private hospitals are not accredited to provide TB services, and where most of these hospitals refer their presumptive patients to public health facilities, the application offers a follow-up mechanism of ensuring that the Public hospital is notified about each case identified in these private hospitals. Thus enhancing PPM through garnering efforts from both actors in ensuring that the patient has been followed up to ensure they are not lost along the referral pathway.

Although the application was found acceptable concerns about status disclosure were raised especially if a patient received an SMS reminder telling him or her to go to the place of referral. Issues of status disclosure by SMS reminders have been reported in southwestern Uganda (Musiimenta et al., 2018b), therefore crafting of messages to be sent to patients requires the consideration of privacy and confidentiality. The majority of the patients who seek care in private hospitals are concerned with privacy and confidentiality (Tumuhimbise and Musiimenta, 2021b). The majority of the patients consider private hospitals to be more confidential as far as giving patients the liberty to get their drugs and also making private arrangements for drug delivery are concerned. Therefore there is a need for ensuring that the message does not reveal the status of the referred patient.

Lack of access to the internet by healthcare workers was also noted as a potential limiting factor for the usability of the Tuuka application. In settings like Uganda where internet penetration is still low, and where healthcare workers have to buy their internet bundles to use the intervention, the intervention may not be sustainable in the long run. Future interventions should ensure the development of standalone interventions (Tumuhimbise and Musiimenta, 2021c) which can run without the internet or those that can run both offline to allow data collection without the internet and then when the user gains access to the internet, data can be synchronized.

The study findings have shown that mobile apps that require more internet bundles to be downloaded and consume a lot of space on the users' devices are likely not to be utilized. Users are likely to abandon mobile applications that take up a lot of space or memory on their phones (Dennison et al., 2013). Therefore developers should put this into consideration.

The design of mHealth interventions to be used by healthcare workers must be done with caution because of the nature of their work, they are always busy dealing with patients due to a high patient-doctor ratio. Integrating mHealth interventions in the routine work of healthcare workers requires well-thought approaches and this can be through designing simpler interventions (Tumuhimbise and Musiimenta, 2021c) that require a short period to operate, and interfaces must be well integrated for easy navigation. In addition, monetary incentivizes may play a role in motivating usage among healthcare workers, lest it would require hiring new staff specifically for operating the interventions if the required results are to be achieved.

The results indicate that Tuuka intervention is technically feasible in Uganda since a few technical issues emerged. The healthcare workers were trained on how to use the app and were able to use the application to see how the referrals are made. All healthcare workers owned smartphones and were

able to use the app for a period of one month. This was meant to acquaint them with using the application.

7.6. Train, Restructure, Incentivize, Legalize, and Integrate (TRILI) Policy framework for the implementation of Tuuka Mobile application

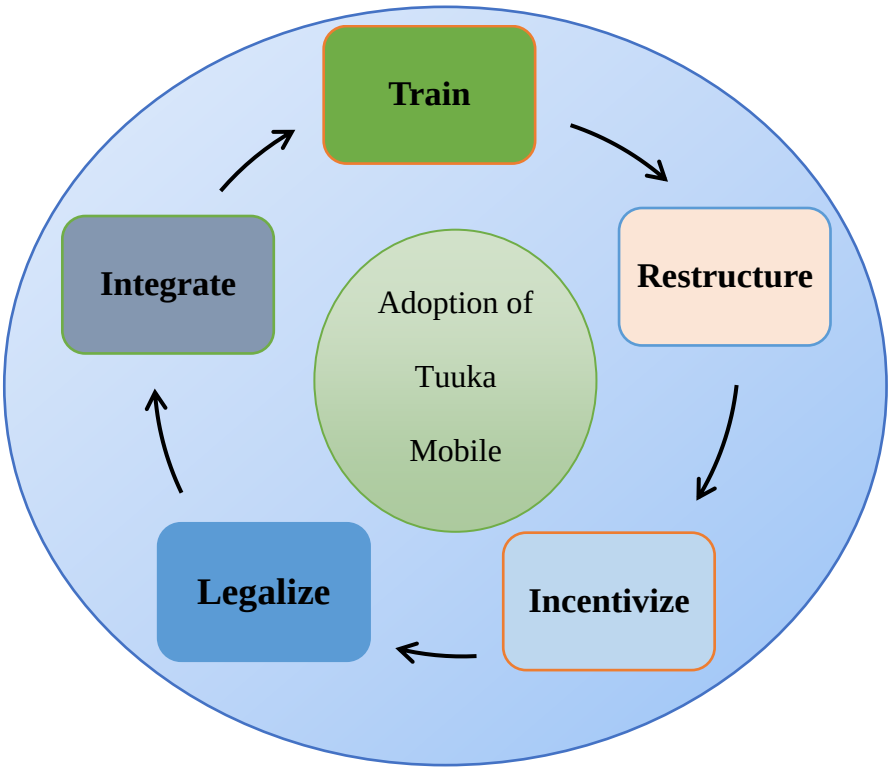


Figure 14.1: Train, Restructure, Incentivize, Legalize, and Integrate (TRILI) Policy framework

The TRILI framework incorporates lessons learnt and recommendations from the Ugandan context which can guide sustainable implementation of a mobile application for following up the referred presumptive TB patients from private to public hospitals. The policy framework highlights key multilevel factors that must be in place to ensure successful sustainable use of a mobile application for following up referred presumptive TB patients from private to public hospitals. The development of the TRILI framework is based on the lessons learnt from the development of Tuuka mobile application and it offers an understanding of how to deal with associated with following up referred

patients from private to public hospitals in Uganda. It incorporates several components of the COM-B model (Michie et al., 2011) but is specific to the Ugandan context. Below is the description of each domain.

7.6.1. Domain 1: Train

This domain is aimed at empowering both the private and public healthcare workers on using the application and educating the healthcare workers about the importance of using a mobile application in following up patients. This is key in increasing awareness about the application to ensure its adequate usage. Workshops and seminars tailored to empowering healthcare workers from both private and public about the use of the Tuuka mobile application for referring patients and following them up to ensure that the referred patients reach their place of referral. This training involves training the private healthcare workers in the basic provision of TB services by following the recommended National Tuberculosis and Leprosy programme guidelines for screening and referring patients. Developing user manuals and tutorials for users may play a role in influencing the use of the intervention. Lack of training arrangements and lack of information resources have been noted as one of the reasons that may cause non-use of the developed mobile applications (Hinze et al., 2017).

7.6.2. Domain 2: Restructure

This domain is aimed at improving or changing the physical or social context around an individual to influence their behavior. Restructuring for the implementation of a mHealth application for following up presumptive Tuberculosis patients referred from private to public hospitals may involve the provision of dedicated internet services and smartphones to healthcare workers, ensuring the availability of technical support for healthcare workers/users, redesigning the software to accommodate future changes that may arise from the users and ensuring compatibility with emerging technologies and platforms like operating systems, mobile devices. Hiring new staff if necessary to

act as change agents within an organization. This is key to enhancing organizational readiness for change by garnering commitment from various stakeholders including the government, private sector, and other funding bodies to ensure continued funding for system implementation (Shea et al., 2014). Limited commitment from key stakeholders has the potential to hinder efforts to effect the change within an organization, thus is a need for unwavering and persistent shared resolve among key stakeholders to have this implementation engagement ongoing. Therefore this domain suggests that the organizational restructuring could enhance the usability of the intervention among healthcare workers.

7.6.3. Domain 3: Incentivize

This domain is aimed at motivating healthcare workers to use the developed application. There is a need for ensuring that the users of the application are motivated to continuously use it. Most mobile applications are always abandoned and do not reach their intended objectives since users lack motivation for sustained use. Low engagement in terms of repeated and consistent usage of mobile applications has been reported by (McCallum et al., 2018). Findings have shown that 90% of mobile apps are uninstalled within the first month (Brower et al., 2020) implying that most major applications being developed might follow suit. This domain proposes the reimbursement of users through both financial and non-financial rewards to ensure that every milestone is achieved. Incentivization is defined as creating an expectation for reward and has proved to influence the behavior of using a given intervention ((Michie et al., 2011). Incentivization can be both financial (monetary) and non-financial (non-monetary) depending on the design of the project. Non-monetary incentives include acknowledging the best users, and promotion of team-based performance offer a higher chance of scalability compared to monetary incentives (Carmichael et al., 2019). A carrot reward application aimed at rewarding users with loyalty points for downloading the application, referring friends to download the app, and quiz completion resulted in higher engagement levels in Canada (Brower et

al., 2020). In India, a non-monetary incentive intervention including monthly training of healthcare workers and reciting the service pledge resulted in a significant increase in the frequency of antenatal home visits among healthcare workers (Carmichael et al., 2019). Monetary incentives involve direct financial reimbursements to participants upon reaching a certain milestone, these can be either conditional or unconditional and these have shown to have a positive influence on specific health behavior (Gardiner and Bryan, 2017). Therefore this domain suggests that the incorporation of incentives could enhance the usability of the intervention among healthcare workers.

7.6.4. Domain 4: Legalize

Legalization is aimed at mandatory authorization to use the intervention for referring and following up on referred patients. The domain is meant to address issues related to resistance to change and lack of trust among physicians. The lack of legislation has been reported among the main reasons healthcare workers do not use mobile applications (Zakerabasali et al., 2021). Therefore ensuring the establishment of both organizational regulations regarding the use of the application and compulsory government mandates on the adoption of the application may enhance usability. However legalization may raise ethical questions for example in India, compulsory installation of a government-backed mobile application for contact tracing during COVID-19 "Aarogya Setu" was made mandatory (Basu, 2021). Some people may be skeptical about the approach and raise questions about the privacy and security of the collected data. However, in terms of public health emergencies, delays in implementing readily available interventions may cause health and economic costs that would have been avoided. Therefore despite the moral questions that may arise several justificatory conditions (effectiveness, proportionality, necessity, least infringement, and public justification) have been proposed by (Childress et al., 2002) to determine whether the implementation of health intervention can override the existing ethical considerations. Although the mandatory installation of apps during public health emergencies is justifiable, there is a need for efforts to ensure that confidence is instilled

among users to be able to use the application (Basu, 2021). This domain suggests both organizational legalization for ensuring that implementation is carried out and government legalization for ensuring that organizations are using the intervention.

7.6.5. Domain 5: Integrate

This domain involves the integration of the developed system into the work routines within hospital settings and workflows within an organization. When key stakeholders are trained about the intervention and incentivized to utilize the intervention, it lays a foundation for integration within the routine workflow of an organization. The legalization domain may play a key role in enabling organizations to work towards implementing the intervention. Integration may involve linking the system with the existing systems like the District Health Information Software (DHIS) or national systems. The need for the development of standards for mobile applications to seamlessly be integrated into Health Information Systems (HIS) has been noted as key in enabling healthcare workers to use developed mobile apps for patient-centered care (Ventola et al 2014). Therefore this domain suggests that sustainable usability of the intervention among healthcare workers can be improved by integrating the application into the routine workflows of healthcare workers.

Putting all these factors into consideration, the TRILI framework should be a realistic and realizable solution for the implementation deficit in the usability of a mobile application for following up presumptive TB patients referred from private to public hospitals in Ugandan context.

CHAPTER EIGHT: CONCLUSION AND RECOMMENDATIONS

8.1. Chapter overview

This chapter discusses the researcher's conclusions, lessons learned from conducting the study, theoretical, knowledge, and technical contributions of the thesis to the field of mHealth plus the recommendations for future research, policy makers as well as other stakeholders involved in TB care. The following section discusses the strengths and limitations of the study that readers should bear in mind during the interpretation of these research findings.

8.2. Research Objectives Achievement

The main aim of this study was to enhance the following up of presumptive TB patients referred from private to public hospitals through the MOHE framework. To realize this goal, four main objectives were formulated to answer their respective questions. The summary of objectives and questions is presented in the table 8.1 below

Table 8.1: Summary of research objectives and questions

#	Objective	Question
1	To analyse the existing mHealth interventions for PPM in order to identify their strengths and weaknesses.	What are the existing mHealth interventions for public private mix in TB care and their strengths and weaknesses?
2	To explore the barriers to and motivators of private hospitals' engagement in Tuberculosis care and the potentials of mHealth technologies	What are the barriers and motivators to private hospital engagement in TB care and the potentials of mHealth technologies in

	in order to inform the design of a potential mHealth intervention using CFIR framework	enhancing PPM among private healthcare workers?
3	To develop a framework for designing a mobile health application for following up presumptive TB patients referred from private to public hospitals.	How can a framework for designing a mobile health application for following up presumptive TB patients referred from private to public hospitals be developed?
4	To assess the initial feasibility and acceptability of the developed mobile health intervention for following up presumptive Tuberculosis patients referred from private to public hospitals using UTAUT model.	What is the initial acceptability and feasibility of a mobile health intervention for following up presumptive TB patients referred from private to public hospitals?

Research objective one

To achieve this objective, the investigator carried out a scoping review aimed at answering the research question concerning "existing mHealth interventions for enhancing PPM, their strength, and weakness". The scoping review study identified nine studies where several mHealth technologies were utilized in enhancing PPM in TB care was carried out. These technologies include mobile apps, SMS reminders, and telephone calls for TB screening, case notification, supporting medication adherence, patient follow-up, eLearning, and data management. Identifying these interventions was proof that implementation of mHealth for enhancing PPM for TB care is possible.

