A MOBILE INTEGRATED SYSTEM FOR ENHANCING TUBERCULOSIS SURVEILLANCE IN KENYA.

BY

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN INFORMATION TECHNOLOGY, DEPARTMENT OF INFORMATION TECHNOLOGY, SCHOOL OF INFORMATION SCIENCES

MOI UNIVERSITY

ELDORET

2019

DECLARATION

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DEDICATION

This work is dedicated to my family especially my dear Wife for the support and inspiration they gave me during the entire study of the Master Degree Program and particular compilation of this thesis.

ACKNOWLEDGEMENT

To the All Mighty God for his love, provision, protection and support through the whole journey of this program. I would like to extend my sincere gratitude to my supervisors Mr. Reuben Oyamo & Prof. David Gichoya for their support encouragement and guidance on this research project; without their support it was very difficult to finalize it.

To the National TB Centre management and all staffs without your support this project could not be finalized and I always remember and forward my sincere gratitude to the Moi University library department for the availability of relevant research materials you availed during the research period.

ABSTRACT

Tuberculosis (TB) is a huge health problem globally whereby about ten million new cases and million deaths are reported yearly. In Kenya, TB affects a significant population proportion and it remains a key cause of morbidity and mortality. Early detection is considered an efficient intervention measure of TB. This can be achieved through surveillance. However, the available surveillance methods focus on the collection of TB related data and disregards patient notification. These methods are also ineffective in gathering real time data for analysis. The study sought to determine how TB Surveillance is done in Kenya with an aim of improving the current systems through integration of mobile phones to capture TB disease occurrences at the village level. The objectives of the study were to; review the existing status of TB surveillance systems, determine the existing challenges that are faced by TB Surveillance system, establish the requirements for TB surveillance system through a user requirements analysis and develop a mobile integrated prototype system for TB surveillance. The study was anchored on the theory of agents and MAS systems in the development of the prototype. Data was analysed using qualitative methods. This offered a deeper understanding of user requirements that were then used to develop a TB surveillance system using the Prometheus agent design methodology. The system was implemented on PHP, My SQL for database and Java Agent Development Framework for multi-agent platform. The designed MITSS prototype proofed that the medical practitioner can interact with the patient in real-time. Usability and functionality tests were done indicating that the application was an effective surveillance and responsive tool. Finally the study concluded that by determining the major areas of future improvements on the existing system and recommendations for research in future.

LIST OF ABBREVIATIONS AND ACRONYMS

ACL	Agent Communication Language
AIDS	Acquired-Immune Deficiency Syndrome
ART	Anti-Retro Viral Treatment
BDI	Belief Desire Intention
CBHC	Community-Based Health Care
CCHIT	Certification Commission for Health Information Technology
CDC	Centre for Disease Control
DLTLD	Division of Leprosy, Tuberculosis and Lung Diseases
DOTS	Directly Observed Treatment Service (for Tuberculosis)
EHR	Electronic Health Records
EMR	Electronic Medical Records
FIPA	Foundation for Intelligent Physical Agents
GTZ	Deutsche Gesellschaftfür Technische Zusammenarbeit
HMIS	Health Management Information System
HPSC	Health Protection Surveillance Centre
HTML	Hypertext Markup Language
IDSR	Integrated Disease Monitoring and response
JADE	Java Agent Development Framework
JSF	JavaServer Faces
MaSE	Multi-agent System Engineering
MAS	Multi-Agents Systems
MITSS	Mobile Integrated Tuberculosis Surveillance System
MOH	Ministry of Health
NNDSS	National Notifiable Diseases Surveillance System
NTP	National TB control Programmes.
PDT	Prometheus Design Tool
SIR	Susceptible Infected Recovered
SMS	Short Message Service
USAID	United States Agency for International Development
WHO	World Health Organization

DEFINITION OF TERMS

Communication Manager is a control module that facilities sending and receiving of messages with the system

M-Health is offering health service through mobile technology.

Mobile Integrated Tuberculosis Surveillance System is a system that uses a mobile feature in its functionality mainly on the communication aspects.

Prometheus is a methodology that has a detailed process for specifying, designing, and implementing intelligent agent systems.

Tuberculosis is an infectious bacterial disease caused by Mycobacterium tuberculosis, which most commonly affects the lungs.

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CHAPTER ONE: INTRODUCTION

1.0 Introduction

Chapter one covers the background information of the study. It highlights disease surveillance in the health sector and then narrows on to Tuberculosis surveillance. It also presents the problem statement, aim and objectives of the study and research questions.

1.1 Background to the Study

Tuberculosis (TB) is a common infectious disease that affects the lungs caused by bacteria called Mycobacterium tuberculosis. A person suffering from this disease losses weight, experiences chest pain, fever and cough composed of sputum as well as mucus. According to World Health Organization (2017), the disease is transmitted from one individual to the other through droplets from the lungs and through of already infected person. TB is ranked as among the highly contagious bacterial disease as well as killer of many people in the globe being second to only HIV/AIDS. In 2013, approximately nine million incident cases with 1.5 million deaths were reported from the mycobacterium tuberculosis. Additionally, TB is still ranked as the major killer among the people with HIV/AIDS accounting to about one out of four co-infected patients (Goldrick, 2004). TB may be propagated through airborne means to other family and community members if the disease is not diagnosed and treated immediately. According to UNAIDS (2013), it is estimated that untreated person is likely to infect about 10 to 15 persons annually.

TB is among the leading causes of morbidity and mortality globally. According to Centre for Disease Control (CDC), 2005); WHO (2007), and Sanjay (2004), the deaths in the globe is estimated to be around 2 million with one-third of the people having the bacilli. In every year, about 9.2 million cases are diagnosed annually.

In Africa countries, TB incidences are estimated to be more than double between the year 1990 and 2005 and the trend is rising (WHO, 2010). The study by Chaisson and Martinson (2008) indicate that burden of the disease carried by Africa is about 29% and account to about 34% of total death rate in the world. Among the 22 countries associated with high TB burden, Kenya is ranked 15th; with the approximated incidence cases of 355 per 100,000 people yearly and annual mortality rate of 84 deaths per 100,000 people (WHO, 2007), (CDC, 2005). According to WHO (2018), about 10.4 million individuals contracted the disease in 2016, and about 1.7 million died (consisting of 0.4 million HIV infected persons). The article also claimed that over 95% of TB related deaths were among low- and middle-income nations.

Moreover, the daily death from TB is estimated to be about 1500 making Africa the only continent with increasing rates of TB. According to AMREF (2012), 10% of these deaths are children. The newly diagnosed cases in 2011 were 5.8 million which were reported to the World Health Organization (WHO) and National TB Control Programmes (NTPs). This was an increase based on 1995 where 3.4 million new cases were reported. Nonetheless, still two-thirds of the approximated population of 8.7 million people got infected with TB in 2011. In the recent years, there has been stagnation of TB notifications (World Bank, 2010).

The goal of TB surveillance is to know the number of cases in order to enhance development of measures to curb the transmission of TB to susceptible persons. According to Barreto*et al* (2005), the reported cases may only depict a small proportion of TB cases. There have been challenges estimating number of TB cases by planners and epidemiologists in their control plans. The current indirect estimation method relies on accuracy of other TB data that include the number of deaths and number of people infected by Mycobacterium tuberculosis (WHO, 2014).

1.1.1 Tuberculosis in Kenya

Tuberculosis in Kenya is still the leading cause of morbidity and mortality cutting across all age groups. The most affected age bracket is between 15 and 44 years which is the productive age. The leading contributing factor of high TB cases in Kenya is high prevalence of HIV which have affected about one million people. Social deprivation and poverty are among other contributing factor to high TB cases. These factors have spurred the growth of informal settlements with poor hygienic conditions, prisons congestion and insufficient access to health care. The notification of TB cases has been rising in the last decade with an annual average rate of 16 percent. In the same period, the Division of Leprosy, Tuberculosis and Lung (DLTLD) had challenges providing integrated HIV and TB services as well as other interventions without a commensurate increase in the human resource available for TB control. Furthermore, there has been a concern regarding drug resistance to TB which is expected to cause more challenges in the fight towards the disease especially in developing countries.

DLTLD is inducing initiatives aimed at achieving internationally agreed Third Sustainable Development Goals (SDGs) in facilitating healthy lives and promoting the well-being across all ages including eradication of diseases such as TB. The short term goal is to achieve 70 out of 85 targets. According to MOH (2018) the TB SDGs are aimed at halting and beginning to reverse the incidence and mortality due to TB by 2025.

Tuberculosis is a major cause of deaths among children especially in the wake of the HIV epidemic. The Kenyan government is implementing all the STOP TB strategy components which have been grouped further into 15 thematic areas in the 2011-2015 National strategic Plan. In 2010, 106,083 patients were notified which represented a 4% decline compared to the 110,065 cases reported in 2009. The increasing TB burden is majorly linked to high HIV prevalence which is now approximated as 7.1% for the entire population (UNAIDS, 2017).

1.1.2 Importance of Tuberculosis Surveillance

Disease surveillance refers to the process of being vigilant and watchful for health problems, and the determinants in order to take control and preventive measures. A single functional disease surveillance system integrated into each level and health care system intervention programme is crucial for identifying problems and resolving them. The incorporation of the epidemiological methods into the surveillance system helps the health personnel to come up with informed polices. It helps policymakers to select the most suitable data that would help to set priorities, develop interventions as well as mobilisation and allocation of resources (Sarah, 2012). Surveillance improves the detection of disease cases, monitoring and development of actions to curb further illness. The surveillance offers key information that can be used to plan, implement, monitor and evaluate intervention programmes for public health. Early epidemics warning is crucial for efficient and quick control, while data and information on endemic communicable diseases is crucial for monitoring purposes. In most countries, surveillance capacities have been developed to monitor high burden diseases, detect the outbreaks of epidemic prone diseases and to monitor progress towards national or global intervention targets. Surveillance of communicable diseases is therefore a national function.

A disease surveillance system is regarded valuable as it helps to contribute, prevent and control of adverse health events, which includes an enhanced understanding of the public health implications of such events. In Kenya, currently, the system is utilized as a basis for requesting drugs.

1.2 Problem Statement

In Kenya, Tuberculosis is still among the major causes of morbidity and mortality. While TB has a cure, it kills a large number of people every year. If the patient are diagnosed early enough, they can be put on medication and the disease treated. There are different intervention methods that can be used to detect, prevent, and control TB. The DLTLD operates and maintains national TB surveillance system where all the cases of TB diagnosed are line-listed and notified. The diagnosis and treatment of patients is conducted in service delivery points. These delivery points have been established in various levels and under different ownership. The paper based and electronic systems are utilized at the sub-county and county level. At the district level, data synchronization is done in a customized access database which allows for generation of reports that guide actions at the lower levels. The access database is then sent to the provinces for synchronization, analysis, and generation of reports. The purpose of all the data gathered is to guide and inform policies in the ministry of health. Early detection and rapid response are crucial for the reduction of the morbidity and mortality. Surveillance is a key means of early detection and an effective intervention measure against TB. However, the surveillance methods available have been criticized that they only concentrate gathering data related to TB and disregard the adherence of patients to the treatment schedules.

To address the fore mentioned drawbacks, the purpose of this study was to devise a prototype to demonstrate how mobile technology can be applied in TB surveillance using Multi-agent System Engineering (MaSE) methodology to benefit the patients and the medical practitioners. It is expected that the prototype prove on mobile integration into the existing system would help to enhance timely multi-level communication and data transmission and promote TB surveillance. This is expected to promote timely reporting and response to cases of TB. In addition, by catering for the patients' needs, this study will help to address the problem of Drug-resistant TB to make sure the patients comply with the treatment. This helps in follow up diagnostic tests, and effective documentation of treatment outcomes.

1.3 Objective of the Study

Thus, the study sought to design and devise s prototype of a mobile integrated Tuberculosis surveillance system to be used to enhance TB surveillance in Kenya.

1.3.1 Specific Objectives of the Study

The study sought to meet the following specific objectives:

1. Review current state of TB surveillance systems in Kenya
2. Establish challenges facing TB Surveillance in Kenya
3. Determine the requirements for TB surveillance system in Kenya
4. Design and develop a prototype of TB surveillance system in Kenya.

1.3.2 Research Questions

The use of TB surveillance system posses' significant questions which form part of the research project scope:-

1. What is the current state of TB surveillance systems in Kenya?
2. What are the challenges facing TB Surveillance in Kenya?
3. What are the requirements for design and development of a prototype for TB surveillance system in Kenya
4. How can theTB Surveillance system process be redesigned and improved to be effective?

1.4 Significance of the Study

Tuberculosis surveillance is a prevention strategy which remains a key intervention in reducing Tuberculosis mortality and morbidity. Therefore developing efficient and effective Tuberculosis surveillance has a significant impact in preventing Tuberculosis spread in Kenya.

The purpose of TB surveillance strategy is to reduce the morbidity that results from TB, curb TB transmission and improve the social economic development as fostered in the Third Sustainable Development Goals (SDGs). Further, the study help to shape policy making on the measures that can be used to control and prevent TB transmission and prescribe appropriate interventions.

1.5 Scope of the Study

The focus of the study was on the analysis of current national TB surveillance systems at DLTLD centre with the aim of developing a prototype of a mobile integration module using a multi-agent based system.

1.6 Limitations of the Study

Limitations refer to the conditions that the researcher cannot control and that influence the study findings, the conclusions and their applications (Best & Kahn, 1993).

Due to the sensitivity of the data to be used, the data provided in the system is dummy data and hence do not depict the real TB prevalence in the presented areas. The cost of analysis too was high and thus limiting sample size and the facilities assessed.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

Chapter two reviews the relevant literatures related to the study of surveillance of tuberculosis. It also focused on the status of the health care in terms of TB infections. This chapter also reviewed the existing disease surveillance methodologies currently used in the surveillance of Tuberculosis disease, the strengths and weakness of the existing methods and the relevance to the solution proposed.

2.1 Tuberculosis Surveillance

According to WHO (2008), disease surveillance is a progressive process in which data is collected, analysed and interpreted for the purpose of planning, implementation and evaluation of public health practices and policies. The two functions served by surveillance system include early warning towards potential public health threat and monitoring of diseases which may be multi-disease in nature. One of the importances of surveillance is measuring the disease burden hence, forming the basis of making informed decision towards planning and targeting of health care interventions. The defining characteristics of an ideal system is accuracy, timeliness in analysis and comprehensive information reporting to those “who need to know” the entire “feedback loop” of robust surveillance system (Castro, 2010). According to Maurice (2010), the objective of disease surveillance is to enhance the ability of entire health care system to detect and respond to conditions and diseases causing high morbidity and mortality.

In this regard, the goal of TB surveillance is to create consciousness and awareness among the people, so that the mitigation strategy to curb transmission to exposed group can be taken. In another definition by HPSC (2014), disease surveillance is an information-based process that entails collecting, analysing and interpreting huge data emanating for various sources. The collected information is utilized in various ways that include:-

i. Evaluation of control effectiveness as well as preventative health measures
ii. Monitoring infectious agents changes such as trends in antimicrobial resistance development
iii. Supporting health planning and appropriate resources allocation in the healthcare system.
iv. Identifying the population at a greater risk or regions for targeting interventions

According to (HPSC, 2014) the goal of TB surveillance is to give information for preventing and controlling tuberculosis. In the TB Action Plan, High-quality surveillance presents information necessary at local, national and international levels for:

- Identifying outbreaks and among other related incidents and guiding immediate action
- Monitoring trends and measuring the disease occurrence and anti-TB drug resistance
- Developing Informed policy
- Informing development of services, and
- Monitoring the success of the TB programme.

According to NICE (2011), the surveillance also focuses on identifying the characteristic of population highly susceptible to infections so as to devise health care actions and health services.

The TB surveillance in Kenya encountered various challenges:

i. The health care facilities located in remote areas that are hard to reach lacked the means of delivering reports
ii. Some health facilities located in sub-county also lacked resources such as motor vehicles, access to courier services and mobile network to deliver report to the next.
iii. Lack of provision for effective feedback and back-communication to the regional levels
iv. After adoption of mobile reporting over time, there was lack of short message service (SMS) standardization to facilitate data accuracy

This study illustrates the urgent need for an enhanced TB surveillance system available in lower levels. Electronic surveillance systems are software based systems that are utilised to gather, transfer and report the TB data elements recommended by WHO. There are numerous merits offered by electronic surveillance compared to paper-based systems utilized in various areas with low resources. The merits include better data security, enhanced quality of data, data completeness, improved data entry feature and analysis and links with better feasibility to other health care programs. However, the merits have to be compared against the electronic surveillance costs and requirements. More so, support and implementation of a quality paper-based surveillance system and other infrastructural costs, training and human resources required to implement an electronic system ought to be considered while assessing the merits. According to MOH (2013), the three factors noted while implementing various TB surveillance system included requirements, feasibility and values of the system to support the enhancement of TB surveillance as recommended by WHO.

WHO postulates that the current investment in health management information systems could accrue numeorus benefits that include aiding decision makers in detecting and controlling epidemics, monitoring the progress towards health goals, and promoting equity. More so, it helps to helps in offering empowerment through up to date health-related information, and help to improve the quality of services offered. Also, it promotes the development and implementation of effective health policies, permits the evaluation of scale-up efforts, and promotes innovation, improve governance, mobilize new resources, and promotes accountability in the manner they are utilised.

2.2 Kenya Healthcare System

Key health impact indicators indicate that the health status in the country has been declining. The deteriorating status is attributed to the prevailing and new conditions, and insufficient response measures. Also, according to the health indicators, there are wide disparities in health countrywide which is mainly attributed to the socio-economic factors, gender and geographical disparities. The recurrence in the measles and polio can in the recent past can also be attributed to low immunisation coverage and cross-border social disturbances that have occurred recently.

Communicable diseases are a large burden with malaria being the key cause of morbidity (30%) seconded by respiratory diseases at 24.5% (WHO, 2009). Currently, the HIV prevalence is about 7.4%, and it is more prevalent among women than among men. A huge proportion of the people infected with HIV are not aware of their status, and only about 35% are in need of anti-retro viral treatment (ART) are accessing treatment. TB prevalence is high, about 319 per 100,000, and there have been challenges in controlling the disease (WHO, 2009).

2.2.1 Health Management Systems (HMS)

Healthcare organizations comprises of a wide range of disparate information systems (IS) that are used to support particular healthcare needs. The information sharing among these systems has always been a huge issue for the management.

A strong health system requires comprehensive and up-to-date health information with Kenya currently facing its greatest challenge with regards to the collection, analysis, evaluation and interpretation of indicator data based on its current Health Management Information System (HMIS). One of the key areas identified is its present failure to capture the necessary data, with particular emphasis placed on chronic disease cases including TB as the largest and most costly challenge in a country with a generalized epidemic.

Jajosky and Groseclose (2004) highlighted the significance of timeliness as a major measure of the performance of public health surveillance. The series of events used to report information may delay information relay to the National level to be utilised for decision making. Health incidents are reported to the National Public Health System as shown in the figure below.

