TUBERCULOSIS (TB) SCREENING SYSTEM INTEGRATION WITHIN RWANDA’s RapidSMS HEALTH SYSTEM

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TUBERCULOSIS (TB) SCREENING SYSTEM INTEGRATION WITHIN RWANDA’s RapidSMS HEALTH SYSTEM

A dissertation submitted in partial fulfillment of requirements for the Award of Master of Science in Health Informatics.

In the college of Medicines and Health Sciences

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November, 2016
DECLARATION

I, USABIMANA HONORE, hereby declare that this thesis has been written by me without any external unauthorized help, that it has been neither presented to any institution for evaluation nor previously published in its entirety or in parts. Any parts, words or ideas, of the thesis, however limited, which are quoted from or based on other sources, have been acknowledged as such without exception.

Done on November 2016

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USABIMANA HONORE
SUPERVISOR’S APPROVAL

I, Dr. NIYOYITA Jean Paul, In my capacity as a Supervisor, I do hereby authorize USABIMANA Honore to submit his final thesis.

Issued date:

November 2016

Dr. NIYOYITA Jean Paul
ABSTRACT

Sustainable development of a country is basically built on its healthy population. To provide the worthy healthcare requires a well structured health system, strategies and measures on pandemic, endemic as well as epidemic diseases that are major causes of mortally and morbidity of the community and consequently alienates the socio-economic situation of the country.

Recently, the Maternal and Child Health Integrated Program reinforced by the introduction of mobile health application technology used by community health workers, commonly known as RapidSMS has significantly reduced the prevalence of pregnant women and infant deaths. The RapidSMS-MCH system was customized to allow interactive communication between a community health workers (CHW) following mother-infant pairs in their community with a national centralized database and the health facility and in case of an emergency alert, the ambulance driver. Tuberculosis as the second most common cause of death from infectious disease after HIV, with several absolute new cases of infection in the community, should be addressed the same way with much effort as furnished in preventing maternal and child deaths with the use of mHealth system to early report critical cases for emergency healthcare.

People living with HIV, young children, elderly people, people with diabetes, and other groups who have compromised immune systems face a high risk of poor outcomes from TB treatment, including relapse and death. Treating only one group of patients looks inexpensive in the short run, but will prove disastrous for all in the long run. Despite measures and procedures used for TB screening, the disease still killing the population. However, there is a need of an effective and active screening system to help community health workers to immediately report the TB cases early screened positive at community level for rapid repost from hospital or health facility level.

This research aims at designing a mHealth system to be integrated within an existing RapidSMS-MCH system as new tool for fast and mobile based systematic TB screening system at community level. This will help to avoid delays for TB suspected cases and reducing bottlenecks in communication associated with other TB cases like pregnant women and children; and document challenges.
RESUME

Le développement durable d’un pays est essentiellement basé sur la population saine. Pour se procurer d’une santé saine, il faut un système de santé bien faite, des stratégies et des mesures propres aux maladies endémiques, épidémiques que des maladies pandémiques. Ces dernières étant des agents dangereux de la mortalité et la morbidité de la population. Part conséquent, ceci handicape le rythme du développement du pays d’une façon sociale que économique.

Très récemment, le programme PECIME renforcée par l’utilisation du Logiciel dans le téléphone portable actuellement utilisée par les Agents de la Santé Communautaire, communément connu sous le nom de RapidSMS a vraiment contribué d’une façon impéccable aux taux des prévalences des mortalités chez les femmes enceintes que chez les enfants surtout les nouveau-nés.

Le système RapidSMS-MCH a été conçu et destiné pour faciliter la correspondance entre les Agents de la Santé Communautaire qui surtout suivent de près la vie des nouveau-nés et celle de leurs mères. Ce system est base sur le database qui amagazine toutes les informations venant d’ici et là et qui a pour objectif, alerter tous les concernées s’il ya un problème sérieux au niveau de la communauté. Et le Centre de Santé ou l’hôpital réagira immédiatement par l’envoi d’un ambulance enfin de sauver cet humanité. Les mesures les plus farouches d’arrêter la propagation de la contamination du Tuberculose devraient être prise en considération comme tuberculose étant la deuxième cause majeur de mort après le SIDA. Ici, nous citerons l’utilisation des nouvelles technologies comme mHealth qui facilite le rapportage a temps des cas des maladies épidémiques retrouvées dans la communauté et enfin y remédier un traitement adéquate.

Les personnes vivant avec le HIV/SIDA, les enfants jeunes, la vieille population, la population avec diabète ainsi que d’autres groupe à haut risque qui ont subit une altération de leur système immunitaire, sont les plus exposées à la contamination de la Tuberculose ce qui leur mène à la mort. La gestion d’un groupe des malades semble être moins couteux pour le début, mais cela engagera un pris désastreux à la longue. Quelques soient les mesures prises, pour faire le Screening de la Tuberculose, la Maladie reste là toujours entrer de tuer les gens jour au jour.
Cependant, il semble qu’il y aurait besoin d’un Système qui pourrait efficacement aider les Agent de Santé Communautaires et le Système de Santé en général à détecter très tôt, les cas soupçonner d’avoir attrapé cette maladie pour faire un riposte rapide en faveur de cette population.

C’est pour ce que cet étude est en cours et propose une introduction d’un système électronique et automatique de Screening dans le Système RapidSMS préexistant pour enfin faciliter les Agent de Santé Communautaire sans pour autant perdre le temps ni tarder à rapporter tout cas soupçonner de TB.
DEDICATION

To my parent;

To my beloved wife to be,

To all our family members and colleagues;

Lecturers and classmates.
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Obviously; special acknowledgements are addressed to the Almighty and Powerful God for keeping us alive all along this period of research that has been carried out within almost three months. This dissertation was made possible through different support of many persons to whom I would like to express my special gratitude.

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This dissertation is a result of material and moral support of my family members, especially my brother and relatives, their contributions remain priceless.

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USABIMANA HONORE
# TABLE OF CONTENTS

DECLARATION ........................................................................................................................................... i
SUPERVISOR’S APPROVAL ...................................................................................................................... ii
ABSTRACT .................................................................................................................................................... iii
RESUME ....................................................................................................................................................... iv
DEDICATION .................................................................................................................................................. vi
ACKNOWLEDGEMENT ................................................................................................................................. vii
TABLE OF CONTENTS ................................................................................................................................. viii
LIST OF SYMBOLS AND ABBREVIATIONS/ACRONYMS ................................................................. xii
LIST OF TABLES .......................................................................................................................................... xiii
LIST OF FIGURES .......................................................................................................................................... xiv

CHAPTER 1. INTRODUCTION ......................................................................................................................... 1

1.1 Definition of key terms ............................................................................................................................ 1

1.2. Background to the study ....................................................................................................................... 2

1.3. Problem statement ................................................................................................................................. 3

1.4. Project objectives ................................................................................................................................. 6

1.4.1. Main objective .................................................................................................................................. 6

1.4.2 Specific objectives ............................................................................................................................ 6

1.5. Research questions ............................................................................................................................. 6

1.6. Research hypotheses ............................................................................................................................ 6

1.7. Significance of the project ................................................................................................................... 7

1.8. Subdivision of the dissertation ........................................................................................................... 8

CHAPTER 2: LITERATURE REVIEW ............................................................................................................. 10

2.1 Introduction ........................................................................................................................................... 10

2.2. TB Propagation risk factors ............................................................................................................... 10
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3. MDR-TB causes and factors</td>
<td>12</td>
</tr>
<tr>
<td>2.4. Tuberculosis Screening</td>
<td>12</td>
</tr>
<tr>
<td>2.4.1 Passive tuberculosis case-finding</td>
<td>12</td>
</tr>
<tr>
<td>2.4.2 Active tuberculosis case-finding</td>
<td>13</td>
</tr>
<tr>
<td>2.5 TB Screening within a Community</td>
<td>13</td>
</tr>
<tr>
<td>2.6 Functional TB Screening framework in Rwanda</td>
<td>14</td>
</tr>
<tr>
<td>2.7 The use of Information Technology in Healthcare Management</td>
<td>16</td>
</tr>
<tr>
<td>2.7.1 Electronic Health Records (EHR)</td>
<td>16</td>
</tr>
<tr>
<td>2.7.2 Electronic Medical Record (EMR)</td>
<td>17</td>
</tr>
<tr>
<td>2.7.3 mHealth</td>
<td>18</td>
</tr>
<tr>
<td>2.9 The Community-Based mHealth Application: RapidSMS</td>
<td>19</td>
</tr>
<tr>
<td>2.9.1 Mobile applications interoperability and Functional Model of SMS System</td>
<td>19</td>
</tr>
<tr>
<td>2.9.2 Conceptual Design of RapidSMS</td>
<td>23</td>
</tr>
<tr>
<td>2.9.3 RapidSMS Platform in Maternal and Childhood Program</td>
<td>24</td>
</tr>
<tr>
<td>2.9.4 The contribution of RapidSMS to the Healthcare for Rwanda's Health System</td>
<td>24</td>
</tr>
<tr>
<td>2.9.5 The effect of RapidSMS to the Community Health Workers (CHWs) attributions</td>
<td>25</td>
</tr>
<tr>
<td>2.10 Current TB Recording and Reporting System within Rwanda's Health System</td>
<td>25</td>
</tr>
<tr>
<td>2.10.1 Recording system</td>
<td>26</td>
</tr>
<tr>
<td>2.10.2 Routine Reporting System</td>
<td>26</td>
</tr>
<tr>
<td>2.11 TB Screening System integration within Rwanda’s RapidSMS Health System</td>
<td>27</td>
</tr>
<tr>
<td>CHAPTER 3. METHODOLOGY</td>
<td>29</td>
</tr>
<tr>
<td>3.1. Introduction</td>
<td>29</td>
</tr>
<tr>
<td>3.2 Study area</td>
<td>29</td>
</tr>
<tr>
<td>3.3 Study design</td>
<td>29</td>
</tr>
<tr>
<td>3.4 Study population</td>
<td>30</td>
</tr>
</tbody>
</table>
3.5 Sample size and sampling strategy .............................................................................. 31
3.6 Inclusion criteria ........................................................................................................ 32
3.7 Exclusion criteria ....................................................................................................... 32
3.8 Data collection methods and procedures used .......................................................... 33
  3.8.1 Data collection methods ....................................................................................... 33
  3.8.2 Data collection procedures .................................................................................. 33
3.9 Data analysis .............................................................................................................. 34
3.10 Problems and limitations of the study ...................................................................... 34
3.11 Ethical consideration ............................................................................................... 34
CHAPTER 4: IMPLEMENTATION OF THE PROPOSED SYSTEM ......................................... 36
  4.1 Description of the proposed system ......................................................................... 36
  4.2 Relevance of the proposed system .......................................................................... 36
  4.3 RapidSMS-TbSS as proposed solution .................................................................... 36
    4.3.1 Relevance of the solution .................................................................................. 37
    4.3.2 Evaluation of the proposed solution .................................................................. 37
    4.3.3 Feasibility study ................................................................................................ 37
      4.3.3.1 Technical feasibility (Interoperability with Classic RapidSMS) .................... 37
      4.3.3.2 Operational/ Usability ................................................................................. 37
  4.4 Financial .................................................................................................................. 39
  4.5 Conceptual system design ....................................................................................... 39
  4.4 Integration within existing RapidSMS ..................................................................... 40
  4.5 Conception .............................................................................................................. 41
    4.5.1 Implementation of TB Screening system ......................................................... 41
    4.5.2 System accessibility ......................................................................................... 44
CHAPTER 5: RESEARCH FINDINGS AND DISCUSSION ..................................................... 51
5.1 Introduction .................................................................................................................. 51
5.2 Identification of respondents ..................................................................................... 51
  5.2.1 Age of respondents ............................................................................................... 51
  5.2.2 Sex and categories of respondents ........................................................................ 52
  5.2.3 Respondents’ level of education ........................................................................... 53
5.3 Awareness of the importance of TB Screening at Community level ....................... 54
5.4 Respondents’ views on the use of Mobile Technology in TB Screening ............... 55
5.7 Views of respondents about TB screening integration within Rwanda’s RapidSMS ....... 56
CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS .............................................. 58
  6.1 Conclusion .................................................................................................................. 58
  6.2 Recommendations ..................................................................................................... 59
    6.2.1 Recommendations on TBSS development and future work ............................. 59
    6.2.2 Recommendations for future beneficial use of the findings from this study ....... 59
REFERENCES ..................................................................................................................... 60
APPENDICES ..................................................................................................................... 62
LIST OF SYMBOLS AND ABBREVIATIONS/ACRONYMS