Research objective two

After understanding the existing mHealth interventions for enhancing PPM in TB care globally, the researcher dug deeper to understand the state of the art of barriers and motivators to private hospitals'

engagement in TB care and the potential of mHealth in enhancing PPM in Uganda. This was aimed at answering the question concerning "the barriers and motivators to private hospitals' engagement in TB care in Uganda" to understand how best a mHealth intervention can address the identified barriers. Through a formative qualitative investigation, guided by the CFIR framework, the investigator was able to identify key barriers including lack of mechanisms for following patients, lack of accreditation from the Ugandan MOH, concerns of payment for services within private hospitals, and motivators to private hospitals' engagement in TB care. The identification of these barriers and motivators was important in informing how a potential mHealth intervention can address the identified barriers and ascertaining which facilitating conditions in the private sector may propel the adoption of the developed intervention. From these barriers, it was noted that private hospitals in Southwestern Uganda lack the capacity to fully treat and manage TB cases thus end up referring presumptive TB patients. However, these facilities lack follow-up mechanisms for ascertaining that the referred patient reached the place of referral. Through an investigation into perceptions of healthcare workers towards enhancing PPM, it was noted that mHealth may offer a low-cost alternative addressing some of these barriers.

Research Objective three

After understanding the existing mHealth interventions that have been utilized for enhancing PPM in TB care, their strengths and weaknesses globally, and delving into barriers and motivators to private hospitals' engagement in TB care and the potentials of mHealth technologies in enhancing PPM for TB care, the investigations laid their foundation and requirements for developing a mHealth framework for following up the referred patients from private to public hospitals. The MOHE framework composed of six modules was developed to guide the development of a mHealth application for following up the referred presumptive TB patients from private to public hospitals.

Subsequently, Tuuka mobile application was developed based on the modules of the MOHE framework.

Research objective four

After developing Tuuka mobile application based on the MOHE framework, the investigator delved deep to understand how acceptable and feasible the developed Tuuka mobile application would be among healthcare workers. This objective was aimed at answering the question concerning "the initial acceptability and feasibility of the developed mHealth intervention" from the mixed-methods investigation, the app was highly acceptable and feasible among healthcare workers for its perceived usefulness in reminding the referred patients to go to the place of referral, notifying healthcare workers about the incoming referred presumptive patient, facilitate communication between health facilities thus enhancing PPM for TB care.

8.3. Research Contribution

This section focuses on the research contributions of this dissertation. This section is divided into three subsections describing contribution to theory, methodology and empiricism.

8.3.1. Knowledge contribution

Findings from the identification of mHealth interventions for PPM based on the scoping review investigation conducted as part of this study revealed that the adoption and utilization of mHealth technologies for PPM in African settings is still limited thus a need for status for studies that focus on assessing the utilization of mHealth for PPM in Africa.

Barriers and motivators to private hospital's engagement in TB care. This study offers a highlight of barriers and motivators to private hospitals' engagement in TB care in southwestern Uganda. The identification of these barriers offers an understanding of potential requirements for MOHE framework.

Potentials of mHealth technologies for enhancing PPM. This study also contributes to the body of knowledge about the potential of mHealth technologies for enhancing PPM which assesses how healthcare workers perceive the role of mHealth technologies in enhancing PPM for TB care.

Evaluation of the initial feasibility and acceptability of the developed mhealth intervention among healthcare Workers. The researcher describes the acceptability and feasibility. The results demonstrate that an mHealth application is feasible and acceptable for following up presumptive TB patients referred from private to public hospitals.

8.3.2. Technological Contribution

Mobile health application (Tuuka mobile application) developed based on the MOHE framework modules. The app is the component of MOHE framework developed based on the MOHE framework and it contribute to the growing body of literature of designing mobile apps based on a software framework.

8.3.3. Theoretical contribution

A Mobile Health (MOHE) framework for following up the referred presumptive TB patient from private to public hospitals. This study proposed and presents the MOHE framework. Thus study contributes to the growing body of literature of designing frameworks for guiding the design of mHealth interventions for TB care.

Train, restructure, incentivize, legalize, and integrate (TRILI) policy framework for implementing the developed Tuuka Mobile application. The study therefore adds to the body of knowledge by highlighting the potential TRILI policy framework if applied in similar settings, could enhance the following up of the referred presumptive TB patients from private to public hospitals

8.4.Strengths of the Study

This study has several strengths, first, it identifies key insights about the existing mhealth technologies for enhancing PPM, their strength and weakness, documents the barriers to and motivators of private hospital's engagement in TB care, and explores healthcare workers' perceptions of mHealth technologies in fostering public-private mix for Tuberculosis care which provides a ground for evidence based development and implementation of future interventions that address the identified barriers faced in the private hospitals in similar settings.

The second strength of this study is that it was guided by the principles of implementation science which include evidence-practice gap identification, conducting formative research, and analysis of data based on a validated theoretical framework — CFIR Framework.

Thirdly, to the best of the investigator's knowledge, this study is the first to report pre-intervention perceptions of healthcare workers from the private hospitals about the potential of mHealth technologies for fostering PPM in TB care which helps in understanding the optimal design of future mHealth interventions to facilitate sustainable PPM in TB care

The study proposes the MOHE framework an application software framework for the design of an mHealth application for linking and following up presumptive TB patients referred from private hospitals to public hospitals.

This study is grounded in a well-known technology acceptance and usability theory—the UTAUT model for assessing the acceptability and feasibility of the developed mHealth intervention. This study offers perspectives from both private and public healthcare workers about an mHealth intervention.

The study proposes the TRILI policy framework which presents various constructs that can help realize successful implementation of mobile interventions for following the referred patients from private to public hospitals in Uganda.

8.5. Limitations of the Study

Nevertheless, this investigation is not without limitations. First, the scoping review investigation carried out in this study, focused on mHealth interventions implemented in PPM settings. Therefore, mHealth interventions for TB care implemented exclusively in public sector settings were not included which might have changed the findings. Secondly, despite the broad search by the

investigator, only nine studies were selected for the scoping review. Therefore, the interpretation of the study findings should be done in this regard. The scoping review only included studies published in English because it's the only International language that the investigator understands, which implies that some relevant studies published in languages other than English were missed which could have limited the search thus a need for future researchers to consider the involvement of additional languages.

The study documents the perceptions of frontline healthcare workers with experience in TB care practices. Whereas this enabled us to get relevant information about the practical barriers and motivators specific to TB care, the experiences of the frontline staff might not effectively represent those of other key stakeholders such as TB patients, other healthcare workers without experience in TB care, and healthcare administrators. These stakeholders could potentially have highlighted structural/contextual/logistical barriers that could have been missed by these frontline practitioners.

A purposive sampling approach for recruiting the respondents was utilized, which has the potential for selection bias. In addition, the sample size was small which limits the ability for generalizing the study findings among the healthcare workers in similar circumstances. This study was conducted in Mbarara City, an urban setting; these findings may not be generalizable in other settings like rural areas, where there might be considerable differences in implementation and practice.

This study didn't assess the preliminary impact of the developed intervention which makes it difficult to ascertain the effectiveness of the intervention. There is a need to determine whether a mobile application is effective in following up the referred patients. A pilot randomized control trial of the Tuuka mobile application is underway to help define the acceptability and efficacy of the developed intervention.

The study did not explore patients' perceptions towards the utilization of the developed mHealth app yet they are the key players and beneficiaries in this framework. It should be noted that there could be other factors like patient counseling and the role of treatment supporters that could influence patients to reach the places of referral (public facility) despite being referred, however, this study didn't explore these factors which could influence the usability of the intervention.

Although our study based on healthcare workers (doctors, nurses and laboratory technicians) to test the developed Tuuka application since they are the main users of the developed Tuuka application, involving the external experts to walk through the solution and provide their opinion, would have increased the confidence in the developed solution. Whereas to the best of our knowledge, our study utilised a user centered approach which involves system users in the intervention development, testing and refinement, including system experts in future studies by developers can enhance the development of systems that can be trusted.

8.6. Implications for Practice and Research

The engagement of private hospitals in Uganda is still limited and requires concerted efforts to ensure successful health outcomes. To enhance private hospitals' engagement in TB care, there is a need for (1) official partnerships between the private and government hospitals, (2) Accreditation, (3) establishment of patient follow-up mechanisms, and (4) training and education. Government accreditation of private hospitals formalizes their eligibility to provide TB services. Second, mHealth technologies can be utilized to follow up patients after they have been referred from private to public hospitals. This can potentially reduce the number of patients who get lost to follow-up along the referral pathway. Training and educating private healthcare workers in TB care equips them with the necessary skills in screening, diagnosis, and management, which could improve the quality of care.

The utilization of mHealth in TB care among private hospitals in Uganda is lacking. This limits the realization of mHealth benefits in the achievement of better TB treatment outcomes and the realization of PPM. Findings from this research imply that mHealth has the potential to revolutionize TB care by establishing a centralized pathway for linking the referred patients from private to public hospitals and ensuring that they are not lost along the TB care pathway, have been diagnosed, and started on medication. This study implies that mHealth can be a cost-effective solution for enhancing the full integration and engagement of the private healthcare facilities in TB care thus the achievement of PPM.

The implementation of the mHealth interventions requires training of users to equip them with skills to enable intervention acceptability and usability. mHealth interventions that entirely rely on the internet to operate, require stable internet connections to ensure thorough operability. Standalone applications that do not require the internet to operate can offer better alternatives. mHealth interventions should at all costs remove the cost burden from the users if the successful implementation is to be ensured.

The Private hospitals, policymakers, researchers, and developers need to bear in mind that the utilization of mHealth technologies not only improves the quality of care among the presumptive TB patients but also could enhance better treatment outcomes like early diagnosis and drug initiation thus limiting the risk of infection at both the community and household level.

8.7. Future Research

Since this study highlights responses from healthcare workers (doctors and nurses), views from patients, administrators, and the MOH could not be investigated. Future studies should explore patients' perceptions of receiving TB care from private hospitals and other stakeholders to understand their opinions. Although the formative qualitative investigation used the CFIR for analysis, findings from this study suggest an exploration of the substantial role of structural/contextual factors and how these factors interact with the inner settings, outer settings, and the process of engaging private hospitals in TB care.

Future research efforts to this work will focus on incorporating a financial incentives component/ a rewards feature for both the private and public healthcare workers to enable sustained use. This can be achieved through incorporating an algorithm that is linked to mobile money accounts of the users that upon notifying a single case by the private healthcare workers and receiving a referred presumptive TB patient at the public hospital, the system shall automatically credit a certain amount (financial incentive) to the healthcare workers' mobile money accounts. This will ensure sustained efforts in notifying presumptive TB cases since healthcare workers will be reimbursed therefore this might result in high usability of the developed mHealth interventions.

Future research efforts should consider utilizing Tuuka app in following up and linking patients referred from lower-level public health facilities like Health center twos and threes to high-level public facilities like Health center fours and referral hospitals and smaller clinics if results are to be realized and also assess the impact of the developed mHealth intervention on following up patients to assess its effectiveness in enhancing PPM.

The TRILI framework is recommended as a viable practical policy framework for implementing a mobile application for following up presumptive TB patients from private and public hospitals in

Uganda due to its superiority in terms of local contextualization and consideration of healthcare workers' needs. This thesis recommends future work efforts in assessing the effectiveness of these particular domains in implementing the developed application.

There is a need for enforcement and strict adherence to the Ugandan MOH screening guidelines among private hospitals to ensure that none of the patients are missed.

8.8. Conclusion

This thesis has explored the existing mHealth interventions for PPM, the barriers, and motivators for private hospitals' engagement in TB care, healthcare worker's perceptions of mHealth technologies in fostering PPM, the process of designing a framework for following up presumptive TB patients referred from private to public hospitals and the initial acceptability and feasibility of the mHealth intervention developed based on the MOHE framework.

The study affirms that several mHealth interventions (Mobile apps, SMS reminders, Telephone calls) have been utilized to enhance PPM in TB care for TB screening and notifying cases, patients' referral and follow up, monitoring TB medication adherence, data management, and educating clinicians about TB. Our findings reveal that mHealth could offer an alternative approach for health services utilization, especially in settings where face-to-face approaches are difficult.

Identifying barriers and motivators to the engagement of private hospitals in TB care in southwestern Uganda was key in informing the development of the MOHE framework and its m-Health intervention to address the identified barriers. The engagement of private hospitals in TB care requires official partnerships between the public and private hospitals and commitment from key stakeholders supplemented with the organizational shared beliefs towards change (change efficacy) towards implementing this change.

Findings from this study revealed that mHealth technologies could provide acceptable and feasible approaches to map and link TB patients to the referral units, enhance patient care and medication adherence and notify TB cases. Understanding how mHealth technologies are perceived by private healthcare workers is key in informing the development of interventions that are acceptable and feasible and effective in enhancing the engagement of private hospitals in TB care

The underlying technological development used to develop the MOHE framework and Tuuka mobile application can be expanded in other infectious diseases like Coronavirus (COVID-19) since the process automates the process of public-private referrals which offers insights to develop similar interventions in other settings. The developed application based on the MOHE framework has the potential to remind patients to go to referral, notify healthcare workers at the place of referral, and facilitate communication between facilities thus enhancing PPM

Regarding the initial acceptability and feasibility of the developed intervention, this study showed that the developed mHealth application “Tuuka” based on the MOHE framework is acceptable and feasible for following up the referred presumptive TB patients referred from private to public hospitals in southwestern Uganda. Identifying the initial acceptability and feasibility offers a ground for implementation of the Tuuka mobile application on a larger scale and calls for assessing the effectiveness of the developed application in following up the referred patients.

The implementation of mHealth interventions in private hospital settings requires the establishment of organizational policies regarding the streamlining of referrals from private to public hospitals to refer any presumptive patient per the Ugandan MOH TB screening guidelines. This study found that the designing of mHealth interventions for Healthcare workers must be done with caution due to the nature of their work therefore the integration of these interventions in the routine work of healthcare workers must be carefully planned through designing a simpler intervention, incentivizing them in

monetary terms to motivate usability or hiring new staff specifically for operating the interventions if the required results are to be achieved.