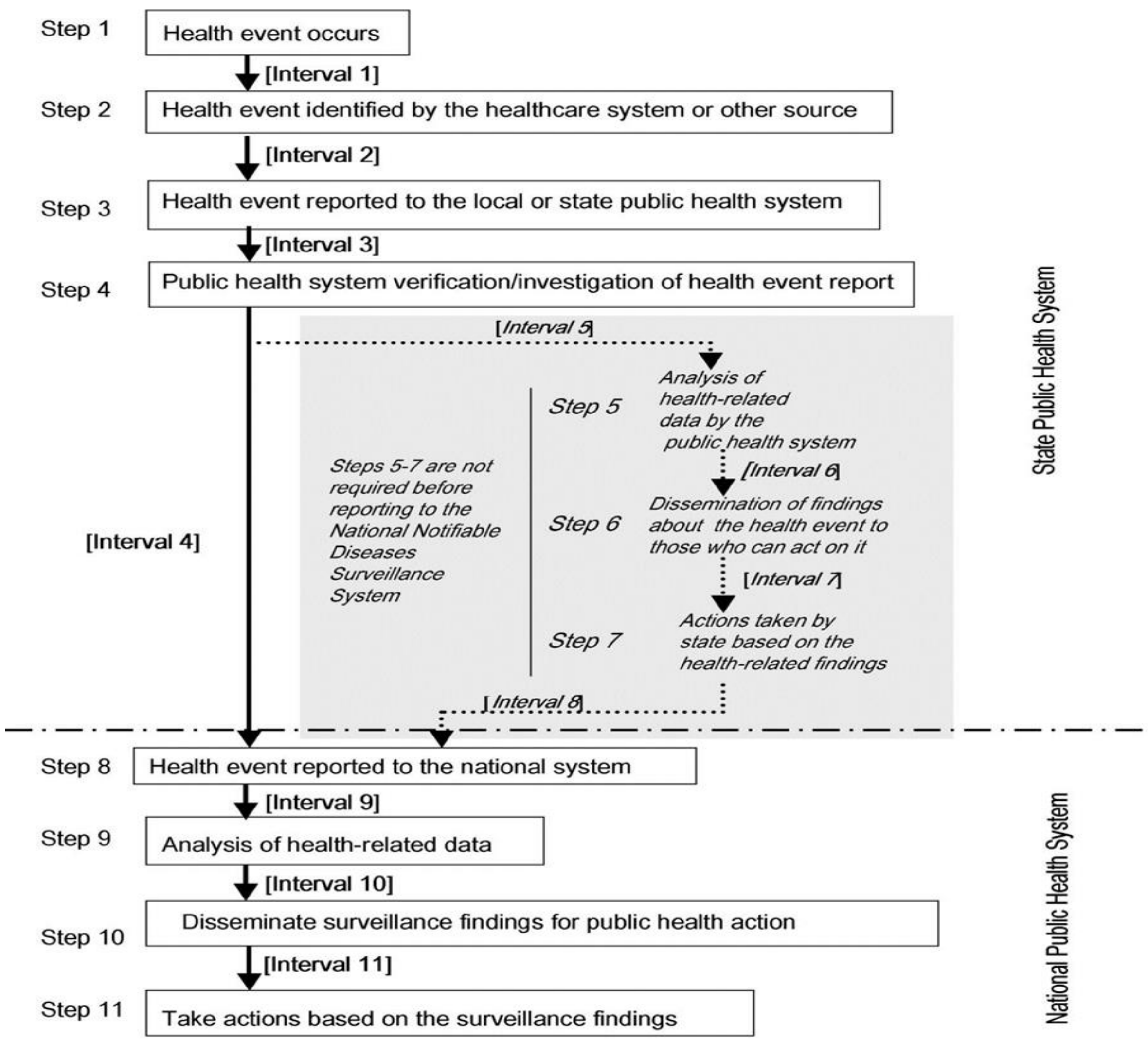

Figure 1: Public Health System

Source: *Jajosky and Groseclose, 2004*

Despite the significance of monitoring and evaluation in the health sector, the system has not received sufficient focus and expansion is still highly uncoordinated and fragmented. Currently, HIV still remains a huge snag in the country and to the economy in Kenya. It is estimated that over 50% of hospital beds are occupied by HIV/AIDS patients and recent figures suggest that the prevalence has risen from 5.1% in 2006 to 7.4% in 2008. The fact that half of the infected population in Kenya is on anti-retroviral (ARV) treatment turns AIDS into a chronic clinical condition that requires effective management systems - lifelong. The 4,500 healthcare facilities registered in Kenya are distributed between the range of providers and across the different levels of care, with a slight majority of those being placed in the control of the government (52%) (GTZ, 2009).

Transforming national human and veterinary disease surveillance systems from paper into integrated electronic form helps to determine infectious illnesses (Burdakov et al, 2012). It shows how Electronic Integrated Disease Surveillance System can be used to improve the health surveillance by utilising an example from Kazakhstan. The available research indicates that real-time disease surveillance data can be generated using smart phone applications. Asif, et al (2013) designed a GIS based system that was beneficial to the public health officials and other decision makers for the development of preventive measures.

Koopmans (2013) conducted a study on application of innovations in disease surveillance with an aim of facilitating early detection of diseases globally through international travel and trade. Chandrasekar (2013) undertook a study on the available disease surveillance systems in the United Kingdom and Sri Lanka. In this study the possibilities of creating an information system that can be used effectively to conduct surveillance of diseases. They also focused on how the available surveillance systems could be computerised for notification to improve the completeness and promote timely reporting.

The summery of other researches is presented as follows;

Table 1 Disease Surveillance Systems

	DISEASE SURVEILLANCE SYSTEM	**DESCRIPTION**
1	National Notifiable Diseases Surveillance System (NNDSS)	Public Health disease surveillance system that offers powerful capabilities to public health officials for use in monitoring the prevalence of the diseases. It helps to collect, manage, analyse, interpret, and disseminate health data for nationally notifiable diseases. It helps to facilitate the development and maintenance of national standards, enable maintenance of the official national notifiable diseases statistics, offers detailed data to CDC programs to assist in the identification of specific disease trends; and improves working with states and partners to implement and assess prevention and control measures
2	National Electronic Disease Surveillance System (NEDSS)	NEDSS is a standards-based method that is used to link public health and clinical medicine. This approach emphasizes on how data and information can be used to improve the development of the most effective surveillance systems both at the local and national levels.
3	TIBU	Below are the main features;

		Electronic registers: i.e. TB facility, drugs and patients, One time data entry at source by use of a mobile tablet, Transfer of data in real time to the central unit, Seamless integration with DHIS2 (National, Health Information System) The ability to generate real time reports, level Automation of referral forms which leads the determination and tracking of suspects. Transfer of funds to NTP staff and MDR-TB patients by use M-Pesa.
4	Jamii Smart Kenya	The mobile solution utilises SMS and web portals to deliver the clinical components for mother and the management of under 5 cases and connect it to a community health monitoring and evaluation system.
5	National Electronic System for Disease Surveillance in Rwanda (eIDSR)	Rwanda has devised a national Electronic System for Disease Surveillance that has helped to identify the outbreak of diseases and put in place prevent measures. The mobile technology based system was funded by the US Centers for Disease Control, and implemented by Voxiva in 2013.

All the above systems despite serving the purpose in which it was intended lacks the element of communication and collaboration with the patient who is the paramount player in the eradication of the diseases.

2.2.2 Telemedicine

Telemedicine is the process in which telecommunication technology is used to offer health care services over a distance Claudia et al. (2013). Most scholars have identified Telemedicine to be always the use of technology in high-level healthcare centres and that it's an expensive venture yet very efficient.

Telemedicine initiatives have helped to improve the health outcomes of people in the marginalized areas (Lemaire, 2011). In addition, the implementation programmes have helped to reduce mortality rates, and reduce the rate at which people contract diseases, leading to long life spans (WHO, 2011). Most countries are yet to adopt technology in the treatment of diseases but have majored in use of technology for data collection. Studies reveal that various systems have been devised to serve the interest of the service providers and exclude the service consumers. MITSS will complete the loop of the service provider and the consumer to ensure that there is complete cycle in the implementation of decisions made to control the TB disease.

2.2.3 Applications of M-Health in Tuberculosis Surveillance

M-heath refers to utilization of mobile technology in offering health service such as prevention and case findings through Mobile phone text messages. Patients details contained in the database includes telephone and email contacts that can be used for both communication and surveillance of the patience adherence to the treatment schedules.

The same technology can help the patients to locate the nearest treatment centre based on their geographical location.

Mobile technology can help to improve communication and overcome language barriers between the health services providers and the patients. They achieve this by offering them translations of information and helping them to access further information in a language the patient can understand. This study successfully developed an application to enhance patient's interactions with the medical support teams, with emphasis on adherence to medical treatment to avert cases of TB drugs resistance.

2.2.4 Standards and Guidelines for HIMS

Standards and Guidelines for Electronic Medical Systems in Kenya, have been developed in adherence to WHO guidelines, international standards and other comparable settings. EMR Technical Working Group coordinates the development of this document through the Ministry of Health. Most referenced standards in development of Health systems are:

1. ISO /TR 20514: Health Informatics – Electronic Health Record – Definition, scope and context
2. ISO/TS 22220: Health Informatics Identification of health care subjects.
3. HL7 Electronic Health Record – System Functional Model, Release 1 February 2007
4. ISO/TS 18303: Health informatics — Requirements for an electronic health record architecture
5. CCHIT Certified 2009 EMR Certification Criteria

2.3 Tuberculosis

Tuberculosis is an infectious disease caused by tubercle bacillus that attacks both human and animals. A common characteristic of this disease is the formation of tubercles on the lungs and body tissues. The person suffering from TB coughs mucus and sputum, lose weight rapidly and experiences chain pain.

In Kenya, TB is a serious health concern particularly among the local travellers than the foreign travellers. The disease is spread through when infected people coughs and sneeze. TB is curable which makes it non-contagious. Also, there people can be vaccinated to protect them from the disease.

Table 2: Comparison of the Advantages and Disadvantages of Paper vs. Electronic

PAPER BASED SURVEILLANCE SYSTEMS	ELECTRONIC SURVEILLANCE SYSTEMS
- Well-established, standardized system of data collection and reporting - Relatively low technology threshold required for implementation - Can be easily implemented at all levels of health care - Low costs to implement and maintain - Difficult to rapidly detect variation in the quality of reporting between quarters and among administrative levels - Time-consuming manual entry, compilation, transfer and analysis of TB data - Restricted 'real-time' quality control and	- Time-saving (record reviews, patient follow-up) - Real-time report generation capability (standardized and ad hoc) - Allows for complex analyses - Increased accuracy and confidentiality controls - Safer data maintenance (i.e., patient confidentiality and integrity) - Dependent on a well-established paper-based system - Increased infrastructure needs (e.g., computers, regular electricity supply)

validation of data for supervision - Limited options for securing data to maintain patient confidentiality and prevent data loss	- Specialized human resource requirements - Specialized training and support requirements - Higher implementation and maintenance costs

2.4 Theory of Agents and MAS Systems

By definition, software agent is an encapsulated flexible computer system that is located in some environment, and has autonomy in that environment in order to meet the design objectives (Wooldridge, 2000).

Encapsulated computer system shows that there is a difference in agent and the environment. Additionally, the boundary is well defined and there exist and concrete interface between the agent and its environment. The autonomy, which is essential in the definition, indicates that the agent can operate independently without guidance from human. An autonomous agent makes a decision of whether to perform the action requested. The agent has responsive behaviour since it can sense and effect. Also, the definition insinuates that agents have problem solving capabilities that have well defined interfaces as well as boundaries for achieving a specific objective. In some cases, agents are referred to as socio-cognitive entities that have the capability of individual social behaviour. According to Wooldridge (2000), agent is referred as cognitive since it has mental attitudes that represent the world and motivating action.

Moreover, the socio-cognitive factor of agent is depicted when it has an intentional stance for environment and has assumption that other agents are cognitive entities with mental attitudes for motivational and representation purposes (Dennett, 1987). Social behaviour is normally defined by the ability co-operate with others and users as well as the ability to communicate with them. Lastly, according to Nwana and Ndumu (1998), truly intelligent agents can learn from their interaction with their environment. Different types of agents including software agents, life-like agent (like humans and artificial life types), and robots are classified under agent taxonomies.

2.5 Agent Architecture

The Agent architectures are essential mechanisms underlying the autonomous components that support the effective real-world behaviour, dynamic and open environments. Intelligent agent architectures development was the initial focus in agent-based computing field, and various architecture lasting styles were determined in the early stages. The architectures ranged from purely active (behavioural) to more deliberative architectures. Purely active architecture operated in a simple stimulus-response manner like Subsumption architecture highlighted in Brooks (1991) while deliberate architecture have reasoning about their actions like those highlighted in belief desire intention (BDI) model (Rao & Georgeff, 1995). There is a layered architecture between the two architecture which involves both reaction and deliberation. Therefore, agent architecture has four major divisions: logic based, reactive, BDI and layered architectures. To begin with, Logic-based architectures are based on the techniques from traditional knowledge-based systems where reasoning mechanism is used to symbolically represent and manipulate the environment. The key benefit of logic-based architecture is that encoding is simple. The demerit of this technique is that it is hard to translate the real world into accurate and adequate symbolic description. Also, it is time consuming to execute and the result are lately available to be useful. Secondly, reactive architectures normally utilise stimulus–response mechanism generated by sensor data to implement decision which are highly related to situation to action. They rarely have central symbolic model and do not use complex symbolic reasoning. Brooks's subsumption architecture is the commonly known reactive architecture. From this architecture, Brook got an idea that an intelligent behaviour can be developed without explicit representations and abstract reasoning and that intelligence is an emergent property of certain complex systems.

2.6 FIPA Specifications

According to IEEE Standards Committee (2004), the FIPA is a global that promotes intelligent agents industry through openly developing specifications that support interoperability among agents and agent-based applications. The five parts contained in FIPA specifications include agent communication, abstract architecture, agent message transportation, agent-based application, and agent management. Agent management provides the normative framework within which agents operates and determines the logical reference model for agent creation, registration, communication, migration and retirement, as shown in figure 2.

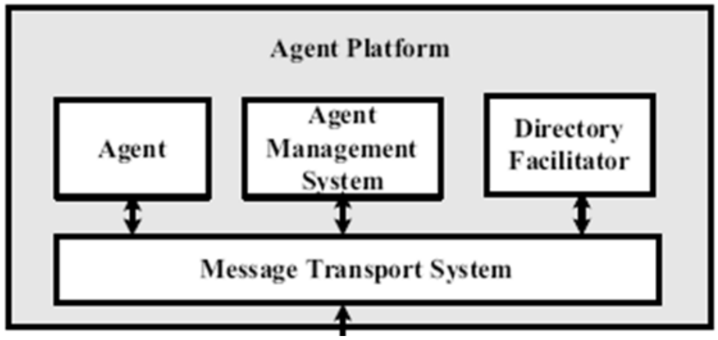

Figure 2: Agent Management Reference Model (IEEE Standards Committee, 2004)

2.7 Multi-Agents Systems (MAS)

MAS are the new paradigms that are used to comprehend and build distributed systems with the assumption that the computational components are autonomous. Agent-based systems technology is being used as the new paradigm to conceptualize, design, and implement software systems. By definition, agents are complicated computer programs that work independently for the user across distributed and open environment to have a solution for the increasing number of problems. However, applications require many agents that work simultaneously. For instance, according to (Gasser et.al, 2001) multiple agents have illustrated their capabilities in achieving critical needs in content-rich, mission-critical, and high-speed distributed information systems. There are numerous merits offered by MAS approach compared single agent or centralized approach:-

i. MAS have the capability of distributing computational resources across interconnected agent network.
ii. MAS have been modelling problems in form of autonomous interacting component-agents. This approach is proving to be the best natural way of representing user preferences, team planning, , open environments, task allocation and so on.

iii. MAS also retrieve, filters, and efficiently coordinate information from spatially distributed sources.

iv. MAS give remedy in incidences where the expertise is spatially and temporally distributed.

v. MAS boost the overall performance of the system in regard to extensibility, flexibility, robustness, reliability, maintainability, efficiency, reuse and responsiveness of computational dimensions.

Evidently, MAS has numerous agents within the contextual environment. The agents within MAS need compete and cooperate on top of inter-agent communication. Even though they are autonomously selfish, they act like human and in some cases aims to achieve their goals at the expense of other agents but in a social structure which acknowledges that sharing and collaboration is beneficial and profitable (Brian Henderson-Sellers & Paolo G., 2005). Hence, according to Zambonelli et al (2001), the perception of organized agents working within a social structure is a very strong driver in AO methodologies. Among the areas where multi-agent systems are applied is health care (Moreno and Nealon, 2003). For instance, among the proposed areas where the multi-agents are applied in health care are scheduling patients and management, access and manage medical information and supporting decision making. Application of multi-agent systems in health care has proved to offer the right solution for building medical decision support systems (Hudson and Cohen, 2002). According to Lanzola and Boley (2002), it also enhances coordination between the different professionals involved in the health care processes

2.8 The Agent Paradigm

According to Jennings and Wooldidge (2000), intelligent agents are the new paradigm for developing software applications. Currently, they are the focus of interest on various fields of artificial intelligence and computer science. Agents have ensured that representation, co-operation and coordination are supported between heterogeneous processes and their users. Large number of organizations and researchers are using agents in different types of applications. The current real world application of agent cut across various sectors such as commerce, industry, entertainment, and health care. The application is both in small systems, email filters to more complex systems such as air traffic control. The dissertation will cover the characteristics, concepts and architectures of agent rather than the entire agent field.

2.9 Agent Design Methodology

There are numerous methodologies for designing the agent such as Gaia, Prometheus, Tropos and among others. To design the TB surveillance prototype, Prometheus methodology was used.

2.9.1 The Prometheus Methodology

According to Lin Padgham (2004), the Prometheus methodology is a well laid down process for specifying, designing, and implementing intelligent agent systems that was being developed for the past few years.

Prometheus is distinct from other methodologies since it supports intelligent agent development via provision of “start-to-end” support, being detailed and complete, evolved out of practical industrial and pedagogical experience and is applied in both industry and academia. According to Winikoff (2004), Prometheus is amenable tool for support and provides scope for cross checking between designs.

The figure below shows the three phases of methodology:

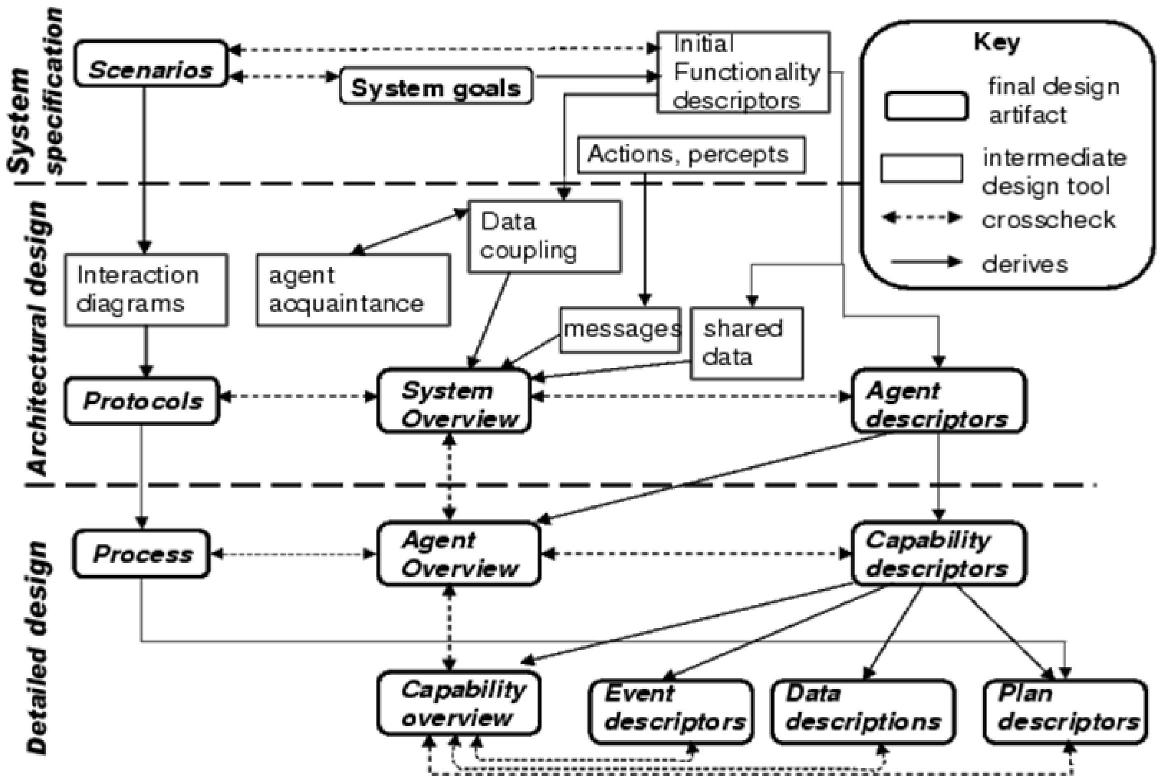

Figure 3: Lin Padgham, (2004).

• **System Specification**: where goals and scenarios are used to define the system.

• **Architectural design**: where the types of agents are identified; the overall structure of the system is captured in a system overview diagram; and scenarios are developed into interaction protocols.

• **Detailed design**: where the details of each agent's internals are developed and defined in terms of capabilities, data, events and plans.

All the phases includes models that focus on the dynamics of the system, (graphical) models focusing on the system's structure or its components, and textual descriptor forms that offer details for individual entities.

2.9.2 Strengths of Prometheus over other Methodologies

Prometheus methodology is practical in nature and it therefore aims to be complete offering all that are required to identify and design agent systems. Other distinctive Prometheus features include:

• Prometheus offers comprehensive guidance on the ways to do different steps that forms the Prometheus process.