AIDS : Acquire Immuno Deficiency Syndrome
CHW : Community Health Worker
CDT : Centre de Diagnostic et Traitemen
DHIS2 : District Health Information System
DOTS : Direct Observed Treatment, Short-Course
EMR : Electronic Medical Records
HMIS : Health Management Information System
HI : Health Informatics
HIV/AIDS : Human Immune Virus/ Acquire Immuno Deficiency Syndrome
MCH : Maternal and Child Health
MCHIP : Maternal and Child Health Integrated Program
MoH : Ministry of Health
MDR-TB : Multi-Drug Resistance Tuberculosis
mHealth : Mobile Health
OpenMRS : Open Medical Records System
PLHIV : People Living with HIV
PDA : Personal Digital Assistant
RapidSMS : Rapid Short Message Service
SMS : Short Message Service
TB : Tuberculosis
WHO : World Health Organization
LIST OF TABLES

Table 1. Distribution of sample size and sampling strategies.......................................................... 31
Table 2. Category of respondents according to their age................................................................. 52
Table 3. Identification of respondents by sex and group .................................................................. 53
Table 4: Identification of respondents according to their level of education ................................. 54
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.</td>
<td>Routine TB Screening Flow Chart in Pre-Initial: Follow-Up for Positive TB Symptom Screen</td>
<td>14</td>
</tr>
<tr>
<td>Figure 2.</td>
<td>TB Screening framework for improved cases detection in Rwanda</td>
<td>15</td>
</tr>
<tr>
<td>Figure 3.</td>
<td>Algorithm for TB screening for ambulatory people living with HIV</td>
<td>15</td>
</tr>
<tr>
<td>Figure 4.</td>
<td>EMR and EHR Environments</td>
<td>17</td>
</tr>
<tr>
<td>Figure 5.</td>
<td>Mobile applications and functions</td>
<td>21</td>
</tr>
<tr>
<td>Figure 6.</td>
<td>Functional Model of SMS System algorithm</td>
<td>22</td>
</tr>
<tr>
<td>Figure 7.</td>
<td>Conceptual Design of the proposed TB Screening System (RapidSMS-TbSS)</td>
<td>40</td>
</tr>
<tr>
<td>Figure 8.</td>
<td>TBB Database relationship</td>
<td>45</td>
</tr>
<tr>
<td>Figure 9.</td>
<td>Login webpage (TBSS entry of users to all levels)</td>
<td>45</td>
</tr>
<tr>
<td>Figure 10.</td>
<td>Creating a user</td>
<td>46</td>
</tr>
<tr>
<td>Figure 11.</td>
<td>CWH Reported cases</td>
<td>46</td>
</tr>
<tr>
<td>Figure 12.</td>
<td>TBSS PHP Codes</td>
<td>46</td>
</tr>
<tr>
<td>Figure 13.</td>
<td>TBSS Data tables</td>
<td>47</td>
</tr>
<tr>
<td>Figure 14.</td>
<td>Users administration at MoH Level</td>
<td>48</td>
</tr>
<tr>
<td>Figure 15.</td>
<td>CHW Database Report at MoH Level</td>
<td>49</td>
</tr>
<tr>
<td>Figure 16.</td>
<td>TBSS SMS Format</td>
<td>49</td>
</tr>
<tr>
<td>Figure 17.</td>
<td>TBSS Dashboard (compiled report)</td>
<td>49</td>
</tr>
</tbody>
</table>
CHAPTER 1. INTRODUCTION

This chapter deals with essential background information of the research topic, describes the aim and objectives of the study, illustrates the research methods to be used, describes the selection of study population, study procedures, ethical considerations, highlights elements of logistics to carry out this research and finally references of authors who wrote on similar topic as well as appendices like additional tools to conduct present research.

1.1 Definition of key terms

**Tuberculosis:** is an infectious bacterial disease caused by Mycobacterium tuberculosis, which most commonly affects the lungs. It is transmitted from person to person via droplets from the throat and lungs of people with the active respiratory disease (WHO, 2015).

**Screening:** is a strategy used in a population to identify the possible presence of an as-yet-undiagnosed disease in individuals without signs or symptoms. This can include individuals with pre-symptomatic or unrecognized symptomatic disease. As such, screening tests are somewhat unique in that they are performed on persons apparently in good health (eMedicine, 2015).

**Integration:** the computation of a definite integral, a fundamental concept of calculus, which allows, among many other uses, computing areas and averaging continuous functions.

**RapidSMS:** is a free and open-source framework for dynamic data collection, logistics coordination and communication, leveraging basic short message service (SMS) mobile phone technology. RapidSMS is easily customized to meet the specific needs of the project and is scalable at an enterprise level (UNICEF, 2013).

**mHealth:** is an abbreviation for mobile health, a term used for the practice of medicine and public health supported by mobile devices. The term is most commonly used in reference to using mobile communication devices, such as mobile phones, tablet computers and PDAs, for health services and information, but also to affect emotional states (Sasan, 2015).

**System:** is a set of interacting or interdependent component parts forming a complex/intricate whole. Every system is delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose and expressed in its functioning (Backlund, 2000).
1.2. Background to the study
The global prevalence of TB and death rates from the disease are steadily declining. The scaling up of high-quality diagnosis and treatment of TB have greatly contributed to these reductions by improving cure rates and reducing case–fatality rates. Still, in 2011, 8.7 million people developed TB and 1.4 million people died from the disease. Moreover, the estimated global incidence of TB is declining slowly, by less than 2% per year. To reach the TB elimination target of less than 1 case/1,000,000 population in 2050, the incidence needs to decline by 20% per year (WHO, 2013).

Missed diagnoses or delayed diagnoses, and problems with access to high-quality care lead to a higher risk of death, suffering, sequelae and catastrophic financial consequences. These missed opportunities also lead to a longer duration of infectiousness for individuals, and thus sustain transmission, especially where population density is high and where living and working conditions are poor, including conditions that are overcrowded and have inadequate ventilation (WHO, 2013).

Detection of TB among PLHIV continues to pose a significant barrier to care and treatment. In recent years, systematic screening for HIV has been promoted for newly diagnosed TB patients (97.4% in 2009), while TB screening among PLHIV has remained low. Rwanda aims for TB screening to be routine for newly enrolled HIV patients and patients already enrolled in HIV care. In order to develop more effective strategies for TB case detection, care, and treatment among PLHIV, it is important to identify the existing gaps and challenges to TB screening (UNAIDS, 2011).

Apart from TB screening problem among PLHIV, it is likely the same to the rest of community and this causes quick propagation of tuberculosis which leads to tremendous deaths especially to vulnerable groups i.e. old population, children and pregnant women. Formal and mobile based systematic TB screening at community level is a big problem, despite the well structured Community Health Workers system from national level to the community level (UNAIDS, 2011).

The Ministry of Health (MOH) of Rwanda has made remarkable gains in maternal and child health. The maternal mortality ratio has been reduced from one of the world’s highest in 2005 at
750 deaths per 100,000 live births down to 487 in 2010, and the under-5 mortality rate has been reduced by half during the same period. To achieve these results, national policy has focused on improving community-level health care through community health workers (CHWs). Approximately 45,000 CHWs have received training in how to monitor and promote maternal and newborn health, identify potential risks and promote antenatal care at health-care facilities. However, these CHWs often work in remote areas, without communication tools (MoH, 2011).

To strengthen community-level and facility-based maternal and child health interventions, the Rwanda MOH, in partnership with UNICEF, has launched an mHealth system – comprising RapidSMS and mUbuzima – to track pregnant women and newborns, promote early detection of life-threatening emergencies, and facilitate reporting on community-level indicators relevant to Millennium Development Goals 4 and 5 (Rwanda MoH, 2011).

This shows clearly that the well trained community health workers with adequate materials can largely contribute at maximum to the mobile based systematic TB screening at community level where this scourge is still disseminated.

The approach of integrating the TB screening system to the successful existing one i.e RapidSMS used by community health workers should revert to success considering the fact that there will be only an addendum to the pre-existing system which was already in use. Only the mobile application might be improved with TB Screening system. However, at central level there will be a particular server dedicated to store data and communicate hierarchically with those in charge of TB at all level.

1.3. **Problem statement**

Globally, tuberculosis (TB) is a leading cause of death and a major public-health problem. Despite dramatic improvements made since the 1990s in providing access to high-quality TB services, many people with TB remain undiagnosed or are diagnosed only after long delays. The high burden of undiagnosed TB causes much suffering and economic hardship, and sustains transmission (WHO, 2012: 4).

During the past few years screening has been implemented in high-burden countries that are striving to close the case-detection gap and reduce the delays in diagnosis that remain a challenge despite scaling up and decentralizing diagnostic and treatment services. The results in
these high-burden countries have been mixed, and there are several outstanding questions about
the pros and cons of screening (Murray, 2012: 34).

However, Tuberculosis remains a significant cause of morbidity and mortality worldwide. In
2008, an estimated 8.9 to 9.9 million new cases and 1.7 million deaths were reported globally. In
Ireland, the incidence of TB has fallen significantly from a high of 230 notifications per 100,000
populations in 1952 when records first began to a low of 9.7 per 100,000 in 2001. The incidence
has remained relatively stable since then with a rate of 11.3 per 100,000 in 2007 and an
incidence rate of 8.0/100,000 in the indigenous Irish population in 2007 (WHO, 2004: 41).

The HIV epidemic has had a significant impact on TB rates globally as individuals with TB and
HIV infection are more likely to develop active TB disease during their lifetime than those who
are HIV negative. Drug resistance, including multidrug-resistant TB and extensively drug-
resistant TB together with the increasing number of TB-HIV co-infected patients is also
challenging TB control. The World Health Organization proposes to reduce the global incidence
of active TB to less than 1 case per million populations by 2050 and thus eliminate TB as a
global public health problem. This offers a challenge to improve TB control in Ireland (WHO,
2012: 11).

Systematic screening for active TB which is the systematic identification of people with
suspected active TB, in a predetermined target group, using tests, examinations or other
procedures that can be applied rapidly to remedy the situation. The screening tests, examinations
or other procedures should efficiently distinguish people with a high probability of having active
TB from those who are unlikely to have active TB. Among those whose screening is positive, the
diagnosis needs to be established by one or several diagnostic tests and additional clinical
assessments, which together have high accuracy (Lozano, 2012: 4).

The burden of undetected TB is high in many settings, especially in some risk groups. The delay
in diagnosing TB and initiating appropriate treatment is often long, especially in groups with
poor access to health care. Many people with active TB do not experience typical TB symptoms
in the early stages of the disease. These individuals are unlikely to seek care early, and may not
be properly diagnosed when seeking care. Passive case-finding therefore leads to missed or
delayed diagnoses for many people. Appropriately diagnosing and treating TB dramatically
Improves health outcomes when compared with not diagnosing and treating the disease. These observations together constitute indirect evidence that screening for active TB in selected risk groups should benefit individuals and public health (Lozano, 2012: 17).

However, while the systematic reviews show that there is some evidence that screening can improve the early detection of TB, the direct evidence remains weak for the impact of screening on health outcomes and TB transmission when compared with passive case-finding alone. Furthermore, data are lacking on the cost effectiveness of screening compared with other interventions to improve early detection, and it is clear that indiscriminate screening can require a lot of resources (MoH, 2013: 17).

Implementation of the national TB/HIV policy and guidelines has resulted in a nation-wide increase in HIV counseling and testing of TB patients from 46% in 2004 to 81% by the third quarter of 2006. In that quarter, 49% of HIV-infected TB patients had initiated cotrimoxazole preventive therapy and 34% were receiving antiretroviral (Greet, 2012).

In recent years, systematic screening for HIV has been promoted for newly diagnosed TB patients (97.4% in 2009), while TB screening among PLHIV has remained low. In 2008, 1,558 HIV patients were diagnosed with TB and received treatment for TB and HIV. This data suggests that only about 9% of the estimated 13,000 HIV-positive incident TB cases received treatment for TB and HIV. The National TB Program has recognized the need to improve TB case detection in order to reduce the number of HIV-positive people dying from TB (UNAIDS, 2011).

According to the World Health Organization (WHO), TB is second only to HIV/AIDS as the greatest killer worldwide. For instance, in 2013, 9 million people fell ill with TB and 1.5 million died from the disease, and over 95% of them (deaths) occur in low- and middle-income countries, and it is among the top 5 causes of death for women aged 15 to 44. The statistics add that an estimated 550,000 children became ill with TB and 80,000 HIV-negative children died of TB in the same year. And it is the leading killer of HIV-positive people causing one fourth of all HIV-related deaths. The report adds that in the same year, an estimated 480,000 people developed multidrug resistant TB (MDR-TB).
Incidence of tuberculosis (per 100,000 people) in Rwanda was last measured at 69 in 2013, according to the World Bank. Incidence of tuberculosis is the estimated number of new pulmonary, smear positive, and extra-pulmonary tuberculosis cases (http://www.tradingeconomics.com accessed on 18th April 2016).