Compared to prevailing studies, this study contributes to the body of literature in five major aspects

- This is the first study to analyze the existing mHealth interventions for PPM for TB care, and their strengths and weaknesses.
- It is the first study to explore the barriers to and motivators for private hospitals' engagement in TB care in Uganda
- This study is the first to investigate healthcare workers' perceptions of mHealth technologies in fostering public-private mix for Tuberculosis care in Uganda
- This is the first study that presents a framework for guiding the development of a mobile application for following up the referred presumptive TB patients
- Lastly, this study is the first to highlight the initial acceptability and feasibility of mobile applications for following up the referred presumptive TB patients from private to public hospitals.

List of papers

The following papers were published from this work

1. Tumuhimbise, W. and Musiimenta, A., 2021. A review of mobile health interventions for public private mix in tuberculosis care. *Internet interventions, 25*, p.100417. DOI: https://doi.org/10.1016/j.invent.2021.100417. PMID: 34401376 PMCID: PMC8350595
2. Tumuhimbise, W. and Musiimenta, A., 2021. Barriers and Motivators of Private Hospitals' Engagement in Tuberculosis Care in Uganda. *Global Implementation Research and*

Applications, *1*(4), pp.279-290. https://doi.org/10.1007/s43477-021-00030-3. PMID: 34927083. PMCID: PMC8682303

3. Tumuhimbise, W., Atwine, D., Kaggwa, F. *et al.* Enhancing Tuberculosis Care in Southwestern Uganda: Facilitators and Barriers to Utilizing Mobile Health Technologies. *Glob Implement Res Appl* (2022). https://doi.org/10.1007/s43477-022-00056-1.
4. Tumuhimbise, W., Atwine, D., Kaggwa, F. and Musiimenta, A., 2022. Acceptability and Feasibility of a Mobile Health Application for Enhancing Public Private Mix for TB care among Healthcare Workers in Southwestern Uganda. *BMC Digital Health*. Under Review.

BIBLIOGRAPHY

Understanding research philosophies and approaches. Available: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.102.4717&rep=rep1&type=pdf.

ACHAN, J. 2019. Uganda health care system can thrive with the involvement of nurses. *New Vision*.

AGARWAL, S., LEFEVRE, A. E., LEE, J., L'ENGLE, K., MEHL, G., SINHA, C. & LABRIQUE, A. 2016. Guidelines for reporting of health interventions using mobile phones: mobile health (mHealth) evidence reporting and assessment (mERA) checklist. *bmj*, 352**,** 1174.

AJZEN, I. 1991. The theory of planned behavior. *Organizational behavior and human decision processes*, 50**,** 179-211.

ALCANTARA, M. F., CAO, Y., LIU, C., LIU, B., BRUNETTE, M., ZHANG, N., SUN, T., ZHANG, P., CHEN, Q. & LI, Y. 2017. Improving tuberculosis diagnostics using deep learning and mobile health technologies among resource-poor communities in Perú. *Smart Health*, 1**,** 66-76.

ALDOSERY, A., MUSAH, A., BIRJOVANU, G., MORENO, G., BOSCOR, A., DUTRA, L., SANTOS, G., NUNES, V., OLIVEIRA, R. & AMBRIZZI, T. 2021. MEWAR: Development of a Cross-Platform Mobile Application and Web Dashboard System for Real-Time Mosquito Surveillance in Northeast Brazil. *Frontiers in public health*, 9.

ALI, S. M., POWERS, R., BEORSE, J., NOOR, A., NAUREEN, F., ANJUM, N., ISHAQ, M., AAMIR, J. & ANDERSON, R. 2016a. ODK scan: digitizing data collection and impacting data management processes in Pakistan's tuberculosis control program. . *Futur. Internet*, 8 51.

ALI, S. M., POWERS, R., BEORSE, J., NOOR, A., NAUREEN, F., ANJUM, N., ISHAQ, M., AAMIR, J. & ANDERSON, R. 2016b. ODK scan: digitizing data collection and impacting data management processes in Pakistan's tuberculosis control program. *Future Internet,* 8**,** 51.

ALIPANAH, N., JARLSBERG, L., MILLER, C., LINH, N. N., FALZON, D., JARAMILLO, E. & NAHID, P. 2018. Adherence interventions and outcomes of tuberculosis treatment: A systematic review and meta-analysis of trials and observational studies. *PLoS medicine,* 15**,** e1002595.

ALIZADEH, F., MFITUMUHOZA, G., STEPHENS, J., HABIMAANA, C., MYLES, K., BAGANIZI, M. & PACCIONE, G. 2019. Identifying and reengaging patients lost to follow-up in rural Africa: the "horizontal" hospital-based approach in Uganda. *Global Health: Science and Practice,* 7**,** 103-115.

ANAND, T., BABU, R., JACOB, A. G., SAGILI, K. & CHADHA, S. S. 2017. Enhancing the role of private practitioners in tuberculosis prevention and care activities in India. *Lung India: Official Organ of Indian Chest Society,* 34**,** 538.

ARKSEY, H. & O'MALLEY, L. 2005. Scoping studies: towards a methodological framework. *International journal of social research methodology,* 8**,** 19.

ASUQUO, A. E., POKAM, B. D. T., IBENEME, E., EKPEREONNE, E., OBOT, V. & ASUQUO, P. 2015. A public–private partnership to reduce tuberculosis burden in Akwa Ibom State, Nigeria. *International journal of mycobacteriology,* 4**,** 143-150.

BABIKAKO, H. M., NEUHAUSER, D., KATAMBA, A. & MUPERE, E. 2011. Patient satisfaction, feasibility and reliability of satisfaction questionnaire among patients with pulmonary

tuberculosis in urban Uganda: a cross-sectional study. *Health Research Policy and Systems,* 9**,** 1-13.

BABIRYE, D., SHETE, P. B., FARR, K., NALUGWA, T., OJOK, C., NANTALE, M., OYUKU, D., AYAKAKA, I., KATAMBA, A. & DAVIS, J. L. 2019. Feasibility of a short message service (SMS) intervention to deliver tuberculosis testing results in peri-urban and rural Uganda. *Journal of clinical tuberculosis and other mycobacterial diseases,* 16**,** 100110.

BAJPAI, N. 2011. *Business research methods,* Pearson Education India.

BANGOR, A., KORTUM, P. & MILLER, J. 2009. Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of usability studies,* 4**,** 114-123.

BANGOR, A., KORTUM, P. T. & MILLER, J. T. 2008. An empirical evaluation of the system usability scale. *Intl. Journal of Human–Computer Interaction,* 24**,** 574-594.

BANOS, O., GARCIA, R., HOLGADO-TERRIZA, J. A., DAMAS, M., POMARES, H., ROJAS, I., SAEZ, A. & VILLALONGA, C. mHealthDroid: a novel framework for agile development of mobile health applications. International workshop on ambient assisted living, 2014. Springer, 91-98.

BANOS, O., VILLALONGA, C., GARCIA, R., SAEZ, A., DAMAS, M., HOLGADO-TERRIZA, J. A., LEE, S., POMARES, H. & ROJAS, I. 2015. Design, implementation and validation of a novel open framework for agile development of mobile health applications. *Biomedical engineering online,* 14**,** 1-20.

BASU, S. 2021. Effective contact tracing for COVID-19 using mobile phones: an ethical analysis of the mandatory use of the aarogya setu application in India. *Cambridge Quarterly of Healthcare Ethics,* 30**,** 262-271.

BENNETT, A., AVANCEÑA, A. L., WEGBREIT, J., COTTER, C., ROBERTS, K. & GOSLING, R. 2017. Engaging the private sector in malaria surveillance: a review of strategies and recommendations for elimination settings. *Malaria journal,* 16**,** 1-19.

BERGER, P. 1991. The Social Construction of Reality/Peter L. Berger and Thomas Luckmann, 1966. *Reprinted in Penguin Books*.

BETJEMAN, T. J., SOGHOIAN, S. E. & FORAN, M. P. 2013. mHealth in sub-Saharan Africa. *International journal of telemedicine and applications,* 2013.

BHATTACHARYA, S., KUMAR, A., KAUSHAL, V. & SINGH, A. 2018. Applications of m-Health and e-Health in Public Health Sector: the challenges and opportunities. *International Journal of Medicine and Public Health,* 8.

BROOKE, J. 1996a. Sus: a "quick and dirty'usability. *Usability evaluation in industry,* 189.

BROOKE, J. 1996b. Sus: a "quick and dirty'usability. *In:* WEERDMEESTER, B. A., JORDAN, P. W., MCCLELLAND, I. L. & THOMAS, B. (eds.) *Usability evaluation in industry.*

BROWER, J., LABARGE, M. C., WHITE, L. & MITCHELL, M. S. 2020. Examining responsiveness to an incentive-based Mobile health app: longitudinal observational study. *Journal of medical Internet research,* 22**,** 16797.

BUREGYEYA, E. 2020. MILEAGE4TB: Using short message service reminders and mobile money incentives to enhance linkage to care of presumptive tuberculosis patients in uganda: a randomised controlled trial. EDCTP.

BUREGYEYA, E., CRIEL, B., NUWAHA, F. & COLEBUNDERS, R. 2014. Delays in diagnosis and treatment of pulmonary tuberculosis in Wakiso and Mukono districts, Uganda. *BMC Public health,* 14**,** 1-10.

BUREGYEYA, E., KASASA, S. & MITCHELL, E. M. 2016. Tuberculosis infection control knowledge and attitudes among health workers in Uganda: a cross-sectional study. *BMC Infectious Diseases,* 16**,** 1-10.

BUREGYEYA, E., RUTEBEMBERWA, E., LARUSSA, P., LAL, S., CLARKE, S. E., HANSEN, K. S., MAGNUSSEN, P. & MBONYE, A. K. 2017. Comparison of the capacity between public and private health facilities to manage under-five children with febrile illnesses in Uganda. . *Malaria Journal,* 16**,** 1-7.

BYONANEBYE, D. M., MACKLINE, H., SEKAGGYA-WILTSHIRE, C., KIRAGGA, A. N., LAMORDE, M., OSEKU, E., KING, R. & PARKES-RATANSHI, R. 2021. Impact of a mobile phone-based interactive voice response software on tuberculosis treatment outcomes in Uganda (CFL-TB): a protocol for a randomized controlled trial. *Trials,* 22**,** 1-13.

CARMICHAEL, S. L., MEHTA, K., RAHEEL, H., SRIKANTIAH, S., CHAUDHURI, I., TREHAN, S., MOHANTY, S., BORKUM, E., MAHAPATRA, T., WENG, Y. & KAIMAL, R. 2019. Effects of team-based goals and non-monetary incentives on front-line health worker performance and maternal health behaviours: a cluster randomised controlled trial in Bihar, India. *BMJ global health,* 4**,** 001146.

CATTAMANCHI, A., MILLER, C. R., TAPLEY, A., HAGUMA, P., OCHOM, E., ACKERMAN, S., DAVIS, J. L., KATAMBA, A. & HANDLEY, M. A. 2015. Health worker perspectives on barriers to delivery of routine tuberculosis diagnostic evaluation services in Uganda: a qualitative study to guide clinic-based interventions. *BMC health services research,* 15**,** 1-10.

CDC. 2016. *TB and HIV Coinfection* [Online]. Available: https://www.cdc.gov/tb/topic/basics/tbhivcoinfection.htm [Accessed 7th April 2022].

CDC. 2019. *Innovative Mobile Health Initiatives Poised to Transform Tanzania's Tuberculosis and HIV Response. Centers for Disease Control and Prevention* [Online]. Available: https://www.cdc.gov/globalhivtb/who-we-are/success-stories/success-story-pages/tanzania-mhealth.html [Accessed 29th March 2022].

CHADHA, S., TRIVEDI, A., NAGARAJA, S. & SAGILI, K. 2017a. Using mHealth to enhance TB referrals in a tribal district of India. *Public Health Action,* 7**,** 123-126.

CHADHA, S., TRIVEDI, A., NAGARAJA, S. B. & SAGILI, K. 2017b. Using mHealth to enhance TB referrals in a tribal district of India. . *Public health action,,* 7**,** 123-126.

CHARLES, S. H., EDWARD, F., SOPHIA, W. & PETER, B. 2014. Assessing the impact of mHealth interventions in low- and middle-income countries – what has been shown to work? *Global Health Action,* 7**,** 25606.

CHILDRESS, J. F., FADEN, R. R., GAARE, R. D., GOSTIN, L. O., KAHN, J., BONNIE, R. J., KASS, N. E., MASTROIANNI, A. C., MORENO, J. D. & NIEBURG, P. 2002. Public health ethics: mapping the terrain. *Journal of Law, Medicine & Ethics,* 30**,** 170-178.

CHOUN, K., ACHANTA, S., NAIK, B., TRIPATHY, J. P., THAI, S., LORENT, N., KHUN, K. E., VAN GRIENSVEN, J., KUMAR, A. & ZACHARIAH, R. 2017a. Using mobile phones to ensure that referred tuberculosis patients reach their treatment facilities: a call that makes a difference. *BMC Health Services Research,* 17**,** 1-7.

CHOUN, K., ACHANTA, S., NAIK, B., TRIPATHY, J. P., THAI, S., LORENT, N., KHUN, K. E., VAN GRIENSVEN, J., KUMAR, A. M. & ZACHARIAH, R. 2017b. Using mobile phones to ensure that referred tuberculosis patients reach their treatment facilities: a call that makes a difference. *BMC Health Services Research,* 17**,** 1-7.

COHEN, J., SARAN, I. & YAVUZ, E. 2016. Drug Packaging, Health Information and Medication Adherence: Evidence from Malaria Treatment in Uganda.