• Prometheus promotes the design of agents on the basis on goals and plans. The goals and plans are used to realise flexible and robust agents.

• Prometheus incorporates different activities from requirements specification through to detailed design.

• Prometheus is designed in a way that facilitates tool support which is available freely.

2.10 JADE –Agent Development Framework

JADE (Java Agent Development Framework) is a software that is used to develop multi-agent systems and applications that conforms to FIPA standards. It is composed of a FIPA-compliant agent platform and a package that is utilised to develop Java agents. JADE is developed using Java language and comprises of different Java packages. Java was suitable due to its numerous attractive features. These features include Object Serialization, Reflection API and Remote Method Invocation (RMI). In this study, JBuilder is integrated with JADE to enable the development of agents in the system. The sole essential thing is make the JADE libraries known to JBuilder through the addition of jade.jar, jadeTools.jar, iiop.jar, and base64.jar into the configuration libraries of JBuilder.

JADE has an all-inclusive set of API functions, which enable the development of a MAS system for example:

1. Built-in XML codec which implements the Agent Communication Language (ACL) format specified by FIPA. However, user defined communication language codec is also supported (Naso D, Maione G, 2002).
2. Widely used SL content language is built-in according to FIPA specification. Application defined ontologies and content languages are also supported (Naso D, Maione G, 2002).
3. Common interaction protocols (such as FIPA contract net protocol) are also built-in and ready for direct utilization (Bellifemine et al, 2008).

There are many more add-on components developed for JADE. For example, support for J2ME to enhance the usability of JADE in terms of integrating mobile applications, as well as its portability to embedded platforms

2.11 Unified Modelling Language

The UML is enables clear communicate of requirements, architectures and designs. This language is complements different design process methodologies. The business use case of the system is established first through the identification of all the external entities that will interact with the system and allows for the definition of the nature of the interaction at a high-level. This involves the identification and description of all use cases. The business case comprises of risk assessment, success criteria, estimate of the required resources, and a phase plan that shows dates of key milestones (Kruchten, 2003). The analysis of the probe domain is then done to establish an effective architectural foundation. The description of the functions of the system is then done. Actors are determined, representing the users, and any other system that may interact with the system under development. Use cases are determined, representing the system behaviour. Because use cases are developed based on the needs of the actors, the system is likely to be more relevant to the users. The purpose of modelling is the establishment of the between the different process that will complete the task.

2.12 Modelling Infectious Diseases

The use of a mathematics to model the spread of diseases is vital in the preparation of other possible outbreaks. Besides informing the health workers about the vaccination levels required to protect a population, it also helps govern first response actions when new diseases potentially emerge on a large scale (for example, Bird flu, SARS and Ebola have all merited much study over the past few years)

The most common variant is the SIR model, named after the categories used— “susceptible”, “infectious” and “recovered”. Models of this nature have small computational requirements, and are thus commonly used as first pass attempts to characterize outbreaks or infections.

2.13 Susceptible Infected Recovered (SIR Model)

SIR Model was derived by Kermack–McKendrick as a hypothesis for predicting the number and distribution of incidences of an infectious disease over time. The model was proposed to explain the rapid increase and decline in the infected patients observed in epidemics. This model is founded on a number of assumptions. One of the assumptions is that there are no births and deaths in the population. The other assumption is that the population is closed and there are no chances of accessing or leaving the population. Finally it is assumed that all recovered individuals cannot be re infected.

The model is made up of three nonlinear ordinary differential equations,

$$\frac{dS}{dt} = -\beta S I \quad (1)$$

$$\frac{dI}{dt} = \beta S I - \gamma I \quad (2)$$

$$\frac{dR}{dt} = \gamma I, \quad (3)$$

where t is time, $S(t)$ is the number of vulnerable people, $I(t)$ is the people who have the , $R(t)$ is the people who have recovered and have string immunity, β is the rate of infection, γ is the rate of recovery.

Epidemiological threshold is the key value governing the time evolution of these equations

$$R_0 = \frac{\beta S}{\gamma}. \quad (4)$$

R_0 is the number of secondary infections that result from primary infections; that is the people are infected through contact with an infected individual.

When $R_0 < 1$, every infected person infect fewer than one person before death or recovery, the outbreak will therefore peter out ($dI/dt < 0$). When $R_0 > 1$, every infected individual infects more than one individual, and the infection will therefore spread out($dI/dt > 0$). R_0 is the most crucial quantity in epidemiology. Note that the result $R_0 = \beta S/\gamma$ derived above, is only applicable to the basic Kermack-McKendrick model, with alternative SIR models having varied formulas for dI/dt and hence forR_0.

This study utilized this model to design agents in the Prototype that simulates the hypothesis in this model where the variation in the number of people with the infection s observed in an outbreak of a disease needs to be predicted with an utmost accuracy.

2.14 Theoretical Framework

Kumar (2005) defined a theoretical framework as a structure that supports research work and offers a general data analysis framework. The synthesis of the available theories, concepts and empirical research would assist in the development of a foundation for the development for new theories

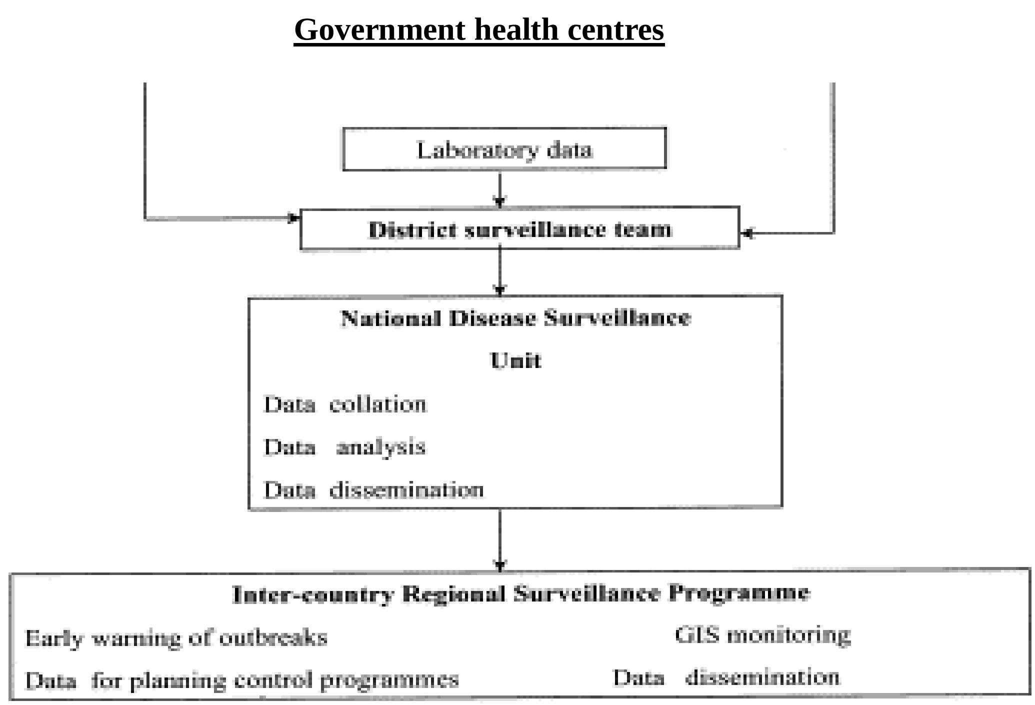

Figure 4: (Lin Padgham, 2004)

2.15 Conceptual Framework

In order to have a better visualization of the concepts presented in the thesis, a conceptual framework was developed. Qualitative research often explores the understudied areas and searches for emergent theory (Creswell, 2003). This conceptual framework is crucial as this study demonstrates the ability to adopt agent technology in the development of TB Surveillance system. In figure 5 an enhance surveillance system is depicted with an improved communication mechanism using email and SMS services. The communication manager represents the developed application to be integrated into the existing system which is then accessible at all levels of the hospitals that are linked through the national database.

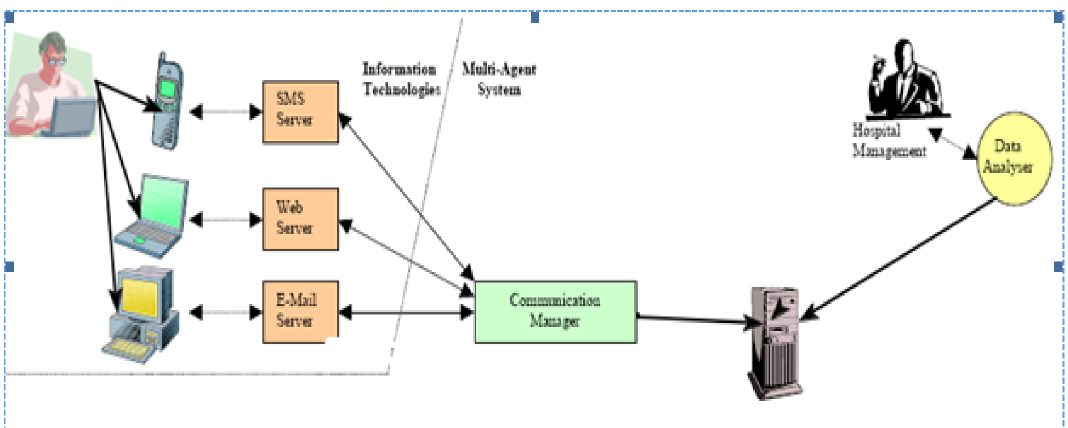

Figure 5: Developed Conceptual Framework by the Researcher

2.16 Summary of Reviews

From the existing literature, it is evident from that the use of mobile and communication technologies have enabled the use of IT-based solutions to enhance the surveillance of diseases. There are numerous measures that are used to address factors that influence the widespread use of software systems for surveillance. However, a key challenge that has not been addressed sufficiently is that of a TB surveillance system which is available at lower levels. This creates the need for the development of a mobile integrated software solution that can enhance TB surveillance. Thus, this research works to provide a practicable platform to make invaluable contributions to software surveillance systems on the availability and usability at lower levels. A theoretical framework synthesizes the available theories and interrelated concepts and empirical research, to create a foundation for the development of new theories.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This section reviewed the design, the population targeted, sampling procedure, data collection methods and their instruments, system development methodology and system testing and validation. In the research design, the research explored how the study was conducted to establish the effectiveness of the developed solution in Tuberculosis surveillance. Sampling and data collection explains the sampling method used and the data collection methods and tools respectively. The testing and validation section explains how the system was tested. System development methodology explores the steps that were taken to develop the system from feasibility study phase.

3.1 Research Design

According to Ngechu (2004), research design may be defined as the plan used in the study to solve the problem of interest. In this study, qualitative research methodology was used. That is, data and requirements will be gathered and analysed qualitatively. Descriptive methods will be employed in analysing data on the current Tuberculosis surveillance system. The methods have been used to carry out investigations through observation, interviews and questionnaire applications, documents reviews, etc as ways of obtaining information on the current states of affairs.

3.2 Target Population

Target population is the whole population of subjects or objects the researcher in interested in studying and generalizing the results of the study (Cox, 2010). Kothari (2004) defines it as all the items under consideration in any field of inquiry which constitute a 'universe' or 'population'. The target population in the study constituted the employees of Ministry of Health (MOH) working in Tuberculosis surveillance centre in Nairobi. The population is categorized as illustrated below in table 3.

3.2.1 Sampling Frame

Dempsey (2003) defines sampling frame as the source of list of respondent from which sample has to be drawn; it contains all the components of the targets population. In this study, the sampling frame was the list of staff working for National Tuberculosis Surveillance Centre. The sources of the data were chosen based on the assumption that the sample has the characteristics of the target population of the research. Then, the participants of the study were chosen. The chosen sample was believed to be representative of the population targeted.

3.2.2 Sampling Technique

Generally, sampling is the procedure of selecting the sample size of interest from the targeted population to deduce something of interest regarding the population. According to Kothari (2004), a sample is subset of the population targeted derived using a systematic manner.

The study will adopt a purposive sampling for choosing staff at Tuberculosis surveillance Centre. The study sample was composed of 17 staffs. This was considered sufficient for the feasibility study of the current system.

Table 3: Sample Size

Profession	No. of staff	No. interviewed
ICT officer	5	3
Clinical officer	8	5
Nurses	12	4
Data clerks	8	2
Registry officers	7	2
Monitoring and Evaluation Officer	5	1
TOTALS	45	17

3.3 Research Instruments

Questionnaires, interviews, and document reviews were used in this study. The questionnaires have well organized questions dispatched to the respondents to get the data for the problem under consideration. Kothari (2004) defines questionnaire as compilation of questions that are sent to the sample to capture the desired information. According to McMillan and Schumacher (2001) questionnaire is a set of questions assessing the opinions, beliefs, attitudes, and demographic information about the people.

Questionnaires in this study were administered to the Ministry of Health, TB surveillance Centre staff. Questionnaires were used since they are economical, standardized questions are used and they have uniform procedure. Refer to appendix 2.

3.4 Data Analysis

Interviews and questionnaires data was entered into excel for cleaning, classification, and coding. Refer to tables 4,5,6,7 and 8.Qualitative data was analysed. Descriptive statistics were used and results presented in graphs and tables. Refer to figures 6,7,8,9, and 10.

3.5 Confidentiality and Privacy

Ermakova (2015) provides the description of the theory of social roles as important to the overall understanding of information confidentiality and proposes a number of moral principles to guide healthcare workers' dealing with database integrity, accessibility and confidentiality. He further points out that any kind of access to a given information regarding individuals need to be related systematically in the appropriate manner to the overall linkage of social relationships under which they are accessible to others by virtue of their position within the role they play in the overall structure. This study took cognizance of the need for confidentiality and privacy of the information to be handled within the system and access will be based on the roles played by each actor/user of the system. During the course of this study the privacy of the respondents will be protected by making the privilege information obtained confidential. The data used in the MITSS prototype as shown in figures 19, 20, 21, 22 and 23 are dummy data and therefore doesn't represent any cases of TB occurrence.

3.6 System Development Methodology

3.6.1 Requirements Gathering

3.6.1.1 Interviews

The research was conducted on structured, unstructured and semi-structured interviews based on the stakeholders. The interviews questions were both open and closed to allow responded express their opinion regarding the functioning of existing system, its problems, strength, processing and flow of information.

3.6.1.2 Documentation Reviews

The study reviewed the relevant documents, World Health Organization (WHO) infectious diseases surveillance systems, Kenya Ministry of Health (MOH) surveillance guides and regulations governing the disease surveillance systems being used at present. The most preferred sources of our documents reviews were the Ministry of Health policy documents, WHO documentation guides, other books of Tuberculosis literature, internet resources and journals. The study gathered information on concepts and challenges of the current surveillance systems. It also examined reports from the manual system which helped to identify the inputs, processes and outputs of the system.

3.6.2 System Analysis and Design

3.6.2.1 System Analysis

Systems analysis refers to the process that identifies and summarizes data with the intention of extracting meaningful information and deducing conclusions. In system analysis requirements were determined. Based on the study of the system, the requirements were both functional and non-functional.

3.6.2.2 System Design

Process Modelling: The process was actualized using flow diagrams to illustrate external entities as well as processes while the final product was comprehensive description of the involve processes. Data Dictionary was used to acquire information for constructing flow diagram.

Data Modelling: It was actualized though Entity-Relationship Diagrams to depict the model and requirements of the data. As a result, relation structure was obtained in relation schema.

3.6.3 System Development Tools

In this phase, there was physical realization of the database and the application design. It involved database and application programs implementation. The following procedure was used:-

- Eclipse Java EE IDE for Web Developers *version 4.3* was used as Integrated Development Environment (IDE).
- *Microsoft Visio* 2007 was used to draw design artifacts of the prototype.
- *MySQL* Manager was used to browse MySQL database.
- *The ObjectAid UML Explorer for Eclipse* was used for generating class diagrams.
- *Macromedia Fireworks MX 2004* was used for image editing

3.6.3.1 PHP

PHP is a web programming language mostly used for web script. It is a common server-side scripting language developed to integrate with HTML. In most cases, PHP is used in association with (MySQL) in web applications and Content Management Systems. The content management system was developed using the tool. The program is available in numerous platform such as Mac OS X, window, and Linux.

3.6.3.2 MySQL

MySQL is an open source Relational Database Management System (RDBMS) that utilizes Structured Query Language (SQL), is the common language used to add, access and process data in the database. Everyone has the capability of downloading MYSQL since it is an open source program. Thus, one can develop the program to suit the needs but they must be in line with general public agent. Some of the advantage of MySQL is speed, reliability, and flexibility. In this study, MySQL was used since it is designed as multi-tasking database which is the main factor in database.

3.6.4 System's Testing, Validation and Implementation

3.6.4.1 Testing

Testing involves running the application program with an aim of identifying errors.The process entails the use of well-laid strategies and actual data for the system to detect faults in the program as well as database structure. Once the faults are corrected, the process is repeated until proven that the system is performing well in-line with the specification given by the users and the performance requirements.

3.6.4.2 Validation

TB surveillance System validation process yielded assurance of high level that a given processes consistently give products that meet specified quality and specifications. The factors under consideration were comparing the existing system and operating environment. Validation also involved identifying compliance to specifications, quality management procedures, and life cycle definition. For instance, assessing the procedures used for testing, documentation for administrator, user requirements specification and functional specification, control documentation and among others.

3.6.4.3 Implementation

Tuberculosis Surveillance System (TSS) prototype was implemented on Java 6 Enterprise Edition (JEE 6) platform deployed on JBoss Application Server 7.1.1 that supports Boss seam 2.3.0 application framework, the Multi-Agents platform was implemented using Java Agent Development Framework (JADE).

CHAPTER 4: PRESENTATION OF RESEARCH FINDINGS

4.0 Introduction

This chapter presents data analysis, presentation and discussion of the findings. Descriptive statistics were used to carry out preliminary data analysis and to give a description of the features of the data. This was done using percentages, means and standard deviation. The findings were presented in form of frequency tables and figures.

4.1Demographic Information

The study was conducted at the Ministry of Health staff (National Tuberculosis surveillance centre). The respondents comprised of various professions as shown in the table below;

Table 4: Demographic Information

Profession	Total population	Number of Response	Percentage
ICT officer	5	3	60%
Clinical officer	8	5	63%
Nurses	12	4	33%
Data clerks	8	2	25%
Registry officers	7	2	29%
Monitoring and Evaluation Officer	5	1	20%

The respondents were sampled based on their professions and roles. The respondents were therefore better placed to give reliable and valuable information. Their distributions are indicated in Table 4 above.

4.2 Data Analysis

4.2.1 Demographic Information

Table 5: Gender

GENDER	No.	PERCENTAGE
Male	12	70.58%
Female	5	29.42%

Source: Fieldwork, (2017)

Table 5above shows that out of the 17 respondents 12 (70.58%) were male while 5 (29.42%) were female.

Table 6: Age

AGE RANGE	No.	PERCENTAGE
18-30	2	11.76%
30-40	7	41.17%
41-60	8	47.05

Source: Fieldwork, (2017)

Table 6 above shows that out of the 17 respondents 2 (11.76%) were in the 18-30 age range, 7(41.17%) were in the 30-40 age range 8(47.05%) were in the 41-50 age range (29.42%) were female.

Table 7:Education

EDUCATION	No.	PERCENTAGE
Secondary	3	17.65%
Mid-level college	6	35.3%
University	8	47.05

Source: Fieldwork, 2017

Table 7 above shows that out of the 17 respondents 3 (17.65%) had secondary level of education, 6(35.3%) had mid-level college level of education while 8(47.05%) had university level of education.

Table 8: Participants

POSITION	No.	PERCENTAGE
ICT officer	3	17.65%
Clinical officer	5	29.41%
Nurses	4	23.53%
Data clerks	2	11.76%
Registry officers	2	11.76%
Monitoring and Evaluation Officer	1	5.88%

Source: Fieldwork, (2017)

Table 8 above shows that out of the 17 respondents 3 (17.65%) were ICT officers, 5(29.41%) were clinical officers, 4 (23.53%) were nurses, 2 (11.76%) were data clerks, 2 (11.76%) were registry officers while 1(5.88%) was Monitoring and evaluation officer.

4.2.2 Research Related Questions

4.2.2.1 NGO's and Health Volunteers Involvement

On the question of Surveillance units collecting data from non-governmental organizations of the respondents 17 indicated they are not involved. This is an indication that data is only collected from government clinics, therefore missing a lot of data which could help to enhance the accuracy of the figures collected. This shows that the sources of information are narrowed down to only those cases that reaches the government health facilities. The unit should therefore allow for a wider scope of data sources, to increase the accuracy and hence a better representation of the real cases on the ground.