1.4. Project objectives
The undertaken research is conceived with the following aim and objectives:

1.4.1. Main objective
The overall core objective of this study is to elaborate a conceptual design of TB Screening System (TB-SS) and its integration within RapidSMS existing system to streamline and fasten the TB screening at community level.

1.4.2 Specific objectives
- To evaluate the effectiveness and efficiency of RapidSMS reporting system used by community health workers at community level.
- To innovate an SMS based conceptual design for TB screening reporting system at community level.
- To elaborate an integrated conceptual design of proposed TB Screening System within existing Rapid SMS reporting system.

1.5. Research questions

1. Why the informal and non-systematic ineffective TB screening at community level may be one of the main causes of endless tuberculosis propagation and resistance?

2. How can an integrated TB screening system within Rwanda's RapidSMS reporting system contribute to the reduction of Tuberculosis (TB) new cases and Multi-Drugs Resistance-Tuberculosis in the community?

1.6. Research hypotheses
To answer these research questions, the following anticipated answers have been proposed and ought to be verified based on the results of this research:
1. The lack of formal and effective mobile based systematic TB screening at community level is one of the major causes of endless TB propagation and resistance because of population’s agglomerated dwelling place, easy TB contamination mode, delayed and inaccurate screening and population’s ignorance.

2. Integrated TB screening system within Rwanda's RapidSMS reporting system can greatly contribute to the reduction of TB new cases and MDR-TB by insuring early detection of new TB cases, ease of screening system, screening data management, and immediate intervention from health facilities and increase of efficient usability due to existing system.

1.7. Significance of the project
The project aims at designing a TB screening system to be integrated within an SMS based community health workers' tool that greatly impacted on the improvements of population's health. So, as it might conform to this in order to overcome the TB propagation within community by providing the very early TB detection using SMS reporting and alerts on the suspected screened cases find within community by community health workers.

Detecting TB cases only from among persons presenting themselves to health facilities with suggestive symptoms has until recently been the principal approach to case-finding. But the remaining case-detection gap, particularly in certain vulnerable populations in the community, along with the persistence of delays in diagnosis and the accompanying continued transmission in the community, highlight the need for a more active approach to detect TB early, hence the need to consider systematic screening for active TB in selected risk groups (WHO, 2012).

Actually, the design process is very important to the usability and understandability of the system (Zhu, 2005). Design allows not only finding out how the RapidSMS-TbSS is going to look like, but also allows both software owners and developers to realize how it's going to function (Fielding, 2000).

A conceptual design of RapidSMS-TbSS to automated TB screening might assist in the development and implementation of the tool which ought result into the measurement and report on adherence rate to TB therapy, contribute to the solving of problems of data quality and workload. It must also strive to check the errors, inconsistencies in medical records and timely
access to historical records on adherence to therapy all of which had impact on planning and decision-making (WHO, 2012b).

1.8. Subdivision of the dissertation
The dissertation is mainly divided into the following chapters:

- **Chapter 1: Introduction**
The general introduction contains key terms used in the context of the present study and describes the usability and healthcare improvements drawn by the RapidSMS existing system, highlights challenges of TB Screening at community level that community health workers and health professionals are facing and suggests the feasibility of an integration of TB Screening systematic system within an existing Rwanda’s RapidSMS.

- **Chapter 2: Literature review**
The second chapter dedicated to literature review provides details on tuberculosis theories, its propagation factors within a community, TB screening existing routinely system and its functional framework in Rwanda. It presents details on the importance of the use of Information Technology in healthcare management.

  In this chapter, a review on existing Health IT tools now useful, especially the progress the RapidSMS has brought in Maternal and Childhood healthcare. In addition, the chapter proposes the integration of TB Screening System within RapidSMS to enable an early detection of TB cases within community and stop the TB propagation and MTDR cases. It presents its functional conceptual framework and the key features of the entire integrated system.

- **Chapter 3: Methodology**
This chapter describes the approaches used for and techniques used for the conceptual design of an integrated TB Screening system within Rwanda’s RapidSMS health system.

- **Chapter 4: Results**
The chapter four presents findings from the informants, showing benefits and contribution that can bear an integrated TB Screening system within Rwanda’s RapidSMS health system. This chapter demonstrates features of the conceptual design for the proposed integrated system.
Chapter 5: Discussions
In the chapter five, results are discussed comparing them with currently used standards and with similar findings from other studies. It states the implications of the outcome of the comparison of the results with the established standards or earlier findings on the use of information technology in TB screening and explains how the results fit in with existing knowledge on the present study.

Chapter 6: Conclusions and recommendations
The last chapter of the present study provides conclusions based on dissertations findings compared to the research questions and provide key recommendations for further work to improve or develop and implement the TB screening system integration within Rwanda’s RapidSMS health system.
CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The second chapter addresses a wide discussion of various scientific views and techniques to evaluate the existing nowadays TB screening system, its strengths and weaknesses that justifies the continuous TB propagation within our community. The same chapter talks about the use of IT in healthcare management where some of IT tools like RapidSMS dramatically improved the healthcare system and evaluates the feasibility integration of TB screening within Rwanda’s RapidSMS, to harmonize and systematize the TB screening in the community. We demonstrate the relationship between variables based on literature and hypothesized ideas for our topic.

2.2. TB Propagation risk factors

The risk of progression from exposure to the tuberculosis bacilli to the development of active disease is a two-stage process governed by both exogenous and endogenous risk factors. Exogenous factors play a key role in accentuating the progression from exposure to infection among which the bacillary load in the sputum and the proximity of an individual to an infectious TB case are key factors (Padmanesan et al., 2013).

Most of TB cases and deaths in the world occur in poor countries. Increase of TB incidence has been observed in developed countries as well. In industrialized countries, more than 80% of individuals infected with *M.tuberculosis* are over the age of 50. By contrast, in the developing world, over 75% of TB cases are found in individuals below the age of 50, the most economically productive age group (Olga, 2001).

During the past 4 decades national TB control programs have failed to reduce TB transmission. Health policies in most low and middle-income countries have not given priority to TB control. Inadequately funded programs have led to an increase in the pool of chronic infectious sources. The overwhelming problem with the treatment of TB is that cure takes months of treatment. The great majority of TB patients in the world have poor health care facilities. Therefore, patients do not complete their treatment. Premature stop of the treatment for TB results in relapse and the emergence of drug resistance.
Demographic factors have played a major role in the global reemergence of TB. Childhood mortality rates have declined much more rapidly than birth rates over the past 30 years, resulting in dramatic increase in the size of adolescents and young adult population in the world. The highest incidence of TB across the world are in central Africa and Southern Asia, particularly in India, where the population increase is known to be the most rapid. Current annual population growth in these countries is about 100 million, which means that global TB incidence in absolute numbers will continue to increase by around 100,000 cases every year (Toungoussova, 2001).

Factors associated with the resurgence of TB in many countries include HIV epidemic. It is known that co-infection with HIV increases the risk of TB infection developing into disease by a 100 fold. In countries with high TB prevalence, HIV infection is the most important factor making a person liable to get clinical TB. Among people already infected with TB their life time risk of clinical TB is about 50% if they have been infected with HIV. This compares with a 5-10% risk if they are HIV negative. In addition, HIV infection elevates the risk of rapid progression from primary infection to the disease. HIV infection has led to increase of TB incidence especially in young and middle-aged adults and it has also caused sharp increase in TB case fatality rates particularly in the absence of effective case management. Social and economic trends have also contributed to the spread of TB (Olga, 2001).

Population movement in the form of migration of labor, general migration, armed conflicts and refugee movement is more common to take place nowadays than at any other time in history. It facilitates the increase of TB transmission. In recent years, TB has become confined to definable population groups, such as disadvantaged populations, immigrants from countries with a high prevalence of TB, refugees, displaced, the elderly, homeless, substance abusers, persons in correctional facilities and nursing homes. A high incidence of the disease in these groups is not unexpected because the rates of TB are higher in lower socio-economic groups. Poverty leads to bad and overcrowded housing or poor work conditions. These may lower defenses as well as making infection more likely. People living in these conditions are often badly nourished, suffer from alcohol abuse or drug addiction. The whole complex of poverty makes it easier for the M. tuberculosis to cause the disease (Toungoussova, 2001).
2.3. MDR-TB causes and factors

Multidrug-resistant tuberculosis (MDR-TB) caused by Mycobacterium tuberculosis resistant to both isoniazid and rifampicin with or without resistance to other drugs is among the most worrisome elements of the pandemic of antibiotic resistance. Globally, about three per cent of all newly diagnosed patients have MDR-TB. The proportion is higher in patients who have previously received anti-tuberculosis treatment reflecting the failure of programs designed to ensure complete cure of patients with tuberculosis. While host genetic factors may probably contribute, incomplete and inadequate treatment is the most important factor leading to the development of MDR-TB (Sharma, 2004).

2.4. Tuberculosis Screening

A successful tuberculosis (TB) control program should be able to answer three key questions: what proportion of cases has been identified? How quickly have cases been identified? And what proportion of patients has successfully completed treatment? Case-finding in most TB programs is less than the global target of 70%. In the developing world, many people with TB live and die without the disease ever being diagnosed, or face delay in diagnosis and treatment. Studies from sub-Saharan Africa have reported delays in case-finding ranging from 50 to 180 days. Early detection is key in reducing the duration of infectivity and thus the transmission of bacilli. Intensified case-finding among household members of infectious TB cases is an effective approach (Estefanos, 2006).

2.4.1 Passive tuberculosis case-finding

It is a patient-initiated pathway to TB diagnosis involving: (1) a person with active TB experiencing symptoms that he or she recognizes as serious; (2) the person having access to and seeking care, and presenting spontaneously at an appropriate health facility; (3) a health worker correctly assessing that the person fulfils the criteria for suspected TB; and (4) the successful use of a diagnostic algorithm with sufficient sensitivity and specificity to diagnose TB. Passive case-finding may involve an element of systematic screening if the identification of people with suspected TB is done systematically for all people seeking care in a health facility or clinic (WHO, 2013).
2.4.2 Active tuberculosis case-finding

Active case-finding is synonymous with systematic screening for active TB, although it normally implies screening that is implemented outside of health facilities. There is also growing evidence that a significant number of new TB cases in Africa result from recent transmission and casual contact. This approach is used in household contacts of smear-positive pulmonary TB (PTB) cases. However, an ‘active case finding’ strategy in individual households of smear-positive TB cases might allow earlier diagnosis of TB and thus facilitate decisions for either anti-tuberculosis treatment or preventive therapy. This ‘active’ approach may reduce TB transmission as well as morbidity and mortality among individual patients (Zachariah, 2015).

2.5 TB Screening within a Community

TB case-finding may be passive or active. Passive case-finding requires that affected individuals are aware of their symptoms, have access to health facilities, and are evaluated by health workers or volunteers who recognize the symptoms of TB and who have access to a reliable laboratory. Patients with symptoms compatible with TB are usually identified in health facilities, and all health workers and volunteers should be aware of the symptoms of TB, and how to proceed if TB is suspected. Health workers should also be aware of the circumstances in which a patient must be assessed for potentially drug-resistant TB (WHO, 2014).

Early detection is key in reducing the duration of infectivity and thus the transmission of bacilli. Intensified case finding among household members of infectious TB cases is an effective approach. However, in areas with high TB incidence, the principal source of infection may be contacts outside the household, thus a broader perspective is needed to improve case-finding in such communities (Shargie, 2006).