COOPER, V., CLATWORTHY, J., WHETHAM, J. & EMERGE, C. 2017. mHealth Interventions To Support Self-Management In HIV: A Systematic Review. *The open AIDS journal,* 11**,** 119.

DAMSCHRODER, L. J., ARON, D. C., KEITH, R. E., KIRSH, S. R., ALEXANDER, J. A. & LOWERY, J. C. 2009. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. *Implementation science,* 4**,** 1-15.

DARAMOLA, O. & NYASULU, P. A Multistakeholder-Centric Data Analytics Governance Framework for Medication Adherence and Improvement in Rural Settings. Conference on e-Business, e-Services and e-Society, 2020. Springer, 402-413.

DARAMOLA, O. & NYSAULU, P. A digital collaborative framework for improved tuberculosis treatment adherence of patients in rural settings. 2019 Open Innovations (OI), 2019. IEEE, 297-303.

DÉGLISE, C., SUGGS, L. S. & ODERMATT, P. 2012. SMS for disease control in developing countries: a systematic review of mobile health applications. *Journal of telemedicine and telecare,* 18**,** 273-281.

DENKINGER, C. M., GRENIER, J., STRATIS, A. K., AKKIHAL, A., PANT-PAI, N. & PAI, M. 2013. Mobile health to improve tuberculosis care and control: a call worth making. *The International Journal of Tuberculosis and Lung Disease,* 17**,** 719-727.

DENNISON, L., MORRISON, L., CONWAY, G. & YARDLEY, L. 2013. Opportunities and challenges for smartphone applications in supporting health behavior change: qualitative study. *Journal of medical Internet research,* 15**,** e2583.

DEWAN, P. K., LAL, S., LONNROTH, K., WARES, F., UPLEKAR, M., SAHU, S., GRANICH, R. & CHAUHAN, L. S. 2006. Improving tuberculosis control through public-private collaboration in India: literature review. *Bmj,* 332**,** 574-578.

ETIKAN, I., MUSA, S. A. & ALKASSIM, R. S. 2016. Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics,* 5**,** 1-4.

EVANS, C., TURNER, K., SUGGS, L., OCCA, A., JUMA, A. & BLAKE, H. 2016. Developing a mHealth intervention to promote uptake of HIV testing among African communities in the UK: a qualitative study. *BMC Public Health,* 16**,** 1-16.

FAYAD, M. E-Frame: A Process-Based Object-Oriented Framework for E-Commerce. International Conference on Internet Computing 2001. 124-128.

FINITSIS, D. J., PELLOWSKI, J. A. & JOHNSON, B. T. 2014. Text message intervention designs to promote adherence to antiretroviral therapy (ART): a meta-analysis of randomized controlled trials. *PloS one,* 9**,** e88166.

FONTOURA, M., PREE, W. & RUMPE, B. 2000. UML-F: A modeling language for object-oriented frameworks. In European Conference on Object-Oriented Programming . . Berlin, Heidelberg.: Springer.

GARDINER, C. K. & BRYAN, A. D. 2017. Monetary incentive interventions can enhance psychological factors related to fruit and vegetable consumption. *Annals of Behavioral Medicine,* 51**,** 599-609.

GELDSETZER, P., VAIKATH, M., DE NEVE, J.-W., BOSSERT, T. J., SIBANDZE, S., MKHWANAZI, M. & BÄRNIGHAUSEN, T. 2017. Distrusting community health workers with confidential health information: a convergent mixed-methods study in Swaziland. *Health policy and planning,* 32**,** 882-889.

GETNET, F., DEMISSIE, M., ASSEFA, N., MENGISTIE, B. & WORKU, A. 2017. Delay in diagnosis of pulmonary tuberculosis in low-and middle-income settings: systematic review and meta-analysis. *BMC pulmonary medicine,* 17**,** 1-15.

GLANZ, K. & BISHOP, D. B. 2010. The role of behavioral science theory in development and implementation of public health interventions. *Annual review of public health,* 31**,** 399-418.

GOOLD, P., BUSTARD, S., FERGUSON, E., CARLIN, E., NEAL, K. & BOWMAN, C. 2006. Pilot study in the development of an interactive multimedia learning environment for sexual health interventions: a focus group approach. *Health education research,* 21**,** 15-25.

GOULD, J. D. & LEWIS, C. 1985. Designing for usability: key principles and what designers think. *Communications of the ACM,* 28**,** 300-311.

GRANICH, R., BINKIN, N. J., JARVIS, W. R., SIMONE, P. M., RIEDER, H. L. & ESPINAL, M. A. 1999. Guidelines for the prevention of tuberculosis in health care facilities in resource-limited settings: World Health Organization.

GSMA 2017. The mobile economy sub-Saharan Africa 2017. London: GSM Association.

GSMA 2021. Accelerating mobile internet adoption Policy considerations to bridge the digital divide in low- and middle income countries.

GURUPUR, V. P. & WAN, T. T. 2017. Challenges in implementing mHealth interventions: a technical perspective. *Mhealth,* 3.

GUTIERREZ, R., TESHOME, S. & NEILSON, M. 2018. Uganda's health care quality improvement journey. *Technical Report*.

GYAMFI, J., ALLEGRANTE, J. P., IWELUNMOR, J., WILLIAMS, O., PLANGE-RHULE, J., BLACKSTONE, S., NTIM, M., APUSIGA, K., PEPRAH, E. & OGEDEGBE, G. 2020. Application of the Consolidated Framework for Implementation Research to examine nurses' perception of the task shifting strategy for hypertension control trial in Ghana. *BMC health services research,* 20**,** 1-11.

HAGGER, M. S. & WEED, M. 2019. DEBATE: Do interventions based on behavioral theory work in the real world?. *International Journal of Behavioral Nutrition and Physical Activity,* 16**,** 1-10.

HERMANS, S. M., ELBIREER, S., TIBAKABIKOBA, H., HOEFMAN, B. J. & MANABE, Y. C. 2017. Text messaging to decrease tuberculosis treatment attrition in TB-HIV coinfection in Uganda. *Patient preference and adherence,* 11**,** 1479.

HESAM, K., HAMID, C., NILOOFAR, K., MOHAMMAD, H., RAVANDI, A. N. & REZA, S. 2020. Mobile health applications for improving the sexual health outcomes among adults with chronic diseases: A systematic review. *Digital Health,* 6**,** 1-15.

HINZE, A., VANDERSCHANTZ, N., TIMPANY, C., SARAVANI, S.-J., CUNNINGHAM, S. J. & WILKINSON, C. Use of mobile apps for teaching and research–implications for digital literacy. International Conference on Asian Digital Libraries, 2017. Springer, 173-184.

HIRSCH-MOVERMAN, Y., DAFTARY, A., YUENGLING, K. A., SAITO, S., NTOANE, M., FREDERIX, K., MAAMA, L. B. & HOWARD, A. A. 2017. Using mHealth for HIV/TB treatment support in Lesotho: enhancing patient–provider communication in the START study. *Journal of acquired immune deficiency syndromes (1999),* 74**,** S37.

HOUSER, S. H., RAY, M. N., MAISIAK, R., PANJAMAPIROM, A., WILLIG, J., SCHIFF, G. D., ENGLISH, T., NEVIN, C. & BERNER, E. S. 2013. Telephone follow-up in primary care: can interactive voice response calls work? *Studies in health technology and informatics,* 192**,** 112.

HSIEH, H. F. & SHANNON, S. E. 2005. Three approaches to qualitative content analysis. *Qualitative Health Research,,* 15**,** 1277-1288.

HUDSON, M., RUTHERFORD, G. W., WEISER, S. & FAIR, E. 2018. Linking private, for-profit providers to public sector services for HIV and tuberculosis co-infected patients: A systematic review. *PLOS ONE,* 13**,** e0194960.

IBENEME, S., UKOR, N., DROTI, B., KARAMAGI, H., OKEIBUNOR, J. & ZAWAIRA, F. 2021. Geospatial Clustering of Mobile Phone Use and Tuberculosis Health Outcomes among African Health Systems. *Frontiers in public health,* 9.

ISLAM, S., HIRAYAMA, T., ISLAM, A., ISHIKAWA, N. & AFSANA, K. 2015. Treatment referral system for tuberculosis patients in Dhaka, Bangladesh. *Public Health Action,* 5**,** 236-240.

ISTEPANIAN, R., LAXMINARAYAN, S. & PATTICHIS, C. S. 2006. *M-health.*, New York, NY, Springer Science+ Business Media, Incorporated.

ITU. 2020. *International Telecommunication Union Statistics.* [Online]. Available: https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx [Accessed 29th March 2022].

JURCEV-SAVICEVIC, A., MULIC, R., KOZUL, K., BAN, B., VALIC, J., BACUN-IVCEK, L., GUDELJ, I., POPIJAC-CESAR, G., MARINOVIC-DUNATOV, S. & SIMUNOVIC, A. 2013. Health system delay in pulmonary tuberculosis treatment in a country with an intermediate burden of tuberculosis: a cross-sectional study. *BMC public health,* 13**,** 250.

KAK, N., AL IMRAN, A. N. M. & MATJI, R. 2016. Impact of mHealth on Retention and Management of MDR TB Patients Living in the Community. *University Research Co., LLC*.

KÄLLANDER, K., TIBENDERANA, J. K., AKPOGHENETA, O. J., STRACHAN, D. L., HILL, Z., TEN ASBROEK, A. H., CONTEH, L., KIRKWOOD, B. R. & MEEK, S. R. 2013. Mobile health (mHealth) approaches and lessons for increased performance and retention of community health workers in low-and middle-income countries: a review. *Journal of medical Internet research,* 15**,** e2130.

KAY, M., SANTOS, J. & TAKANE, M. 2011. mHealth: New horizons for health through mobile technologies. *World Health Organization,* 64**,** 66-71.

KEESARA, S. R., JUMA, P. A. & HARPER, C. C. 2015. Why do women choose private over public facilities for family planning services? A qualitative study of post-partum women in an informal urban settlement in Kenya. *BMC Health Services Research,* 15**,** 335.

KEITH, R. E., CROSSON, J. C., O'MALLEY, A. S., CROMP, D. & TAYLOR, E. F. 2017. Using the Consolidated Framework for Implementation Research (CFIR) to produce actionable findings: a rapid-cycle evaluation approach to improving implementation. *Implementation Science,* 12**,** 1-12.

KEUTZER, L., WICHA, S. G. & SIMONSSON, U. S. 2020. Mobile health apps for improvement of tuberculosis treatment: descriptive review. *JMIR mHealth and uHealth,* 8**,** e17246.

KHAN, A. J., KHOWAJA, S., KHAN, F. S., QAZI, F., LOTIA, I., HABIB, A., MOHAMMED, S., KHAN, U., AMANULLAH, F., HUSSAIN, H. & BECERRA, M. C. 2012a. Engaging the private sector to increase tuberculosis case detection: an impact evaluation study. *The Lancet infectious diseases,* 12**,** 608-616.

KHAN, A. J., KHOWAJA, S., KHAN, F. S., QAZI, F., LOTIA, I., HABIB, A., MOHAMMED, S., KHAN, U., AMANULLAH, F., HUSSAIN, H. & BECERRA, M. C. 2012b. Engaging the private sector to increase tuberculosis case detection: an impact evaluation study. *Lancet Infect. Dis. ,* 12**,** 608–616.

KHAN, B., KUMAR, A., STEWART, A., KHAN, N., SELVARAJ, K., FATIMA, R. & SAMAD, Z. 2017. Alarming rates of attrition among tuberculosis patients in public-private facilities in Lahore, Pakistan. *Public Health Action,* 7**,** 127-133.

KIWUWA, M. S., CHARLES, K. & HARRIET, M. K. 2005. Patient and health service delay in pulmonary tuberculosis patients attending a referral hospital: a cross-sectional study. *BMC Public Health,* 5**,** 1-7.

LAAKKO, T., LEPPÄNEN, J., LÄHTEENMÄKI, J. & NUMMIAHO, A. 2008. Mobile health and wellness application framework. *Methods of information in medicine,* 47**,** 217-222.

LABRIQUE, A., VASUDEVAN, L., KOCHI, E., FABRICANT, R. & MEHL, G. 2013. mHealth innovations as health system strengthening tools: 12 common applications and a visual framework. *Global health: science and practice,* 1**,** 160-171.

LAW, S., PIATEK, A. S., VINCENT, C., OXLADE, O. & MENZIES, D. 2017. Emergence of drug resistance in patients with tuberculosis cared for by the Indian health-care system: a dynamic modelling study. *The Lancet Public Health,* 2**,** e47-e55.

LEE, Y., RAVIGLIONE, M. C. & FLAHAULT, A. 2020. Use of digital technology to enhance tuberculosis control: scoping review. *Journal of medical Internet research,* 22**,** e15727.

LEI, X., LIU, Q., ESCOBAR, E., PHILOGENE, J., ZHU, H., WANG, Y. & TANG, S. 2015. Public–private mix for tuberculosis care and control: a systematic review. *International Journal of Infectious Diseases,* 34**,** 20-32.

LENTFERINK, A. J., OLDENHUIS, H. K., DE GROOT, M., POLSTRA, L., VELTHUIJSEN, H. & VAN GEMERT-PIJNEN, J. E. 2017. Key components in eHealth interventions combining self-tracking and persuasive eCoaching to promote a healthier lifestyle: a scoping review. *Journal of medical Internet research,* 19**,** e7288.

LESTARI, B. W., ARISANTI, N., SIREGAR, A. Y., SIHALOHO, E. D., BUDIMAN, G., HILL, P. C., ALISJAHBANA, B. & MCALLISTER, S. 2017. Feasibility study of strengthening the public–private partnership for tuberculosis case detection in Bandung City, Indonesia. *BMC research notes,* 10**,** 1-6.