4.2.2.2 Frequency of Data Collection

In regards to the frequency in which data is received by the TB surveillance unit, the study established that the data is mostly reviewed on a quarterly basis. This implies that there was no instant reporting and the time taken to act to a new infection is so long. This gives room for multiple infections before the reporting is done.

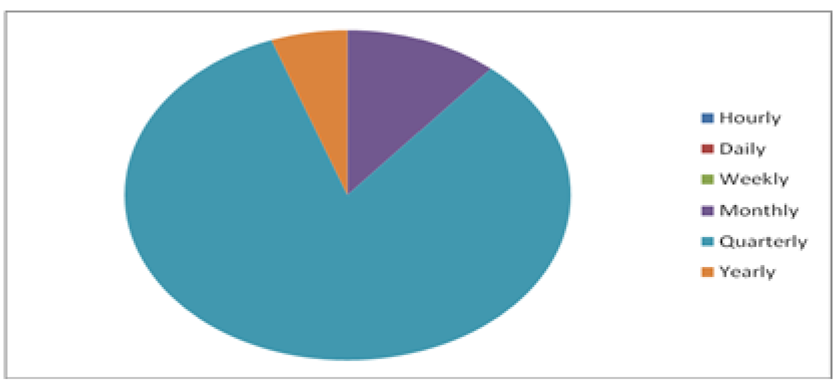

Figure 6: Frequency of Data Collection

The unit should thus reduce the duration taken to receive the cumulative reports from different community health centers across the country

4.2.2.3 Computerized Information Systems to aid the Surveillance of TB

The question on the availability of an online system used for data collection on TB infections, the response was 80% of the respondents indicated that the system exists. The remaining percentage has never had an experience with the system.

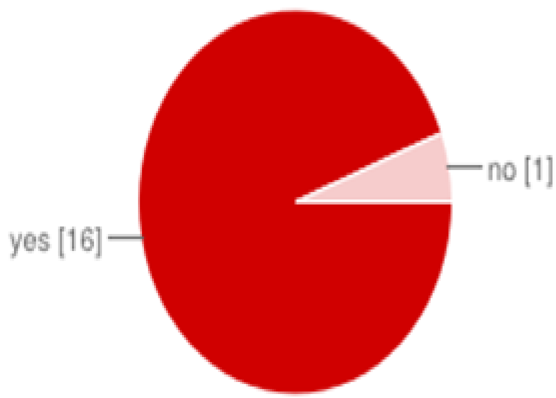

Figure 7: Computerized Information Systems to the Aid Surveillance TB System

4.2.2.4 Efficiency and Effectiveness of TB Surveillance System

Regarding the efficiency and effectiveness of the system in reporting; 76% of the respondents indicated that they feel the system is ineffective and inefficient. The major factor that was considered was on the time taken to collect data and the time it took for the data to be analysed and relayed for decision making.

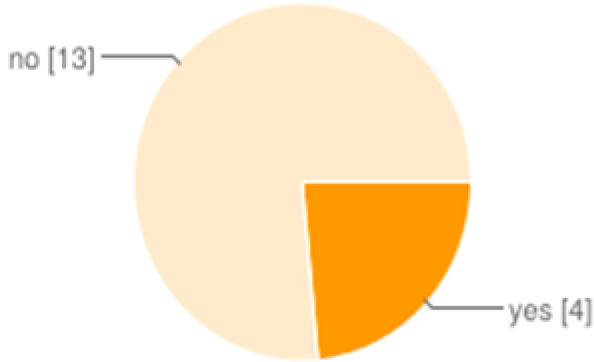

Figure 8: Efficiency and Effectiveness of TB Surveillance System

4.2.2.5 Are Systems Integrated?

The response to the question on whether the system was integrated where, 71% of the respondents indicated that the systems were integrated meaning other systems where feeding data into the system. This would mean the system is critical in the process of TB surveillance and therefore its enhancement would increase its accuracy and effectiveness.

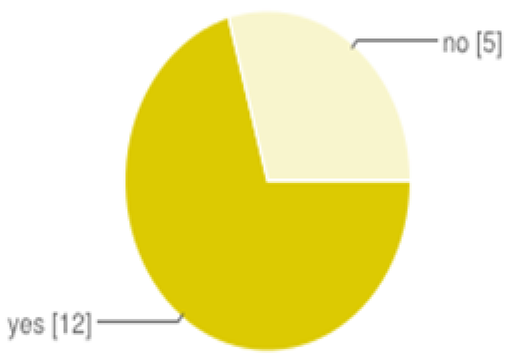

Figure 9: Integrated System

4.2.2.6 Providing Information on Real Time Basis

One of the key points of the analysis was to find out whether the system would provide information on real time basis and the response received was that 100% indicated that the system did not provide real time information and hence delayed decision making on new cases of Tb infections. This actually rendered the system ineffective and therefore the objective of controlling the spread of TB not achieved. Despite Positive response on whether the system is web based and whether it supports the mobile Technology.

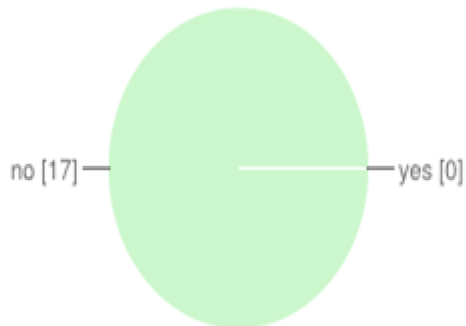

Figure 10: Providing Information on Real Time Basis

4.3 The need for a new TB Surveillance System

It was evident from this study that there is need to have a redesign of the system to allow for data collected by non-government entities to be included in the central database for TB surveillance. The system is expected to address the shortcoming of the current TB Surveillance System which includes lack of mapping of the cases to the region where it occurs.

4.4 The Benefits of the new TB Surveillance System

Based on the findings, most of the respondents expressed dissatisfaction with the current system, hence the need to integrate surveillance with response to enhance the efficiency of the system. The new TB Surveillance system has a broader scope for data capture to allow for accuracy. The system also has the ability to map the identified cases to specific regions that the cases are reported.

The specification activities of the system are as follows: identification of the basic system functionalities together with inputs, outputs, and any key data sources. System Specification phase of Prometheus methodology entails defining the goal diagram, user case scenarios and functionality descriptors

CHAPTER FIVE: SYSTEM DESIGN AND IMPLEMENTATION

5.0 Introduction

This chapter covers the development of the prototype using Prometheus methodology. The methodology involves three stages that include prototype specification using goals and scenarios, architectural design and detailed design of the prototype to be presented for development and feedback.

5.1 System Specification

The system description was carried out using business use cases (figure 12) to guide in understanding the process. The health personnel dealing with disease surveillance required information of diseases falling under the three categories i.e. epidemic, diseases targeted for eradication and those for general information as they occur in the field. Diseases falling under the first two categories need urgent reporting by the system when a case is identified. Use cases (figure 13) can help to understand informal requirements. Use cases aid in separating the system into actors and use cases. Use cases form a set of possible sequences of interactions between system and users within the environment relating to a particular. Java was chosen based on the following features:-

i. *Simple* - It is easy to write, learn and use.
ii. *Secure* – It offers a secure means of developing internet applications and a safe means of accessing web applications.
iii. *Portable* - Java programs are executable in all environments with Java run-time system (JVM).
iv. *Object-oriented* - Java programming is object-oriented programming language.

v. *Robust* - It enables error-free programming as it is strictly typed and perform run-time checks.

vi. *Multithreaded* – It gives integrated support for multithreaded programming.

vii. *Architecture-neutral* – It can used in all machines and operating systems.

viii. *Interpreted* - Java supports cross-platform code through the use of Java byte code.

ix. *Distributed* – The design was done with the distributed environment in mind and it can therefore be transmitted and run over internet.

x. *Dynamic* - Java programs carry with them substantial amounts of run-time type information that is used to verify and resolve accesses to objects at run time.

5.1.1 Goal Diagram

The overall goal was to do the TB Surveillance System

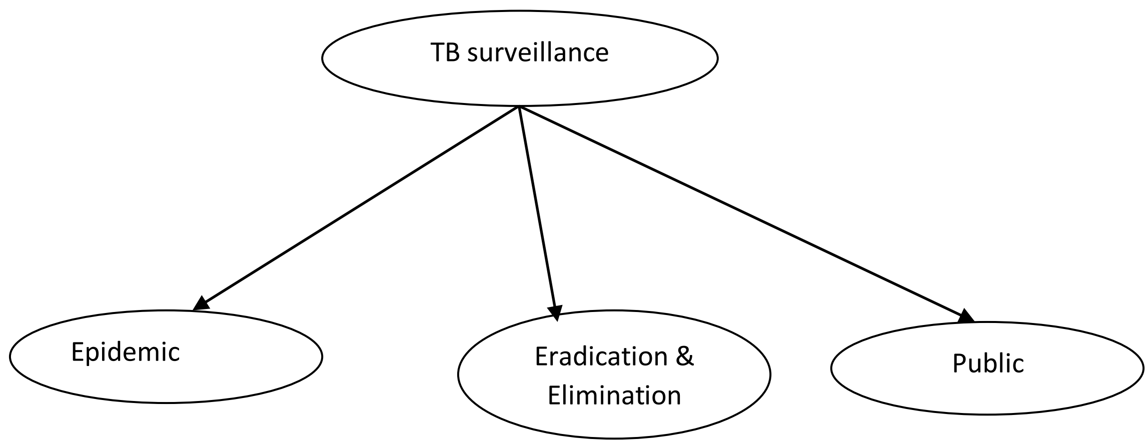

Figure 11: Goal Actors

The main actors in the surveillance system are as follows:-

- Health Practioner
- Alert Monitors
- System Administrator

A sick person avails him/herself for medical attention. The patients Information is entered in the system. The information covered includes both inpatients and outpatients. The data collected includes name, date of presentation for medical attention, date of discharge, village, age, diagnosis, treatment and outcomes.

The clinician reports any disease or condition suspected that required to be eliminated or eradicated. Obtaining laboratory confirmation is among the key steps taken if an outbreak is suspected. Laboratory specimens are obtained the details recorded. The details include the specimen type, date obtained, date sent to the lab, condition of specimen when received and the lab outcomes. The investigation outcomes are utilised to inform response actions.

The surveillance team at the headquarters waits for data to be sent from various health facilities across the country before analysis on the data is carried out.

5.1.2 Use case Scenarios

Based on the analysis of the data gathered during feasibility study, various actors were identified and used to develop a diagrammatic representation of their interactions showing how a health practitioner records details of a patient in the public health surveillance system if the patient does not exist in the registration database. The illustration is as shown below:-

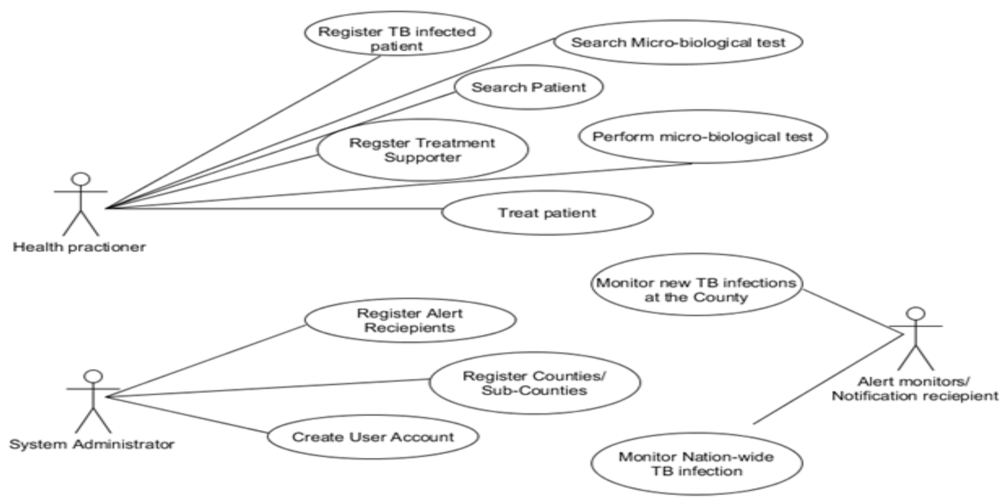

Figure 12: Use Case Diagram Actors Interactions

A medical clinical officer examines a patient for a particular ailment and can recommend further analysis to be done on the patient by way of medical laboratory if the doctor is not sure about the disease the patient is suffering from. The use case diagram is as shown below:-

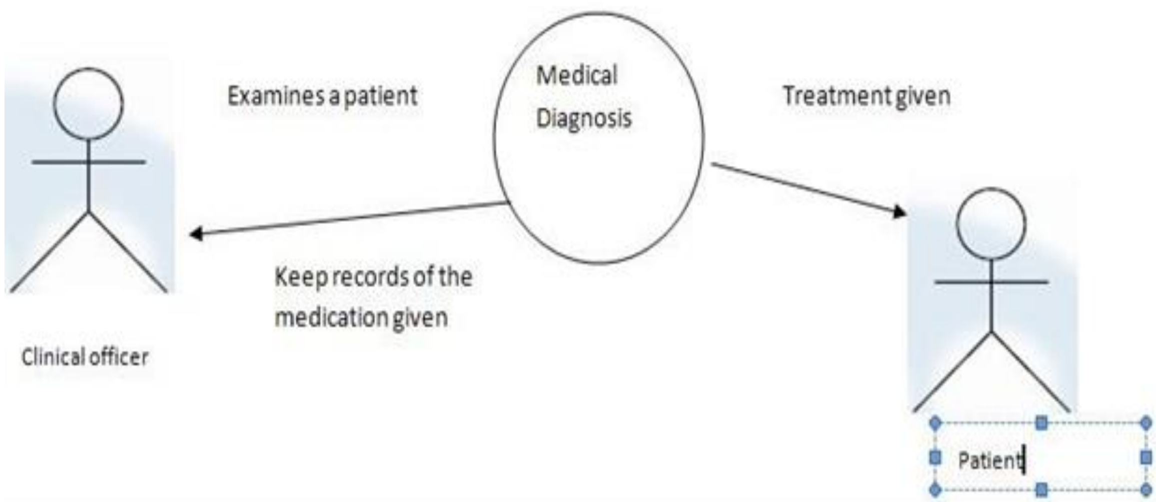

Figure 13: Patient Examination use case

The public health surveillance officer requests information from the surveillance database

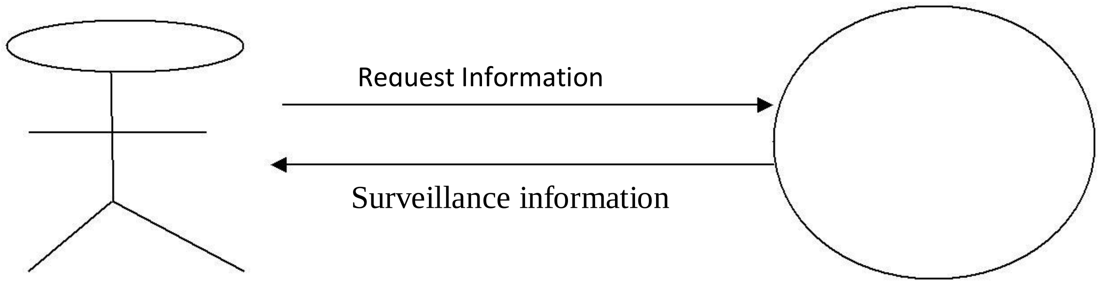

Figure14: Retrieving Information Form Surveillance System

Information Given

Surveillance Officer

Percepts/Actions

Analysis of the above scenarios point out the need for the following percepts/actions:-

Percepts

Clinical officer sending information collected from the patient using the mobile phone

Doctor diagnosis of the patient using the form filled by the clinical officer

Laboratory officer filling the laboratory form after collecting the results from the patient

Actions

Sending mails to the surveillance officers

Sending SMS Alerts to the surveillance officers on the TB control updates

5.2 Architectural Design

The different types of agents are identified in view of the general system structure and the functional nodes that the system architecture comprises of. The details of the design are as shown in the figure 11 below on class diagrams.

