UNIVERSITY OF NAIROBI

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SCHOOL OF COMPUTING AND INFORMATICS

HEALTH INFORMATION SYSTEM FOR REAL-TIME TRACKING AND SURVEILLANCE OF TB DISEASE CONTROL EFFORTS

By:

MATHENGE RICHARD
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Supervisor:
Dr. ELISHA ABADE

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DECLARATION

I declare that this project is my original work and has not been submitted to any institution for an award of any degree.

Student
Name: Mathenge Richard

Date: …………………………………

Signature……………………..………

Supervisor
Name: Dr. Elisha Abade

Date……………………………………..…

Signature…………………………………..

DEDICATION

This project is dedicated to my family for their endless support and generosity. The huge chunks of encouragement inspired me in this course. They have facilitated my entire course up-to and including this final project. Their unwavering love and inspiration kept me going even when I wanted to give up.

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I'm grateful too for the support and advice of my supervisor Dr. Elisha Abade who offered unflagging support and assistance in this research.

ABSTRACT

Kenya has struggled to build a health information system that can efficiently improve the delivery of quality health services to its population. The Demographic and Health Surveys have shown persistently high morbidity and mortality rates from Tuberculosis (TB) disease. At present, the country lacks a comprehensive spatially referenced disease database for Tuberculosis. With lack of such a crucial disease database, it has become quite difficult to fully identify and map the disease prevalence across the country. In addition, lack of such limits the identification, prioritization, and surveillance of the disease and the patients. The primary objective of this research was to design a more comprehensive TB disease geo-database that links to a dynamic web-based platform for TB surveillance and tracking in Juja Sub County. The specific objectives of this research were; to assess the magnitude and spatial prevalence of TB disease as reported in health facilities of Juja Sub County; to examine health facilities' TB registry Information Systems in developing a geo-referenced TB database from the existing TB patient registry records; to assess gaps in the type of TB patient's health information recorded in the existing TB registry, to design a spatially referenced TB database on a Web platform with a reporting system for TB surveillance and tracking and finally to create thematic maps to facilitate visualization of TB cases and aid in monitoring health facilities. This study used a retrospective study design to investigate all reported cases of TB from the year 2015 to 2017 in the TB register of health facilities of Juja Sub County. Two main data collection approaches were used; Spatial mapping of health facilities using GPS and Health facilities assessment using a geo-coded questionnaire. Data collection entailed carrying out key experts interviews in order to get first-hand information. Quantitative data analysis was done using SPSS while spatial data analysis was done using ArcGIS mapping software. Finally, a functional integrated TB disease database was developed linked to a reporting module to help tracking and surveillance of TB disease.

Keywords: GIS, Tuberculosis, Disease Surveillance, Health Information System, Disease database

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ABBREVIATIONS

CDC……….Centre for Disease Control

CHW………Community Health Workers

DHIS…….…District Health Information System

GIS …………Geographical Information System

GPS…………Geographical Positioning System

HRIO….……Health Records Information Officer

HTML ….… Hyper Text Markup Language

HTTP ………Hyper Text Transfer Protocol

ICT..………..Information Communication Technology

IDSR….…… Integrated Disease Surveillance and Response

KEMRI……..Kenya Medical Research Institute

MDR TB……Multi-Drug Resistant Tuberculosis

MVC………. Models View Controller

NCICE………Norwegian Centre for International Cooperation in Education

SPSS….……Statistical Package for Social Scientists

TB ………….Tuberculosis

WHO………World Health Organization

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CHAPTER ONE

1. BACKGROUND

1.1. The upsurge of Tuberculosis disease burden in Kenya

The increasing burden of diseases caused by respiratory infections in Kenya has become a major public health concern. The Demographic and Health Surveys have shown persistently high morbidity and mortality rates from Tuberculosis (TB) disease (WHO, 2011, KEMRI, 2012). According to the Global Health Facts release of 2012, Kenya is ranked number 13 among the 22 High Burden Countries (HBCs) that accounts for 80% of tuberculosis (TB) cases in the world (Kaiser Family Foundation, 2011). In the year 2011, 106,083 TB cases with more than 4,000 deaths were reported in Kenya - making it among the highest cause of morbidity and mortality in the country (KEMRI, 2012). In addition, Multi-Drug Resistant (MDR) TB is the biggest challenge that the country is facing in efforts to control the disease. MDR TB cases are on the rise and could be transmitting the disease to unsuspecting Kenyans, especially children (KEMRI, 2012).

In spite of the enormous challenges caused by TB disease, there is a scarcity of basic data and records. In addition, there is a lack of understanding of the spatial prevalence of the disease in Kenya (Republic of Kenya, National Assembly, 2011). The geographic location, trend, pattern and official numbers of TB patients are largely unknown in Kenya. Research on the challenges of the existing method used to identify, document and treat this disease prevalence (especially on preventive measures) is limited. Furthermore, remarkably, little mapping and disease database development has been done in Kenya on the major diseases that still dominate today's disease burden. Yet, mapping diseases have a long history and have been widely applied for even the rarest diseases in developed countries (Craglia and Maheswaran, 2016).

1.2. Increasing adoption of ICT enabled application in Kenya

In Kenya, ICT and internet access continues to increase in scope and capacity. Similarly, mobile phone use and connectivity are among the highest in Africa. Kenya has emerged as a leading player in mobile phone technology Applications for development; an example is the use of M-PESA mobile payment system that is used by a majority of the population. Furthermore, the use of mobile phone coded Short Messaging Services in Kenya is not new; the media fraternity is leading in this front and has become popular with Kenyan of all calibre (CA, 2015).

Government and the private sector players are not left behind and are increasingly using ICT based platforms and mobile phone SMS to improve service delivery and provide interactive citizen feedback mechanisms. On the other hand, individual citizens are increasingly embracing the use of smartphones Apps to create new livelihoods and enhance their lifestyles. There is need to tap this opportunity to improve healthcare information systems and especially on disease tracking and monitoring efforts.

1.3. GIS in spatial health information database development

Geographic Information Systems is a useful tool for health research that can be used to develop interactive and easy to use spatial health information databases at the community level (Cromley, E. and McLafferty, S. 2011; Jardine et al, 2014). It enables users to store, harmonize, query, scrutinize and display location-based data at various scales. GIS technology supports the creation of interactive geographically referenced health geo-databases that can be used to record and store with precision the health information database at the local level. The GIS technology can allow the users to not only interact with data but also enhance visualization of spatial relationships and patterns through data integration that can aid decision-making processes (Kwakkel, et al, 2014).

1.4. Linking GIS with ICT for real-time disease tracking

ICT have developed superior tools and functionalities that can easily be used in disease mapping and surveillance interventions strategies. The merger of Geographical Information System (GIS), ICT and Geographical Positioning Systems (GPS) supports the creation of dynamic and interactive geographically referenced database (geo-databases) that can be used to record and store with precision the location coordinates of patient's information (Mays, 2002; Auchincloss et, 2012). According to Mays (2002), these dynamic Geo-ICT enabled databases allow the users not only interact with them but also combine (multi-layering) of other datasets.

GIS is particularly useful for disease mapping, tracking, surveillance and monitoring processes (Eisen, R. and Eisen, L.2014).

It has been used in analyzing the spread of as well as a management strategy for allocating resources and for understanding high-risk areas of disease. Integrating GPS with Mobile Phone technology can equip public health officers with important information and communication channels that can aid in tracking and monitoring of TB patients thereby improving containment efforts of the disease.

1.5. Problem Statement

Kenya has experienced a challenge in developing a health information system that can adequately improve the delivery of quality health services to its population. At present, the country lacks a spatially referenced disease database for TB. This makes it not only extremely difficult to identify and map the disease prevalence across the country but also limits the identification, prioritization, and surveillance of the disease and the patients (Luo, 2004).
With lack of such a crucial disease database, spatial targeting of the disease and strategic action planning by relevant health ministries and other institutions is greatly constrained.

TB disease is among the highest cause of morbidity and mortality in the country (KEMRI, 2012). This increasing burden of TB disease that is caused by respiratory infection has become a major public health concern. The Demographic and Health Surveys have shown persistently high morbidity and mortality rates from Tuberculosis (TB) disease (WHO, 2011, KEMRI, 2012). In the year 2011, 106,083 TB cases with more than 4,000 deaths were reported in Kenya. In spite of the enormous challenges caused by TB disease, there is a scarcity of basic data and records. In addition, there is a lack of understanding of the spatial prevalence of the disease in Kenya (Republic of Kenya, National Assembly, 2011). The geographic location, trend, pattern and official numbers of TB patients are largely unknown in Kenya. Such information should, therefore, be identified, collected and analyzed for an effective surveillance of the disease.