LEVIN, D. M. 2008. *The opening of vision: Nihilism and the postmodern situation*, Routledge.

LEWIS, E., SAMPERI, S. & BOYD-SKINNER, C. 2017. Telephone follow-up calls for older patients after hospital discharge. *Age and ageing,* 46**,** 544-546.

LIU, X., LEWIS, J. J., ZHANG, H., LU, W., ZHANG, S., ZHENG, G., BAI, L., LI, J., LI, X. & CHEN, H. 2015. Effectiveness of electronic reminders to improve medication adherence in tuberculosis patients: a cluster-randomised trial. *PLoS medicine,* 12**,** e1001876.

LÖNNROTH, K., UPLEKAR, M. & BLANC, L. 2006. Hard gains through soft contracts: productive engagement of private providers in tuberculosis control. *Bulletin of the World Health Organization,* 84**,** 876-883.

MACKINTOSH, M., CHANNON, A., KARAN, A., SELVARAJ, S., CAVAGNERO, E. & ZHAO, H. 2016. What is the private sector? Understanding private provision in the health systems of low-income and middle-income countries. *The Lancet,* 388**,** 596-605.

MARABA, N., HOFFMANN, C. J., CHIHOTA, V. N., CHANG, L. W., ISMAIL, N., CANDY, S., MADIBOGO, E., KATZWINKEL, M., CHURCHYARD, G. J. & MCCARTHY, K. 2018. Using mHealth to improve tuberculosis case identification and treatment initiation in South Africa: Results from a pilot study. *PloS one,* 13**,** e0199687.

MBUAGBAW, L., VAN DER KOP, M. L., LESTER, R. T., THIRUMURTHY, H., POP-ELECHES, C., YE, C., SMIEJA, M., DOLOVICH, L., MILLS, E. J. & THABANE, L. 2013. Mobile phone text messages for improving adherence to antiretroviral therapy (ART): an individual patient data meta-analysis of randomised trials. *BMJ open,* 3**,** e003950.

MCCALLUM, C., ROOKSBY, J. & GRAY, C. M. 2018. Evaluating the impact of physical activity apps and wearables: interdisciplinary review. *JMIR mHealth and uHealth,* 6**,** 9054.

MCINTOSH, A. I., JENKINS, H. E., HORSBURGH, C. R., JONES-LÓPEZ, E. C., WHALEN, C. C., GAEDDERT, M., MARQUES-RODRIGUES, P., ELLNER, J. J., DIETZE, R. & WHITE, L. F. 2019. Partitioning the risk of tuberculosis transmission in household contact studies. *PloS one,* 14.

MEYER, A. J., ARMSTRONG-HOUGH, M., BABIRYE, D., MARK, D., TURIMUMAHORO, P., AYAKAKA, I., HABERER, J. E., KATAMBA, A. & DAVIS, J. L. 2020. Implementing mHealth interventions in a resource-constrained setting: case study from Uganda. *JMIR mHealth and uHealth,* 8**,** e19552.

MEYER, A. J., BABIRYE, D., ARMSTRONG-HOUGH, M., MARK, D., AYAKAKA, I., KATAMBA, A., HABERER, J. E. & DAVIS, J. L. 2018. Text messages sent to household tuberculosis contacts in Kampala, Uganda: process evaluation. *JMIR mHealth and uHealth,* 6**,** e10239.

MHODE, M. & NYAMHANGA, T. 2016. Experiences and impact of stigma and discrimination among people on antiretroviral therapy in Dar es Salaam: A qualitative perspective. *AIDS research and treatment,* 2016.

MIAH, S. J., GAMMACK, J., HASAN, N. & HOQUE, R. Design methodologies for M-health innovations: a content analysis. 27th Australasian Conference on Information Systems. Australasian Conference on Information Systems, 2016.

MICHIE, S., VAN STRALEN, M. M. & WEST, R. 2011. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation science,* 6**,** 1-12.

MOH 2011. Uganda national guidelines for tuberculosis infection control in health care facilities, congregate settings and households. Kampala: Ministry of Health, Uganda. https://www.who.int/hiv/pub/guidelines/uganda_hiv_tb.pdf

MOH 2017a. Annual Health Sector Performance Report: Financial Year 2017/18.

MOH 2017b. National Tuberculosis and Leprosy Control Programme. Revised National Strategic Plan 2015/16 - 2019/20. .

MOH 2018. National Tuberculosis and Leprosy Programme. National Tuberculosis Agenda for Operations and Implementation Research.

MOH 2019. Direct and Indirect costs due to Tuberculosis and proportion of Tuberculosis-affected households experiencing catastrophic costs due to TB in Uganda. Ministry of Health Uganda.

MOHAMMED, S., GLENNERSTER, R. & KHAN, A. J. 2016a. Impact of a daily SMS medication reminder system on tuberculosis treatment outcomes: a randomized controlled trial. *PloS one,* 11**,** e0162944.

MOHAMMED, S., GLENNERSTER, R. & KHAN, A. J. 2016b. Impact of a daily SMS medication reminder system on tuberculosis treatment outcomes: a randomized controlled trial. . *PloS one*, 11.

MONTAGU, D., GOODMAN, C., BERMAN, P., PENN, A. & VISCONTI, A. 2016. Recent trends in working with the private sector to improve basic healthcare: a review of evidence and interventions. *Health policy and planning*, 31**,** 1117-1132.

MOULLIN, J. C., DICKSON, K. S., STADNICK, N. A., ALBERS, B., NILSEN, P., BRODER-FINGERT, S., MUKASA, B. & AARONS, G. A. 2020. Ten recommendations for using implementation frameworks in research and practice. , 1(1), pp.1-12. *Implementation science communications*, 1**,** 1-12.

MUGISHA, M. 2018. *Reviving the Functionality of the Referral System in Uganda.* [Online]. Available: https://www.udn.or.ug/udn-media/news/147-reviving-the-functionality-of-the-referral-system-in-uganda.html [Accessed 26th October 2019].

MUMMAH, S. A., ROBINSON, T. N., KING, A. C., GARDNER, C. D. & SUTTON, S. 2016a. IDEAS (Integrate, Design, Assess, and Share): a framework and toolkit of strategies for the development of more effective digital interventions to change health behavior. *Journal of medical Internet research*, 18.

MUMMAH, S. A., ROBINSON, T. N., KING, A. C., GARDNER, C. D. & SUTTON, S. 2016b. IDEAS (Integrate, Design, Assess, and Share): a framework and toolkit of strategies for the development of more effective digital interventions to change health behavior. *Journal of medical Internet research*, 18**,** e5927.

MUSIIMENTA, A. 2021. My Mobile Wallet: An Intervention to Support Access to Tuberculosis Care and Medication Adherence in Rural Uganda. National Institutes of Health.

MUSIIMENTA, A., ATUKUNDA, E. C., TUMUHIMBISE, W., PISARSKI, E. E., TAM, M., WYATT, M. A., WARE, N. C. & HABERER, J. E. 2018a. Acceptability and feasibility of real-time antiretroviral therapy adherence interventions in rural Uganda: mixed-method pilot randomized controlled trial. *JMIR mHealth and uHealth,* 6**,** e9031.

MUSIIMENTA, A., ATUKUNDA, E. C., TUMUHIMBISE, W., PISARSKI, E. E., TAM, M., WYATT, M. A., WARE, N. C. & HABERER, J. E. 2018b. Acceptability and feasibility of real-time antiretroviral therapy adherence interventions in rural Uganda: mixed-method pilot randomized controlled trial. *JMIR mHealth and uHealth,* 6**,** e122.

MUSIIMENTA, A., TUMUHIMBISE, W., ATUKUNDA, E. C., MUGABA, A. T., MUZOORA, C., ARMSTRONG-HOUGH, M., BANGSBERG, D., DAVIS, J. L. & HABERER, J. E. 2020a. Mobile health technologies may be acceptable tools for providing social support to tuberculosis patients in rural Uganda: a parallel mixed-method study. *Tuberculosis research and treatment,* 2020.

MUSIIMENTA, A., TUMUHIMBISE, W., MUGABA, A. T., MUZOORA, C., ARMSTRONG-HOUGH, M., BANGSBERG, D., DAVIS, J. L. & HABERER, J. E. 2019. Digital monitoring technologies could enhance tuberculosis medication adherence in Uganda: Mixed methods study. *Journal of clinical tuberculosis and other mycobacterial diseases,* 17**,** 100119.

MUSIIMENTA, A., TUMUHIMBISE, W., MUGYENYI, G., KATUSIIME, J., ATUKUNDA, E. C. & PINKWART, N. 2020b. Mobile phone-based multimedia application could improve

maternal health in rural southwestern Uganda: mixed methods study. *Online Journal of Public Health Informatics,* 12.

MUSIIMENTA, A., TUMUHIMBISE, W., PINKWART, N., KATUSIIME, J., MUGYENYI, G. & ATUKUNDA, E. C. 2021. A mobile phone-based multimedia intervention to support maternal health is acceptable and feasible among illiterate pregnant women in Uganda: Qualitative findings from a pilot randomized controlled trial. *Digital Health,* 7**,** 2055207620986296.

MUSTAFA, A. S., ALI, N. A., DHILLON, J. S., ALKAWSI, G. & BAASHAR, Y. User Engagement and Abandonment of mHealth: A Cross-Sectional Survey. Healthcare, 2022. Multidisciplinary Digital Publishing Institute, 221.

MUTTAMBA, W., KYOBE, S., KOMUHANGI, A., LAKONY, J., BUREGYEYA, E., MABUMBA, E. & BASAZA, R. K. 2019. Delays in diagnosis and treatment of pulmonary tuberculosis in patients seeking care at a regional referral hospital, Uganda: a cross sectional study. , 12(1), pp.1-5. *BMC Research Notes,* 12**,** 1-5.

NANDI, A. 2015. *Early Diagnosis and Treatment of Tuberculosis: Improving Care in India through a Public Private Interface Agency* [Online]. Available: https://cddep.org/blog/posts/early_diagnosis_and_treatment_tuberculosis_improving_care_india_through_public_private/.

NANSERA, D., BAJUNIRWE, F., KABAKYENGA, J., ASIIMWE, P. & MAYANJA-KIZZA, H. 2010. Opportunities and barriers for implementation of integrated TB and HIV care in lower level health units: experiences from a rural western Ugandan district. *African Health Sciences,* 10.

NEUENDORF, K. A. 2017. *The content analysis guidebook,* sage.

NGWATU, B. K., NSENGIYUMVA, N. P., OXLADE, O., MAPPIN-KASIRER, B., NGUYEN, N. L., JARAMILLO, E., FALZON, D. & SCHWARTZMAN, K. 2018. The impact of digital health technologies on tuberculosis treatment: a systematic review. *European Respiratory Journal,* 51.

NHAVOTO, J. A. & GRÖNLUND, Å. 2014. Mobile technologies and geographic information systems to improve healthcare systems: a literature review. *JMIR mHealth and uHealth,* 2**,** e21.

NSHUTI, L., NEUHAUSER, D., JOHNSON J, L., ADATU, F. & WHALEN C, C. 2001. Public and private providers' quality of care for tuberculosis patients in Kampala, Uganda. *The International Journal of Tuberculosis and Lung Disease,* 5**,** 1006-1012.

NWE, T. T., SAW, S., WIN, L. L., MON, M. M., GRIENSVEN, J. V., ZHOU, S., CHINNAKALI, P., SHAH, S., THEIN, S. & AUNG, S. T. 2017. Engagement of public and private medical facilities in tuberculosis care in Myanmar: contributions and trends over an eight-year period. *Infectious diseases of poverty,* 6**,** 21-27.

O'DONOVAN, J., BERSIN, A. & O'DONOVAN, C. 2015. The effectiveness of mobile health (mHealth) technologies to train healthcare professionals in developing countries: a review of the literature. *BMJ Innovations,* 1.

O'HANLON, B., NAKYANZI, A., MUSEMBI, V., BUSULWA, I., HUSBAND, R., OKUMU, R. & KANNEGANTI, S. 2017. Exploring partnership opportunities to achieve universal health access: 2016 Uganda Private Sector Assessment in Health.

OGBUABOR, D. C. & ONWUJEKWE, O. E. 2019. Governance of tuberculosis control programme in Nigeria. *Infectious diseases of poverty,* 8**,** 1-11.

OKETHWANGU, D., BIRUNGI, D., BIRIBAWA, C., KWESIGA, B., TURYAHABWE, S., ARIO, A. R. & ZHU, B. P. 2019. Multidrug-resistant tuberculosis outbreak associated with poor treatment adherence and delayed treatment: Arua District, Uganda, 2013–2017. *BMC infectious diseases,* 19**,** 1-10.

OLIWA, J. N., ODERO, S. A., NZINGA, J., VAN HENSBROEK, M. B., JONES, C., ENGLISH, M. & HOOG, A. V. T. 2020. Perspectives and practices of health workers around diagnosis of paediatric tuberculosis in hospitals in a resource-poor setting – modern diagnostics meet age-old challenges. *BMC Health Services Research,* 20.

OPOKU, D., STEPHANI, V. & QUENTIN, W. 2017. A realist review of mobile phone-based health interventions for non-communicable disease management in sub-Saharan Africa. *BMC medicine,* 15**,** 1-12.

OPON, S. O., TENAMBERGEN, W. M. & NJOROGE, K. M. 2020. The effect of patient reminders in reducing missed appointment in medical settings: a systematic review.

PADMANABHAN, B. 2012. Unified modeling language (UML) overview. EECS810–Principles of Software Engineering.

PANDE, T., SARAVU, K., TEMESGEN, Z., SEYOUM, A., RAI, S., RAO, R., MAHADEV, D., PAI, M. & GAGNON, M.-P. 2017a. Evaluating clinicians' user experience and acceptability of LearnTB, a smartphone application for tuberculosis in India. *Mhealth,* 3.