5.3 Class Diagram- MULTI-AGENTS

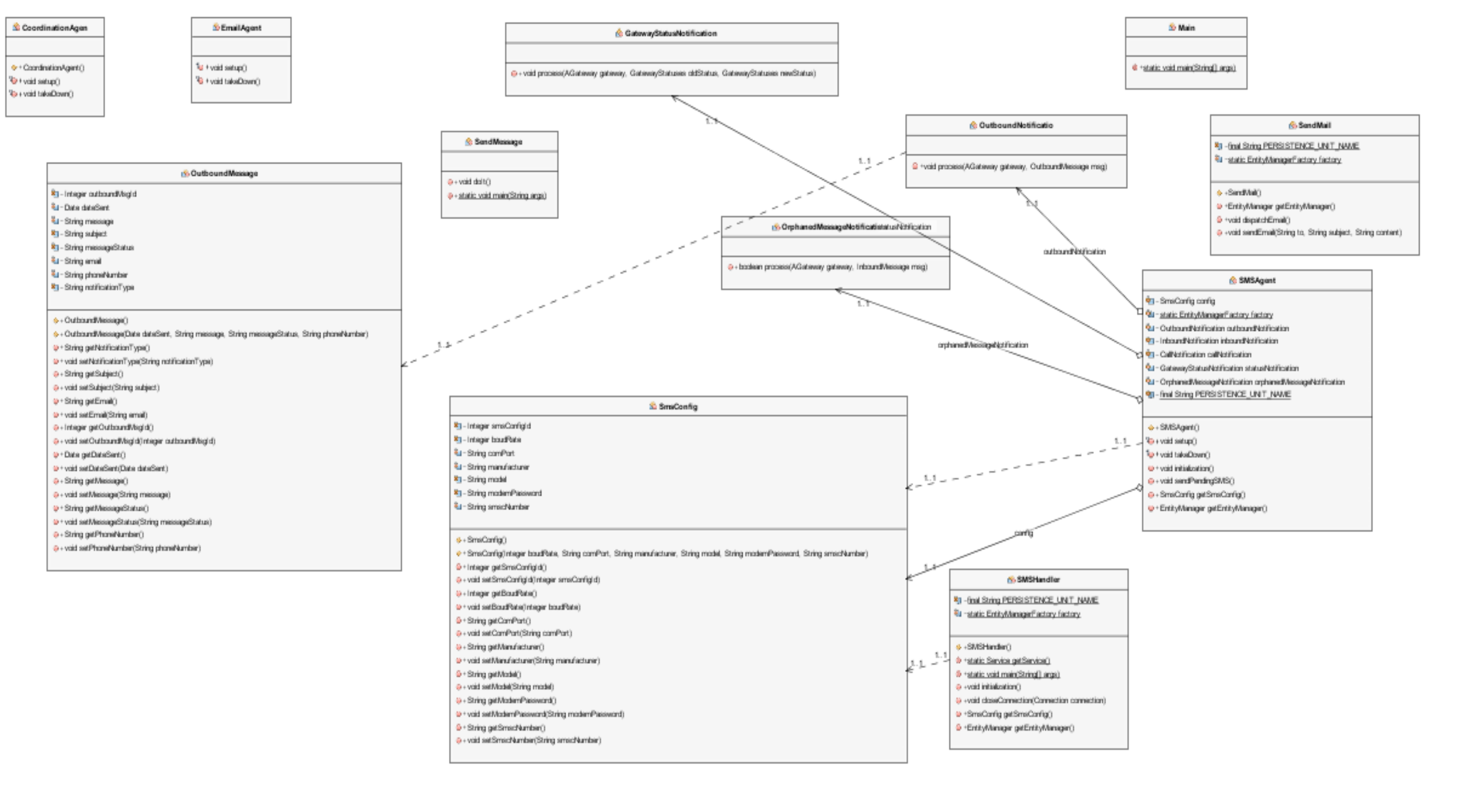

Figure 15: Multiagent Class Diagram

Source: Author's compilation

5.4 Detailed Design

5.4.1 Class Diagram - Web Module

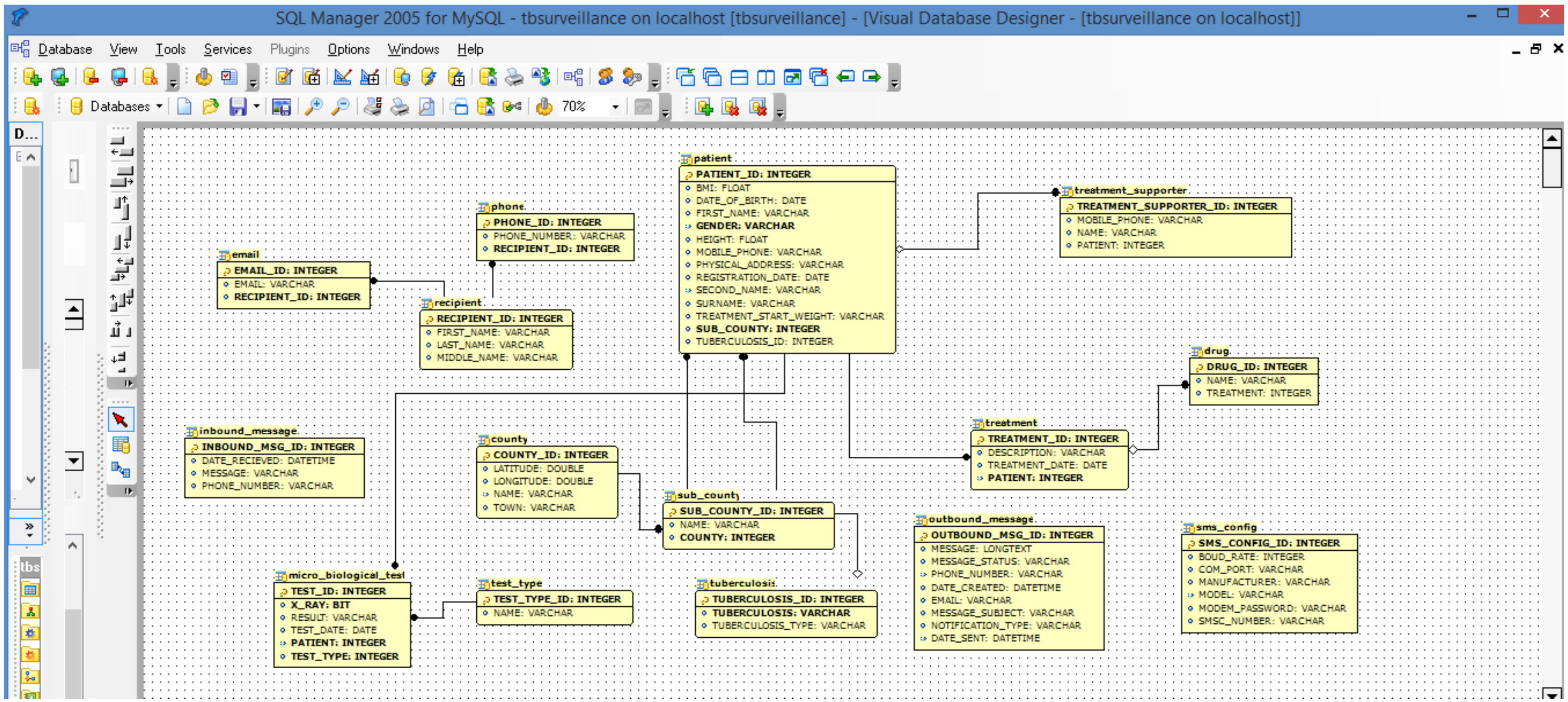

Figure 16: Web Class Diagram

Source: Author's compilation

5.5 Database Implementation

The database was implemented on MySQL database. The schema of the **TB Surveillance** database is illustrated below. Though it is possible to **TB Surveillance** database from standard SQL language, the prototype system was implemented using **Hibernate ORM**, to facilitate Rapid Application Development (RAD) by transparently addressing type mismatch between our Object-Oriented application entity objects and the SQL statements required to query/update the database since MySQL is a relational database

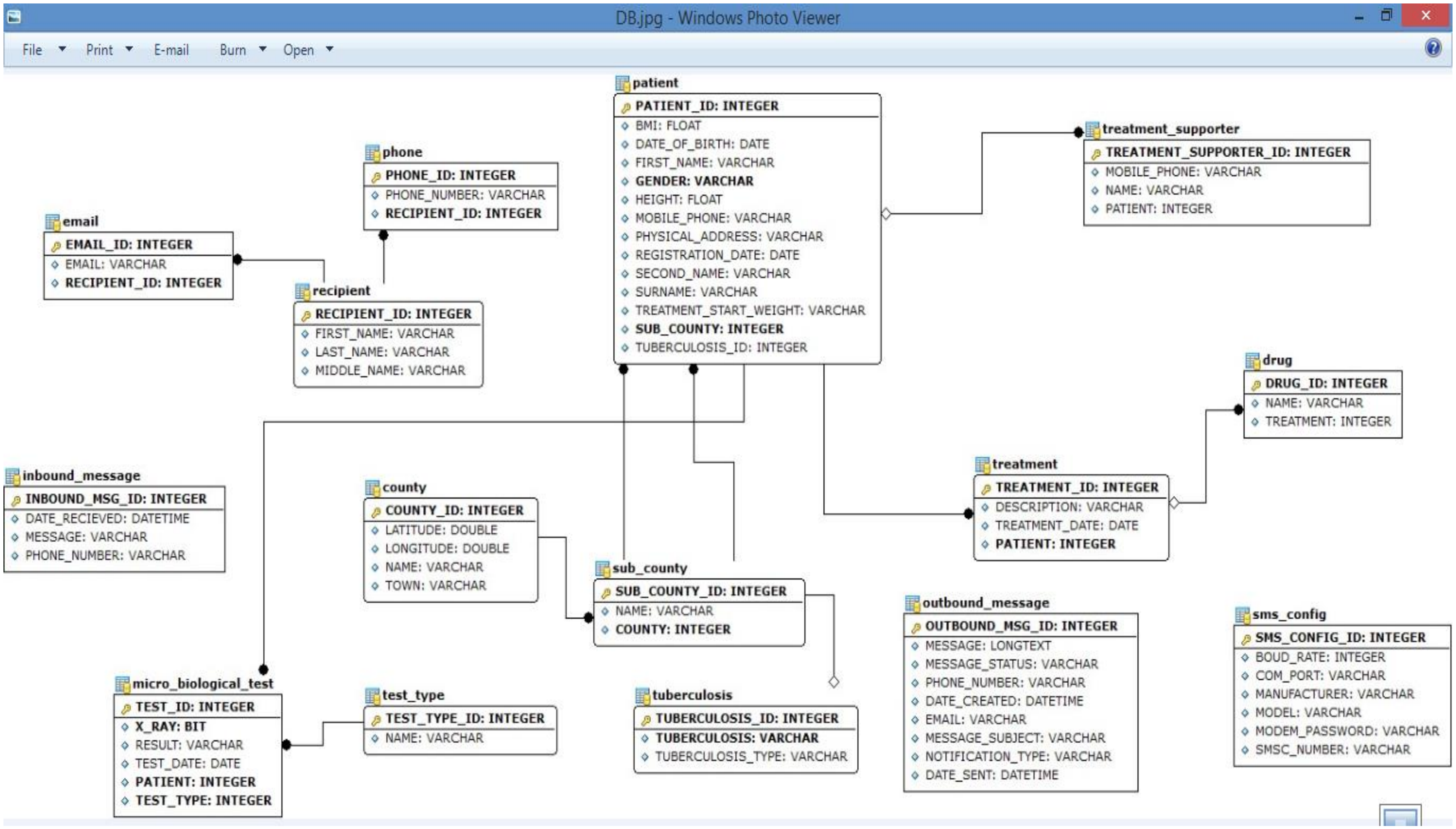

Figure 17: Tb Surveillance Database Schema

Source: Author's compilation

5.6 Coding

Java programming language was used to implement virtually the whole prototype except user interface of Web-management module that relied on JSF, JSTL, JavaScript and HTML for dynamic web pages implementation.

5.7 Integration

The integration between Multi-agent platform and web based application was done at database level whereby both modules accessed the outbound message table in order to facilitate their communication.

5.8 Testing

Three types of test were conducted during the implementation of the prototype system as highlighted below.

i. **Unit testing** – The functionalities implemented within each java classes written were tested to ensure they methods returns the expected results. Refer to Figure 18. Testing login credentials

ii. **Integration testing** – This test was conducted to on **multi-agent are not only able to communicate among themselves but also with the web interface application.**

iii. **System testing** – This test was carried out after the entire prototype system was implemented to ascertain whether it was implemented as per the requirements specified in the Use-Cases. This was done by running the prototype to test for overall functional requirements specification. This was achieved through display of data capture in a topographical representation of the counties as show in figures 29 and 30

5.9 Evaluation of the Prototype Results

Based on the above testing types the prototype was then evaluated to determine the extent to which the user requirements were satisfied. The prototype was subjected to users who had been earlier on conducted during the user requirements gathering.

a) Usability

The respondents evaluated the system for usability testing. System usability attributes that were tested included usefulness, ease of use (user-friendly), Satisfaction, ease of learning. Results for analysis for each usability attribute were represented in a table format. The overall rating by the respondents was 93%. The respondents also indicated that the application was useful as it helped them to report TB surveillance emergencies country wide.

Table 9: Researcher, 2017

Evaluation Parameter	**Percentage Rating**
Ease of learning	23.8
Satisfaction	22.2
Usefulness	24
Ease of use	23
Grand Total	93%

b) Functionality

The proposed solution was subjected to functionality analysis. Respondents evaluated the application's ability to accomplish 5 main tasks in the application.

Table 10: Researcher, (2017)

Evaluation Parameter	**Percentage Rating**
Analysis results	20
Accurate Analysis	17.3
Meets the needs of TB surveillance	20
Efficiency and Effectiveness	18.7
Covers the entire country	20
TOTALS	96%

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

The use of mobile phones has substantially increased throughout the world over the last decade. This has opened up opportunities for the integration of mobile phones as health intervention tools in many aspects of care for patients with TB. M-health has the potential to bridge gaps and improve TB care on a larger scale. Proof of concept has been shown for the possible application on the field of TB surveillance.

The purpose of this study was to examine how a software model based on multi-agent technology could be used to perform National Tuberculosis Surveillance by using the feedback system to achieve the objectives. The system was tested against the set overall goal of the study which was to develop a prototype of a Tuberculosis surveillance solution to be used to enhance TB surveillance in Kenya. Data on actual use of the system was collected over a period of two weeks. A satisfaction data collection then conducted at the end of the evaluation period through a questionnaire. The questionnaire had two sections which entirely relied on the prototype. The first section related to usability of the prototype; these were set to evaluate how easy it was to use the prototype with minimal or no training. The second section considered the functionality of the prototype as spelled out by the research objectives that is, the requirements of TB surveillance system using and implementing the same using software agents.

6.1.1 Achievements

The results discussed above indicate that the MITSS was able to achieve the overall aim and objectives of the study. The study was able to address the challenges of the current Tuberculosis surveillance systems to National TB surveillance Centre. The feedback was timely and was based on individual staff needs both on data collection and analysis needs.

6.2 Conclusion

The importance to adherence to treatment schedules is a key factor to eradication of TB cases. Mobile technology will play a big role in ensuring patients are reminded through SMS and emails on the due dates for reviews and collection of doses at their various clinics of treatment.

The general objective of the study was to establish the challenges in the current TB surveillance system at DLTLD center, the findings were clear that the data collected is purely on TB detected cases neglecting on the key entity the patient. This research was able to proof that mobile phones can play a critical role if integrated with the existing system to enhance the efficiency and effectiveness in eradication of TB in Kenya.

Patients who received SMS reminders had significantly better compliance than those who did not, with attendance and response to medication improved. Use of SMS reminders has the potential to improve patient’s compliance in other treatment regimens that require repeat clinic visits or administration of treatments.

The study sought to identify the challenges in TB surveillance in Kenya. The study established that in Kenya, TB surveillance systems were ineffective and health authorities would rather use manual surveillance techniques to cover the entire country. Therefore, this study, informed by literature review set out to propose a developed TB surveillance solution based on multi-agent methodology to address reporting and response for TB-related cases in the country. The solution was targeted at National TB surveillance center where all TB reporting and response cases are managed.

6.3 Recommendations

Based on the study findings, of this study, the component of technology advancement in the system in the Ministry of Health should be improved in include mobile technology th9at would help to link the Medical practitioner and patient. This will help to improve the quality of medical services and information quality. This will lead to quality decisions, well timed mitigation and corrective measure against TB cases. An urgent intervention is therefore required to develop an updated system. Furthermore, there is need to develop a strong collaborative link with the laboratories network with use of mobile integrated surveillance system.

There is need for MIST system to implement proper documentation methods for all the data gathered mainly for the urgent notification of TB data and zero reporting. In addition, there is need for TB surveillance system to design a standard system that would ensure regular and effective feedback. The study established that a key challenge faced is how to respond properly and quickly to epidemics, and there is therefore the need to formulate the standard rapid response team at all levels. This would help to build effective epidemic preparedness in the country.

Further, there is need to strengthen TB Surveillance support functions in Ministry of Health. There is need for sufficient human resources at all levels and an incentive system that would increase personnel commitment in the DLTLD. There is need for supported, documented supervisory visits to the various levels and well timed feedback in order create additional support for use in sustaining effective TB Surveillance System that guides the public health decision making in Kenya. Needs assessments should be conducted followed by pre studies and post studies.

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APPENDIXES

Appendix1: Current TB Surveillance Tools

2a) REGISTRATION FORM.

CONTACT REGISTRATION FORM					
Facility Name		District		Province	
Today's Date:			Site		
Patient's Name in Full					
Contact's name in FULL					
Birth Date		AGE			
Home Address					
Nearest Church/School					
Patient'sPhone(Mobile Phone):					
Contact's Phone(Mobile Phone):					
Emergency Contact Phone			Sex	M	F
Marital status	Married	Single	Divorced	Separated	Polygamous
Contact Association					
Pregnant	Yes		No		
Clinical History					
TB Symptoms (Check all that apply)					
		Follow Up			

Symptom	Initial Visit	1st Month	2nd month	3rd month	
None					
Cough > 2 weeks					
Productive Y / N					
Hemoptysis Y / N					
Fever, unexplained					
Unexplained weight loss					
Poor appetite					
Night Sweats					
Fatigue					
Additional Individual Risk for Infection: Check all that apply					
Immigrant		Yes		No	
State from which country					
Resident/employee congregate setting(Where)					
Previous TB Treatment		Yes		No	
Name the drugs/regimen					
Previous exposure to SLD		Yes		No	
Name the drugs/Regimen					
Homeless Y / N					
Past known contact		When		Where	
Individual Risk for Progression to Disease					
HIV Infected		Yes		No	
Medical conditions that increase risk		Diabetes		Cancer	
		Immunosuppressive therapy (steroids, cancer		Low weight	
		Other			

History of inadequate TB treatment	**Yes**		**No**	

Laboratory				
	Follow Up			
	Initial Visit	**1st Month**	**2nd month**	**3rd month**
Sputum Smear (Pos/Neg)				
Remarks				

Individual Risk for Progression to Disease				
HIV Infected	**Yes**		**No**	
Medical conditions that increase risk	**Diabetes**		**Cancer**	
	Immunosuppressive therapy (steroids, cancer		**Low weight**	
	Other			
History of inadequate TB treatment	**Yes**		**No**	

Laboratory & Radiological Investigation				
	Follow Up			
	Initial Visit	**1st Month**	**2nd month**	**3rd month**
Sputum Smear (Pos/Neg)				
Sputum culture (Pos/Neg)				
DST(drug Sensitivity Test)				
Chest XR				

Referred TO	
Discharged	
MDr TB Clinic	
Other	
Remarks	

1 b) REPORTING FORM HEALTH WORKERS

Community based TB Care

MONTHLY REPORTING FORM FOR COMMUNITY HEALTH WORKERS

Province ------------------------------- District------------------------- CU/ Facility -------

Name of CHEW/Facility i/c/ CSO -----------

--

Period of reporting (Beginning --------

Ending------------------- Year-------------

Measurements/Indicators		**Number**	**Remarks**
1.	Number of New TB suspects referred by CHWs		
2.	Total number of New TB patients enrolled under care of CHWs		
3.	Proportion of TB patients HIV positive who are under your care		
4.	Proportion of TB defaulters traced by CHWs		
5.	Number and percentage of patients under CHWs with successful treatment completion		
6.	Total number of new CHWs trained during the reporting period.		
7.	Total number of active CHWs in your CU/district		
8.	Proportion of TB patients on nutrition support		
This information is additive. The CHEW totals up from the CHWs, The health facility from the CHEWs, the DTLC from the facilities and the PTLC from the DTLCs for transmission to the Central Uni			

1C) Referral form

Community client/patient referral form

Name of patient/Client …………………..Patient's mobile number -----------------

Date of referral___________________

TB Reg. No --- **CCC No.__________________**

Serial No.________________________________

Sex: ☐Male☐Female **Age____**

Physical address (Community Unit /
Village/landmark/)________________________________

____

Mobile phone (Treatment supporter/ gurdian)

____

Referred from: ______________________________ **Referred to**:_________________

Reasons for referral:

☐To continue /start anti-TB treatment ☐☐TB suspect(Screening)

☐Default from treatment (TB /ARVs) ☐☐ARVs

☐Nutritional support

☐Complications

- ☐ Palliative care
- ☐ Psycho-social support
- ☐ HTC
- ☐ Others (specify)____

  ____

Comments____

____

____

____

Referred by (Name)__________Designation________ Signature________Date_________

Received by (Name)___________Designation________Signature________Date------------

Appendix 2: Data Collection Tools

INTERVIEW GUIDE FOR MINISTRY OF HEALTH,DIVISION OF LEPROSY, TUBERCULOSIS AND LUNG DISEASE (D.L.T.L. D).

Section A: Demographic Information (Please tick the option that is most appropriate)

1. Sex: [ ] Male [ ] Female

2. Age: [ ] 18- 30 [ ] 31-40 [ ] 41- 50 [ ] 51-60 [ ] more than 60

3. What is your level of education?

[ ] Primary [ ] Secondary [ ] Mid-level college [ ] University

4. What is your position? [ ] Doctor [ ] Clinical officer [ ] Nurse [ ] ICT officer [ ] Data entry clerk [ ] Registry officer [ ] M&E Officer [ ] Officer Other (Specify)____________________

5. How long have you been with MOH? [ ] 1- 5 [ ] 5- 10 [ ] Above 10 years

Section B: Tuberculosis surveillance unit (please indicate with an x or √ where it applies)

1. Are there ANY challenges faced by health personnel currently in addressing TB surveillance?

   [ ] Yes [ ] No

2. In your own assessment, are we making progress in the way the emergence of TB cases are reported? [ ] Yes [ ] No

3. How does the TB surveillance unit collect its data from the field?

   [ ] Paper based technique [ ] Using Information system

4. How efficient and effective are the surveillance systems in relaying TB surveillance data? [ ] Efficient [ ] Not Efficient

5. In your own opinion what should be the best strategy to ensure an effective TB surveillance in Kenya? ____

6. How do you analyze the data collected from the various collection centers?

   ____

SECTION C: Involvement of NGOs and volunteers in TB surveillance. (Please indicate with an x or √ where it applies)

7. Do the Surveillance units collect data from non-governmental organizations?

   [ ] Yes [ ] No

8. If YES how is the data collected?

   [ ] Paper based [ ] Using information system

9. How is the TB surveillance center interlinked with the Headquarters?

   ____

SECTION D: Design of web based TB surveillance system. (Please indicate with an x or √ where it applies)

10. How is ICT unit engaged with the TB Surveillance unit?_ _ _ _ _ _ _ _ _ _ _ _ _ _

    _

    _

11. Does the TB Surveillancen unit have any computerized information systems to aid the surveillance of TB? [ ]Yes [ ]No

12. In your own experience is the system efficient and effective in reporting?

    [ ] Yes [ ] No

13. If NO what do you propose should be done?_ _

    _

    _

    _

14. Are the systems integrated? [ ] Yes [ ] No

15. If Yes what do you propose should be done? _

    _

    _

    _

16. Are the systems Networked? [ ] Yes [ ] No
17. Do the systems provide information on real time basis? [ ] Yes [ ] No
18. Are the systems web based? [ ] Yes [ ] No
19. Can the information be relayed using mobile technology? [ ] Yes [ ] No
20. Is the reports relayed on a digital dashboard? [ ] Yes [ ] No
21. How often do Tb surveillance unit receive data?
    [ ] Hourly
    [ ] Daily
    [ ] Weekly
    [ ] Monthly
    [ ] Quarterly
    [ ] Yearly
22. How effective is the systems in terms of geographical coverage?
    [ ] Effective [ ] Not effective

Appendix 3: Usability and Functionality Questionnaire

TB SURVEILLANCE PROTOTPE EVALUATION QUESTIONNAIRE

Section A: Usability

The questionnaire constructed as five- rating scales with following questions each with 5 response options.