However, an untapped opportunity exists in developing integrated spatially referenced health information systems in Kenya. ICT and internet access continues to increase in scope and capacity. Similarly, mobile phone use and connectivity in Kenya among the highest in Africa. On the other hand, the merger of ICT, Geographical Positioning Systems (GPS), mobile phone technology and Geographical Information System (GIS) present an opportunity to build integrated health systems. GIS supports the creation of dynamic and interactive geographically referenced database (geo-databases) that can be used to record and store with precision the location coordinates of patient’s information (Blanton et al, 2006).

There is need to tap on these technologies to build dynamic databases and applications that can facilitate to map, collect and analyze all reportable TB diseases cases. Such health information systems promise to adequately improve the disease control and monitoring efforts.

1.6. Justification

Providing timely and adequate health data is an essential pre-requisite of evidence-based health planning and management, which is increasingly applied to all areas of public health. Research that combines spatial location of disease with spatial analysis present new opportunities to develop tools for disease surveillance and improve our knowledge on the epidemiology and control of contagious disease.

The availability of relevant and updated information to decision makers at all levels is vital for an efficient management, monitoring and planning of the public health system. Automated Geo-ICT based web platforms linked to mobile phone handsets to collect, and map all reportable TB diseases cases can fill this gap by providing real-time data when needed. Disease mapping using GIS is valuable in linking disease control to prevention efforts, which can aid in developing better treatment and patient follow up programs. This improves the efficacy of disease control efforts (Melnick, 2002; Queensland Health, 2002).

Research on the challenges of the existing method used to identify, map, document and treat this disease prevalence (especially on preventive measures) is limited. Furthermore, remarkably, little disease mapping and disease database development have been done in Kenya. There is a need to seize the opportunities offered by such technologies to devise innovative approaches and develop TB mapping and tracking tools to help health professionals in intervention strategies. These will be of prime importance in the disease surveillance and improve greatly in the fight against the upsurge.

1.7. Research Objectives

1.7.1. Main Objective

The main objective of this research was to design a TB disease database linked to a dynamic web-based platform for TB real-time surveillance and tracking in Juja Sub County.

1.7.2. Specific Objectives

1. To develop a disease geo-database from the existing TB patient registry records.
2. To find outpatient data gaps in the TB patients registry records.
3. To design a spatially referenced TB database on a Geo-ICT enabled Web platform with a reporting system for TB surveillance and tracking.
4. To create thematic maps to facilitate visualization of TB cases and aid in monitoring health facilities.

CHAPTER TWO

2. LITERATURE REVIEW

This chapter provides a comprehensive analysis and emphasis of the theoretical foundation of the research through a review of the relevant and applicable literature.

2.1. Existing public health information system in Kenya

In Kenya, there are two reporting systems anchored in digital platforms in use by the government to collect, consolidate and transmit diseases information from various facilities. These include:

2.1.1. The District Health Management Information System (DHIS2)

The DHIS2 is an open-source and free health management information system. It is also a data warehouse built by Health Information Systems Programme (HISP). DHIS2 is monitored and controlled by the Department of Informatics at the University of Oslo. The system is also supported by the Norwegian Research Council (NORAD). The solution offered by HISP covers aggregated routine data, semi-permanent data, survey data, and particular forms of a case or patient-based data (Reidpath and Allotey, 2009). The system enables data collection, data capturing at all organizational levels and a high degree of input and out streams customization. Key issues for further interrogation for DHIS includes;

- Ownership concerns- who is authorized to update the information and who becomes the owner of the health information once posted on this platform?
- Privacy- Since it’s an open source system, what is the level of information ownership and privacy? At what health facility level can it be applied?
- Ease of use- how customizable is it and to what level of customization?
- Data capture- to what detail and level of visualization can the system capture.
- System ownership- Who is the ultimate owner of the systems?
- Usability concerns- How widespread is its use by Kenya health facilities
- Technical feasibility- What technical expertise is needed for its use and adoption by medical personnel?
- Can it be a substitute for the formal health management information systems used by the health ministry in Kenya?

- Accuracy concerns- What variables of patient information does the system capture and how accurate is the information posted?
- Systems integration- Can the system be integrated into/with other health information systems. What is the ease of integration?

While the Ministry of Health adopted the *community strategy data model* like District Health Information Systems to try and respond to the health needs of communities in order to improve their health status, this is so far not well organized and supported. Data consumption is dismal at the local level where health issues emanate and most needed for local based intervention. Again, most data at the community level is in hard copy form and hence difficult to analyze and interpret for decision-making support.

2.1.2. Integrated Disease Surveillance Response (IDSR)

Another system in use is known as the IDSR which is used by the World Health Organization (WHO) and its member states. It improves data availability and usage for timely detection, diagnosis, and response to the dominating causes of disease, disability and mortality. The operations of IDSR Surveillance involves the collection of the information that is solely vital to achieving disease control objective. The data requested may differ from one disease to the other whereby particular diseases may have specific information needs that call for specialized systems (World Health Organization Report, 2011).

Key issues that will need further interrogation for IDSR

- What data (disease variables) is captured by IDSR?
- Who consumes data captured using IDSR locally or nationally?
- Does ISDR operate on a manual or electronic database?
- Who is involved in collecting data in these systems?
- Does all health facility prescribe to and use IDSR
- How is the captured data, recorded, analyzed and interpreted using IDSR?
- Who owns, implement and maintains the system?
- Does the data captured using this system have a spatial component/variables?
- Is IDSR a system or a framework and how can it be used to improve disease mapping?

The weakness of the above two systems

The weakness of the above two systems is that the disease data in the platforms are highly aggregated and only limited inferences can be deduced from it. The data reporting and aggregation is mostly done using the nationally defined indicators. Whereas the global and national indicators may have a defined focus that may not be specifically relevant to lower level facilities, the lower level facilities at the counties do not have their own location-specific indicators. A key question that emerges is; do the counties and sub-counties need region-specific indicators for their monitoring and evaluation purposes?

The health system in Kenya relies on a Sector Wide Approach which aims at harmonizing the private and public health facilities efforts into a unified mission towards "health for all." This is according to the National Health Sector Strategic Plan II. However, the Sector Wide Approach has hitherto recorded mixed results, whereby some facilities have collected and shared data with the larger health system while others have failed to integrate successfully.

2.1.3. The manual TB Trace Programmes

This involves contact tracing, a vital component of TB control, which depends on the prompt alert of the disease. Credible clinical and epidemiological indications are used to determine contact tracing decisions. Community Health Workers (CHW) are involved in tracking and monitoring of TB patients. They also trace defaulters. Contact tracing aims at identifying cases of infection via contact with a TB patient, counselling and treatment of Latent TB Infection patients as well as identification of new TB infections upon contact with the index case. (Luo 2004; Getahun, Matteelli, Chaisson, & Raviglione, 2015)

The approximation of transmission risk should offer guidance on the promptness and response to investigations of contact tracing. People have the right to be enlightened about the health risks that face them in conjunction with recommended remedies and risk mitigation criteria. However, public enlightenment about potential TB exposure could provoke health concerns at individual, community or organizational level. It must, therefore, be done after an initial comprehensive assessment of the infectivity risk around the source case, as well as prior structuring of a contact screening strategy. In the event that a person has to be screened, such a person should be made aware of their potential exposure, its risk and screening recommendations immediately (Gesler, Hayes, Arcury, Skelly, Nash, 2004; WHO, 2010)

2.1.4. Manual TB registers

Most TB treating hospitals have TB registers where TB cases are recorded. However, despite the two registers capturing location-specific information on the reported cases the distribution of cases is not spatially defined. Therefore, the spatial distribution of patients who are diagnosed and treated at the hospital is not known. On the issue of data analysis, once the records are stored, no further probing or analysis is done. Only simple arithmetic calculation and analysis are carried out using simple tables that were displayed on the wall.

2.2. Emerging GIS technology use in Disease mapping

There exists a significant correlation between a disease and space. Geographical information systems (GIS) has proven to be a strong evidence-based technology that aids in early detection and subsequent rapid response to disease outbreaks (Musa et al, 2013).

GIS technology helps in the timely collection, analysis, display and sharing of geo-referenced data. This makes it a vital tool in early alerting of a disease, which eases the containment of the disease, achieved through surveillance. GIS helps in responding to a disease outbreak by releasing information concerning emerging threats of contagious diseases and their causative agents. This enhances effective decision making at the local, regional and national levels. GIS technology helps in formulating disease surveillance hence minimizing expenses associated with public health and clinical interventions. The cost-minimizing is made possible through prior prediction of potential outcomes before financial plans are made. Additionally, GIS can help in prioritizing resources allocation. The maps and spatial analysis in GIS reproduce trends, correlations and interdependencies that would otherwise be impossible in table formats. It also displays information on the levels of disease occurrence ranging from individual to regional cases. Moreover, a graphical representation of maps effectively displays the distribution pattern and intensity of the disease in question (ESRI, 2000).

The collaboration of advancements in GIS-based statistical and spatial analysis systems, with high-resolution geo-referenced health databases present new opportunities in the evaluation of behavioural, social and environmental factors that determine the variations of disease rates geographically at small area scale. (Shamsul, 2004). Evidence shows that GIS is gradually shifting from a technological tool to a scientific one (Schuurman, N. C, 2009).