Community outreach workers are needed to deliver directly observed TB therapy, thereby ensuring continuity and completion of treatment. The recent increases in TB morbidity have placed additional demands on state and local TB control programs, which already had been substantially weakened by inadequate staffing and funding support (CDC, 1995).
Figure 1. Routine TB Screening Flow Chart in Pre-Initial: Follow-Up for Positive TB Symptom Screen

Source: Policy and Procedures for Tuberculosis Screening of Health-Care Workers, 2004

2.6 Functional TB Screening framework in Rwanda

Accurate, timely diagnosis is the backbone of a sound national TB control program. Drug-resistant TB must be diagnosed correctly before it can be treated effectively. Case-finding strategies may vary depending on the epidemiological situation and local capacity (WHO, 2008). Thus, Rwanda is close to achieving the WHO target for treatment success, but is below the target for case detection. Concerted efforts are being made to ensure that effective smear microscopy and directly-observed therapy are available nationwide. Further efforts are needed to reach the goals, especially for case detection. A recent national survey showing that the prevalence of multidrug resistance among new TB patients is 3.9% gives cause for concern (Gasana et al., 2000).
Figure 2. TB Screening framework for improved cases detection in Rwanda

Source: Strategy for TB high risk and vulnerable populations, Nikishiori 2011

Figure 3. Algorithm for TB screening for ambulatory people living with HIV

Source: A revised framework to address TB-HIV co-infection. WHO, 2006
2.7 The use of Information Technology in Healthcare Management

Technology is a crucial ingredient of health care. Indeed, all health care consists of either human interaction, the application of technology, or, most commonly, both. Consideration of technology is important in any examination of the organization and functioning of health care services and systems for many reasons: Technology is a major component of current health care costs and perhaps the key driver of future cost. Major regulatory frameworks and institutions exist solely to manage the introduction and use of safe, effective and efficient technology in health care (Michael, 2000).

Information systems (IS) have much to offer in managing healthcare costs and in improving the quality of care, the embedded role of information technology (IT) in clinical and diagnostics equipment seem to uniquely positioned to capture, store, process, and communicate timely information to decision makers for better coordination of healthcare at both the individual and population levels (Fishman et al., 2011).

The healthcare industry has experienced a proliferation of innovations aimed at enhancing life expectancy, quality of life, diagnostic and treatment options, as well as the efficiency and cost effectiveness of the healthcare system. Information technology has played a vital role in the innovation of healthcare systems. The introduction of new tools for TB control and prevention should be regarded as a means of improving the quality of care by making available a wider choice of technologies to address unmet needs; it is also an opportunity to align the new tools with the capacity of health systems to deliver care, to address the changing nature of the epidemic and to meet the needs of communities with or at risk of TB (WHO, 2007).

2.7.1 Electronic Health Records (EHR)

The Electronic Health Record (EHR) is a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data, and radiology reports. The EHR automates and streamlines the clinician's workflow. The EHR has the ability to generate a complete record of a clinical patient encounter, as well as supporting other care-related activities directly or indirectly
via interface including evidence-based decision support, quality management, and outcomes reporting (Mitre, 2006).

Electronic health record (EHR) systems enable hospitals to store and retrieve detailed patient information to be used by health care providers, and sometimes patients, during a patient’s hospitalization, over time, and across care settings. Embedded clinical decision support and other tools have the potential to help clinicians provide safer, more effective care than is possible by relying on memory and paper-based systems. In addition, EHRs can help hospitals monitor, improve, and report data on health care quality and safety (Silow-Caroll et al., 2012).

### 2.7.2 Electronic Medical Record (EMR)

The major goal of the medical record is to serve as a repository of the clinician’s observations and analysis of the patient. Any clinician’s recorded interactions with a patient usually begin with the history and physical examination (Hersh, 1995).

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**Figure 4. EMR and EHR Environments**

Source: Electronic Health Records Overview, Mitre 2006
Source: The conceptual framework of interoperable Electronic Health Record and ePrescribing systems, Dobrev et al., 2012

2.7.3 mHealth

The use of mobile and wireless technologies to support the achievement of health objectives (mHealth) has the potential to transform the face of health service delivery across the globe. A powerful combination of factors is driving this change. These include rapid advances in mobile technologies and applications, a rise in new opportunities for the integration of mobile health into existing eHealth services, and the continued growth in coverage of mobile cellular networks (Misha, 2011).

Mobile phones are used in international development and disaster risk reduction (DRR) programs by non-governmental organizations (NGOs), the United Nations (UN) and international agencies to collect data about many different subjects, such as agriculture, micro-credit and finance. Likewise in the health sector, the potential for mobile technology to make an impact is immense. In the health sector, mobile phones, tablets and other devices are not only data-collection tools; they can support health staff in the diagnosis of patients’ illnesses, by using specific algorithms that can be embedded into the devices, and they can spread awareness messages or health alerts to health practitioners and to patients. In recent years, sophisticated
software has been developed to allow mobile phones to operate almost like medical devices, changing the way health care is delivered to patients (Paola, 2014).

2.9 The Community-Based mHealth Application: RapidSMS

RapidSMS is an open source information technology platform using mobile technology innovation. RapidSMS is a SMS-based (text message) open-source framework that manages data collection, complex workflows, and group coordination using basic mobile phones, and can present real-time collected information on web-based dashboards as soon as it is received. It is not a turn-key application, but a framework which can be used to tailor the system to the specific needs of a given setting. RapidSMS allows customizing messaging formats and processes relevant for the desired workflows to be implemented (Rwanda MoH and UNICEF, 2014).

RapidSMS was introduced by the Government of Rwanda in 2009, with technical and financial support from UNICEF, to address and track the high rate of maternal and newborn deaths as a national development priority. RapidSMS is a community based approach used by CHWs to transmit maternal and child health related indicators (early pregnancy identification, antenatal care, postnatal care, nutrition, disabilities, immunization and life threatening emergencies) which contribute to high maternal and child morbidities and mortalities (UNICEF, 2014).

2.9.1 Mobile applications interoperability and Functional Model of SMS System

Short Message Service (SMS) is understood as one of the revolutionary development of the Information and Communication Technology (ICT). The increasing data transfer rates of mobile technology has complimented this development with a great extents. People irrespective of their socio-economic background use mobiles as information access terminals. It has become the most reachable bridge to link up the digital divide. The underline power of data exchange using SMS service is playing a key role to evolve the applicability of mobiles in information systems and retrieval. With this background a comprehensive research and development have been already started by the researchers. Number of SMS based Information
Systems (SMSbIS) are being developed by the researchers, developers and professional vendors (Joshi, 2001).

In any generic SMS based Information System, a text query in the form of SMS is send from mobile to an appropriate server of the service provider. The query is received by the server then processed and relevant data, text or image is accessed from the available data source like database or the WEB. The resultant data/text and even image is then returned back as a response to the sender’s mobile unit (Joshi, 2001).

The enhanced development of mobile technology into 3G technology has come up with fast internet access, multimedia data transfers, video SMS and high data transfers rates. The penetration of mobile networks up to remote places and natural language support has made “SMS based information retrieval” as a new challenge to the researchers and developers. Query construction mainly depends on query format defined in the system. A text based query in SMS form needs to include attributes of the information to be retrieved. There are two major methodologies extracted from the reviewed systems (Varsha, 2001):

- Fixed form, planned query: Many of the telemarketing SMS, provide a format that people are asked to use to type the query. This predefined form of query is send as SMS to specific service provider’s number. Service originated SMS query use this type of format. Such queries are planned and simple but have limited functionality.

- Free form, unplanned query: User originated queries are by and large of free form. User can conveniently write query if there is no any restriction of predefined fixed format. A free form natural language query is thus one of the important demand parameters and a focused objective of most of the research work in this area.

The SMS sent by a user is stored in SMS Center (SMSC) of the service provider’s server. The text query is transformed into a standard query form. The standard query is used to access relevant information from the knowledge source. Validation checks are used to check if a submitted query is syntactically correct or not. It involves separation of tokens and matching them with a predefined format. The query formats are defined in terms of different key words and their types.

Parsing and Normalization are mainly related to NLQs. They are rather the mandatory steps for refining the query to make it sensible. Parsing includes separation of terms, checking their
relevance with the expected query form. Normalization involves eliminating noise or distortion from the received query (Pathik, 2001).

The feedback assures the user’s satisfaction is meeting by the alternate query. This system is related to a “SMS find” algorithm for information extraction in response to the SMS based flexible query send from mobiles. It uses surface pattern matching technique as the extraction method. It applies mean ranking and minimum distance (from hint) as relevance check mechanism. After validation and parsing of the received query in internal format that is acceptable / feasible to the application server is the necessary feature. In most of the related projects it is mentioned that the SMS text is received in Protocol Data Unit (PDU) form. It needs to be converted in to Plain Text form or HTML query form alternatively. This conversion depends upon the compatibility of the application server software and its back end support (Joshi, 2001).

The core logic of the service is mainly featured by the domain of the application. Practically the core service logic is built upon either single domain or multiple domains. Information/data source of the service is built with two options. One is the Static Knowledge Base. RDBMS like ORACLE, SQL server hold static data. Another option is Dynamic Knowledge Base. The Web based data/information is driven using search engines interface or WAP (Manish, 2001).

**Figure 5. Mobile applications and functions**

Source: Android Tech Demo, Feigin 2009
Figure 6. Functional Model of SMS System algorithm

Source: A survey of SMS based Information Systems, Marish 2012
2.9.2 Conceptual Design of RapidSMS

Source: Présentation de RapidSMS, Alioune 2014
2.9.3 RapidSMS Platform in Maternal and Childhood Program

Source: mHealth and Neonatal Resuscitation, Agrawat 2013

2.9.4 The contribution of RapidSMS to the Healthcare for Rwanda's Health System

There have been dramatic improvements in Rwanda in the last decade as far as maternal and child health is concerned. Progress made can be attributed to a combination of factors that contributed to strengthen the Rwanda health system and to make quality of services accessible to the population. To achieve its objectives on MDGs, Rwanda adopted implementation of RapidSMS as an innovation that intends to contribute to the existing efforts in bridging gaps to further reduce maternal and child mortality (Rwanda MoH and UNICEF, 2014).

The Ministry of Health (MoH) of Rwanda has made remarkable gains in maternal and child health. The maternal mortality ratio has been reduced from one of the world’s highest in 2005 at 750 deaths per 100 000 live births down to 487 in 2010, and the under-5 mortality rate has been reduced by half during the same period. To achieve these results, national policy has focused on improving community-level health care through community health workers (CHWs) (WHO, 2013).
2.9.5 The effect of RapidSMS to the Community Health Workers (CHWs) attributions

The CHW System was designed to act as community outreach workers, participate with community diagnosis, and provide links to facility-based care. They are supposed to spend 80% of their time in the community, with 20% at the health clinic (Michael et al., 2010).

Mobile phones support health system building by allowing data collection and reporting on patients, and by enabling the tracking and management of work for CHWs and other health cadres. They can streamline and add value to varying key operational components of CHW systems, particularly when applied with an awareness of minimizing the reporting burden on health providers. The potential benefit increases when reporting systems are linked with national health systems, particularly in the areas of supply chain management, disease surveillance and identification of seasonal priorities and epidemics. A number of studies have demonstrated that data collection on mobile phones can both reduce the number of errors and omissions compared to paper-based data collection, and reduce the amount of time required for preparing data for analysis. Upgrades to national CHW subsystems should include mHealth options and aim to enable real-time monitoring and surveillance, ideally linked with national health information systems (Michael et al., 2010).

2.10 Current TB Recording and Reporting System within Rwanda's Health System

The monitoring, recoding and reporting system of TB cases aims to provide a management information system for better management of tuberculosis program at national, district and center of diagnostic and treatment level and is used to evaluate the progress of patient and treatment outcome (Jagannatha, 2002).

A good recording practice is necessary for effective patient management and effective monitoring depends on appropriate recording and reporting systems. The WHO recording and reporting system consists of detailed patients forms that are filled out at the point of care and summarized in laboratory and medical registers. These data are aggregated to prepare quarterly report on activities and results as well as annual management reports at the basic management unit or center of diagnostic and treatment (CDT), usually the district level aggregate for its catchment area then sent to central level (WHO, 2008).
2.10.1 Recording system

The patient registration is to ensure continuous evaluation of the activities against tuberculosis. The data recorded regularly are transformed into useful information to improve quality of care, management and tuberculosis control. The recording system comprises tools used for TB detection (laboratory registers, register of TB suspects, Register of TB contacts) and TB treatment (Tuberculosis treatment card, Tuberculosis patient Register, Patient’s identity card, TB transfer form, Community treatment card) (Rwanda NTP, 2009).

2.10.2 Routine Reporting System

The reporting system consists of quarterly reports on TB case registration, which summarize the number of TB patients started treatment, laboratory tests performed and HIV tests and results obtained; quarterly reports which detail treatment outcome and TB/HIV activities after all patients in cohort have completed their course of treatment and annual reports on TB activities management and on contribution of each health facilities, community and private sector in diagnosis and treatment of Tuberculosis(Rwanda NTP, 2009).

In smear positive pulmonary TB patients, the six standard outcomes of treatment for reporting purpose are: cured, treatment completed treatment failure, dead, default and transferred out.