(On a scale of 1 to 5; 1- Strongly Agree, 2- Agree, 3- Not sure, 4-Disagree 5-Strongly Disagree)

1. **Usefulness?**

1. The system is useful.

2. The system gives me more control over the activities I do

3. The system saves me time when I use it.

4. The system meets my needs.

5. The system does everything I would expect it to do.

2. **Ease of use?**

1. The system was easy to use.

2. The system user friendly.

3. Using the system was effortless.

4. I can use the system without written instructions.

5. I can use the system successfully every time.

3. **Ease of learning?**

1. I learned to use the system quickly.

2. I easily remember how to use the system.

3. The system is easy to learn to use it.

4. I quickly became skillful with the system.

5. Can easily demonstrate to someone else how to use the system

4. Satisfaction?

1. I am satisfied with the system.

2. I would recommend the system to a friend.

3. The system is fun to use.

4. The system works the way I want it to work.

5. The system is pleasant to use.

Section B: Functionality

The questionnaire constructed as five- rating scales with following questions each with 5 response options.

(On a scale of 1 to 5; 1- Strongly Agree, 2- Agree, 3- Not sure, 4-Disagree 5-Strongly Disagree)

	1	**2**	**3**	**4**	**5**
Surveillance systems will enable users get analysis results from the system.					
Allow patients get feedback information					
The system address the requirements of TB surveillance					
The system is efficient and effective					
With the system, it’s possible to collect TB surveillance data from the entire country					