PANDE, T., SARAVU, K., TEMESGEN, Z., SEYOUM, A., RAI, S., RAO, R., MAHADEV, D., PAI, M. & GAGNON, M. P. 2017b. Evaluating clinicians' user experience and acceptability of LearnTB, a smartphone application for tuberculosis in India. . *Mhealth*, 3.

PATH 2019. Public Private Interface Agency (PPIA) ACCELERATING TB ELIMINATION IN INDIA THROUGH PRIVATE SECTOR ENGAGEMENT.

PERRI-MOORE, S., KAPSANDOY, S., DOYON, K., HILL, B., ARCHER, M., SHANE-MCWHORTER, L., BRAY, B. E. & ZENG-TREITLER, Q. 2016. Automated alerts and reminders targeting patients: a review of the literature. *Patient education and counseling*, 99**,** 953-959.

PEW_RESEARCH_CENTER. 2019. *Smartphone Ownership Is Growing Rapidly Around the World, but Not Always Equally* [Online]. Available: https://www.pewresearch.org/global/2019/02/05/smartphone-ownership-is-growing-rapidly-around-the-world-but-not-always-equally/ [Accessed 29th March 2022].

PHILLIPS, S., KANTER, J., RUGGIERO, K. J., MUELLER, M., JOHNSON, M. A. & KELECHI, T. J. 2019. An approach to revising mHealth interventions for children and families: A case example in sickle cell disease. *Research in nursing & health*, 42**,** 483-493.

RACHLIS, B., NAANYU, V., WACHIRA, J., GENBERG, B., KOECH, B., KAMENE, R., AKINYI, J. & BRAITSTEIN, P. 2016. Community perceptions of community health workers (CHWs) and their roles in management for HIV, tuberculosis and hypertension in Western Kenya. . *PloS one*, 11**,** 0149412.

RAINGRUBER, B. 2014. Health promotion theories. *Contemporary health promotion in nursing practice*, 53**,** 53-94.

RODRÍGUEZ-CASTELÁN, C., OCHOA, R., LACH, S. & MASAKI, T. 2021. Mobile Internet Adoption in West Africa.

SACHS, J. 2008. *The digital war on poverty.* [Online]. London. Available: http://www.guardian.co.uk/commentisfree/2008/aug/21/digitalmedia.mobilephones.

SEKANDI, J. N., ONUOHA, N. A., BUREGYEYA, E., ZALWANGO, S., KAGGWA, P. E., NAKKONDE, D., KAKAIRE, R., ATUYAMBE, L., WHALEN, C. C. & DOBBIN, K. K. 2021. Using a mobile health intervention (DOT selfie) with transfer of social bundle incentives to increase treatment adherence in tuberculosis patients in Uganda: protocol for a randomized controlled trial. *JMIR research protocols,* 10**,** e18029.

SENDAGIRE, I., SCHIM VAN DER LOEFF, M., MUBIRU, M., KONDE-LULE, J. & COBELENS, F. 2010. Long delays and missed opportunities in diagnosing smear-positive pulmonary tuberculosis in Kampala, Uganda: a cross-sectional study. *PLOS one,* 5**,** e14459.

SHANI, R. & OMER, F. 2021. *The Uninstall Threat: 2020 App Uninstall Benchmarks 2021* [Online]. Berlin, Germany: AppsFlyer Ltd. Available: https://www.appsflyer.com/resources/reports/app-uninstall-benchmarks/ [Accessed 3rd March 2022].

SHEA, C. M., JACOBS, S. R., ESSERMAN, D. A., BRUCE, K. & WEINER, B. J. 2014. Organizational readiness for implementing change: a psychometric assessment of a new measure. *Implementation science,* 9**,** 1-15.

SIRRIYEH, R., LAWTON, R., GARDNER, P. & ARMITAGE, G. 2012. Reviewing studies with diverse designs: the development and evaluation of a new tool. *Journal of evaluation in clinical practice,* 18**,** 746-752.

SPAHR, J., CODDINGTON, J., EDWARDS, N. & MCCOMB, S. 2018. Implementing Comprehensive Primary Care Referral Tracking in a Patient-Centered Medical Home. . *Journal of nursing care quality,* 33**,** 255-262.

SPORREL, K., DE BOER, R. D., WANG, S., NIBBELING, N., SIMONS, M., DEUTEKOM, M., ETTEMA, D., CASTRO, P. C., DOURADO, V. Z. & KRÖSE, B. 2021. The design and development of a personalized leisure time physical activity application based on behavior change theories, end-user perceptions, and principles from empirical data mining. *Frontiers in Public Health***,** 711.

STALLWORTHY, G., DIAS, H. M. & PAI, M. 2020. Quality of tuberculosis care in the private health sector. *Journal of clinical tuberculosis and other mycobacterial diseases,* 20**,** 100171.

STEINHUBL, S. R., MUSE, E. D. & TOPOL, E. J. 2015. The emerging field of mobile health. *Science translational medicine,* 7**,** 283rv3-283rv3.

SUBBARAMAN, R., DE MONDESERT, L., MUSIIMENTA, A., PAI, M., MAYER, K. H., THOMAS, B. E. & HABERER, J. 2018. Digital adherence technologies for the management of tuberculosis therapy: mapping the landscape and research priorities. *BMJ global health,* 3**,** e001018.

SULIS, G. & PAI, M. 2017. Missing tuberculosis patients in the private sector: Business as usual will not deliver results. *Public Health Action,* 7**,** 80.

TANIMURA, T., JARAMILLO, E., WEIL, D., RAVIGLIONE, M. & LÖNNROTH, K. 2014. Financial burden for tuberculosis patients in low-and middle-income countries: a systematic review. *European Respiratory Journal,* 43**,** 1763-1775.

THU, T. D., KUMAR, A. M., RAMASWAMY, G., HTUN, T., LE VAN, H., VO, L. N. Q., DONG, T. T. T., CODLIN, A., FORSE, R. & CREWSELL, J. 2020a. An innovative public-private mix model for improving tuberculosis care in Vietnam: How well are we doing? *Tropical medicine and infectious disease,* 5**,** 1-13.

THU, T. D., KUMAR, A. M. V., RAMASWAMY, G., HTUN, T., VAN, H. L., QUANG, L. V. N., THU, T. D. T., CODLIN, A., FORSE, R., CREWSELL, J., THANH, H. N., VIET, H. N., VAN, H. B., BINH, H. N. & VIET, N. N. 2020b. An Innovative Public-Private Mix Model for Improving Tuberculosis Care in Vietnam: How Well are We Doing? *BMC Infect Dis,* 5.

TOMBS, M. & PUGSLEY, L. 2020. How to: understand research philosophies and paradigms in medical education. *How To Series*.

TONGCO, M. D. C. 2007. Purposive sampling as a tool for informant selection. *Ethnobotany Research and applications,* 5.

TUMUHIMBISE, W., ATUKUNDA, E. C., AYEBAZA, S., KATUSIIME, J., MUGYENYI, G., PINKWART, N. & MUSIIMENTA, A. 2020. Maternal health-related barriers and the potentials of mobile health technologies: qualitative findings from a pilot randomized controlled trial in rural southwestern Uganda. *Journal of family medicine and primary care,* 9**,** 3657.

TUMUHIMBISE, W. & MUSIIMENTA, A. 2021a. Barriers and Motivators of Private Hospitals' Engagement in Tuberculosis Care in Uganda. *Global Implementation Research and Applications,* 1**,** 279-290.

TUMUHIMBISE, W. & MUSIIMENTA, A. 2021b. Barriers and Motivators of Private Hospitals' Engagement in Tuberculosis Care in Uganda. *Global Implementation Research and Applications*, 1-12.

TUMUHIMBISE, W. & MUSIIMENTA, A. 2021c. A review of mobile health interventions for public private mix in tuberculosis care. *Internet Interventions*, 100417.

TUMUHIMBISE, W. & MUSIIMENTA, A. 2021d. A review of mobile health interventions for public private mix in tuberculosis care. *Internet interventions,* 25**,** 100417.

UBOS 2018. Uganda Bureau of Statistics. Uganda National Household Survey, 2016/2017. https://www.ubos.org/wp-content/uploads/publications/03_20182016_UNHS_FINAL_REPORT.pdf

UCC 2021a. Uganda Communications Communication. Market Perfomance Report 2Q21. *In:* COMMUNICATION, U. C. (ed.).

UCC 2021b. Uganda Communications Communication. Market Perfomance Report 3Q21.

UNDP. 2015. *Sustainable Development Goals. 17 goals to transform our world* [Online]. Available: http://www.undp.org/content/undp/en/home/sustainable-development-goals.html [Accessed 19th May 2022].

UPLEKAR, M. 2003. Involving private health care providers in delivery of TB care: global strategy. *Tuberculosis,* 83**,** 156-164.

UPLEKAR, M. 2016. Public-private mix for tuberculosis care and prevention. What progress? What prospects? *The International Journal of Tuberculosis and Lung Disease,* 20**,** 1424-1429.

USAID 2015. Mobile Money for health case study compendium. United States Agency International Development. .

USAID 2017. Uganda's Private Health sector: Opportunities for Growth. United States Agency for International Development. .

USTB 2014. A Public private Partnership to control Tuberculosis in an Urban setting, Kampala Uganda. A Stepwise Approach and Results from the Slum Partnerships to Actively Respond to Tuberculosis in Kampala District (SPARK-TB), October 2011- June 2014.

VAN DE VEN, P., O'BRIEN, H., HENRIQUES, R., KLEIN, M., MSETFI, R., NELSON, J., ROCHA, A., RUWAARD, J., O'SULLIVAN, D. & RIPER, H. 2017. ULTEMAT: A mobile framework for smart ecological momentary assessments and interventions. *Internet interventions,* 9**,** 74-81.

VAN DER KOP, M. L., MEMETOVIC, J., SMILLIE, K., COLEMAN, J., HAJEK, J., NATASHA VAN BOREK, M., TAYLOR, D., ALASALY, K., JOHNSTON, J. & LESTER, R. T. 2013. Use of the WelTel mobile health intervention at a tuberculosis clinic in British Columbia: a pilot study. *Journal of Mobile Technology in Medicine,* 2**,** 7-14.

VANDELANOTTE, C., MÜLLER, A. M., SHORT, C. E., HINGLE, M., NATHAN, N., WILLIAMS, S. L., LOPEZ, M. L., PAREKH, S. & MAHER, C. A. 2016. Past, present, and future of eHealth and mHealth research to improve physical activity and dietary behaviors. *Journal of nutrition education and behavior,* 48**,** 219-228. e1.

VARSHNEY, U. 2014. A model for improving quality of decisions in mobile health *Decision Support Systems,* 62**,** 66-77.

VELAYUTHAM, B., T.,, B., N., D., THIRUVENGADAM, K., PRASHANT, S., KITTUSAMI, S.,, VIJAYAKUMAR, H., CHIDAMBARAM, M., SHIVAKUMAR, S.V.B.Y., JAYABAL, L., & JHUNJHUNWALA, A., SWAMINATHAN, S. 2015a. The usefulness and feasibility of mobile interface in tuberculosis notification (MITUN) voice based system for notification of tuberculosis by private medical practitioners- a pilot project. *PLoS One,* 10.

VELAYUTHAM, B. T., NAIR, D., THIRUVENGADAM, K., PRASHANT, S., KITTUSAMI, S., VIJAYAKUMAR, H., CHIDAMBARAM, M., SHIVAKUMAR, S. V. B. Y., JAYABAL, L., JHUNJHUNWALA, A. & SWAMINATHAN, S. 2015b. The Usefulness and feasibility of mobile interface in tuberculosis notification (MITUN) voice based system for notification of tuberculosis by private medical practitioners–A pilot project. *PloS one,* 10.

VENKATESH, V., MORRIS, M. G., DAVIS, G. B. & DAVIS, F. D. 2003. User acceptance of information technology: Toward a unified view. *MIS quarterly***,** 425-478.

WALD, D. S., BUTT, S. & BESTWICK, J. P. 2015. One-way versus two-way text messaging on improving medication adherence: meta-analysis of randomized trials. *The American journal of medicine,* 128**,** 1139. e1-1139. e5.

WARE, N. C., PISARSKI, E. E., TAM, M., WYATT, M. A., ATUKUNDA, E., MUSIIMENTA, A., BANGSBERG, D. R. & HABERER, J. E. 2016. The Meanings in the messages: how SMS reminders and real-time adherence monitoring improve antiretroviral therapy adherence in rural Uganda. *AIDS (London, England),* 30**,** 1287.

WEI, Y., ZHENG, P., DENG, H., WANG, X., LI, X. & FU, H. 2020. Design features for improving mobile health intervention user engagement: systematic review and thematic analysis. *Journal of medical Internet research,* 22**,** e21687.

WELLS, W. A., UPLEKAR, M. & PAI, M. 2015. Achieving systemic and scalable private sector engagement in tuberculosis care and prevention in Asia. *PLoS medicine,* 12**,** e1001842.

WEVER, R., VAN KUIJK, J. & BOKS, C. 2008. User-centred design for sustainable behaviour. *International journal of sustainable engineering,* 1**,** 9-20.

WHITTAKER, R. 2012. Issues in mHealth: findings from key informant interviews. *Journal of medical Internet research,* 14**,** e1989.

WHO 2001. Involving private practitioners in tuberculosis control: issues, interventions, and emerging policy framework. *Involving private practitioners in tuberculosis control: issues, interventions, and emerging policy framework.*

WHO 2004. Public-private mix for DOTS: report of the second meeting of the PPM subgroup for DOTS expansion. Geneva: WHO; 2004. Report No WHO/HTM/TB/2004.338. http://whqlibdoc. who. int/hq/2004 ….