Cure: A patient who was initially culture or sputum smear microscopy at the beginning of the treatment but who was smear-negative in the last month of treatment and on at least one previous occasion;

Treatment completed: A patient who completed treatment but who did not meet the criteria to be classified as a cure or a treatment failure (WHO, 2013). Treatment failure is defined depending on patient’s category: A new patient who is culture or sputum smear microscopy positive at five months or later during treatment, or who is switched to Category IV treatment because sputum culture revealed MDR - TB;

A previously-treated patient who is culture or sputum smear microscopy positive at the end of the re-treatment regimen or who is switched to Category IV treatment because sputum culture revealed MDR -TB(World Health Organization, 2013). Dead: A patient who died from any cause before stating or during the course of treatment. Defaulted: is defined as a patient whose
treatment was interrupted for two consecutive months or more (World Health Organization, 2013). And transferred out: A patient who was transferred to a health facility in another basic management unit and for whom the treatment outcome is not known (WHO, 2013).

2.11 TB Screening System integration within Rwanda’s RapidSMS Health System

Tuberculosis (TB) is a major global health problem. It causes ill-health among millions of people each year and ranks alongside the human immunodeficiency virus (HIV) as a leading cause of death worldwide. In 2014, there were an estimated 9.6 million new TB cases: 5.4 million among men, 3.2 million among women and 1.0 million among children. There were also 1.5 million TB deaths (1.1 million among HIV-negative people and 0.4 million among HIV-positive people), of which approximately 890 000 were men, 480 000 were women and 140 000 were children. The number of TB deaths is unacceptably high: with a timely diagnosis and correct treatment, almost all people with TB can be cured (Lewandowisky, 2015).

The use of mobile and wireless devices to support medical and public health practice and research (mHealth) is gaining increased attention as it provides opportunities to rapidly connect people, reducing therefore delay across the chain of health decisions, and positively affecting the lives of millions of underserved population (Ngwimfack, 2016).

The RapidSMS system was designed to provide an SMS-based platform, enabling effective and real-time two-way communication for action, between CHWs at community level, and the rest of the health system (ambulance, health facility staff, District Hospital and Central level) through mobile phones. The primary expected result of the system is an improved access to antenatal, postnatal care, institutional delivery, and emergency obstetric care. In addition, RapidSMS provides a database for keeping clinical records of maternal care delivery (Muhoza, 2016).

This study aims at designing an integrated TB Screening system to interoperate with RapidSMS as this has effectively shown its great impact in improving the healthcare system at community level. Routine TB screening engages much efforts and time consuming which implies the delays that contribute to the TB propagation within community. Thus, integrating the TB screening
system within Rwanda's RapidSMS would be a way of easing and shortening the TB detection period as well as minimizing contamination risk to the exposed community. It is also intended to omit the CHWs burden of making long journey from their respective communities to the health facilities or hospitals accompanying the suspected persons for TB diagnosis. Given the existing functional design, the proposed TB Screening system requires only its module and algorithm that must interoperate complementarily with the RapidSMS. The RapidSMS platform is upgraded with TB Screening system features.
CHAPTER 3. METHODOLOGY

3.1. Introduction
In this chapter, we discuss the approaches used to achieve the objectives of our research project on design of TB screening system integration within Rwanda’s RapidSMS health system. The techniques and methods used to attain the feasibility integration, key features of a proposed eTB conceptual design integrated system within RapidSMS, user requirement and the technologies used in designing of the system.

3.2 Study area
Considering the nature of our research, its study site covers all health facilities located in catchment area of MUHIMA District Hospital, specifically centers of TB screening, diagnostic and treatment (CDTs) at the Hospital and Health Facility's level. Besides the CDT centers based at health facility, the research covers the site of community health worker system operations for each health facility.

The site is a place of convenience to the researcher to meet objectives of the study because of the fact that the area documents 30% of the total TB cases countrywide (Rwanda NTP, 2013c). The community health workers site of operation at health facility is the entire catchment area of that health facility. This area is strongly targeted by the researcher to attain objectives of the research which mainly focuses on TB screening at community level. This means that all catchment area of MUHIMA District Hospital composed of 10 health facilities being Muhima HC, Biryogo HC, Rwampara HC, Kabusunzu HC, Mwendo HC, PCK HC, COR UNUM HC, Kanyinya HC, Rugarama HC and Butamwa HC are also considered.

3.3 Study design
A conceptual qualitative research design is used to provide both architectural designs for tuberculosis screening system (TB-SS) and for an integrated TB-SS within RapidSMS reporting system. Research design is the overall plan for connecting the conceptual research problems to the pertinent (and achievable) empirical research. A conceptual research design was primarily employed to develop theories on how psychosocial interventions may work, it can also be designed to put in place abstracts ideas or theory about a program or intervention (Greene J.C et al., 1998).
For the purpose of the present study, a new concept about TB screening system integration within Rwanda’s RapidSMS ought to be designed to enable early detection of new TB cases at community level with systematic guided TB screening SMS based algorithm to improve data quality, maximize timely data accessibility and reduce bottlenecks of communication between community health workers and health providers at health facility level for a better service delivery in real time to a large number of populations with limited resources.

The study aims at elaborating a suitable and mobile based systematic tuberculosis screening system in the community but integrated within an existing useful system commonly known as RapidSMS to avoid burdening community health workers having many report systems in different platforms as well as spending money and time caring for the TB cases when accompanying them to the health facilities.

This study is qualitative and evaluates the usability, effectiveness, efficiency and integration of TB screening system features within an existing SMS based reporting system now used at community level. It has to elaborate a similar conceptual design that focuses on TB screening incorporated within an existing RapidSMS to reduce prevalence of TB mortality and morbidity cases in the community by streamlining routine screening.

The study involves all health professionals from District Hospital level to community health workers at community level especially those who are directly linked to tuberculosis program. Questionnaires has been distributed to the selected respondents for data collection.

3.4 Study population

The population of interest in the present research includes nurse TB focal points from 10 Centers of TB diagnostic and treatment (CDTs), 10 in-charges of community health workers, 10 Data Managers in all 10 Health facilities reporting at MUHIMA District Hospital, 5 Community health workers from each health facility, 1 MDR-TB patient at each CDT and at District Hospital, the study includes 1 Data Manager, 1 TB focal point and 1 in-charge of Community Health Workers at District Hospital level.

Except Community health workers and TB patient at community level to be selected randomly, others implicated population have been selected purposely. Considering the nature of our
research, views of CDT focal points, CHWs, Data Managers are of paramount importance to accurately attain our objectives.

3.5 Sample size and sampling strategy
The sample size has been retrieved from all Health facilities composing the catchment area of MUHIMA District Hospital (10 health facilities) being Muhima HC, Biryogo HC, Rwampara HC, Kabusunzu HC, Mwendo HC, PCK HC, COR UNUM HC, Kanyinya HC, Rugarama HC and Butamwa HC. In the research to be undertaken, the sample size is determined by the nature of study that forcedly involve at least 1 Nurse CDT Focal point from each health facility, at least 5 community health workers from each health facility’s catchment area, 1 Community health workers Supervisor from each health facility, 1 Data Manager from each health facility and 1 MDR-TB patient from each health facility’s catchment area. At hospital level, there are 3 respondents to address to (1 Data Manager, 1 CHWs Supervisor and 1 TB focal point). The total sample size for this research is 93. Multistage sampling will be used to meet the objectives of the present study as shown as highlighted in the following table hereby:

Table 1. Distribution of sample size and sampling strategies

<table>
<thead>
<tr>
<th>Category of respondent</th>
<th>Level of institution</th>
<th>Sample Size</th>
<th>Sampling Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDT-TB Focal point at Hospital</td>
<td>District Hospital</td>
<td>1</td>
<td>Purposive sampling</td>
</tr>
<tr>
<td>Data Manager at Hospital Level</td>
<td></td>
<td>1</td>
<td>Purposive sampling</td>
</tr>
<tr>
<td>CHWs Supervisor at Hospital</td>
<td></td>
<td>1</td>
<td>Purposive sampling</td>
</tr>
<tr>
<td>Nurse CDT-TB Focal point</td>
<td>Health Facility</td>
<td>10</td>
<td>Purposive sampling</td>
</tr>
<tr>
<td>Data Manager</td>
<td></td>
<td>10</td>
<td>Purposive sampling</td>
</tr>
<tr>
<td>CHWs Supervisor</td>
<td></td>
<td>10</td>
<td>Purposive sampling</td>
</tr>
<tr>
<td>Community Health Worker</td>
<td>Community Level</td>
<td>50</td>
<td>Random sampling</td>
</tr>
<tr>
<td>MDR-TB Patient</td>
<td></td>
<td>10</td>
<td>Random sampling</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>93</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Own drawing, 2016*
3.6 Inclusion criteria

Considering the research objectives, participants who might be directly linked to TB screening activities and/or involved in RapidSMS reporting system being in the community, at health center or at District Hospital of our case study. The research includes only 5 community health workers from each health facility as healthcare providers based in the community. Considering that these community workers have cross-cutting attributions, the researcher intends to only include those who might be in charge of TB screening in the community. CHWs report to the nurse CDT focal point and their Supervisor at HC level and this focal point report to Health Facility’s Data Manager. Considering the crucial role of these informants in our research, they are potentially included. In addition, Supervisors of Community health workers and Data Managers at both levels and community health workers at community level are strongly included as they have cross-cutting activities to both TB screening and RapidSMS reporting activities which are major subjects of our research. They are rights respondents to ascertain the existing and relevancy of TB screening system and the proposed conceptual design of integrated TB screening within RapidSMS system.

Few TB patients (1 for each health facility) who have been screened in the community and after all tested TB positive, as beneficiaries from TB healthcare who are under TB treatment, will be also involved to know their views on the TB screening system and their expectations to the new conceptual design of mobile based TB screening system.

3.7 Exclusion criteria

All health personnel at health facility as well as at hospital level, other than those delivering TB services will be excluded in the present research due to the fact that they are not actively involved either in TB screening activities. All health personnel at health facility as well as at hospital level, other than those who are not directly linked to RapidSMS reporting system activities are excluded from this research. Not all community health workers at each health facility will be considered due to the fact that the needed information is supposed to be accurate. Thus, CHWs who have not been trained on TB are excluded. The research also excludes all CHWs who have not completed their secondly school education. In addition, TB patients who are severely sick or suffering from any other disease except TB are excluded from interview. Non MDR-TB Patients are excluded from the research.
3.8 Data collection methods and procedures used

3.8.1 Data collection methods
The present study is qualitative in nature due to the fact that a new concept to be designed depends on views of all parties involved in implementation. Therefore, an in depth interview was conducted to collect views on the contribution of the integrated TB screening system within Rwanda’s RapidSMS system comparison to a routine TB screening at community level. The interview guide was developed based on existing screening and reporting system and adapted in the context of an integrated TB screening system within RapidSMS to ensure an early and systematic TB detection to prevent the ongoing TB propagation in the community. The components to be covered were focused on views of an integrated eTB screening system. The interviewer oriented the interviewee on the following key areas: Strengths of the existing screening system; weaknesses of existing screening system; challenges of community health workers, causes of TB propagation and persistence and the role might play the integrated TB Screening system within RapidSMS.

3.8.2 Data collection procedures
The study proposal was submitted to the research and ethical committee of University of Rwanda /College of Medicine and Health Sciences for approval. After the ethical clearance was obtained the application for authorization to conduct data collection in the selected sites namely Muhima HC, Biryogo HC, Rwampara HC, Kabusunzu HC, Mwendo HC, PCK HC, COR UNUM HC, Kanyinya HC, Rugarama HC and Butamwa HC. The research categorized the informants into three categories depending on their area of interventions or working position and for each category, the interviewer used specific in-depth interview guide. On health professionals and IT specialists, as well as for the staff at Hospital and Central Level the researcher used specific interview guide.

The in-depth interview guide related to alert and reminder aspect was used for all informants. However, the researcher translated that part in Kinyarwanda only for CHW and patients to facilitate interviewee to answer questions related to the present study. Data was captured by writing answers on the elaborated in-depth interview guide. The researcher compiled all in-depth interview guides and kept them in secure location.
3.9. Data analysis
Data was analyzed qualitatively. Information collected by means of in depth interview guide was transcribed into themes before being analyzed and it was then categorized by objectives. Finally, views from the respondents were used along with the reviewed concepts from elsewhere in the screening systems of health care delivery to draw an integrated concept that can be used as an Integrated TB Screening system within Rwanda’s RapidSMS that effectively ensures a real-time TB detection at a very effective cost with very less time consuming.

Proposed analysis will not only answer our questions but also gives the directions for future data collection. Data analysis procedures help to arrive at the data analysis. The uses of such procedures put our research project in perspective and assist in testing the hypotheses with which that verifies the relevancy of the undertaken research. Hence with this, we will be able to contribute to the resolution of reducing the TB propagation and MDR-TB cases in MUHIMA Hospital’s catchment area. For this study, the researcher in fact, preferred 2 statistical Software (SPPS and Stata) to facilitate data analysis. Similarly tools like spreadsheets and word.