Appendix 4: Screen Shots

User interfaces

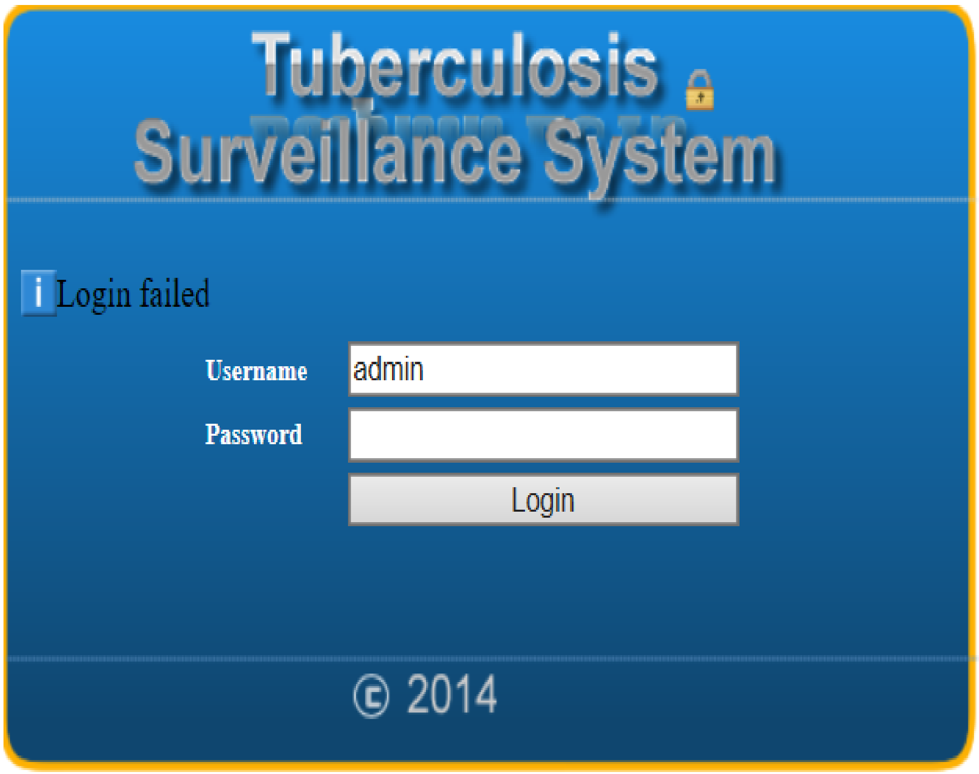


Figure 18: User Interface Login Screen

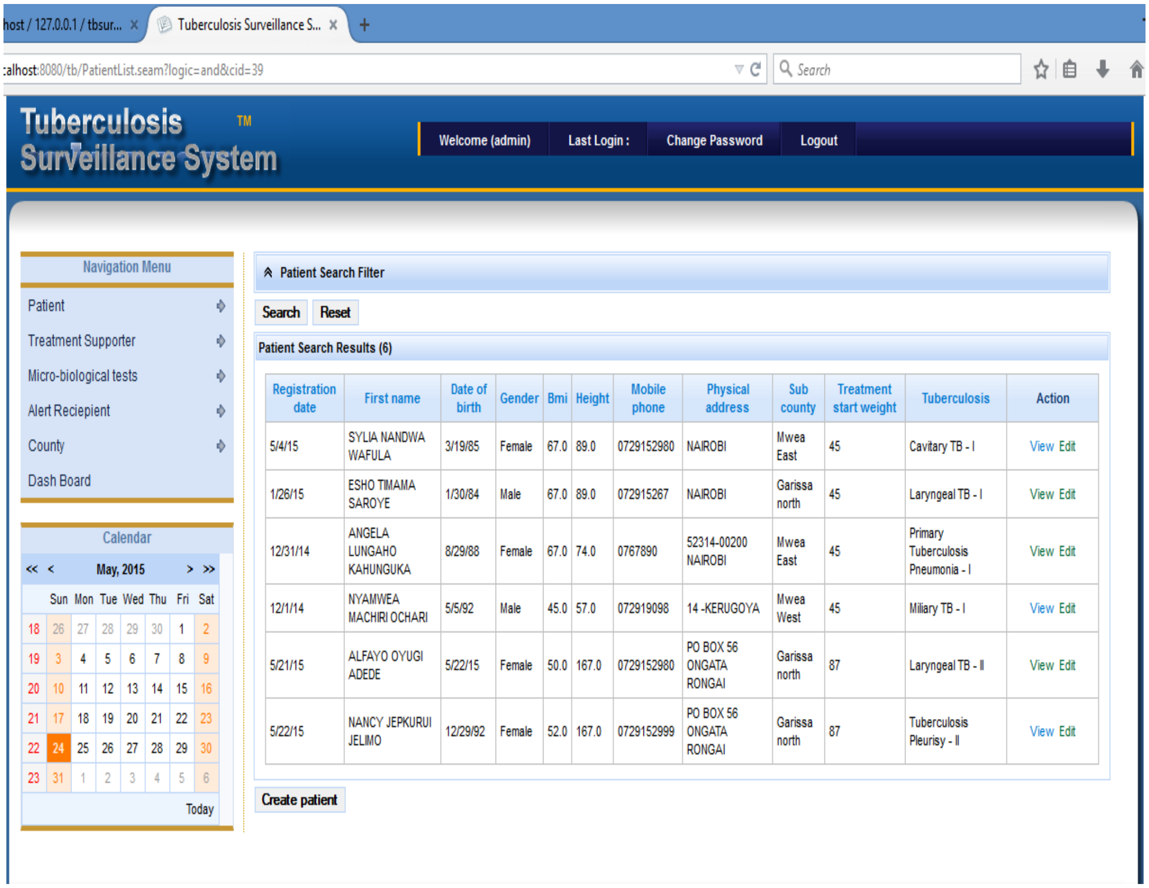


Figure19: Patient RecordSearch

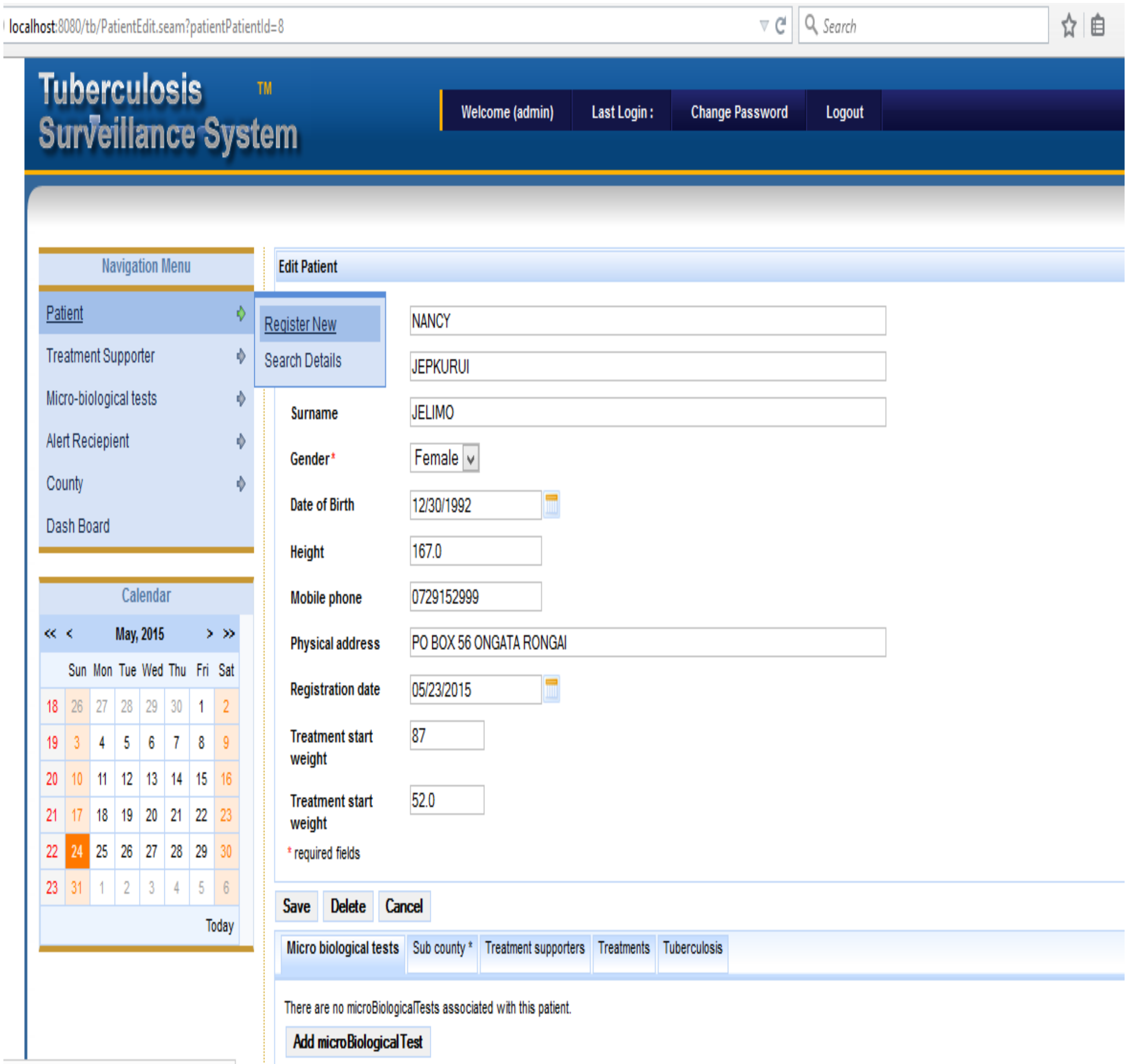


Figure 20: Edit Patient Record

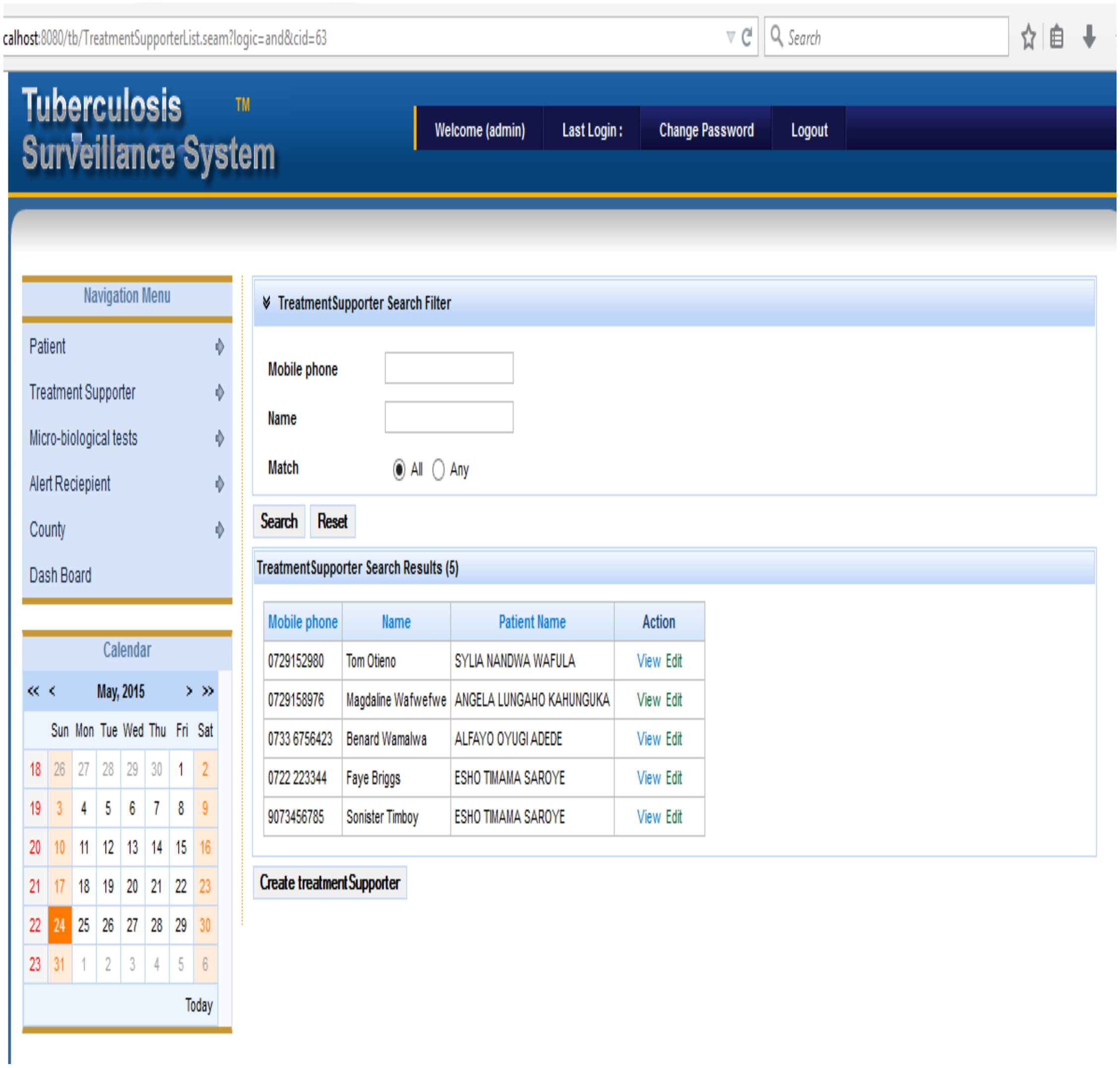


Figure 21: Treatment Support Staff

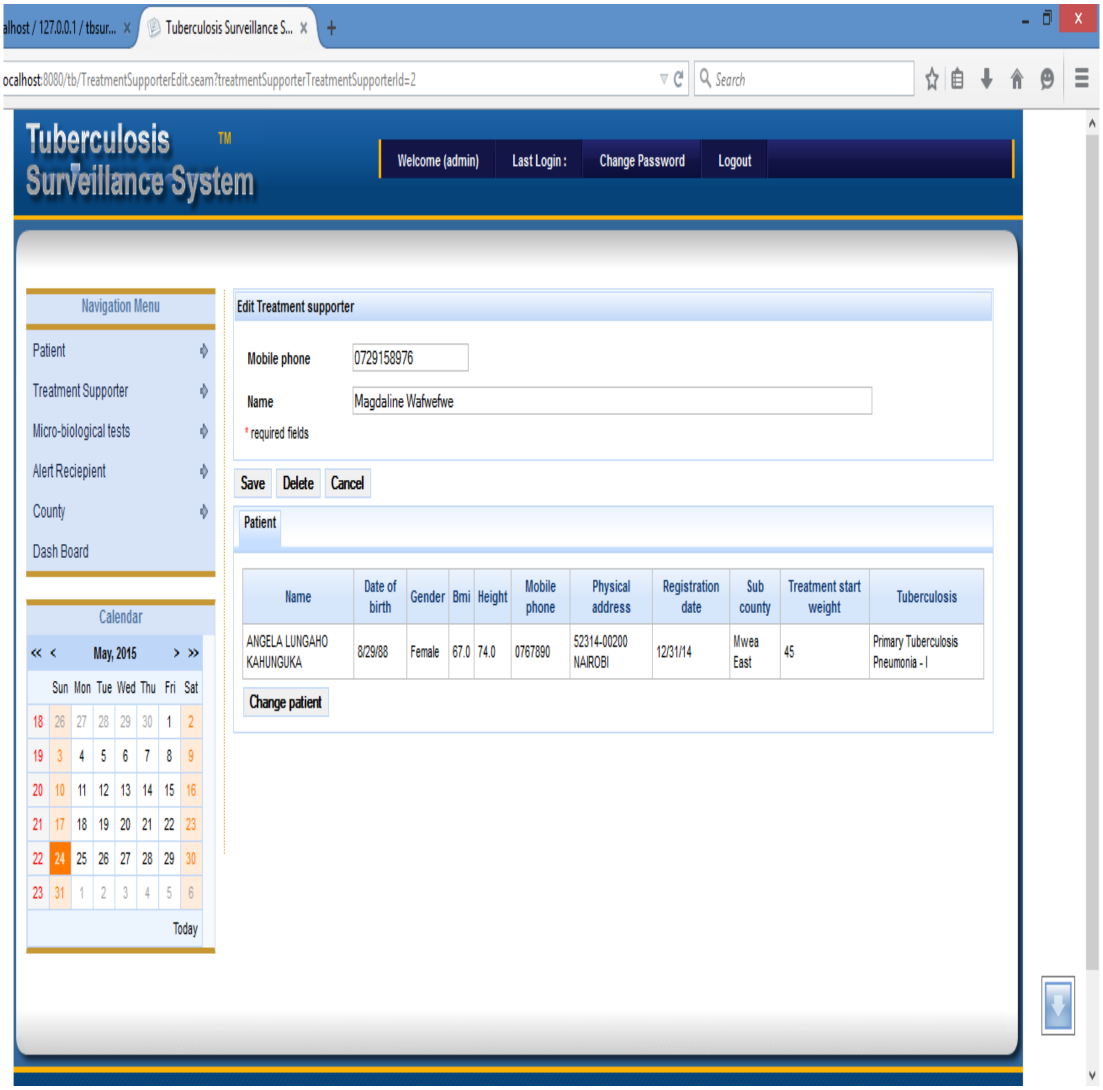


Figure 22: Edit Treatment Support Record

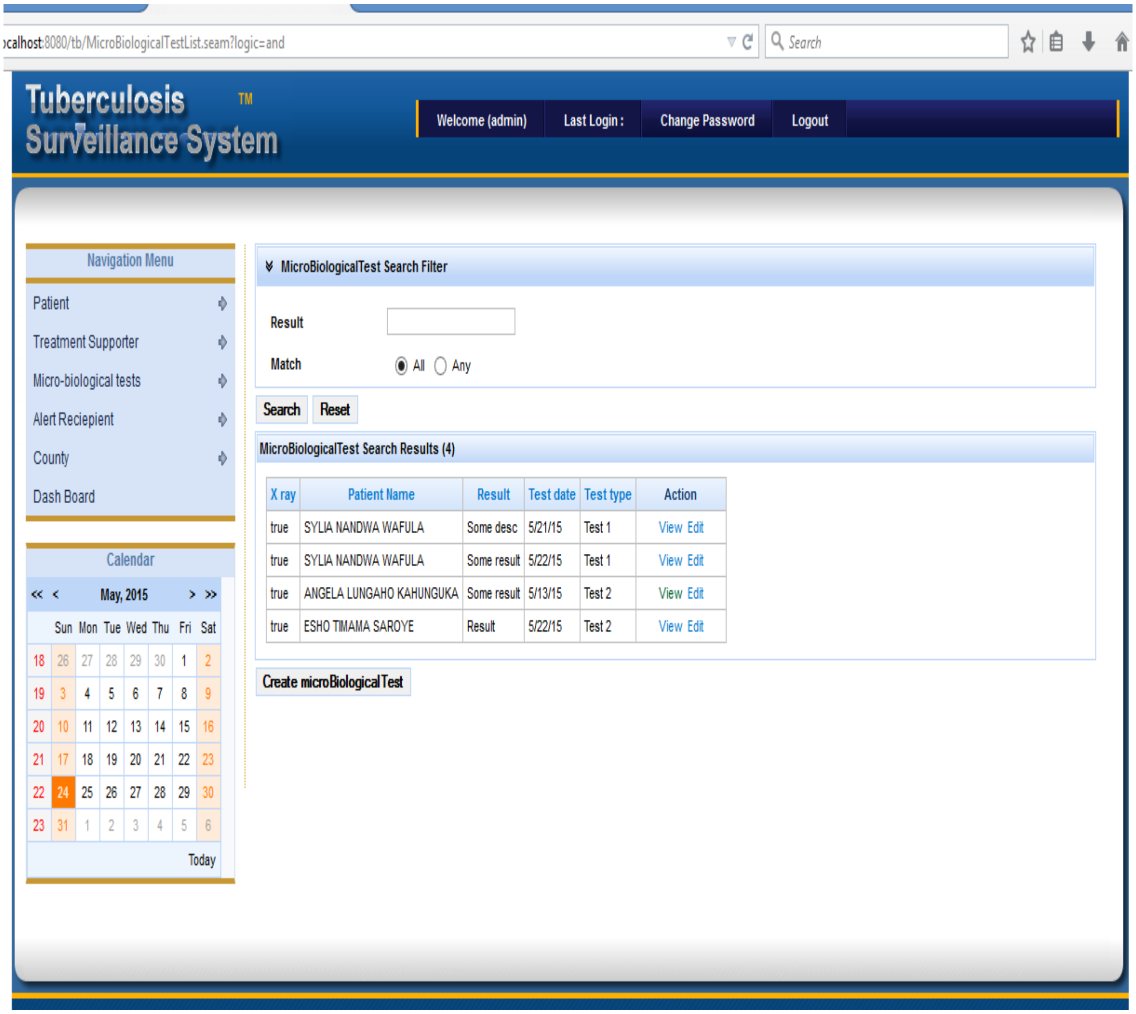


Figure 23: Micro Biology Records

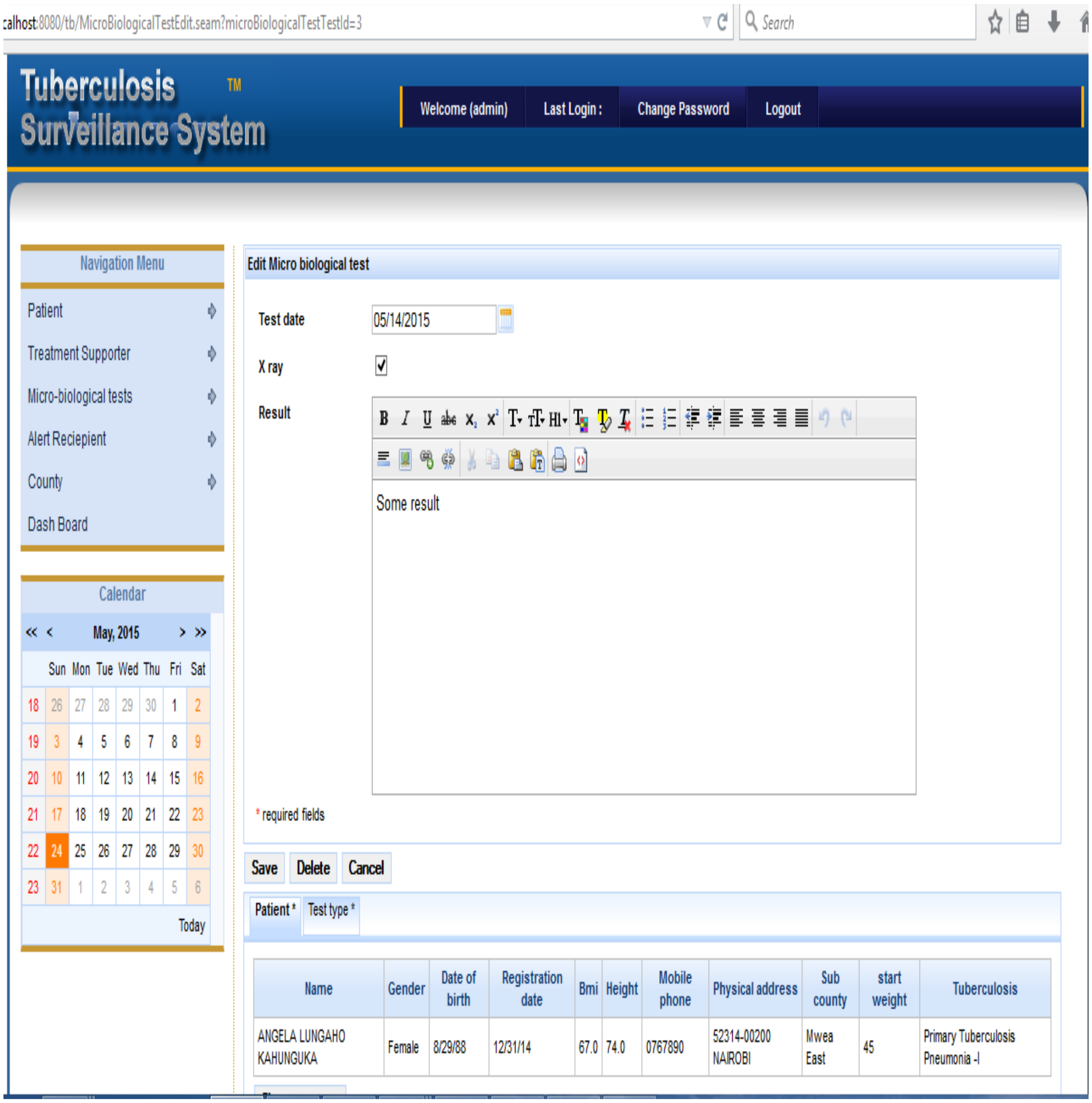


Figure 24: Editing Micro Biology Records

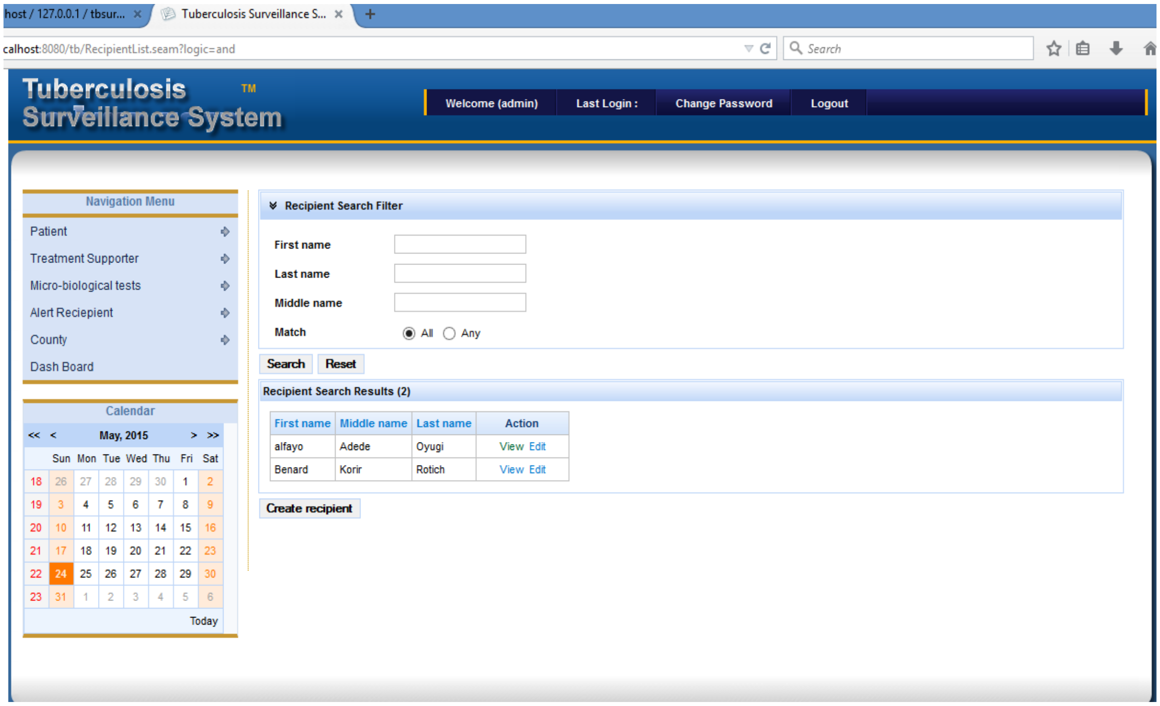


Figure 25: Recipients

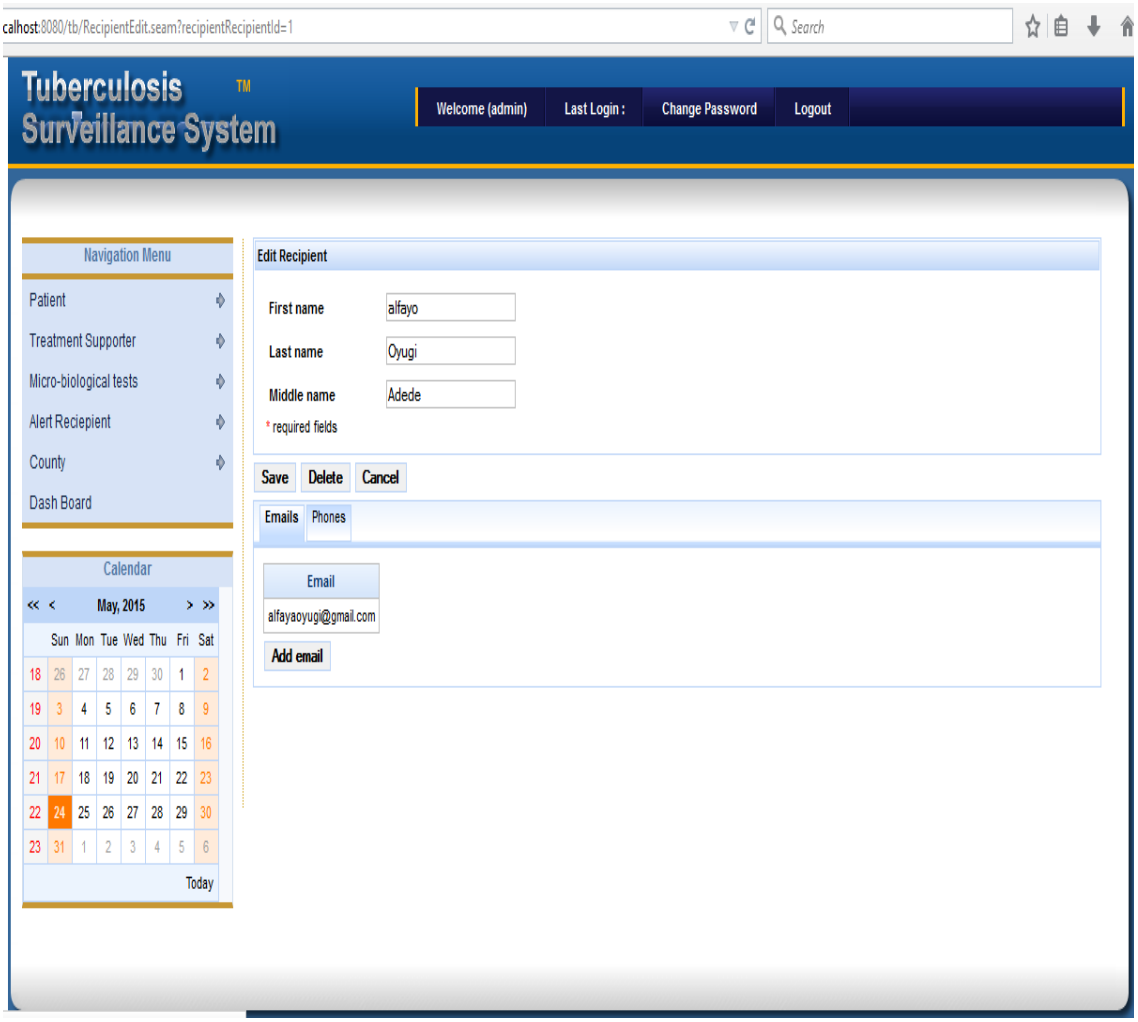


Figure 26: Editing Recipients

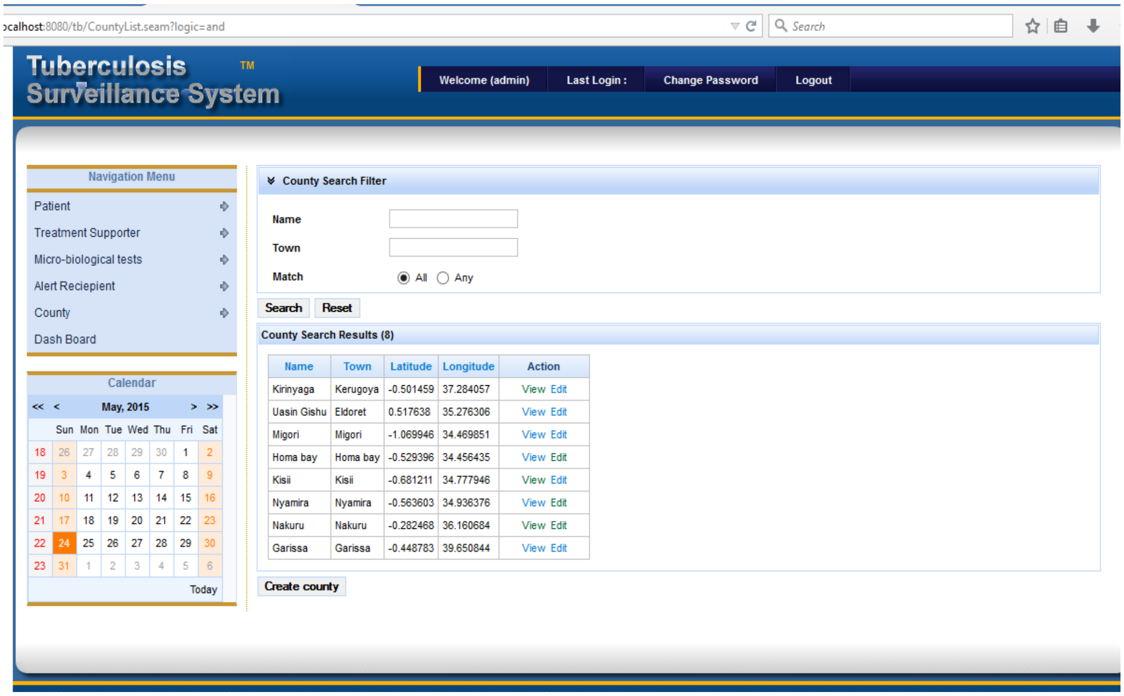


Figure 27: County Records

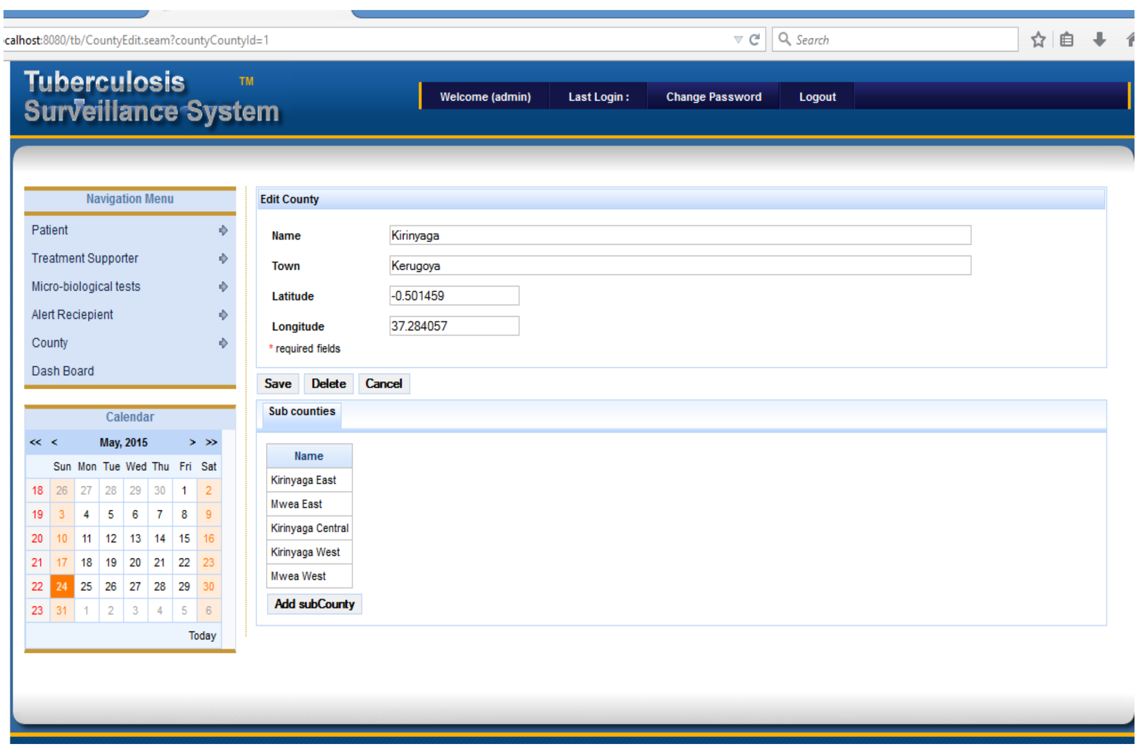


Figure 28: Editing County Records

-

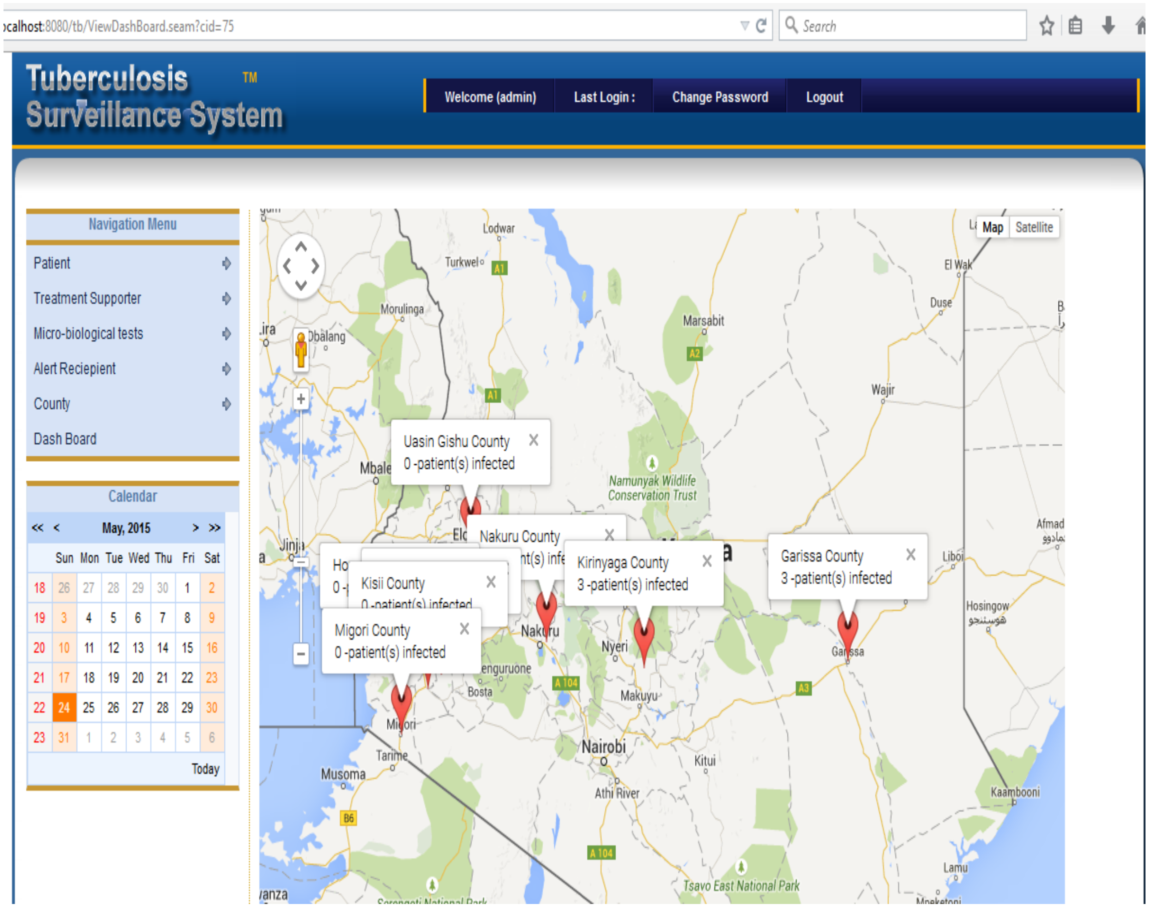
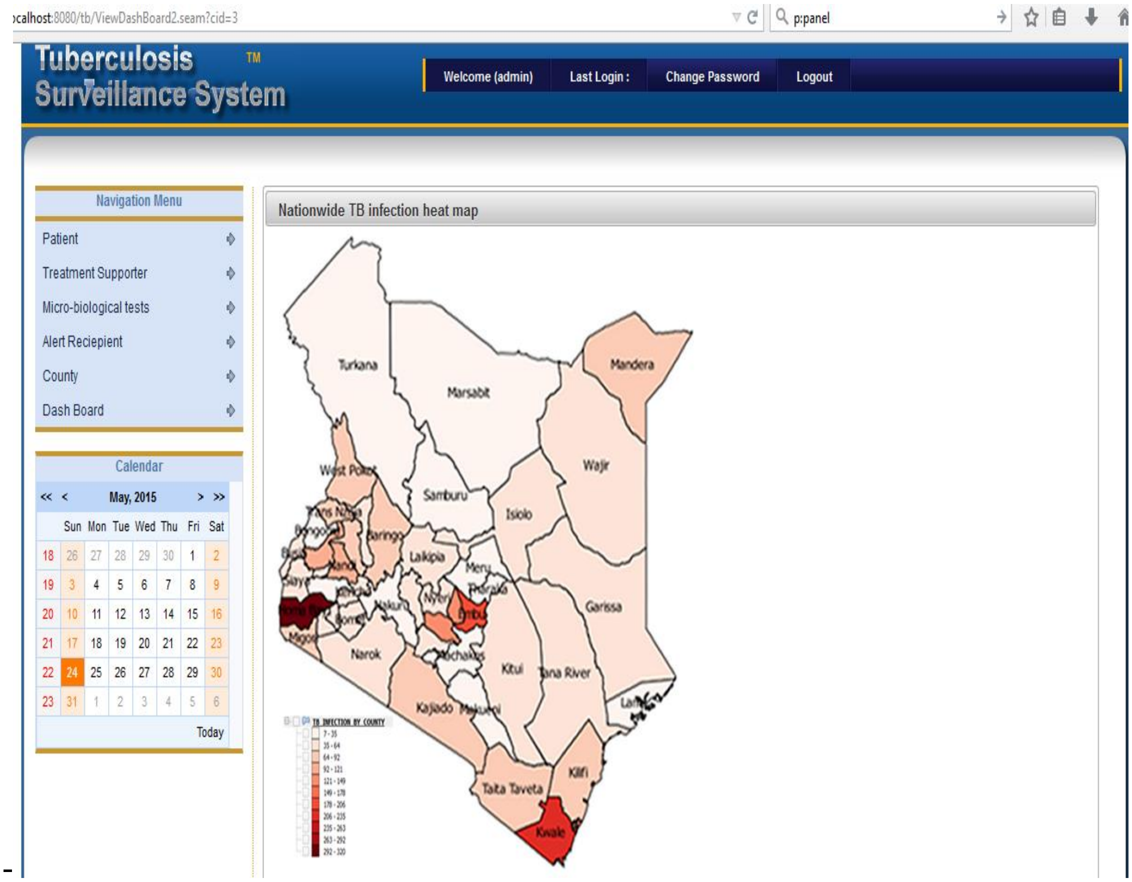


Figure 29: Geographical Representation of Data



-

Figure 30: TB Infection Index on Map of Counties

-

-

Appendix 5: Sample Source Code Listing

```
/*
* @Author: Benard
* Email and SMS Coordination Agent
*/
packagecom.core.action.agent;
importjade.core.AID;
importjade.core.Agent;
importjade.core.behaviours.Behaviour;
importjade.core.behaviours.WakerBehaviour;
importjade.lang.acl.ACLMessage;
importjade.lang.acl.MessageTemplate;
public class CoordinationAgent extends Agent {
publicCoordinationAgent() {
super();
-   }
   // Referee agent initializations
   @Override
protected void setup() {
        String agentName = null;
Object[] args = getArguments();
if (args != null &&args.length> 0) {
agentName = (String) args[0]; //read the agent name
        } else {
            // Make the agent terminate immediately
System.out.println("Error: name not specified!!!!");
doDelete();
        }
  //Add the WakerBehaviour (wakeup-time 10 secs)
addBehaviour(new WakerBehaviour(this, 60000) {
```

```
protected void handleElapsedTimeout() {
myAgent.addBehaviour(new NotifySMSAgent());
myAgent.addBehaviour(new NotifyEmailAgent());

            }
        });

    }
    @Override
protected void takeDown() {
    }
private class NotifySMSAgent extends Behaviour {
privateMessageTemplatemessageTemplate; //The template to receive replies

        @Override
public void action() {
            //create ACMessage.CFP type message
ACLMessagecoordinatorCFP = new ACLMessage(ACLMessage.CFP);
            AID smsAgent= new AID("smsAgent", AID.ISLOCALNAME);
coordinatorCFP.addReceiver(smsAgent); //set the receiver of the message
coordinatorCFP.setContent("Send SMS");
coordinatorCFP.setConversationId("tbsurveillance");
coordinatorCFP.setReplyWith("cfp" + System.currentTimeMillis());
myAgent.send(coordinatorCFP);
            //Prepare the template to get proposals
messageTemplate                                                   =
MessageTemplate.and(MessageTemplate.MatchConversationId("tbsurveillance"),
MessageTemplate.MatchInReplyTo(coordinatorCFP.getReplyWith()));
        }
    @Override
```

```
publicboolean done() {
                        return false;
                }
   }
private class NotifyEmailAgent extends Behaviour {

privateMessageTemplatemessageTemplate; //The template to receive replies
      @Override
public void action() {
        //create ACMessage.CFP type message
ACLMessagecoordinatorCFP = new ACLMessage(ACLMessage.CFP);
        AID smsAgent= new AID("emailAgent", AID.ISLOCALNAME);
coordinatorCFP.addReceiver(smsAgent); //set the receiver of the message
coordinatorCFP.setContent("Send Mail");
coordinatorCFP.setConversationId("tbsurveillance");
coordinatorCFP.setReplyWith("cfp" + System.currentTimeMillis());
myAgent.send(coordinatorCFP);

        //Prepare the template to get proposals
messageTemplate                                                   =
MessageTemplate.and(MessageTemplate.MatchConversationId("tbsurveillance"),
MessageTemplate.MatchInReplyTo(coordinatorCFP.getReplyWith()))
      }
   @Override
publicboolean done() {
                        return false;
                }
   }
private class NotifyAnalystAgent extends Behaviour {
```

```
privateMessageTemplatemessageTemplate; //The template to receive replies


	@Override
public void action() {
		//create ACMessage.CFP type message
ACLMessagecoordinatorCFP = new ACLMessage(ACLMessage.CFP);
		AID smsAgent= new AID("analystAgent", AID.ISLOCALNAME);
coordinatorCFP.addReceiver(smsAgent); //set the receiver of the message
coordinatorCFP.setContent("Send Analyst");
coordinatorCFP.setConversationId("tbsurveillance");
coordinatorCFP.setReplyWith("cfp" + System.currentTimeMillis());
myAgent.send(coordinatorCFP);
		//Prepare the template to get proposals
messageTemplate                                                    =
MessageTemplate.and(MessageTemplate.MatchConversationId("tbsurveillance"),
MessageTemplate.MatchInReplyTo(coordinatorCFP.getReplyWith()));
	}
    @Override
publicboolean done() {
					return false;
				}
    }



}
/*
* @Author: Benard
* Email dispatching Agent
*/
```

```
packagecom.core.action.agent;

importcom.core.email.SendMail;
importjade.core.Agent;
importjade.core.behaviours.CyclicBehaviour;
importjade.domain.DFService;
importjade.domain.FIPAAgentManagement.DFAgentDescription;
importjade.domain.FIPAAgentManagement.ServiceDescription;
importjade.domain.FIPAException;
importjade.lang.acl.ACLMessage;
importjade.lang.acl.MessageTemplate;
importjava.util.logging.Level;
importjava.util.logging.Logger;

public class EmailAgent extends Agent{

  @Override
protected void setup() {
          String agentName=null;
        Object[] args = getArguments();
        if (args != null &&args.length> 0) {
                agentName= (String) args[0];
          }
        else {
          // Make the agent terminate immediately
        System.out.println("Error: Agent name not specified!!!!");
        doDelete();
          }
        /*
         * Create directory facilitator description (DF)  for the agent
```

```
            * and register this agent & its service type
            * */
DFAgentDescriptiondirectorFacilatorDescription = new DFAgentDescription();
directorFacilatorDescription.setName(getAID());
ServiceDescriptionserviceDescription = new ServiceDescription();
serviceDescription.setType("tbsurveillance");
serviceDescription.setName("tbsurveillance-email");
serviceDescription.setName(agentName);
directorFacilatorDescription.addServices(serviceDescription);
try {
DFService.register(this, directorFacilatorDescription);
    }
catch (FIPAExceptionfe) {
fe.printStackTrace();
    }
    //add behaviors
addBehaviour(new SendEmailAlert());


  }
  @Override
protected void takeDown() {
try {
DFService.deregister(this);
    }
catch (FIPAExceptionfe) {
fe.printStackTrace();
    }
  }


           private class SendEmailAlert extends CyclicBehaviour {
```

```
@Override
public void action() {
MessageTemplatemessageTemplate = MessageTemplate.MatchPerformative(ACLMessage.CFP); //Requested by the Coordinating agent to dispatch sms to play
ACLMessage message = myAgent.receive(messageTemplate);
if (message != null) {
try {
ACLMessage reply = message.createReply();
reply.setPerformative(ACLMessage.PROPOSE);
//To do: invoke email pool service
newSendMail().dispatchEmail();
myAgent.send(reply);  //Reply to request from the client
} catch (Exception ex) {
Logger.getLogger(SMSAgent.class.getName()).log(Level.SEVERE, null, ex);
}
}
else {
block();
}
}
}
}
/*
* @Author: Benard
* SMS dispatching Agent
*/
packagecom.core.action.agent;
importcom.core.email.SendMail;
importcom.core.entity.SmsConfig;
```

```
importcom.core.sms.SMSHandler;
importjava.sql.Connection;
importjava.sql.PreparedStatement;
importjava.sql.ResultSet;
importjade.core.Agent;
importorg.smslib.Service;
importjade.core.behaviours.*;
importjade.domain.DFService;
importjade.domain.FIPAException;
importjade.domain.FIPAAgentManagement.DFAgentDescription;
importjade.domain.FIPAAgentManagement.ServiceDescription;
importjade.lang.acl.ACLMessage;
importjade.lang.acl.MessageTemplate;
importjava.sql.DriverManager;
importjava.sql.SQLException;
importjava.util.Date;
importjava.util.List;
importjava.util.concurrent.Executor;
importjava.util.concurrent.Executors;
importjava.util.logging.Level;
importjava.util.logging.Logger;
importjavax.persistence.EntityManager;
importjavax.persistence.EntityManagerFactory;
importjavax.persistence.EntityTransaction;
importjavax.persistence.Persistence;
importjavax.persistence.Query;
importorg.smslib.AGateway;
importorg.smslib.AGateway.GatewayStatuses;
importorg.smslib.ICallNotification;
importorg.smslib.IGatewayStatusNotification;
```

```
importorg.smslib.IInboundMessageNotification;
importorg.smslib.IOrphanedMessageNotification;