The integrated GIS features sufficiently aid in summarizing the intricate relationship between human population, environment, infectious disease-pathogens, associated reservoirs and vectors. The greatest strength of GIS is that it is based on an active integration of real-world data. It integrates spatial and their non-spatial data into one "system" that allows a simultaneous interaction of both aspects for the user. It stores information about the world as a collection of thematic layers that are linked together through geo-referencing. Using GIS technology to study the spread of diseases and support decision making has influenced the migration from ancient social medicine to a technology-enhanced public healthcare. The development of health informatics, cheap computer systems and accessible geo-referenced medical data can successfully get incorporated into GIS technology to solve the Tuberculosis pandemic (Gesler et al, 2004).

The geographical positioning system (GPS) and GIS certainly provide opportunities to determine the challenge, generate hypotheses then establish strategies to monitor communicable diseases such as TB (Cesario et al, 2012).

GIS has previously been employed in monitoring contagious diseases. However, very little efforts have been made on tuberculosis.

2.3. GIS role in early detection of disease

GIS technology plays a very important role in the timely detection and rapid response to the outbreak of a disease. It informs the health experts together with the public on emerging infectious diseases and their causes. Furthermore, it enhances decision making locally, regionally and even globally. GIS as a tool collects, analyses, displays and shares data with locational aspect and hence enhancing detection of the disease.

GIS is a useful tool for health research that can be used to develop early-targeted spatial interventions and control for diseases. GIS enables users to store, harmonize, query, display, and evaluate location-based data at various scales (Rambaldi, G., 2006). Most importantly, the merger of GIS technology and Geographical Positioning Systems (GPS) supports the creation of an interactive geographically referenced database (geo-databases) that can be used to record and store with precision the location coordinates of patient's information (Mays, L., 2002). According to Mays (2002), these geo-databases allow the users not only to interact with them but also enhance visualization of spatial relationships and patterns through data integration. As such, users can perform spatial analysis to come up with new information that can aid decision-making processes.

Disease mapping using GIS is valuable in linking disease control and prevention efforts to their geographical distribution, which can aid in developing better immunization, treatment and patients' follow up programs. They can also be used to distinguish the low and high-risk areas, as well as integrating and visualizing patient's physical and socio-cultural factors and variables that contribute to the causation of disease.

Although health professionals are usually aware of the probable associations between disease risk and environmental variables, they lack spatial analytical techniques and methods that can be used to show the existence of such associations (Shamsul, 2004; Krieger, 2003). Understanding disease diffusion, disease spatial pattern and underlying background variables of patients would give health professionals a better understanding of how to improve their services to the public.

2.4. Cases of Application of GIS technology in the public health sector

There exists adequate information on the successful use of GIS technology within public health, ranging from creating communicable disease early warning systems, disease mapping to assessing health facility placement (Kumar, 2004; Rosero, 2004; Luo, 2004). Such applications have played an important role in developing interventions that have resulted in better healthcare and cheap health services. There are various documented works of literature that show the positive impact of applying spatial information in identifying and managing public health issues (Rytkonen M., 2004). However, there are limited applications of the same in Kenya with most being applied in developed countries.

GIS has been used in North Carolina TB mapping spatial analysis, database management and data visualization (Queensland Health, 2005). In the 1970s, National TB Institute (NCI) in the US utilized GIS to extract TB data from a tabular form and map it graphically. Mapping led to the emergence of geographical patterns in the data that had been stored for long in tabular form.

GIS has also been applied in the identification of optimal locations to facilitate diabetes prevention awareness program as well as distribute material for educating individuals who are at a high risk of developing Type 2 Diabetes at a town in the south USA (Gesler, et al, 2004). GIS has also been used in the Communicable Disease Control (Elliott et al, 2000).

In Kenya, KEMRI-Welcome research programme in conjunction with the Center for Disease Control has applied GIS technology to map out malaria and to develop a Malaria Atlas map of Africa. The results of this show a promising use of GIS application in disease mapping.

However, the use of GIS in the Kenyan health sector is low, yet the possibilities this technology provide is enormous. This could be attributed to lack of health experts trained in GIS technology and geospatial analysis hence hampering disease mapping and spatial targeting strategies (Cockings and Dunn 2004). While stringent competency prerequisites have been put to place for particular health professions, little efforts have been directed toward data managers and analysts in the public health sector. In order for GIS technology to be successful in Kenya, a number of obstacles must be overcome: lack of trained staff, lack of suitable datasets, minimal cooperation amongst the stakeholders, and that outsiders and not the Kenyan control most GIS health-based studies themselves.

2.5. Integrating GIS and ICT to improve the efficiency of disease monitoring and control efforts

In recent times, the GIS and ICT sectors are increasingly providing essential services for Kenya's socio-economic development. Kenya's new development blueprint is the Vision 2030 goals, whose aspiration is to have a nation that is globally competitive and prosperous by 2030, whose citizens enjoy a high-quality life. The vision is to be achieved by the implementation of key projects, identified under its economic, social, political and economic pillars (GoK, 2011). Among the six economic pillars identified in Vision 2030 is IT-enabled services. From the Vision, it is envisioned that realization of the socio-economic transformation is founded on the prudent and sustainable utilization of key finite resources, particularly ICT service development. The IT-enabled service pillar, like other economic pillars, is to be achieved by the implementation of key flagship projects. Towards achieving this, one of the objectives of the ICT master plan is to "Develop a Knowledge-based society and thereby enhance the quality of life for citizens" (GoK, 2011).

On the other hand, GIS and ICT tools can be integrated to develop a web-based platform that can be used to transmit real-time information of TB when it is identified in the health facilities.

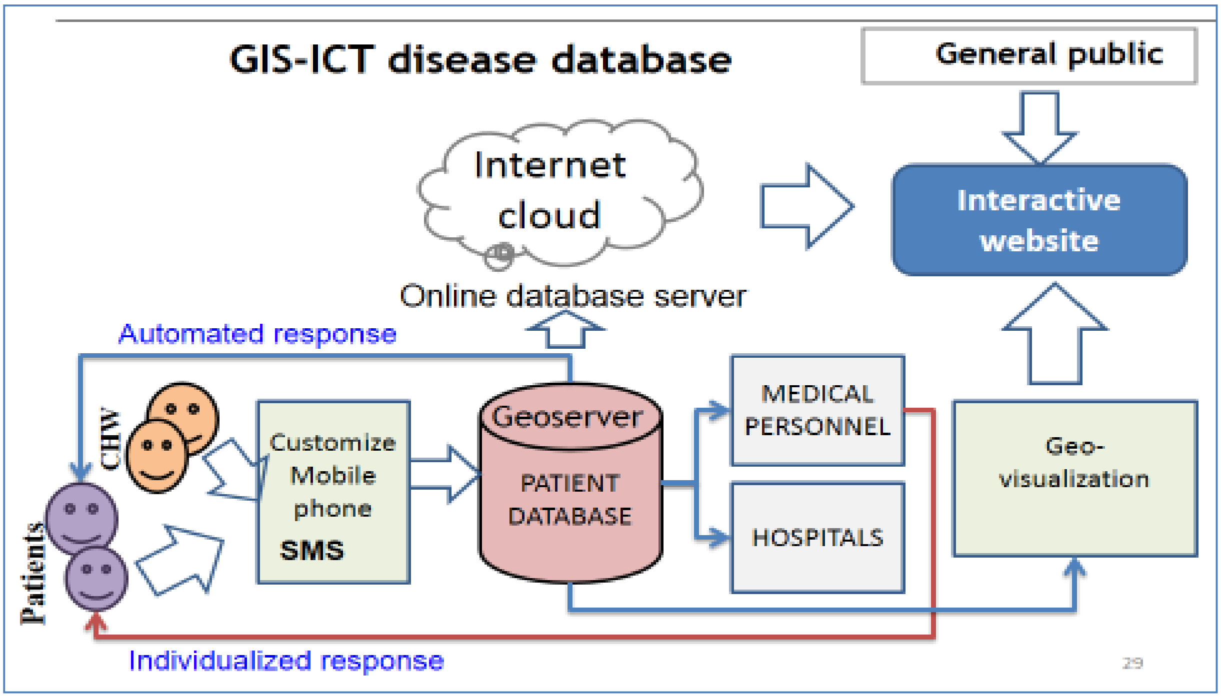
Android-based App can be linked to web-based platforms in TB tracking, disease mapping, and surveillance. Patient's tracking systems can be developed to monitor drug administration especially for TB drugs doses that take up to 6 months to administer. Defaulting to such doses has led to developing a deadly case of TB called Multi-Drug Resistant (MDR TB). For example, TB patients can be sent coded Short Messaging Services (SMS) on their mobile phone handsets that reminds them to take up the drug. These coded SMS's can be mapped and visualized on internet platforms like Google Earth in real time to track patients, show disease spread and act as public health information dissemination avenues. This has the potential to enhance TB surveillance and tracking and raise disease awareness (Hoffman, Cunningham, Suleh, Sundsmo, Dekker, Vago, & Hunt-Glassman, 2010).