3.10 Problems and limitations of the study

The limitations were faced in terms of scope as data was collected within the confinements of Kigali City in MUHIMA District Hospital while other centers for TB Screening, monitoring and adherence to TB therapy exist across the country. Thus generalization of the study results to the country level may be not possible. In addition, the study was qualitative in nature and reflects the views of the respondents at the study setting which limits the generalization of the results to other settings. The second limitation is that the design is limited to the functional requirement and architecture design. We didn’t go to the phases of software development (Programming, implementation, testing and validation). Problems of accessing MDR-TB cases in all corners of chosen places of the research never ceased to rise.

3.11 Ethical consideration

Though all researchers (student, professional, or academic) are well intentioned, there is the possibility that interaction with participants may inadvertently harm them in some unintended way. This could include:
• Psychological harm—for example, researching the use of nudity in advertising may show participants images that offend them.

• Financial harm—researching unethical behavior within a given firm may provide management with information on individual employees that results in an individual getting fired, or undertaking industry-based research may inadvertently share sensitive information with a firm’s competitors, resulting in financial harm to the organization.

• Social harm—researching how lifestyle affects consumption may unintentionally disclose a person’s sexual orientation when that person (Polonsky et al., 2011).

To successfully conduct this study, the researcher strongly considers some ethical assumptions like respondents confidentiality; provide informed consent and having an ethical approval from National Ethical Committee to legally conduct the research. Before data collection process may start, all approvals will be granted by research and ethical Committee of University of Rwanda/College of Medicine and Health Sciences. Thereafter, through TB District coordinator’s permission is expected to be granted to collect data from research sites were applied. After permission will be given, study participants will be approached and given an informed consent form to be filled as a testimony of the willingness to participate in the study, then, the researcher will keep them for further reference. Confidentiality of information and right to withdraw from the study at any time will be highlighted in information sheet that was given to the participants prior to data collection process. The information to be obtained from an interview guide must be kept with strictest care.
CHAPTER 4: IMPLEMENTATION OF THE PROPOSED SYSTEM

This chapter radically describes the proposed TB screening system design integrated within RapidSMS. The chapter intends to highlight the relevance of the proposed system, its conceptual design, integration and implementation of that proposed system.

4.1 Description of the proposed system

TB Screening integration within Rwanda’s RapidSMS system is thought to be an endless TB propagation prevention tool within communities. RapidSMS is written in Python and Django and is a framework for building highly customized applications. The increase of more and more pre-configured applications being created for RapidSMS also enables the proposed system to successfully operate within it. The proposed system will use the same programming language of existing system for effective interoperability.

4.2 Relevance of the proposed system

The relevance of the proposed system is based on its simplicity and smartness usability with an easy access via mobile device. The system will reduce the cost of TB treatment, transport of patients and CHWs to Health Facilities for only TB screening service and the loss of labor income for all implicated persons in that healthcare activity. CHWs will no longer take long journey on their own ticket fee toward HCs accompanying suspected patients. There will no longer be a bid deal to negotiate the patient to go at HC for TB screening, and thus immediate reporting system will intervene in preventing TB contamination. The system will also enables the TB department to retrieve the database of screened people for monthly, quarterly and annually reports.

4.3 RapidSMS-TbSS as proposed solution

The imminent TB propagation in communities is a great threat that harms lives of population in different corners of the world. TB screening is a primordial medical action to riposte against TB propagation as the first and fast key prevention of the scourge. Routinely existing TB screening needs a reinforcement of an e-TB screening system to maximize early detection and prevention of TB propagation at community level. The undertaken study proposes the solution to the TB screening gaps:"Tuberculosis (TB) screening system integration within Rwanda’s RapidSMS
Health System”. This proposed solution as an automated TB screening system within community is thought to be the right answer to the endless TB propagation.

4.3.1 Relevance of the solution
The proposed solution intends to lowering the rates of TB new cases within communities by providing a systematic, easy and early e-reporting system integrated within an existing and successful reporting system (RapidSMS).

4.3.2 Evaluation of the proposed solution
The system evaluation of the proposed solution is expected to be the key roadmap for the implementation of the proposed e-TB screening system. This evaluation will test the solution's application and its impact on the prevention of TB propagation (whether new TB cases are being detected early and easily reported at health facility). Hence, the evaluation of the proposed solution ought to justify the importance of the project implementation.

4.3.3 Feasibility study
A feasibility study evaluates the project’s potential for success and precedes technical development of a project implementation, operational and financial requirements.

4.3.3.1 Technical feasibility (Interoperability with Classic RapidSMS)
Technically, the proposed solution is expected to fit into existing RapidSMS. The TB screening system's algorithm ought to be integrated within Rwanda’s RapidSMS Health System. The embedded system might be hosted onto central server and the end users (CHWs) access the system on their mobile devices dotted with an e-TB screening application. The system's templates, urls, views, models, apps and backbends are similarly same as those for the RapidSMS which guaranties the system interoperability after the e-TB algorithm integration within RapidSMS. This one being an open source and pre-configured application, technically it easy to customize it and integrate other apps like TB screening system.

4.3.3.2 Operational/ Usability
Given the existing and successful RapidSMS that was initiated to save lives by tracking pregnant women and children under two years of age. RapidsSMS is a tool used by Ministry of Health to collect data from the level of the community through the use of CHW provided cell phones in all the Districts. RapidSMS was introduced to provide better information on risks and to avoid
delays in that caused maternal death. All pregnant women are registered and followed by CHWs with regular reports being sent via SMS. They follow up on all risky and risk pregnancies and are provided with reminders through SMS sent from the central hub.

Likely, RapidSMS-TbSS as an integrated TB screening module within an existing RapidSMS for the early TB cases detection at community level to prevent from TB propagation. The intent is to operate seemingly as the existing one expecting same results. The usability is as simple as possible considering that users are familiar with RapidSMS.

- **HC Manager**

At health facility level, the Manager must know everything regarding the RapidSMS-TbSS to ensure the effectiveness of the system in his/her Health Center's catchment area and the progress of the scourge prevention. Once a TB case is suspected after RapidSMS-TbSS test, it is reported by the Community Health Worker and the SMS notification that prompts the immediate riposte by sending the Nurse in the community to assess and confirm the case for medical care. In fact, the manager uses the system in viewing reports.

- **Data Manager and CHWs Manager**

The Data Managers together with CHWs Managers at Health Facility level as well as Hospital level are key persons to manage the RapidSMS-TbSS in monitoring daily activities on reported screened cases within communities. The Data Manager accesses the RapidSMS-TbSS portal to view all reported screened cases. And share the report with the HC Manager, Lab Manager and HC CDT-Nurse to assess which screened cases have been tested TB positive and then report to the upper level. All screening data are found into RapidSMS-TbSS database and retrieved for analysis and error tracking. Within RapidSMS-TbSS, for each Health Facility there is a sub set of CHWs list which helps the HC Data Manager and CHW Manager to monitor each CHW's activities.

- **CHWs**

Community Health Workers are primordial key success of the implementation of RapidSMS-TbSS. They are also end users of the system. Failure or success of the system is basically rooted to its usability among Community Health Workers (CHWs), as the CHW is now the healthcare
provider in the community. CHWs are enough trained and familiar with existing RapidSMS, and thus the use of an improved system may probably be easy.

Following its algorithm, a CHW is obliged to report through RapidSMS-TbSS any person suspected to be a TB case due to either having a cough lasting more than 3 weeks, having a significant loss of weight, and/or having a body temperature ≥38°C.

Once a such case is detected in the CHW's catchment area, immediately should be reported using a mobile phone. The system uses a short-code to report the case. Each CHW is attributed an ID onto the system. The system itself attributes patient ID, and then the CHW records patients addresses as well as observed TB indicators (signs).

- Patient

Patients are first beneficiaries of the system. The system was not designed for patient use. Only patients has the crucial opinion on the usability of the system and impact on the acceptability of the system as important beneficiaries.

4.4 Financial

Financially, the feasibility of the system implementation is possible. There will be no extra charges to be engaged in the implementation of the project. The implementation will require the training sessions for CHWs nationwide, hiring experts (programmers and system analysts) and others related funds. However, the cost of the system is too effective and affordable comparing to the cost of TB treatment and the socio-economic impact of communities' mobility.

4.5 Conceptual system design

The proposed system obviously has a conceptual system design that might severe as a model when implementing the system. The functionality of the proposed system is the same as the one for RapidSMS and they differ from their logical algorithm. Following is the life cycle of the conceptual design of the proposed RapidSMS-TbSS.
4.4 Integration within existing RapidSMS

The integration of Tb screening system with RapidSMS is quick and simple as it only consist of incorporating the TB Screening module within a working system. Considering that system’s
templates, urls, views, models, apps and backends are same as those for RapidSMS which enables their compatibility and interoperability.

4.5 Conception

After developing codes for the proposed system, testing its integration and workability as a new feature of existing RapidSMS is a key element for the system interoperability before the implementation.

The implementation includes many steps i.e embedding the TbSS with RapidSMS, this will be executed at central level. And then, there must be a test on mobile devices to ensure the system effectiveness. Thereafter, training of trainers ought to be planned for the success of system implementation. These trainers will be training CHWs at community level.

RapidSMS-TbSS intends to be a web application conceived with PhP and Java Script. It must be integrated with existing RapidSMS. This one is a free and open-source Django based framework that must be hub Tb-SS.

4.5.1 Implementation of TB Screening system

The implementation of Tb-SS initially consists of creating databases of users (to all levels), administrators and patients. The system is a web application that must be accessible whenever and wherever the accepted user might be in need of using the system. Following are screenshots of the system under implementation that shows how the system will operates.

4.5.1.1 TB Screening System features

The implementation of TB Screening system has been made possible by using different technologies. This system is intended to be a web based with two version of applications (computer based and mobile based application). The implemented demo has been designed and implemented on computer and has 3 major features:

**Programming language:** The implemented TBSS uses PHP as a programming language. The advantage of this technology prompted to use it in Demo System Implementation.
PHP is a server-side scripting language designed primarily for web development but also used as a general-purpose programming language. PHP code may be embedded into HTML code, or it can be used in combination with various web template systems, web content management systems and web frameworks. PHP code is usually processed by a PHP interpreter implemented as a module in the web server or as a Common Gateway Interface (CGI) executable. The web server combines the results of the interpreted and executed PHP code, which may be any type of data, including images, with the generated web page. PHP code may also be executed with a command-line interface (CLI) and can be used to implement standalone graphical applications. PHP has been widely ported and can be deployed on most web servers on almost every operating system and platform, free of charge. PHP version used is 5.7.

**System Database** : This system uses MySQL as an open-source relational database management system (RDBMS). The advantage of this tool is that support can be obtained from the official manual. Free support additionally is available in different IRC channels and forums. MySQL has received positive reviews, and reviewers noticed it performs extremely well in the average case and that the developer interfaces are there, and the documentation (not to mention feedback in the real world via Web sites and the like) is very, very good. It has also been tested to be a fast, stable and true multi-user, multi-threaded sql database server. MySQL version used is 5.7.

**Web Server** : TBSS is using XAMPP as a web server. XAMPP is a free and open source cross-platform web server solution stack package, consisting mainly of the Apache HTTP Server, MariaDB database, and interpreters for scripts written in the PHP and Perl programming languages. XAMPP stands for Cross-Platform (X), Apache (A), MariaDB (M), PHP (P) and Perl (P). It is a simple, lightweight Apache distribution that makes it extremely easy for developers to create a local web server for testing and deployment purposes. Everything needed to set up a web server – server application (Apache), database (MariaDB), and scripting language (PHP) – is included in an extractable file. XAMPP is also cross-platform, which means it works equally well on Linux, Mac and Windows. Since most actual web server deployments use the same components as XAMPP, it makes transitioning from a local test server to a live server extremely easy as well. This XAMPP web server embeds the entire used software but its version is 3.2.2.

The system has a System Admin and this one should provide priorities of other main users. These ones will at their level be enabled as admins with priorities of managing other users.
All used software are open source (software that enables customization for further uses).

### 4.5.1.2 Users' roles
TBSS has three major categories of users and at each category there is an Administrator who has the rights of Creating, Editing and Deleting users. Apart from the overall system admin, those right are limited to each level of the admin. The first category of administrator is the central level (Ministry of Health [MoH], and Rwanda Biomedical Center [RBC]), the second category of administrators is at Hospital level, here there is one admin who has all system rights to monitor the level of health centers.