WHO 2009. WHO policy on TB infection control in health-care facilities, congregate settings and households. http://apps.who.int/iris/bitstream/handle/10665/44148/9789241598323_eng.pdf?sequence=1

WHO 2014. The End TB Strategy. Global strategy and targets for tuberculosis prevention, care and control after 2015. Geneva: World Health Organization.

WHO 2015a. Implementación de la estrategia Fin de la TB. Available from: http://www.who.int/tb/publications/2015/end_tb_essential_spanish_web.pdf.

WHO 2015b. Implementing the end TB strategy: the essentials (No. WHO/HTM/TB/2015.31). World Health Organization.

WHO 2017a. Global Tuberculosis Report 2017. Geneva: World Health Organization; 2017.

WHO 2017b. Handbook for the use of digital technologies to support tuberculosis medication adherence. World Health Organization. World Health Organization.

WHO 2018a. Engaging private health care providers in TB care and prevention: a landscape analysis.

WHO 2018b. Public–private mix for TB prevention and care: a roadmap. Geneva: World Health Organization.

WHO 2018c. Public–private mix for TB prevention and care: a roadmap. World Health Organization.: World Health Organization.

WHO 2019. Global Tuberculosis Report 2019. Geneva: World Health Organization; 2019.

WHO 2020. Global tuberculosis report 2020. In Global tuberculosis report 2020. World Health Organization.

WHO 2021a. Global Tuberculosis Report 2021. Geneva, Switzerland: World Health Organization.

WHO 2021b. World Health Organization. Global tuberculosis control: WHO report 2021.

WOOD, R., JOHNSTONE-ROBERTSON, S., UYS, P., HARGROVE, J., MIDDELKOOP, K., LAWN, S. D. & BEKKER, L.-G. 2010. Tuberculosis transmission to young children in a South African community: modeling household and community infection risks. *Clinical infectious diseases,* 51**,** 401-408.

WYNNE, A., RICHTER, S., BANURA, L. & KIPP, W. 2014. Challenges in tuberculosis care in Western Uganda: health care worker and patient perspectives. *International Journal of Africa Nursing Sciences,* 1**,** 6-10.

ZAKERABASALI, S., AYYOUBZADEH, S. M., BANIASADI, T., YAZDANI, A. & ABHARI, S. 2021. Mobile health technology and healthcare providers: systemic barriers to adoption. *Healthcare Informatics Research,* 27**,** 267-278.

ZHOU, Y., LU, Y., NI, Y., WU, D., HE, X., ONG, J. J., TUCKER, J. D., SYLVIA, S. Y., JING, F. & LI, X. 2022. Monetary incentives and peer referral in promoting secondary distribution of HIV self-testing among men who have sex with men in China: A randomized controlled trial. *PLoS medicine,* 19**,** e1003928.

Appendix 1: Health Care workers Engagement survey (Key Informant survey).

Study title: A Mobile health Framework for Public Private Mix in Tuberculosis prevention and Care.

Study Objective: To explore the barriers and motivators to private hospitals engagement in TB care among private healthcare workers with particular focus on understanding the current referral systems in Uganda.

My name is Wilson Tumuhimbise, a PhD student of Mbarara University of Science and Technology, REG NO, 2018/PhD/030/PS. I am carrying out a study entitled "A Mobile health Framework for Public Private Mix in Tuberculosis prevention and Care". Mobile health (mHealth) is defined as the use of mobile and wireless technologies to achieve health objectives and this study is about exploring the challenges faced by the private hospitals in supporting TB patients and how mobile health and how mHealth can help address the identified challenges and also assessing the readiness of using mHealth among healthcare workers. Participation is voluntary, filling this questionnaire will only take you 15 to 20 minutes. The response you give will be treated with utmost privacy.

Circle the Alternative of your choice.

PART A: SOCIAL DEMOGRAPHIC DATA	
Participant No…….. ***(****For the researcher****)***	
1. Date of Birth |___|___|___|	2. Gender **MALE** ☐ **FEMALE** ☐
3. Marital Status: **Married** ☐ **Single** ☐	4. Name of the Health Facility: **……..**
5. Type of the Facility: Private for Profit ☐ Faith based ☐ Private Not for Profit ☐	6. Highest level of education achieved:

	Certificate ☐ Diploma ☐ Degree ☐ Masters ☐ PhD ☐
7. Designation: Nurse ☐ Doctor ☐ Lab Technician ☐ Pharmacist ☐ Other …….. ……..	8. Number of years of practice <1 ☐ 1-3☐ 4- 5 ☐ >5 ☐

9. What do you do when you have a suspected TB patient?

   a) Diagnose then refer ☐

   b) Diagnose and Manage ☐

   c) Refer ☐

10. If you refer TB patients, where do you refer them?

   1 Another private clinic/Hospital ☐

   2 Public hospital facility ☐

   If Public, which level

   1 Level 2 *(HC2)* ☐

   2 Level 3 *(HC3)* ☐

   3 Level 4 *(HC4)* ☐

   4 Referral ☐

11. Which methods do you use to refer a suspected TB case?

	0= No	1= Yes
a) Mouth to mouth	☐	☐
b) Referral note	☐	☐
c) Text Messages	☐	☐
d) None of the above	☐	☐

12. Which mechanisms do you have in place for tracking TB patients referred to public hospital?

……...……

……

……

……

……

13. What challenges do you face in following up patients referred to the public hospital?

……...……

……

……

……

……

14. a) Do you think a mobile Health app may have a role in tracking patients referred from private to public hospitals?

1 Yes ☐

2 No ☐

b) If Yes, why do you a think a mobile health app would be helpful in tracking presumptive TB cases? (tick all that applies)

1 Time saving ☐

2 Less costly ☐

3 Ensures that the patient reaches the referral unit ☐

4 Ensures that no patient is lost to contact ☐

5 Ensures early anti TB drug initiation ☐

6 Eliminates diagnostic delays ☐

7 Other reasons ----------

---

c) If No, What are the reasons

……

…….....

.....

.....

.....

d) If Yes, which of these would you consider right in regard to the use of mobile health in your way of working?

1= **Strongly Disagree 2= Disagree, 3= Not Sure, 4= Agree, 5= Strongly Agree**	**1**	**2**	**3**	**4**	**5**
Helping me make quicker medical decisions					
Help me communicate with other healthcare workers about TB disease					
Enhance patient follow up					
Facilitate partnership with other health institutions					
Quick TB case notification					
Quick and efficient referral system					
Real-time Consultation with other healthcare workers about the disease					

a) Which Other ways do you think mobile health would be helpful

……

……

……

15. What challenges are faced by private hospitals in supporting TB patients?

……

……

……

……

……

Thank you for your response and time

Appendix 2: Interview Guide for Private healthcare workers (Key Informant).

Study Title: A Mobile health Framework for Public Private Mix in Tuberculosis prevention and Care.

Study objective: To explore the barriers and motivators for private hospitals engagement in TB disease management and how Mobile health can address these challenges.

<u>TB disease management</u>

- Tell me your experience with TB cases
- What happens when you receive a TB case at the hospital?
    - Probe: Manage vs Referral
    - What are the reasons for the above?
        - If referral, what are the reasons for not managing the TB patients?
        - **If manage, what challenges do you normally face in supporting TB disease management?**

            Probe: Lack of Support from the government

            - *Lack of drugs*
            - *Costs related to TB treatment*
            - *Lack of diagnostic skills*
            - *Adequate tools for disease management*
            - *Medication adherence related challenges (Implementation of DOT at a clinic level)*
                - *(Probe for: How these challenges affect private practitioners' support for TB/HIV patients?)*

- ***Why are the private practitioners not engaged in the management of TB case in Uganda?***
    - *Reporting*

Partnership

How can the public/ government sector work together with the private hospitals to enhance TB treatment services?

Probe for: drug subsidization, Established referral systems, contracting etc.

- What best ways or approaches do you feel the public and private hospitals should use or be involved in to support TB patients?
- What are the anticipated benefits of ensuring partnership between the public and private hospitals in TB care? *Probe for impact on: TB disease management, medication adherence, case notifications and referrals*
- What challenges do you anticipate in private hospitals partnering with the government in supporting TB patients?

Mobile health

How can mobile phone technology be used to enhance the public private engagement in supporting TB treatment? (Probe for Potential advantages and challenges).

- Probe for influence on: *Linking and connectivity, Quick access to information about TB drugs, Partnering/Information sharing, Case notification and Patient Referrals, Ease in Bureaucratic process, Policy formulation*
- Probe for Challenges on
    i. *Senior/ administrative buy in, Time and resource, Staff commitment.*

How do you feel about the use of mobile phone/ Mobile phone technology to support TB treatment (Potential advantages and challenges?)

- *Probe for influence on:*
    - *Smart phone usage: monitoring, app usage experience*
    - *Attitudes towards using mobile health for engaging*
    - *Adoption*
    - *Level of interactivity*

Appendix 3: INTERVIEW GUIDE for assessing acceptability

Objective: To assess the initial acceptability and feasibility of using mobile health for tracking TB patients referred from private to public hospitals.

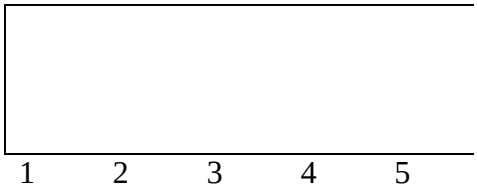
Performance Expectancy.

1. How are you doing today?
2. Tell me about your experience with using a mobile phone based application for tracking TB patients referred from private to public hospital? Probe More Is it easy or difficult to use, is it flexible? Can you use it any time you want?
3. Tell me about your experience with using a mobile phone based application for TB care that you received. (Referral, notification and identification, linking to different health Centers).
4. In what ways was it easy/hard to learn to use the mobile phone based application?
5. How did it help you in caring for TB patients? What do you like/ dislike about it?
6. What challenges have you encountered in using this application? (probe for: app failure, network connectivity, convenience)
7. How do you feel about the usage of mobile health for tracking TB patients referred from private to public hospitals?
8. How do you compare the use of a mobile phone based app for tracking TB patients referred with other traditional means (e.g. Referral notes)
9. What do others (family members, friends, and people around you) think about your usage of mobile health for tracking TB patients referred from private to public hospital? Do they understand it? What is their reaction when they see you use that application for TB disease management?
10. Any questions for me?
11. Thank you for your response and thank you for being part of the study and interview.

The System Usability Scale for assessing acceptability of using the intervention

		Strongly Disagree				Strongly agree
1	I think that I would like to use this app frequently	1	2	3	4	5
2	I found the app unnecessarily complex	1	2	3	4	5
3	I thought the app was easy to use	1	2	3	4	5
4	I think that I would need the support of a technical person to be able to use this app	1	2	3	4	5
5	I found the various functions in this app were well integrated	1	2	3	4	5
6	I thought there was too much inconsistency in this app	1	2	3	4	5
7	I would imagine that most people would learn to use this app very quickly	1	2	3	4	5
8	I found the app very cumbersome to use	1	2	3	4	5
9	felt very confident using the app	1	2	3	4	5

10 I needed to learn a lot of things before I could get going with this app



Appendix 4: MUST REC approval

MBARARA UNIVERSITY OF SCIENCE AND TECHNOLOGY
P.O. Box 1410, Mbarara Uganda. Tel: +256 485433795; Fax: +256 4854 20782
RESEARCH ETHICS COMMITTEE
E-mail: sec.rec@must.ac.ug

Our Ref: MUREC 1/7 **Date**: 10th June, 2020

Mr. Tumuhimbise Wilson
Postgraduate student

Re: Submitted protocol on "A mobile health framework for public-private mix in tuberculosis prevention and care in Uganda"32/03-20

Type: [√] Initial Application
[ ] Protocol Amendment
[ ] Letter of Amendment (LOA)
[] Continuing Review
[ ] Material Transfer Agreement
[ ] Other, specify: _____

Reference is made to the above protocol which was resubmitted to the Research Ethics Committee for reconsideration and approval.

It is noted that you have addressed all the concerns earlier raised by the Committee.

I am pleased to inform you that your study has been approved for a period of one year from **June 10, 2020** up to **June 09, 2021.**

As Principal Investigators of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the REC for review and approval **prior** to the activation of the changes. The REC application number assigned to the research should be cited in any correspondence.
3. Reports of unanticipated problems involving risks to participants or other must be submitted to the REC. New information that becomes available which could change the risk: benefit ratio must be submitted promptly for REC review.
4. Only approved consent forms are used in enrolment of participants. All consent forms signed by subjects and/or witness should be retained on file. The REC may conduct audits of all study records, and consent documentation may be part of such audits.
5. Regulations require review of an approved study not less than once per 12-month period. **Therefore, a continuing review application must be submitted to REC eight weeksprior to the above expiration date of June 09, 2021 in order to continue the study beyond the approved period.** Failure to submit a continuing review application in timely fashion may result in suspension or termination of the study, at which point new participants may not be enrolled and currently enrolled participants must be taken off the study.