Integrating GIS with ICT technology can supply public health officers with crucial information communication channels that can aid in monitoring and managing TB and TB diseases. It is also necessary to have relevant and updated information available to all levels of decision making to enhance an adequately monitored, controlled and planned public health system. The use of mobile phone application tools can fill this gap by providing real-time data when needed (Hoffman, et al, 2010).

Kenya has emerged as a leading player in mobile phone technology Applications for development. Mobile phone handsets and networks are now being used even in the most marginalised communities in Kenya. Furthermore, the use of mobile phone coded Short Messaging Services in Kenya is not new; media fraternity is leading in this front and has become popular with Kenyan of all calibre (Hoffman, et al, 2010).

The Geo-ICT health App, when linked to the web-based platform, can have usage beyond TB database development. For example, community health assessment surveys and mapping of other diseases can be conducted on handheld computing devices like GPS or Smart Phones with capacity for real-time tracking and reporting systems. The data from these can be easily integrated with existing open spatial data sets that are increasingly being availed in the public domain. This can result in enhanced accuracy, sampling, monitoring, and timely analysis of public health. Open Data Kit is a data collection tool mounted on android phones that streamline the collection of data in the field by substituting traditional paper survey with Android phones and a web-based server. The phone application component of the ODK suite is ODK Collect. ODK Collect influences Google's open-source Android platform to enable a single device to capture and store a diverse array of reporting data such as text, video, barcodes, and GPS coordinates.

2.1. Conceptual model



CHAPTER 3

3. METHODOLOGY

3.1. Case study Approach

This research employed two different approaches; exploratory and case study approach. According to Yin (2013), the case study aid to gather data and information and also to narrow and focus it to the area under study. In the area of focus, a thorough analysis of numerous issues under study is conducted. According to Kumar (2005), the case research method is an empirical probe that scrutinises a contemporary phenomenon within its real-life perspective. It is used to investigate social occurrences via a scrutiny of an individual or communities.

For this study, Juja Sub County was used as the case study site where a detailed investigation of TB disease was conducted. The study narrowed its case to the TB disease as it is among the highest cause of morbidity and mortality in the country. Furthermore, the choice to investigate TB is because it's an airborne disease that is highly contagious if not well contained. TB patients take their drug doses for six months hence the need for constantly tracking due to the risk of developing multi-drug-resistant (MDR) TB strain that is highly deadly if they fail to administer the drug for the given period.

3.2. Research design and approach

This study employed a retrospective study design to investigate all reported cases of TB from the year 2015 to 2017 in the TB register of health facilities of Juja Sub County was examined. TB data collected from the health facility included TB registration data, demographic data of TB patients and the geographic coordinates of the patients that were derived from their listed physical address. The unit of analysis was dispensaries in Juja Sub County since they are the first point of contact for the patients. Data was aggregated to the respective wards.

The study approach was sub-divided into three phases. Initial phase included theoretical study framework, which consists of the literature review on TB and health information system and management. Phase 2 involved data collection – where data collection from health facilities was done. Spatial data were collected using GPS across the study site. The research employed in-depth interviews with health professionals in the health facilities within the study area to investigate the disease incidence, prevalence, its relationships with social demographic data. Data compilation and analysis was done using SPSS and ArcGIS software. Various spatial analysis methods were used in visualizing the TB disease prevalence. The final stage involved designing of a web-based geo-database for the TB disease.

3.3. Data collection technique

Various data collection methods were employed in order to methodically gather relevant data for this study. An amalgamation of qualitative, quantitative and spatial data gathering methods was used in collecting spatial and non-spatial data for this study.

3.3.1. Secondary data collection

Prior to collecting data from the field, secondary sources of information were collected to complement primary data. This helped to get thorough knowledge and understanding of the study as well as problem under investigation beforehand. The secondary data was gathered from the published work such as books and articles among others. This was intended to complement primary data as well as fill knowledge gaps that were not addressed during field work.

3.3.2. Primary data collection

The main data collection involved collection of spatial and non-spatial data. Three main approaches were used; (1) GPS coded questionnaire to collect spatial data (2) administering questionnaires in order to collect non-spatial data. (3) And key expert's interviews.

3.3.3. Spatial Mapping of health facilities

All levels of health facilities within Juja were visited and mapped. The spatial location of health facilities was collected by use of Handheld GPS devices (Global Positioning System) where X, Y coordinates of each health facility were collected. The spatial extent (administrative boundaries) of Juja Sub County were gotten from spatial data that was obtained from Kenya Map Geodatabase. ArcGIS 10.3 software was the main software used for spatial analysis. These spatial data collected aided the researcher in preparing TB geo-database that showed the distribution of health facilities, TB distribution, and variations in population density, disease incidence, and prevalence. This helped to identify and visualize the hotspots for TB and subpopulation suppressed by TB.

3.3.4. Health facilities assessment

A detailed health assessment was conducted on all health facilities (selected- those offering treatment and diagnosis) in Juja Sub County. A geo-coded questionnaire was used in the health facility assessment. TB Patient data and records in existing health registry records from 2015 to 2017 in all the health facilities in Juja Sub County were collected and analyzed. These datasets were integrated with other datasets in order to build a comprehensive disease database in identifying health information gaps.

Data collection entailed carrying out key experts interviews in order to get firsthand information. The interviews covered a wide range of stakeholders, including key experts from national government, county government, sub-county administrators and private sector involvement in public health.

3.4. Data processing and analysis

Initial sorting of collected information was implemented based on the key data collection techniques described in the preceding subchapter. Data coding was certified by quality control and spatial data sorted. During field work, data was checked and certified during collection. At the same time, to eliminate any inconsistency or errors, the quality control check was further carried out. To make sure that there were less mistakes during entry, verification of data was carried out immediately after the data was entered.

Both qualitative and quantitative pre-coded data from the questionnaires were input in SPSS for processing according to the coding categories assigned to different variables during data collection time. Data analysis involved frequencies, cross-tabulations and descriptive statistics of different variables and the production and interpret MODEL represents the application data and behaviour in terms of the problem definition of the domain. The model is independent of the user interface. VIEW represents the HTML mark-up displayed to the end user. CONTROLLER is fully responsible for handling all the Hypertext Transfer Protocol (HTTP) requests.ation of different tables and charts.

3.5. Spatial database development

Combined with hospital records data, the compilation of empirical data led to the creation of a database, which provided the basis for patient health profiling, and development of functional TB disease repository database. The Spatial database development entailed the following processes.

3.5.1. Geo-database Design:

Creation of a geo-database schema: Feature different domain classes and geo-database behaviours and methods such as relationship classes, subtypes, topology rules, and other relevant schemas.

3.5.2. **Data Cleaning:**

Design of Data Warehouse: this was designed to ensure data is of good quality. This helps eliminate redundant data, and match the requirements of the geo-database.

3.5.3. **Cartography and Map Design**

Loading map layers and defining map symbology according to general cartography standards. Map layers include, but was not limited to;

- District administrative boundaries
- Road transport network
- Major towns/municipalities
- Operational layers (medical & research facilities)

This process also involved setting up attributes to enable map querying and optimizing layers among other map operations.

The web-map application has the following functionalities:

- Interactive map viewer with Zoom and panning capabilities
- Dynamic online styling based on the indicator selected
- Charting
- Metadata

3.6. **Interactive web platform development**

An interactive online web-based GIS system for public health information system was designed and implemented using databases such as MSSQL.

This project was implemented using the MVC architectural pattern. It has been widely adopted for web applications. The ASP.NET MVC framework guided both the server side and client side development. MVC stands for Model View Controller. MODEL represents the application data and behaviour in terms of the problem definition of the domain. The model is independent of the user interface. VIEW represents the HTML mark-up displayed to the end user. CONTROLLER is fully responsible for handling all the Hypertext Transfer Protocol (HTTP) requests. This provides an efficient way of separation of concerns. The resulting application is sustainably maintainable. In addition, routes select the right controller to handle the issued requests. The actions in the controllers a responsible for handling user requests.