At health center level there are three users (Health Center System Admin, TB Focal Point, Data Manager) whose roles are different according to their functions.

The Data Manager has only the role of viewing data, extracting data and reporting. The CHW Manager has the same roles as the Data Manager but he can create and edit the new Community Health Worker. She/He has not the right to delete any record. While the Health Center System admin has full roles.

### 4.5.1.3 Data sharing (distributed system- web based)
Considering that the TBS is a web based system, it is designed and made of distributed system which enables data sharing properties. The great aim of the system being to spread the information, it enables a data sharing to users. The principle of the system is that if a CHW in the community reports a TB suspected case from his/her community, the report (SMS) text must reach three destinations at the same time (MoH, Health Center and RBC). Then the Health Center Manager will send the Focal Point to the community where the SMS came from and thus identifies the case.

### 4.5.1.4 System maintenance
Any system may have errors and or crashes that however obliges troubleshooting maneuver. The System admin has the privileges to troubleshoot the system once crashed. He is the one who can edit codes and or change features.
4.5.2 System accessibility

The implemented TB Screening system has an easy accessibility. After the approval of its usability, the system will be accessible via url as a web application on a computer as well as on smart phones and there will be a mobile based application that will be using a short code to prompt (*777#) the interface.

4.5.3 Systems compatibility, data migration and integration

Functional similarities for Python (a programming language in which existing RapidSMS is written) and PHP (the language in which TBSS is written) enable compatibility to both systems. They have several similar features that can facilitate their interoperability not only to the system on that level but also in data migration and integration. In fact both PHP and Python are interpreted, high level languages with dynamic typing, are supported by large developer communities, easy to learn (compared to C++, Perl), easy to extend in C, C++ and Java, are extremely portable. They run on almost all platforms in existence without recompilation, support for variable number of function arguments, support namespaces, support for docstring (pydoc / reflection + phpDocumenter), support method chaining, have several debuggers and IDEs, support for dates that aren't limited to UNIX timestamps (<1970, >2038), built-in support for cached byte-code (built-in support was added in PHP5.5), have a standardized database API, have a single statement (unset/del) for all data types and both can be used for scripting and general programming (CLI sapi, embedded etc., in the case of PHP).

Considering the feasibility of both system's interoperability, data migration and integration from one system to another is an easy exercises. The TBSS provides mean of exporting data either in excel or pdf format for reporting purposes. It is the same in exporting phone numbers for all users as well as any other reports.

When data are exported in from TBSS, it is important to rearrange them according to the purpose of needed data. Considering the fact that TBSS is not a standalone system but purposively designed to be integrated within RapidSMS, most of features are those already used by RapidSMS.

Further research is required to work on some data error prone in system compatibility, data migration and data integration. The emphasis should be but on enhancing the security.
Figure 8. TBB Database relationship

4.6 Implemented TB screening system screenshots

Figure 9. Login webpage (TBSS entry of users to all levels)
Figure 10. Creating a user

![Creating a user](image1.png)

Figure 11. CWH Reported cases

![CWH Reported cases](image2.png)

Figure 12. TBSS PHP Codes

![TBSS PHP Codes](image3.png)
Figure 13. TBSS Data tables
Figure 14. Users administration at MoH Level
Figure 15. CHW Database Report at MoH Level

Figure 16. TBSS SMS Format

Figure 17. TBSS Dashboard (compiled report)
CHAPTER 5: RESEARCH FINDINGS AND DISCUSSION

This chapter discusses findings of the present study in line with objectives. It gives an insight on the present study in relation to the existing standards and similar studies. It explains the implications of the outcomes with the established standards or earlier findings on the conceptual design and quasi implementation of a TB Screening System intended to be integrated within RapidSMS.

5.1 Introduction

The undertaken research is qualitative and focuses on three major categories of respondents i.e Health professionals, Community Health Workers and MDR-TB Patents in MUHIMA District Hospital’s catchment area. This chapter outlines the key findings from respondents on their awareness of a TB screening system importance, their views on the implementation of an integrated TB Screening System within RapidSMS.

5.2 Identification of respondents

In order to meet the set research objectives which are highlighted in the introduction; the conducted research i.e researcher beforehand ought to obtain right, clear and true information from the selected sample of respondents representing the population in which they are drawn through. This part includes some identification of the study among which the researcher consider the age and gender of respondents, their level of education, and mostly their categories considering the nature of the study.

5.2.1 Age of respondents

The age of respondents is an important variable to be considered in a research to get clear and meaningful answers that helps a research to attain his/her objectives. As shown by the below table that comprises respondents aged between 18-55 years and above where the majority ranges between 32 and 54 years. All these groups include three categories of respondents (MRD-TB Patients, Community Health Workers and Health Professionals). Out of 93 (100%) people who
were the subject of this study, 69 people equivalent to 72.6% were very adult people in (32-54) age group, 19 people representing 20% of the sample are in range of 18-31 years, while 7 people equivalent to 7.3% have more than 55 years.

Below table indicates the identification accordingly to the age, which the researcher has preferred to split into categories by classes with equal intervals.

**Table 2. Category of respondents according to their age**

<table>
<thead>
<tr>
<th>Age range</th>
<th>Respondents</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age between 18-24 years</td>
<td>8</td>
<td>8.6</td>
</tr>
<tr>
<td>Age between 25-31 years</td>
<td>11</td>
<td>11.8</td>
</tr>
<tr>
<td>Age between 32-39 years</td>
<td>21</td>
<td>22.5</td>
</tr>
<tr>
<td>Age between 40-47 years</td>
<td>25</td>
<td>26.8</td>
</tr>
<tr>
<td>Age between 48-54 years</td>
<td>21</td>
<td>22.5</td>
</tr>
<tr>
<td>More than 55 years</td>
<td>7</td>
<td>7.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>93</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

**Source:** Primary data, November 2016

The table above describes our respondents in a way that the majority of respondents population has between 32 and 54 years; the age of duly respondents considering the undertaken topic. This enables the researcher to analyze how much elder population matters to deepen the analysis on the contribution of TB screening system in combating TB propagation in the community by giving their view on the proposed system; whereas the remaining part of respondents is the minority made of young population (18-31 years) and very old population (55 years and above) mostly made of MDR-TB patients. The inclusion of very young ones and very old ones justifies their importance in assessing their implication in TB propagation and thus enables the relevant analysis of the study.

**5.2.2 Sex and categories of respondents**

The variable sex and categories of respondents that are associated with the research criteria allowed us to identify the number of female and male and groups they belong to, that answered
to the questionnaire. The table below indicates the identification of respondents by their sex and group.

Table 3. Identification of respondents by sex and group

<table>
<thead>
<tr>
<th>Group of respondents</th>
<th>Sex of respondents</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>MDR-Patients</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Community Health Workers</td>
<td>21</td>
<td>29</td>
</tr>
<tr>
<td>Health Professionals at HC Level</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Health Professional at Hospital Level</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>51</td>
</tr>
</tbody>
</table>

Source: Primary data, November 2016

As represented in the above table, 45.1% of respondents are males while 54.8% is the rate of female respondents. This justifies how the involvement of females in health programs and healthcare delivery matters. However, the percentage of males is not far from female’s. This explains that during the survey the researcher has selected respondents in a manner that includes males and females quite equitable to streamline the study relevance. This surely enabled to know which part of population that is merely linked or may influence remarkable changes in TB issues, especially in the implementation of TBSS-RapidSMS.

5.2.3 Respondents’ level of education

The education levels of respondents illustrates the composition of the research respondents in different capacities i.e knowledge, level of understanding and analysis of the situation of the topic as it is represented in the table below. This greatly impact on the results, especially in qualitative research like this. The accuracy of data is based on the fact that majority of respondents have at least reached the minimum of level of education (Primary).
Table 4: Identification of respondents according to their level of education

<table>
<thead>
<tr>
<th>Respondent’s level of education</th>
<th>Respondents</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No educated</td>
<td>2</td>
<td>2.1</td>
</tr>
<tr>
<td>Primary School P6 Level</td>
<td>34</td>
<td>36.5</td>
</tr>
<tr>
<td>Secondary School S6 Level</td>
<td>46</td>
<td>49.4</td>
</tr>
<tr>
<td>Bachelor’s Degree Level</td>
<td>9</td>
<td>9.6</td>
</tr>
<tr>
<td>Master’s Degree Level</td>
<td>2</td>
<td>2.1</td>
</tr>
<tr>
<td>Total</td>
<td>93</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Primary data, November 2016

This table shows us that the most asked population has 49.4% (those who have secondary school level) of all respondents, a category of Community health workers and some of health professionals. Those who has at least completed the primary education; they occupy the second place of the table with 37.6%. This includes the category of non-educated MDR-TB Patients and some of Community Health Workers. In this research, only 2 non-educated patients were interviewed. 9.6% is the rate of respondents who have undergraduate level and 2.1 of postgraduate level. In order to obtain meaningful results; the research emphasized on educated population due to its nature. Those whose level of education is high; likely understands their impact of TB propagation within community and can positively give their views on the integration of TB Screening system within RapidSMS as they have already the importance and use of Rwanda’s RapidSMS reporting system.

5.3 Awareness of the importance of TB Screening at Community level

In the undertaken research, the assessment of the awareness of the importance of TB Screening at community level was a key point as an entry point to the views on the proposed system. This section intended to know how routine TB screening is being done (identification of suspected cases, data capturing and management). The focus groups of respondents were community health workers at community level and MDR-Patients.

The awareness of importance of TB Screening by the community health workers is highly rated at 92% among Community Health Workers and decreases at 59% for patients. This is related to the degree of knowledge this two groups may have on tuberculosis, its way of contamination and
how to identify suspected cases rather than community health workers who on their behalf are trained enough on the scourge. The most challenging problem with this routine TB screening remains on how patients are being identified, how data is being captured and managed. Some of respondents expressed their views on the importance of TB screening and the existing system work and its challenges.

One of the Community Health Worker identified to be one of respondents said that:

"It is very important to do a regular TB screening within our Communities but the existing routine TB screening is not well done and has many gaps that might be the origin of endless propagation of TB within his respective community and multi-drug resistance tuberculosis. The identification of suspected cases is not structured, no data capturing during screening and thus no records of TB screening on regular basis." To mean:

"Ni ngombwa cyane gukomeza gukora igenzura ry’abakekwaho kwandura igituntu aho dutuye, ariko uburyo buhari bwo gushyira ahagaragara kugenzura abakekwaho igituntu ngo bapimwe kandi bavurwe mumaguru mashya, ntibunoze rwose. Ibi ndetse bikaba byaba intandaro yo gukomeza kwandura igituntu kuri benshi. Usibye n’ibi, abakirwaye babasha kugira igituntu cy’igikatu. Kubona abakekwaho igituntu kare no kugira imibare yabo muburyo bwanditse kandi buhoraho ni ikibazo. "

5.4 Respondents’ views on the use of Mobile Technology in TB Screening

The use of Mobile Technology has immerged and is well appreciated by the Community Health Workers as well as health professionals after the impact of RapidSMS in reducing considerably the infant and maternal death rate. As the use Mobile technology is more and more becoming a lifestyle of Rwandan. The introduction of this technology in health sector would be a key answer to healthcare delivery, especially in the communities.

All respondents are delighted to have an improved TB screening system. Thus might ease their task of screening TB, help them capture and store data on TB screening on regular basis, and thus ease the follow up to revealed TB+ patients. The category of health professionals largely
commented on the impact of the use of Mobile technology in TB Screening to improve the TB healthcare delivery. Some of respondents expressed their views:

"We all know the impact of Mobile Technology in our daily life and how greatly this transformed our entire lifestyle! If this is used in TB Screening, there should be an invaluable improvement, and this might contribute to the remarkable socio-economic development. It will be an interesting input to see our usual tool of RapidSMS being upgraded with TB Screening application."

This result statement explains how much the integration of TB screening system within Rwanda’s RapidSMS should be an important systematic tool for TB screening to facilitate community health workers to early and accurately report the suspected TB cases in their respective communities as well as providing immediate report to upper levels. The routine TB screening system is time consuming not only that but also implicates transport fees for both (suspected case and the Community health worker) from their community to Health Facility. While the use of mobile technology will be immediate and cost effective. 95% of respondents expressed that it is now very crucial to use Mobile technology in TB screening as it is used in some of healthcare activities.

5.7 Views of respondents about TB screening integration within Rwanda’s RapidSMS
In line with the general objective of the undertaken research which is TB Screening System integration within Rwanda’s RapidSMS health system, the researcher preferably wanted address respondents of potential information (who usually knows the use of existing system i.e RapidSMS and/or those who might be aware of TB infection). When collecting information, respondents immediately understood the objective of the research and gave their views on TB Screening system integration within RapidSMS as an existing tool they are familiar with, an appreciated tool due to its impact in improving infant and maternal healthcare.