importorg.smslib.IOutboundMessageNotification;
importorg.smslib.InboundMessage;
importorg.smslib.Message.MessageTypes;
importorg.smslib.OutboundMessage;
importorg.smslib.modem.SerialModemGateway;
public class SMSAgent extends Agent {
privateSmsConfigconfig;
private static EntityManagerFactory factory;
privateOutboundNotificationoutboundNotification;
privateInboundNotificationinboundNotification;
privateCallNotificationcallNotification;
   // Create the notification callback method for gateway statuses.
privateGatewayStatusNotificationstatusNotification;
privateOrphanedMessageNotificationorphanedMessageNotification;

private static final String PERSISTENCE_UNIT_NAME = "TBAgentPU";
   @Override
protected void setup() {
      String agentName = null;
Object[] args = getArguments();
if (args != null &&args.length> 0) {
agentName = (String) args[0];
      } else {
         // Make the agent terminate immediately
System.out.println("Error: Agent name not specified!!!!");
doDelete();
      }
      /*
```

```
        * Create directory facilitator description (DF)  for the agent
        * and register this agent & its service type
        * */
DFAgentDescriptiondirectorFacilatorDescription = new DFAgentDescription();
directorFacilatorDescription.setName(getAID());
ServiceDescriptionserviceDescription = new ServiceDescription();
serviceDescription.setType("tbsurveillance");
serviceDescription.setName("tbsurveillance-sms");
serviceDescription.setName(agentName);
directorFacilatorDescription.addServices(serviceDescription);
try {
DFService.register(this, directorFacilatorDescription);
        } catch (FIPAExceptionfe) {
fe.printStackTrace();
        }
try {
initialization();

            //add behaviors
addBehaviour(new SendSMSAlert());
        } catch (Exception ex) {
Logger.getLogger(SMSAgent.class.getName()).log(Level.SEVERE, null, ex);
doDelete();
        }

    }

    @Override
protected void takeDown() {
try {
```

```
DFService.deregister(this);
        } catch (FIPAExceptionfe) {
fe.printStackTrace();
        }
    }

private class SendSMSAlert extends CyclicBehaviour {

        @Override
public void action() {
MessageTemplatemessageTemplate = MessageTemplate.MatchPerformative(ACLMessage.CFP);   //Requested by the Coordinating agent to dispatch sms to play
ACLMessage message = myAgent.receive(messageTemplate);
if (message != null) {
try {
ACLMessage reply = message.createReply();
reply.setPerformative(ACLMessage.PROPOSE);
                    //send SMS
sendPendingSMS();
myAgent.send(reply);  //Reply to request from the client
                } catch (Exception ex) {
Logger.getLogger(SMSAgent.class.getName()).log(Level.SEVERE, null, ex);
                }
            } else {
block();
            }
        }
    }
```

```
public void initialization() throws Exception {
config = getSmsConfig();
outboundNotification = new OutboundNotification();
inboundNotification = new InboundNotification();

	// Create the notification callback method for inbound voice calls.
callNotification = new CallNotification();
	// Create the notification callback method for gateway statuses.
statusNotification = new GatewayStatusNotification();
orphanedMessageNotification = new OrphanedMessageNotification();
SerialModemGateway gateway = new SerialModemGateway("modem."
		+ config.getComPort(), config.getComPort().trim(),
config.getBoudRate(), config.getManufacturer(),
config.getModel());
	// SerialModemGateway gateway = new SerialModemGateway("modem.com1",
	// "COM4", 115200, "Huawei", "");
gateway.setInbound(true);
gateway.setOutbound(true);
gateway.setSimPin(config.getModemPassword());
	// Explicit SMSC address set is required for some modems.
	// Below is for VODAFONE GREECE - be sure to set your own!
gateway.setSmscNumber(config.getSmscNumber());
	// Set up the notification methods.
Service.getInstance().setInboundMessageNotification(inboundNotification);
Service.getInstance().setCallNotification(callNotification);
Service.getInstance().setGatewayStatusNotification(statusNotification);
Service.getInstance().setOrphanedMessageNotification(
orphanedMessageNotification);
Service.getInstance().setOutboundMessageNotification(
outboundNotification);
```

```
Service.getInstance().addGateway(gateway);
Service.getInstance().startService();
System.out.println();
System.out.println("Modem Information:");
System.out.println("  Manufacturer: " + gateway.getManufacturer());
System.out.println("  Model: " + gateway.getModel());
System.out.println("  Serial No: " + gateway.getSerialNo());
System.out.println("  SIM IMSI: " + gateway.getImsi());
System.out.println("  Signal Level: " + gateway.getSignalLevel()
        + " dBm");
System.out.println("  Battery Level: " + gateway.getBatteryLevel()
        + "%");
System.out.println();
  }

public void sendPendingSMS() {
    // select unsent SMS from DB

EntityManagerentityManager = getEntityManager();
    Query query = entityManager
        .createQuery("select outboundMessage from OutboundMessageoutboundMessage where outboundMessage.notificationType = :notificationType and outboundMessage.messageStatus = :messageStatus order by outboundMessage.outboundMsgIdasc");
query.setParameter("messageStatus", "Pending");
query.setParameter("notificationType", "SMS");

   List<com.core.entity.OutboundMessage>outboundMessageList = query.getResultList();
if (outboundMessageList.size() > 0) {
EntityTransactionentityTransaction = entityManager.getTransaction();
```

```
try {
com.core.entity.OutboundMessage message = outboundMessageList.get(0);
entityTransaction.begin();
        // Send a message synchronously.
OutboundMessagemsg = new OutboundMessage(message.getPhoneNumber(),
message.getMessage());
Service.getInstance().sendMessage(msg);

        //Update the status once successfully sent
message.setMessageStatus("Sent");
message.setDateSent(new Date());
entityManager.merge(message);
entityTransaction.commit();
entityManager.close();
      } catch (Exception e) {

e.printStackTrace();
      }
    }

  }

public class OutboundNotification implements IOutboundMessageNotification {

public void process(AGateway gateway, OutboundMessagemsg) {
System.out.println("Outbound handler called from Gateway: "
          + gateway.getGatewayId());
System.out.println(msg);

    }
```

```
    }

public class CallNotification implements ICallNotification {

public void process(AGateway gateway, String callerId) {
System.out.println(">>> New call detected from Gateway: "
                + gateway.getGatewayId() + " : " + callerId);


        }
    }

public class GatewayStatusNotification implements
IGatewayStatusNotification {

public void process(AGateway gateway, GatewayStatusesoldStatus,
GatewayStatusesnewStatus) {
System.out.println(">>> Gateway Status change for "
                + gateway.getGatewayId() + ", OLD: " + oldStatus
                + " -> NEW: " + newStatus);
        }
    }

public class OrphanedMessageNotification implements
IOrphanedMessageNotification {

publicboolean process(AGateway gateway, InboundMessagemsg) {
System.out.println(">>> Orphaned message part detected from "
                + gateway.getGatewayId());
System.out.println(msg);
          // Since we are just testing, return FALSE and keep the orphaned
```

```
            // message part.
return false;
        }
    }

public class InboundNotification implements IInboundMessageNotification {

public void process(AGateway gateway, MessageTypesmsgType,
InboundMessagemsg) {
try {

if (msgType == MessageTypes.INBOUND) {

System.out.println(">>> New Inbound message detected from Gateway: "
                            + gateway.getGatewayId());
System.out.println("====================================");
System.out.println(msg);
                    //  persistMessage(msg);
System.out.println("====================================");
                } else if (msgType == MessageTypes.STATUSREPORT) {
System.out.println(">>> New Inbound Status Report message detected from Gateway: "
                            + gateway.getGatewayId());
                }
System.out.println(msg);
gateway.deleteMessage(msg);

            } catch (Exception ex) {
Logger.getLogger(SMSHandler.class.getName()).log(Level.SEVERE,
null, ex);
            }
```

```
        }


    }
publicSmsConfiggetSmsConfig() {
SmsConfigsmsConfig = new SmsConfig();
EntityManagerentityManager = getEntityManager();
    Query query = entityManager.createQuery("select smsConfig from
SmsConfigsmsConfig order by smsConfig.smsConfigIdasc");
smsConfig = (SmsConfig) query.getSingleResult();
returnsmsConfig;
    }

publicSMSAgent() {
factory = Persistence.createEntityManagerFactory(PERSISTENCE_UNIT_NAME);
    }

publicEntityManagergetEntityManager() {
returnfactory.createEntityManager();
    }

}
```