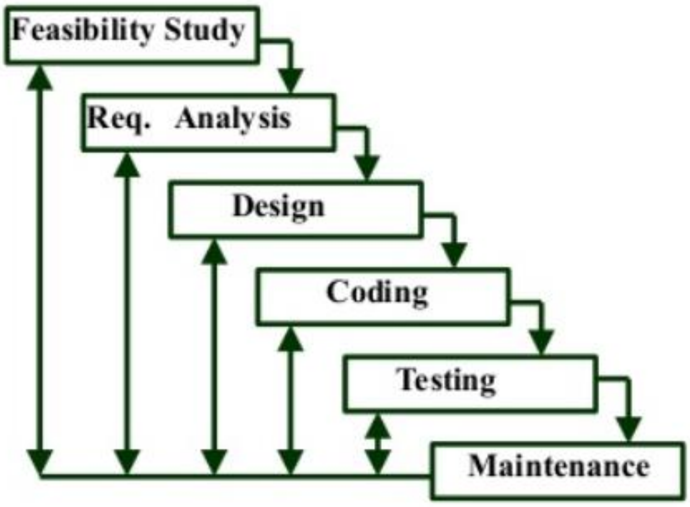
An object-oriented programming language like C# was explored to program the server side that manipulates the knowledge in the database. For the sustainability of the system, users of the system will have to be taken through the use, updating, and maintenance of the system. The system developed has visualization and updating options, which the hospital professionals in the sub-county had to be taken through. This will also ensure that the system is sustainable. The staff were able to visualize these cases for their Monitoring and control interventions because they will be able to relate with other location-based social, cultural, economic data.

3.7. System development methodology

Software development process involves different, well defined tasks that are performed at each stage. This requires a clear framework to be used in the entire software development process. This project employed the Software Development Life Cycle (SDLC). This consists of a well-detailed plan that describes activities carried out in each stage of development.

Iterative waterfall model which is a sequential process stood out to be the best development for this project. This is solely because it provided feedback paths for error correction. Furthermore, there was a working model of the system at a very early stage of development. This made it easier to identify in advance the design and functional flaws. The main stages are as shown in the figure below.

Figure 3.1: *Iterative Waterfall model*



CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. System Analysis

System analysis phase in most software development processes, involves breaking down the system into different components and modules. This ensures that all components work efficiently in order to achieve the desired results.

This approach breaks system analysis into several phases:

- Problem analysis: the process of understanding problems and user needs in order to arrive to an amicable solution
- Requirements analysis: understanding the business process and environment
- Logical design: focussing on the logical relationship between different objects and entities

4.2. Requirement Analysis

The requirement analysis phase in software development involves gathering and analyzing data about the user needs in conjunction with the problem being solved. Distinguishing the required functionality of the final system is vital as a system with incomplete functionality may lead to low user acceptance or complete rejection. In developing this system, the key informants and Juja Sub-County health stakeholders were a rich source of critical information

4.3. Findings

System development involved engaging the end users of the system and key stakeholders. Their contribution gave a better understanding and an insight into how the entire system was developed from the beginning to the end. Further, it helps to better mitigate project risks during and after development. The engagement with stakeholders in the development of this system was done through administering questionnaires and one-on-one interviews. The following are sample analysis results after assessment of end users and key health stakeholders;

Table 4.1 TB trained personnel.

Is there personnel trained to handle TB in this facility?

		Frequency	Percent	Cumulative Percent
Valid	Yes	4	23.5	23.5
	No	13	76.5	100.0
	Total	17	100.0	

There are very few personnel trained to handle TB in various health facilities (23.5%). This was mostly the case in diagnostic and treatment centres. Some health facilities are treatment centres only but do not carry out the diagnosis. A majority of those handling TB cases (76.5 %) either have no formal training or no training at all.

Table 4.2 Health records data officer.

Does the facility have health records data officer?

		Frequency	Percent	Cumulative Percent
Valid	Yes	5	29.4	29.4
	No	12	70.6	100.0
	Total	17	100.0	

Majority of health facilities (70.6%) have no health-records data-officers. The few trained data officers (29.4%) are mainly in major sub-county health facilities.

Table 4.3 Type of recording system in use.

What kind of health recording system is used in this facility?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Manual	14	82.4	82.4	82.4
	Digital	2	11.8	11.8	94.1
	Both	1	5.9	5.9	100.0
	Total	17	100.0	100.0	

Majority of health facilities in Juja ward (84.4%) use manual way to record reported TB cases. These are mainly the ministry of health tools (TB4- Tuberculosis Treatment Unit Register)

Table 4.4 TB recording tools.

Does the facility have standard tools for recording TB?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	6	35.3	35.3	35.3
	No	11	64.7	64.7	100.0
	Total	17	100.0	100.0	

TB4 registers are the standard tool for recording TB cases. Ministry of Health and Public Sanitation is responsible for supplying these tools to all health facilities . Majority of the local facilities in Juja Sub-County (64.7%) do not have standard tools for recording TB cases. Some of these local facilities records reported cases in exercise books which limits the quality of the very required data.

Table 4.5 Analysis of collected TB data.

Is there any analysis done on already collected data for TB?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	2	11.8	11.8	11.8
	No	15	88.2	88.2	100.0
	Total	17	100.0	100.0	

According to the analysis output above, there is very minimal analysis carried out (11.5%). This was evident as merely simple charts were found displayed in a majority of the health facility walls.

4.4. System Requirements

A system is composed of different functional and non-functional requirements as described below;

4.4.1. Functional requirements

.Functional requirements defines the desired system operations and various activities that the system must perform. Some of the core functionalities of the health information system are as follows;

- The system has an interactive map viewer with Zoom and panning capabilities
- The system has a dynamic styling based on the indicator selected
- The system has charting capabilities
- The system accepts different health facilities/patient data with coordinates and shows their respective spatial distribution on a map

4.4.2. Non-functional requirements

Non-functional requirements defines different system attributes. These includes but not limited to system performance, system security, reliability, maintainability, scalability among others. Some non-functional requirements for the system include:

- The web application is easy to use by data entry clerks and other authorized users.
- The web application allows several dashboards to be made at the same time without downgrading performance
- The system is easy to maintain.
- The system provides security to the database by use of hashed passwords.
- The system is available at all times.
- The system is secure against bots and scripts by employing the use of anti-forgery tokens.

4.5. System Design

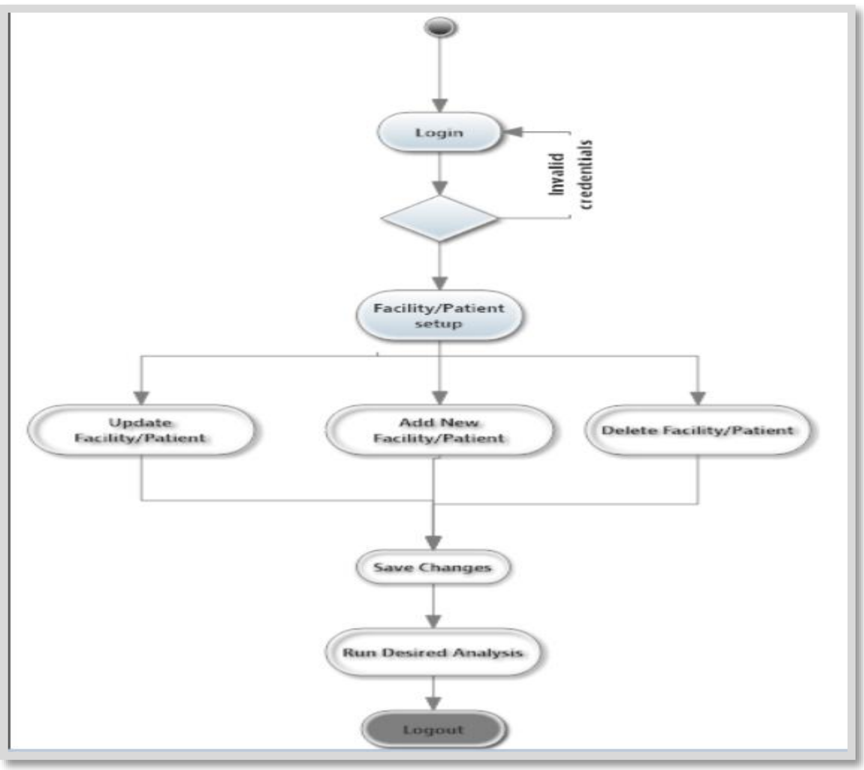
The system includes: Use cases and Flow Charts. The health information system is a web application for visualizing and analyzing the geo-coded patient and health facility data. Each diagram has been used to solve a particular problem in the system since each of them was designed to perform a particular task. Flow charts were used to show how the system is started, how the processes are executed and finally how the system is closed.

4.5.1. Flowcharts

A flowchart represents a process or a workflow using different symbols. It shows the different processes inherent in the system with different flows of control. The start-up page is the login page.