Among all interviewed respondents, 100% supported that the TB Screening be integrated within a well known existing system that has so far brought good results and improvement to healthcare. Some of community health workers expressed the relevance of the TB Screening especially its integration within Rwanda’s RapidSMS reporting system.
"As Community Health Workers, it is our duty and responsibilities to screen any kind of suspected TB case in our respective communities. It will be a very big achievement to have a tool that can help us easily and quickly report any TB case, without taking long, because some of us are far from our Health Facilities and this obliges us to look for transport fees and waste time that should be using in our businesses."

Health professionals reportedly appreciated the idea of TB screening system integration within Rwanda’s RapidSMS and expressed their views on how this might have a great impact on the TB healthcare improvement especially at community level. The TBSS will however help the entire health system from the community level to National level to have an accurate data management on TB screening, provide an immediate response to alarms of suspected cases in the communities and ease CHW’s duties and expenses accompanying suspected cases to health Centers. Nurses TB Focal Point said this:

"Having an integrated TB Screening system within Rwanda’s RapidSMS reporting system would be a key element of harmonizing the TB health care and facilitate their daily job as well as reducing the cost of planned outreach for routine TB screening."
CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The main objective of this study was to elaborate a conceptual design of TB Screening System (TB-SS) and its integration within RapidSMS existing system to streamline and fasten the TB screening at community level.

The feasibility of this study revealed a great importance and improvement of the TB health care from the community level to the Central level. Finding of the undertaken research has shown its relevance in omitting TB screening gaps among the Rwandan Communities and the health system as a whole.

Based on the success of the existing RapidSMS by which this TB screening system will be built on the expectation of its impact on the improvement of healthcare in mitigating the TB propagation is positive. Challenges in identifying TB Cases, delays in reporting suspected TB cases and burden of workload to community health workers will found a duly solution.

Functional specifications of the proposed tool are determined and should be based on in developing and implanting the integrated TB screening system that also will manage data for TB screening. The features of the architectural design show that the system can improve adherence of patients to their medication, reduce workload of healthcare providers and allow immediate reporting and reduce distance from patient to health facility as well all related expenses.

With regards to the use of the paper based tool in TB screening, study results revealed that there are no even TB screening records on papers. The results of the present dissertation emphasizes (like other existing scientific work) that limitation to timely data accessibility and retrieval, limitation to rapid data analysis and information sharing, tedious and workload are the major barrier of the use of paper based tools. It is time consuming and lead to the lack of overview with consequences of lack of continuity of healthcare between health professionals and impede the quality of care of patient (Roukema, 2006b). The findings of this study on the TB screening system integration within Rwanda’s RapidSMS suggest that implementing of this system might be a key solutions to early detection of TB cases within communities and has shown that its usability and success might be as possible as RapidSMS.
6.2 **Recommendations**

To comply with normal standards for the use of RapidSMS an existing system when upgraded by the integration of TB Screening system, some recommendations need to be considered to achieve the objectives of this proposed tool:

It recommended to the developers:

- To use the functional requirements of the system usability from this study;
- To ensure the interoperability of the automatic tool with existing software being used in health sector;
- Include feedback platform between patients and health providers;
- Include component of side effect management of the system.

It is recommended to the future researchers:

- To conduct a cost-effective study of the technology before its implementation especially related expenses.

### 6.2.1 Recommendations on TBSS development and future work

The proposed TB screening system is quasi implemented. It is then recommended to future researchers:

- To enhance the security of the system
- To design friendly interfaces and harmonize links between system user’s roles and data sharing
- To revise front-ends and back-ends designs

### 6.2.2 Recommendations for future beneficial use of the findings from this study

- To maximize the use of the proposed system to make it successful
- To provide refresher trainings, system upgrade and maintenance to serve the purpose
REFERENCES

1. Systematic screening for active tuberculosis: Principles and Recommendations, WHO 2013

2. Tuberculosis Detection, Care, and Treatment for People Living with HIV in Rwanda, UNAIDS and HDI, 2011

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6. Measurement of exposures and outcomes, Dos Santos Silva, Isabel, 1999

7. Polonsky, Michael Jay Waller, David S.; Designing and Managing a Research Project: Ethical Considerations; 2011

8. Greet Vandebriel, Tuberculosis in Rwanda: challenges to reaching the targets, 2012


Electronic references

APPENDICES
Appendix 1: Information sheet

A LETTER ADDRESSED TO RESPONDENT
CONCERNING INQUIRY ABOUT TUBERCULOSIS SCREENING
INTEGRATION WITHIN RWANDA’S RAPIDSMS.
“Case study of MUHIMA District Hospital/ NYARUGENGE District (2012-2013)”

Dear Respondent,

My Name is Honore USABIMANA, I am doing my Master’s studies in University of Rwanda and am conducting a research on “Tuberculosis (TB) Screening integration within Rwanda’s RapidSMS system” study for the partial fulfillment of a Master’s of Science in Health Informatics in the faculty of allied sciences in University of Rwanda College of medicines and health sciences, KICUKIRO Campus.

The study is mainly conducted to an individual respondent who currently is working as health professional operating in MUHIMA District Hospital’s catchment area in one of its 10 health facilities and community health workers selected from that District catchment area and one MDR-TB Patient.

Fortunately, you have been selected to participate in this study. Therefore, I humbly request you to voluntarily and honestly contribute to this survey by answering this pre-established questionnaire. The privacy and anonymity of your answers to this survey is guaranteed.

I proudly thank you very much for your kind participation; hoping that you will be sincere and conscious.

✔ CONCISE RULES FOR PARTICIPANT

There will be short questions for short answers, multiple choice answers and open answers. It’s up to candidate to freely and honestly answer to the asked questions according to his knowledge and adaptability. The maximum time to answer to this questionnaire will not exceed fifteen minutes.

For open questions, you need to be brief, conscious and realistic accordingly to the best of your knowledge.

We faithfully applaud your kind participation.

God bless you.

HONORE USABIMANA

63
Appendix 2: In-depth interview guide for medical professionals and information technology specialists

Annex 3: In-depth interview guide for community health workers and patients

1. Alerts, reminder and notification

Annex 4. Informed consent

When conducting research, the ethical consideration mandatory requires the researcher having an informed consent, following is the informed consent for our research:

**Title of the study: Tuberculosis (TB) Screening integration within Rwanda’s RapidSMS System, Case study of MUHIMA District Hospital 2012-2015.**

I, ______________________________ agree to participate in the study. I am aware that participation in the study is voluntarily and I will not be paid for the participation. In addition, all information provided will be treated with confidentiality and that my anonymity will be maintained. I am aware that the results of this study may be published but I will not be identified as an individual. I reserve the right to withdraw from the study at any time if I so wish.

_________________ …/…/…. Signature of participant

----------------------------------

Signature

Honore USABIMANA, Researcher.

Email: honus.honorino@gmail.com

Cell: +250 788855252/0787044900
Appendix 3: Ethical clearance certificate & approval for data collection

REPUBLIC OF RWANDA

Ministry of Health
P.O. BOX: 84 KIGALI
www.moh.gov.rw

USABIMANA Honore
Principal Investigator

Re: Authorization of research

Reference is made to your letter dated 16 May 2016 requesting authorization to conduct a research entitled: “Tuberculosis screening integration within Rwanda’s RapidSMS health system”;

Based on Rwandan Health Sector Research Policy and approval from the CMHS Institutional review board with dated April 21, 2016;

I am pleased to inform you that the Ministry of Health has granted authorization to conduct this research and to collect data according to the approved protocol.

You are requested to share the results with the Ministry of Health and to provide the final report and dataset to the Ministry.

Sincerely,

Dr. Agaës BINAGWAHO
Minister of Health

Cc:
- Director General of Rwanda Biomedical Center
- Dean of School of Public Health / UR/CMHS
- Director of Muhima Hospital
COLLEGE OF MEDICINE AND HEALTH SCIENCES

CMHS INSTITUTIONAL REVIEW BOARD (IRB)

USABIMANA Honore
School of Public Health, CMHS, UR

Approval Notice: No 159/CMHS IRB/2016

Your Project title "Tuberculosis (TB) Screening System Integration Within Rwanda’s Health System" has been evaluated by CMHS Institutional Review Board.

<table>
<thead>
<tr>
<th>Name of Members</th>
<th>Institute</th>
<th>Involved in the decision</th>
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<tr>
<td>Prof Kato J. Njunwa</td>
<td>UR-CMHS</td>
<td>Yes</td>
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<tr>
<td>Prof Jean Bosco Gahutu</td>
<td>UR-CMHS</td>
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</tr>
<tr>
<td>Dr Brenda Asiimwe-Kateera</td>
<td>UR-CMHS</td>
<td></td>
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<tr>
<td>Prof Ntaganira Joseph</td>
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<td>Dr Tumusiime K. David</td>
<td>UR-CMHS</td>
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<td>Dr Kayonga N. Egide</td>
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<tr>
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<td>Kicukiro district</td>
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<tr>
<td>Dr Mudege Charles</td>
<td>Centre Psycho-Social</td>
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After reviewing your protocol during the IRB meeting of where quorum was met and revisions made on the advice of the CMHS IRB submitted on 19th April 2016, Approval letter has been granted to your study.

Please note that approval of the protocol and consent form is valid for 12 months. You are responsible for fulfilling the following requirements:
1. Changes, amendments, and addenda to the protocol or consent form must be submitted to the committee for review and approval, prior to activation of the changes.
2. Only approved consent forms are to be used in the enrolment of participants.
3. All consent forms signed by subjects should be retained on file. The IRB may conduct audits of all study records, and consent documentation may be part of such audits.
4. A continuing review application must be submitted to the IRB in a timely fashion and before expiry of this approval.
5. Failure to submit a continuing review application will result in termination of the study.
6. Notify the IRB committee once the study is finished.

Sincerely,

Chairperson Institutional Review Board,
College of Medicine and Health Sciences, UR

Date of Approval: The 21st April, 2016
Expiration date: The 21st April, 2017

Cc:
- Principal College of Medicine and Health Sciences, UR
- University Director of Research and Postgraduate studies, UR
Appendix 3. Questionnaire

In-depth interview guide for medical professionals and community health workers:

1. **Awareness of the importance of TB screening at community level**

What is the importance of the TB screening at community level?

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2. **Assessment of current TB screening system at community level**

Currently, how do you proceed when doing TB screening?

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3. **Data capturing**

According to you what is the suitable method should be used to enable the TB screening system to accurately capture data through multiple data entry tools available today?

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4. **TB cases identification and management**

A. How do you identify new TB cases in your respective catchment area community?

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B. How long time does it take you to repost to that case to avoid TB propagation?

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C. Which means do you use to report that case?

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5. Use of Mobile technology as key intervention to systematic TB screening at community level

How do you consider the improvement of TB screening system if there is an introduction of use of information and communication technology (mHealth) in TB screening at community level?

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6. Assessment of RapidSMS awareness and importance in healthcare improvement

A. Are you aware of RapidSMS reporting system nowadays introduced in Healthcare system?

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B. How do you consider its contribution in healthcare improvement specially in TB screening?

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7. About TB screening integration within Rwanda’s RapidSMS system

What do you think may be the advantages and improvements in TB screening if there is an eTB system integration within an existing RapidSMS reporting system?

In-depth interview guide for Community Health Workers and MDR-TB patients

According to you, what is the cause of TB persistence in your community given all efforts provided by the Rwandan government?

Kubwawe, nikigitumaigituntugikomezakugaragarahiryana no hinohejuruy’imbaraganyinshiLetaishyira mu kurwanyaiyindwara?

Considering the gravity and epidemiology of tuberculosis in the community, how can the use of Mobile application technology contribute to the eradication of Tuberculosis in your community?

Uhereyekubukananiyandurary’igituntuahomutuye, ubonaikoreshwa ry’ikoranaabuhangarikoresheje telephone ryafashaiki mu gutsinsuraigituntuahoiwanyuutuye?
As a community health worker who knows the contribution of RapidSMS to the reduction of Maternal and Children deaths, what are your expectations from integration of TB screening system within RapidSMS system?

Nk’umujyanama w’ubuzima wakoreshje uburyo bwa RapidSMS bwafashije mu kugabanyaimfuz’ababyeyibatwiten’abana, nikiwumva wakwitegakuburyobwogusuzumaabakekwa kwanduraigituntubokomatanijen’ubwobwa RapidSMS?