MBARARA UNIVERSITY OF SCIENCE AND TECHNOLOGY
P.O. Box 1410, Mbarara Uganda. Tel: +256 485433795; Fax: +256 4854 20782
RESEARCH ETHICS COMMITTEE
E-mail: rec.rec@must.ac.ug

6. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

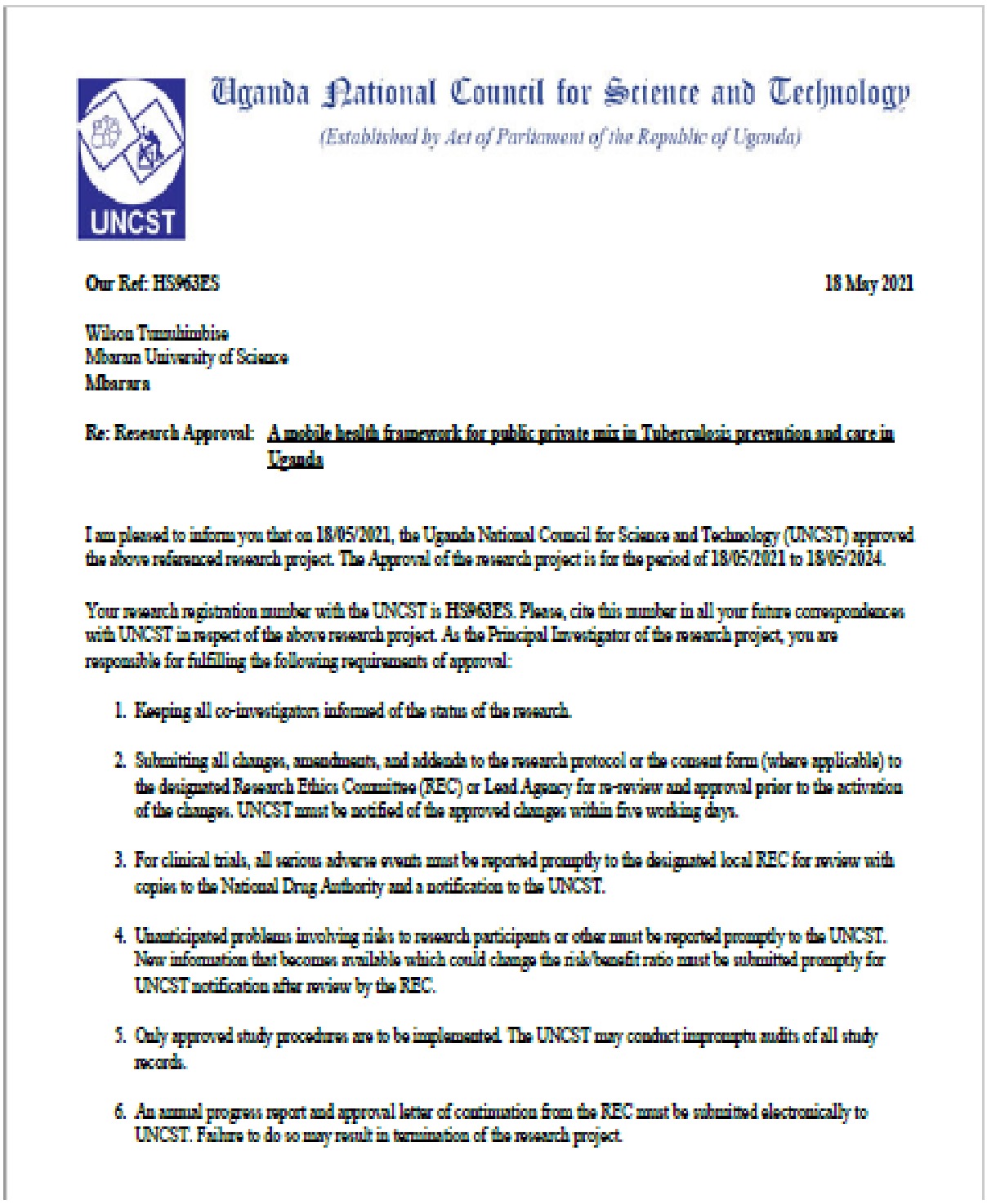
The following is the list of documents approved in the application:

Document	Language	Version
Proposal	English	2
Data Collection Tool	English,	**June 2020**
Consent form	English	**June 2020**

I wish you all the best.

Dr. Francis Bajunirwe
CHAIR,
MUST RESEARCH ETHICS COMMITTEE

Appendix 5: UNCST Approval



Uganda National Council for Science and Technology

(Established by Act of Parliament of the Republic of Uganda)

UNCST

Our Ref: HS963ES 18 May 2021

Wilson Tumuhimbise
Mbarara University of Science
Mbarara

Re: Research Approval: A mobile health framework for public private mix in Tuberculosis prevention and care in Uganda

I am pleased to inform you that on 18/05/2021, the Uganda National Council for Science and Technology (UNCST) approved the above referenced research project. The Approval of the research project is for the period of 18/05/2021 to 18/05/2024.

Your research registration number with the UNCST is HS963ES. Please, cite this number in all your future correspondences with UNCST in respect of the above research project. As the Principal Investigator of the research project, you are responsible for fulfilling the following requirements of approval:

1. Keeping all co-investigators informed of the status of the research.
2. Submitting all changes, amendments, and addenda to the research protocol or the consent form (where applicable) to the designated Research Ethics Committee (REC) or Lead Agency for re-review and approval prior to the activation of the changes. UNCST must be notified of the approved changes within five working days.
3. For clinical trials, all serious adverse events must be reported promptly to the designated local REC for review with copies to the National Drug Authority and a notification to the UNCST.
4. Unanticipated problems involving risks to research participants or other must be reported promptly to the UNCST. New information that becomes available which could change the risk/benefit ratio must be submitted promptly for UNCST notification after review by the REC.
5. Only approved study procedures are to be implemented. The UNCST may conduct impromptu audits of all study records.
6. An annual progress report and approval letter of continuation from the REC must be submitted electronically to UNCST. Failure to do so may result in termination of the research project.

Please note that this approval includes all study related tools submitted as part of the application as shown below:

No.	Document Title	Language	Version Number	Version Date
1	Data Collection tools	English	1	28 September 2020
2	Informed Consent forms	English	1	28 September 2020
3	Project Proposal	English		
4	Approval Letter	English		0000-00-00
5	Administrative Clearance	English		0000-00-00
5	Risk Management Plan (RMP) for the submitted protocol	English	1	04 December 2020

Yours sincerely,

Hellen Opolot
For: Executive Secretary
UGANDA NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

LOCATION/CORRESPONDENCE

Plot 6 Kimera Road, Ntinda
P.O. Box 6884
KAMPALA, UGANDA

COMMUNICATION

TEL: (256) 414 705506
FAX: (256) 414-234579
EMAIL: info@uncst.go.ug
WEBSITE: http://www.uncst.go.ug

Telegrams
Telephones

Dirs' Office: 048521806
Others : 048520007/21086/20024
Dirs mobile: 0772 415875 :
In any correspondence on
This subject please quote ref: No.....

THE RE

Ministry of Health
MBARARA REGIONAL REFERRAL HOSPITAL
P.O.Box 40,
Mbarara - Uganda

August 14, 2020

Mr. Wilson Tumuhimbise
2018/PhD/030/PS
Faculty of Computing and Informatics
Mbarara University of Science and Technology

Re: Approval of Protocol on **"A Mobile Health Framework to Enhance Public-Private Mix for Tuberculosis Prevention and Care in Uganda."**

Mbarara Regional Referral Hospital has received and reviewed your proposal referenced above and hereby grants approval to conduct this study. This approval covers the proposal and the accompanying documents listed below:

- Consent Form (in English and Runyankore)
- Health Care Workers Engagement Survey (Key Informant Survey)
- Interview Guide for Health Care Workers (Key Informant)
- Referred Patients Survey

This approval is subjected to the following conditions:

1. That you will abide by the regulations governing research in the country as set by the Uganda National Council for Science and Technology.
2. That any changes to the protocol and study documents that you may find necessary to make will be reviewed and approved by relevant authorities.
3. That the conduct of your study shall be monitored by the Mbarara Regional Referral Hospital supervisors in the relevant departments/units.
4. That you provide a copy of the final document upon completion of the study, including a summary of the results and any publications to Mbarara Regional Referral Hospital.
5. That you will include Mbarara Regional Referral Hospital in your acknowledgements in all your publications.

My best wishes to you.

MBARARA REGIONAL REFERRAL HOSPITAL
24 AUG 2020
P.O. Box 40, MBARARA
HOSPITAL DIRECTOR

Dr. Barigye Celestine
HOSPITAL DIRECTOR

MAYANJA MEMORIAL HOSPITAL LTD.
Services: "Laboratory, Ultrasound, X-ray, Echocardiography, Mammography, CT Scan, ECG, Contrast Studies, Renal Dialysis Surgical. Primary Health Care and Medical Research"
Plot 175 Masaka Rd.Nyamityobora. P.O. Box 920, Tel.0779219722, 0200923475,0714930500
Mbarara.

26th September 2020

The Executive Secretary

Uganda National Council Of Science and Technology

P.O Box 6884

Kampala, Uganda

Dear Sir

Re: Administrative Clearance for Mr. Tumuhimbise Wilson, 2018/PhD/030/PS to carry out research at Mayanja Memorial Hospital.

This letter serves as a proof of administrative clearance for Mr. Tumuhimbise Wilson a second year PhD student at Mbarara University of Science and Technology- MUST, investigating a study entitled ***"A mobile health framework to enhance public private mix for Tuberculosis prevention and care in Uganda"*** to conduct research at Mayanja Memorial Hospital. His study was cleared by Mbarara University Research Ethics Committee (MUREC) Protocol No: 32/03-20 and we believe the results from his research will be a great contribution to the academic world.

My best wishes to you

Sincerely

ADMINISTRATOR
26 SEP 2020
Mayanja Memorial Hospital Ltd
P.O. Box 920, Mbarara

Mr. Alex Kakama
Hospital Administrator- Mayanja Memorial Hospital,
alexkakama@gmail.com
Tel: 0754889788.

"One can pay back the loan of gold, but one dies forever in debt to those who are kind"

FATHER BASH FOUNDATION (FBF)

P.O.BOX 129

MBARARA

UGANDA

DIVINE MERCY HOSPITAL

TEL. +256 392 850468 Emergency Line +256 706 202282 Ambulance line +256 701 466466
Email: divinemercyhospital2012@yahoo.com, website: www.fatherbashfoundation.com

24th June 2020

The Executive Secretary
UNCST
P.O Box 6884
Kampala, Uganda

Dear Sir,

Re: Administrative Clearance for Mr. Tumuhimbise Wilson, 2018/PhD/030/PS to carry out research at Divine Mercy Hospital

This letter serves as a proof of administrative clearance for Mr. Tumuhimbise Wilson a second year PhD student at Mbarara University of Science and Technology- MUST, investigating a study entitled ***"A mobile health framework to enhance public private mix for Tuberculosis prevention and care in Uganda"*** to conduct research at Divine Mercy Hospital- Father Bash Foundation. His study was cleared by Mbarara University Research Ethics Committee (MUREC) Protocol No: 32/03-20 and we believe the results from his research will be a great contribution to the academic world

My best wishes to you

Sincerely

DIVINE MERCY HOSPITAL FATHER BASH FOUNDATION VERIFIED 24 JUN 2020 P.O. Box 129 Mbarara Uganda Tel. +256 706 202 282

Dr. Mugyenyi Godfrey
Medical Director- Divine Mercy Hospital - Father Bash Foundation
gmugyenyi@must.ac.ug
Mobile Tel: 0772 543238.

RUHARO MISSION HOSPITAL

ANKOLE DIOCESE

P.O.Box 14 MBARARA (U) Tel: Gen: 0485 443999 Ms: 0775 979307, 0382 274052, Email: ruharomission@yahoo.co.uk

OURS
For people with disabilities
'OURS' for people with disabilities
Ankole Diocese
P.O. Box 14,
Mbarara
Uganda
Tel: (256) 0485 420686
Fax: (256) 0485 428818
E-mail: ours@utlonline.co.ug

October 13th, 2020

Mr. Tumuhimbitse Wilson,
Principal Investigator

Dear Wilson,

AUTHORIZATION TO CONDUCT RESEARCH AT RUHARO MISSION HOSPITAL

Christian greetings!

Reference is made to your request to conduct a research titled **'A mobile health framework for public-private mix in tuberculosis prevention and care in Uganda'** at this hospital.

Please be informed that following your interface with the hospital Research and Publications Committee, your study was reviewed and duly approved.

By way of this communication, your research team is therefore granted permission to access the facility and conduct this study as requested.

Sincerely,

RUHARO MISSION HOSPITAL
P.O. Box 14, MBARARA
14 OCT 2020
EXECUTIVE DIRECTOR

Mrs. Nabaasa Stella Busingye
Ag. Medical Superintendent

Copy;

- Chairperson, Research and Publications Committee
- To file

Ruharo Eye Centre
Diocese of Ankole

Prevention and treatment of Blindness' training in Ophthalmology

P.O. Box 14 Mbarara, Uganda
Tel: +256 485 444179
Fax: +256 485 420502
E-mail:ruharo@yahoo.com

HOMELY MEDICAL CENTER (HMC)

"Towards Wholesome Health"

Maternity (OBS/GYN), Surgery, Paediatrics (Child Health), Internal Medicine, Counselling, Admissions, Laboratory, X-Ray/Ultra Sound Scan services

24th June 2020

The Executive Director

Uganda National Council of

Science and Technology

P.O Box 6884

Kampala, Uganda

Dear Sir

Re: Approval of Protocol on a Mobile Health Framework to enhance public private mix for Tuberculosis prevention and care

This letter serves as a proof of administrative clearance for Mr. Tumuhimbise Wilson, a second year PhD student at Mbarara University of Science and Technology- MUST. He is carrying out research on a Mobile Health Framework to enhance public private mix for Tuberculosis prevention and care at Homely Medical Center.

His study was approved by Mbarara University of Science and Technology Research Ethics Committee, Protocol No: 32/03-20. We believe that the results from his research will greatly contribute to the academic world

Looking forward to your much needed support to Wilson Tumuhimbise's application.

Sincerely

Dr. Joseph Ngonzi, PhD

Hospital Director- Homely Medical Center

Email: jngonzi@must.ac.ug, Tel.0703818336