The figure shows an activity diagram to illustrate adding, updating and deleting patients and health facilities in the system

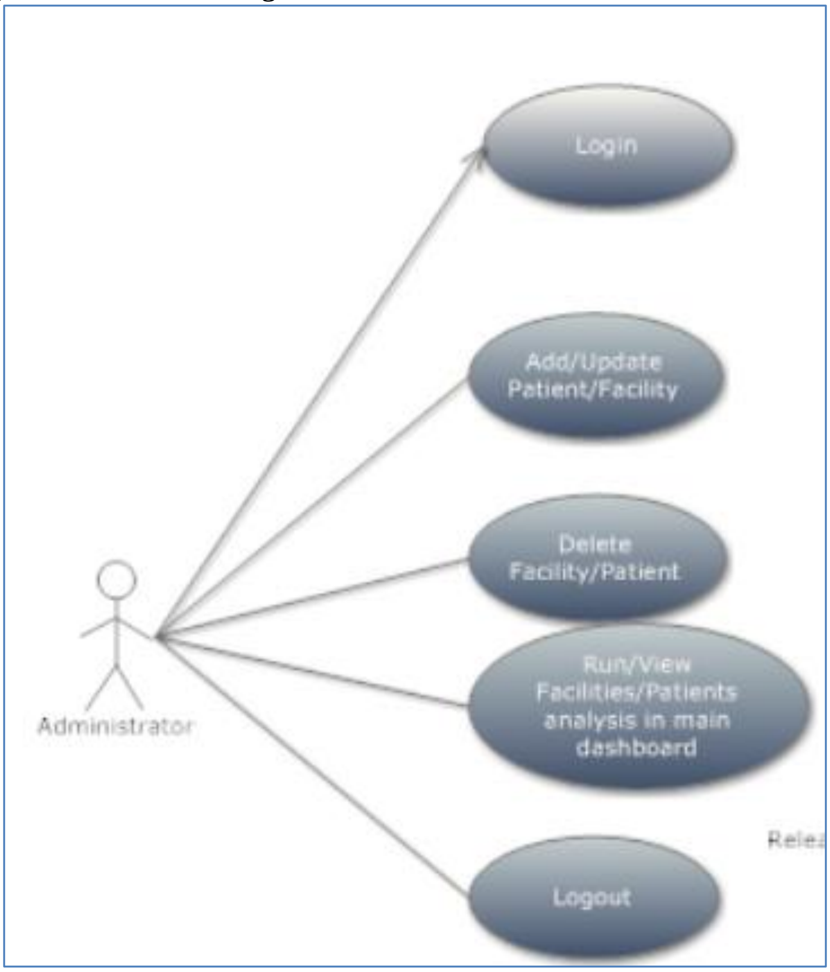
Figure 4.1 System flowchart diagram



The authorized system administrator has to login to the system be verified and be granted access to the system by entering the username and password to access the main system. Once logged in, the system administrator can carry out several activities. The system administrator can add patients/health facilities to the system. S/he can update or delete the existing patient/ health facility in the system. Another core functionality of the system is the ability to analyze and visualize patients' data and health facilities data and other indicators selected. The system administrator can run any desired analysis and visualize the output in charts or on maps.

Use-case that defines the interaction of the administrator of the health information system.

Figure 4.2 Use case diagram



Primary Actor: Administrator

Preconditions: User is identified and authenticated.

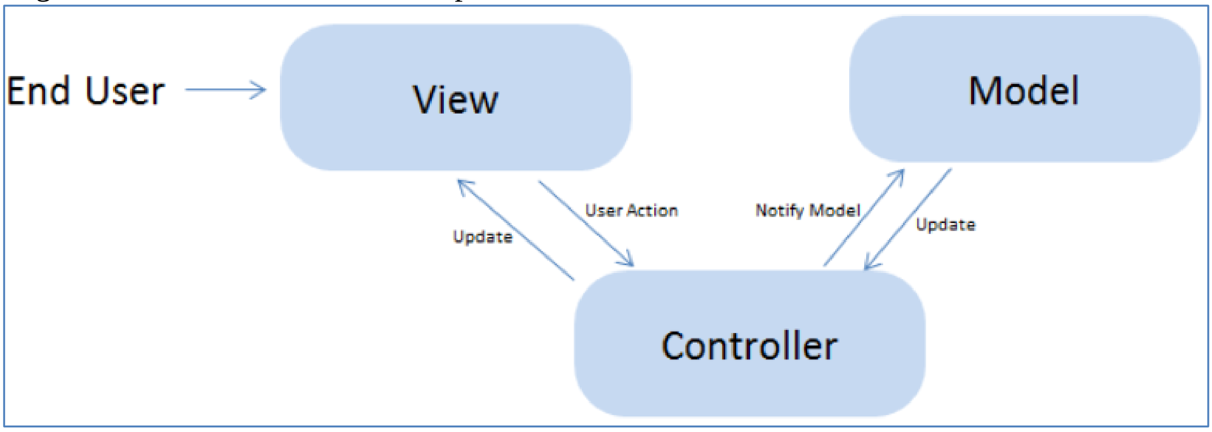
Success guarantees: Patient/ Health facility is added/Updated/Deleted and can analyze patient/health facility data and display analyzed data on maps, charts, and graphs

4.6. System Architectural Design

This system employs the MVC architectural pattern. MVC stands for 'model-view-controller'. Model corresponds to data-related logic of the application. It is not dependent on the user interface. Facilities model and Patients model are examples of models used in this system. These two models are independent of the user interface. View, is the HTML mark-up displayed to the end user. In this web application facilitiesForm and patientsForm are examples of those mark-ups. Controller on the other hand is used to handle all HTTP requests. They get the facilities and patients from the database and return the view the client. Each component has distinct responsibility which results in better separation of concerns.

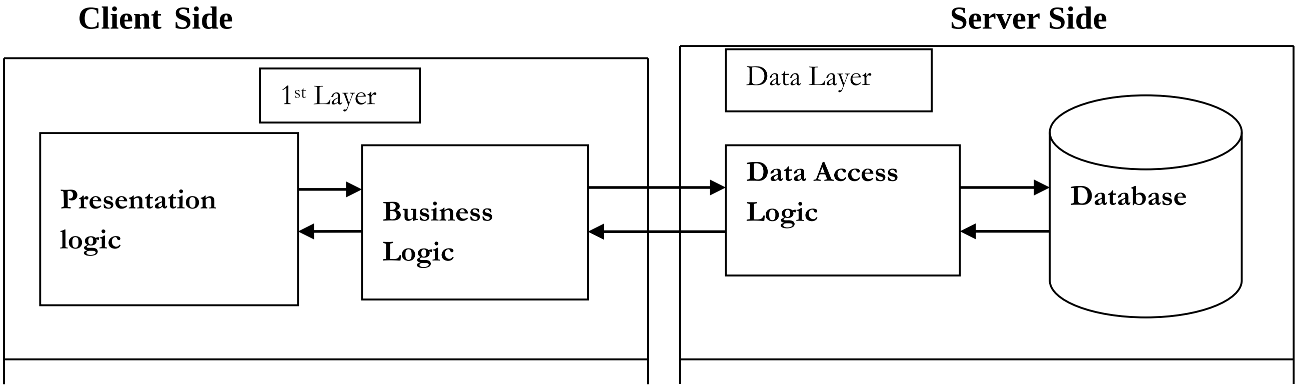
The figure below illustrates the MVC architectural pattern.

Figure 4.3 The MVC architectural pattern.



Systems architectural design is a 2-tier Architecture as shown in the figure below.

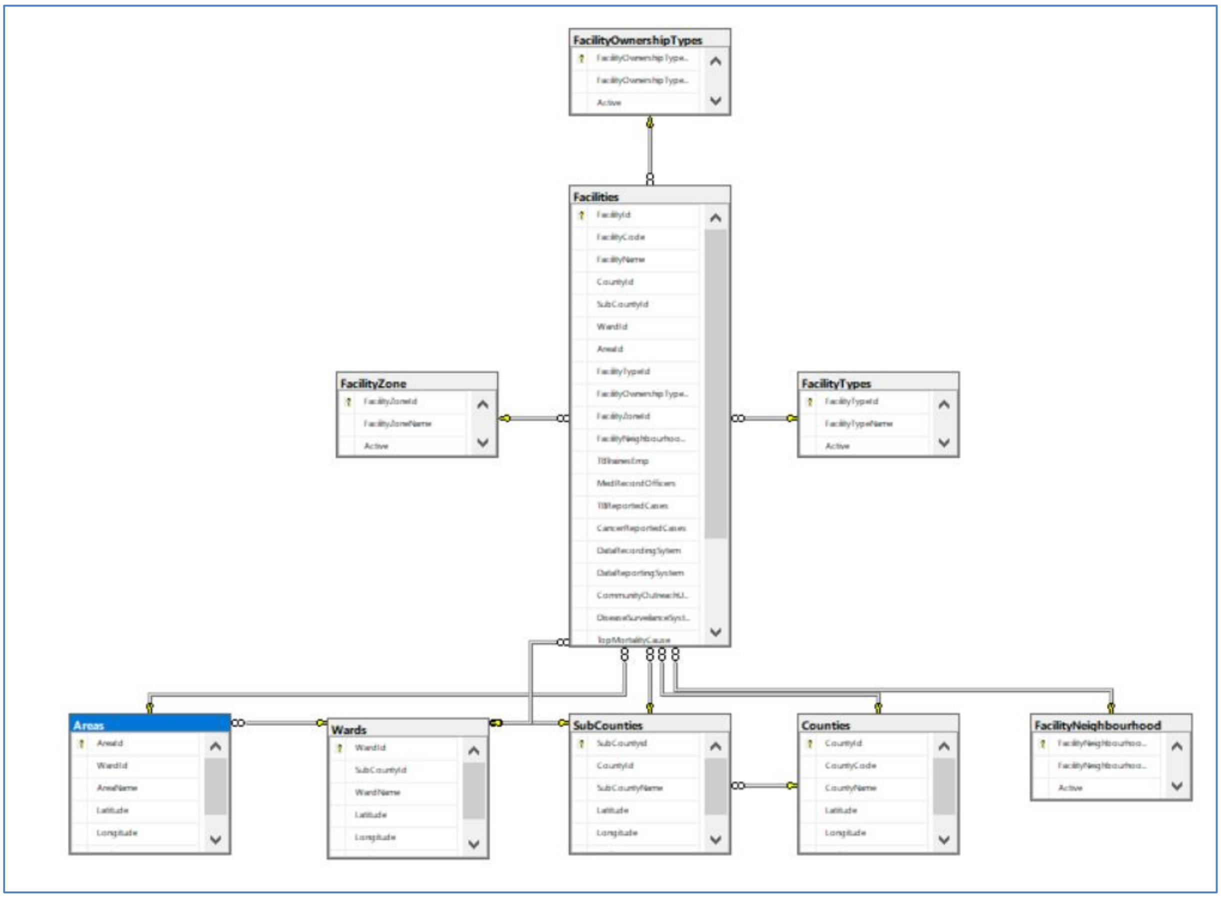
Figure 4.4 Architectural design.



4.7. Entity Relationship (ER) diagram

An entity relationship diagram is composed of different entities. They illustrate how instances relate to different entity types. The figure below illustrates a sample entity relationship diagram for the health information system.

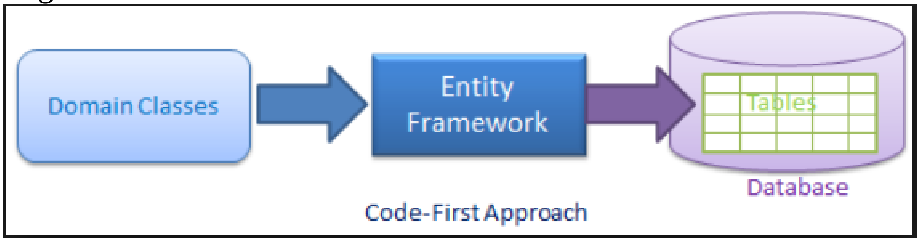
Figure 4.5 Entity relationship diagram



4.8. Database Design

Entity Framework (EF) is an open source object relational mapper. This object relational mapper (ORM) framework, maps data in a relational database into objects of the application. It creates a class which provides a gateway to the database. The research employed one of the workflows of entity framework known as code-first approach. In this approach, domain classes are initially designed after which the entity framework generates the database for the system. This increases productivity by reducing time required to design database tables.

Figure 4.6 Code-first workflow.



This approach allows for full versioning of the database, increased productivity and it is much easier to build an integration test database.

The following screenshots demonstrate sample database tables generated in this model of code first workflow showing the different field names, data types, indexes and foreign keys.

Figure 4.7 Health Facilities table.

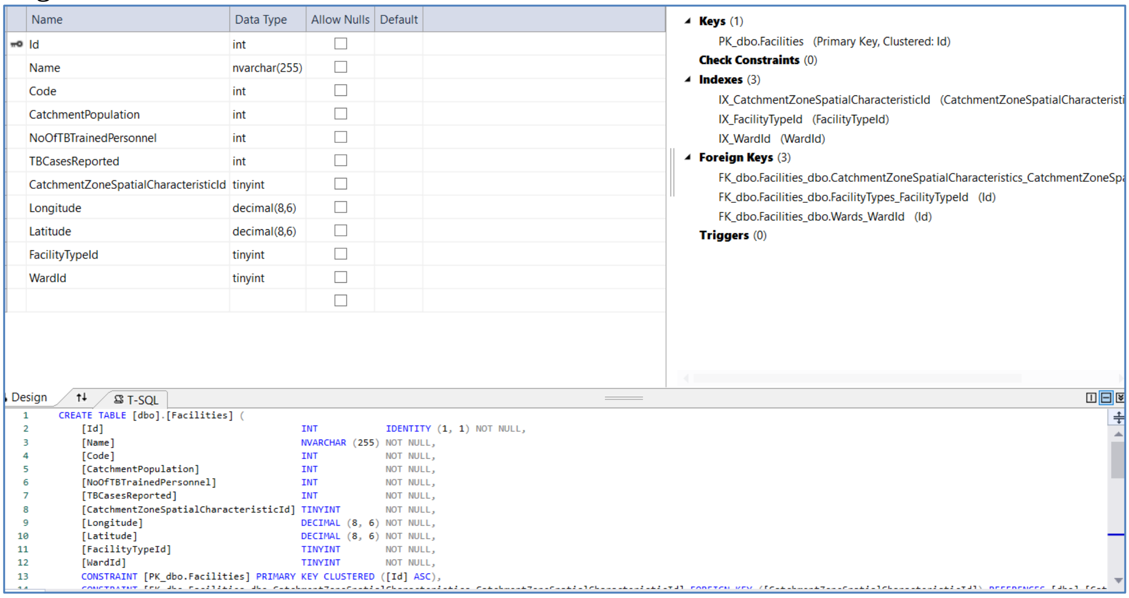
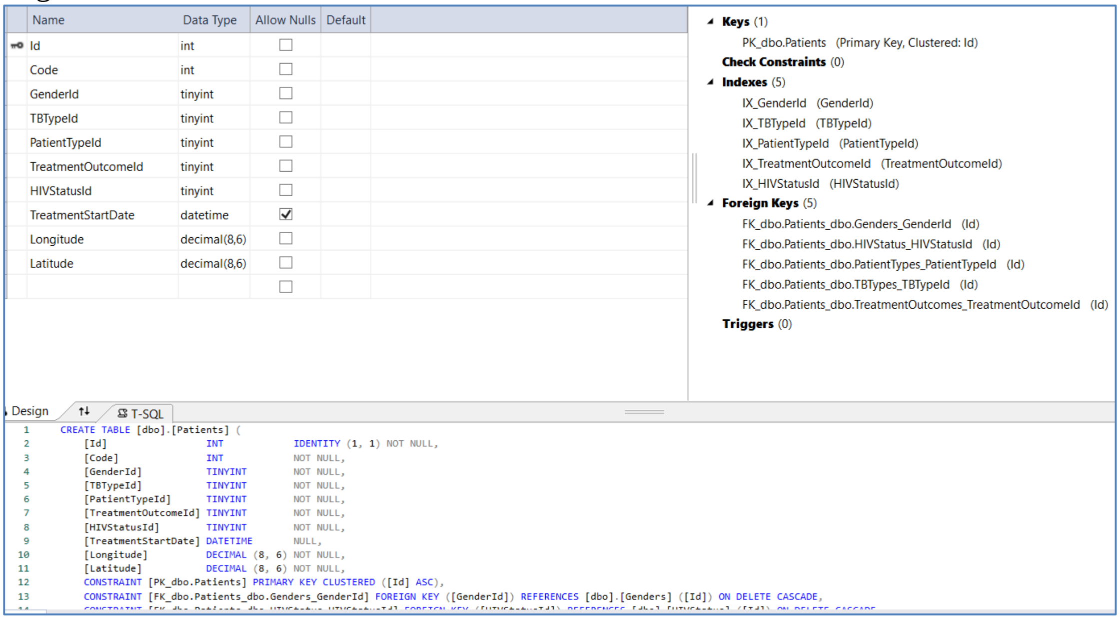


Figure 4.8 Patients table

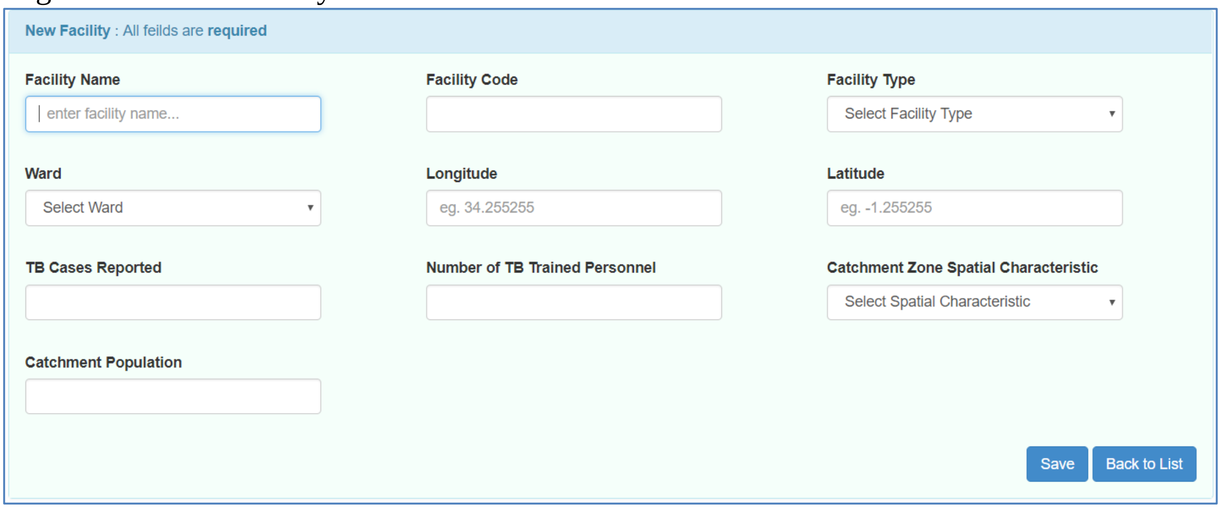


4.9. System Elements

4.9.1. Inputs

Raw data is input to the system for processing. These include details of health facilities including spatial data. Patient data which include spatial and non- spatial characteristics formed part if critical input data to the system. Spatial patient data was deduced from their respective physical locations as entered in the TB registers.

Figure 4.9 Health facility details



4.9.2. Output

The system aids visualization reported TB cases linked to a specific health facilities through maps, charts and graphs. The system facilitated to determine spatial distribution of both patients and health facilities. This will greatly improve tracking and surveillance of all reported TB cases. New incidences become easier to identify and early intervention measures are undertaken

Figure 4.10 Sample health facility report.

Show 10 entries

Search:

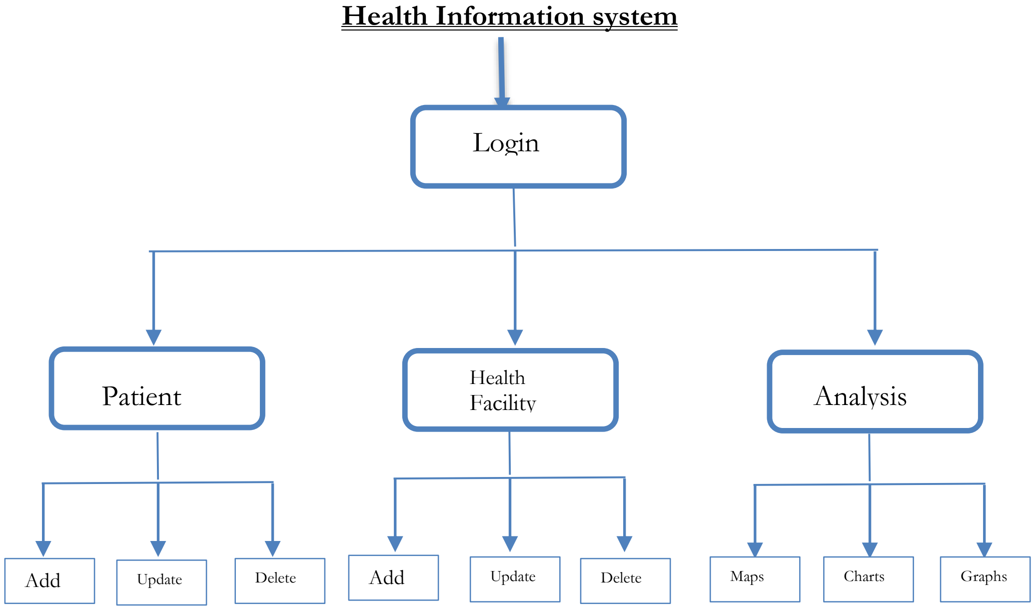
Facility Name	Facility Type	Ward	Catchment Zone	TB Cases Reported	Catchment Population	Longitude	Latitude	Delete
Athi	Dispensary	Murera	Urban	5	900	36.979896	-1.022141	Delete
Gachororo	Dispensary	Witeithie	Peri-Urban	7	1500	37.057662	-1.117025	Delete
Juja Farm Health Centre	Health Center	Murera	Semi-Rural	2	500	37.020881	-1.093726	Delete
Kalimoni	Hospital	Juja	Urban	3	2000	36.950271	-1.115175	Delete
Kenyatta	Hospital	Kalimoni	Urban	50	3000	36.985413	-1.125741	Delete
Kimbo Clinic	Clinic	Witeithie	Rural	4	800	37.022567	-1.053664	Delete
Margaret Njoki Memorial Health Centre	Dispensary	Kalimoni	Rural	5	500	37.00426	-1.094704	Delete
Matangi	Dispensary	Murera	Rural	2	900	36.945754	-1.078125	Delete
MTM	Laboratory	Theta	Peri-Urban	2	500	37.031183	-1.106642	Delete
Spa Nursing Home	Clinic	Kalimoni	Rural	2	300	37.025145	-1.103119	Delete

Showing 1 to 10 of 10 entries

4.9.3. Processes

The integrity and authenticity of data determines the overall reliability of the system. Stringent validation control measures were put in place. The data services improves scalability of the system by ensuring that less server resources are used. They also enhance performance by using less bandwidth. Furthermore, data services support a wide range of clients for getting and modifying data. The web application programming interface returns data not mark-up.

Figure 4.11 Program hierarchy chart.



4.9.4. Integration Testing

At this stage, different modules of the system were combined together and tested as a whole. In this process, the intention was to verify that the individual components integrated can work together and interact well without any conflict. This also was needed to test if the integrated module were able to meet the stated user needs.

4.10. Testing Strategy

System testing is performed to evaluate compliance with the specified system requirements. This tests the various aspects of the system, key among them being design, performance and system behaviour in order to meet the intended end user anticipations.

The following are tests that were carried out;

4.10.1. Validation Testing

Data reliability and accuracy is very critical in any system. The integrity and consistency of data was implemented at both ends of the system. Validation controls were implemented at the server side and client side. These included data annotations applied on the server side to ensure the integrity of data input by the end users. Decorations were added to the domain model properties. Relevant validation messages will be displayed to the user if wrong data was entered.

4.10.2. Unit Testing.

This involves testing individual application system components and subcomponents or modules. The system has three main modules, one is the module for storage of data into the geo-database, the other modules is for processing the data to give visual information and the last is the module for displaying the analyzed information. These modules and their subcomponents were tested and provided the desired results.

4.10.3. Test cases

Table 4.6 Test case 1.

Application Being Tested	Login forms for the system
Type of test	Integration Testing
Reason for testing	To ensure that only authorized users are logged in to the system.
Procedure	i. Run the system. ii. Login with registered credentials
Expected Results	If username and password are correct, the homepage of the system is opened else a message of incorrect password and or username should be displayed immediately.

Table 4.7 Test Case 2.

Application Being Tested	Registering users
Type of test	Unit Testing
Reason for testing	To test whether the system can accept new users
Testing steps	a) Run the application. b) Login as admin. c) Click Register new user d) Enter user credentials. e) Then click the register button
Expected Results	The system adds the new user record to the database.

Table 4.8 Test Case 3.

Application Being Tested	Reports generation.
Type of test	System testing

Reason for testing	To check whether the admin can be able to do analysis in the main dashboard.
Steps of testing	a) Login as admin b) Click on the main dashboard on the main menu c) Select new dashboard d) Specify the tables to be contained in the analysis e) Run the necessary analysis as desired f) Print or save the analysis report.
Expected Results	The system should generate specified analysis reports and display them ready for saving and printing

The following figures illustrates samples of various tests that were carried out and their respective test results

Figure 4.12 Using an invalid email address.

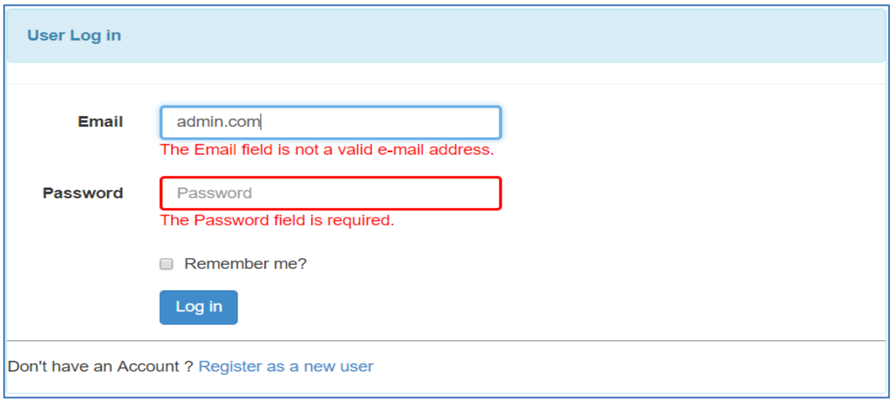


Figure 4.13 Using the wrong password.

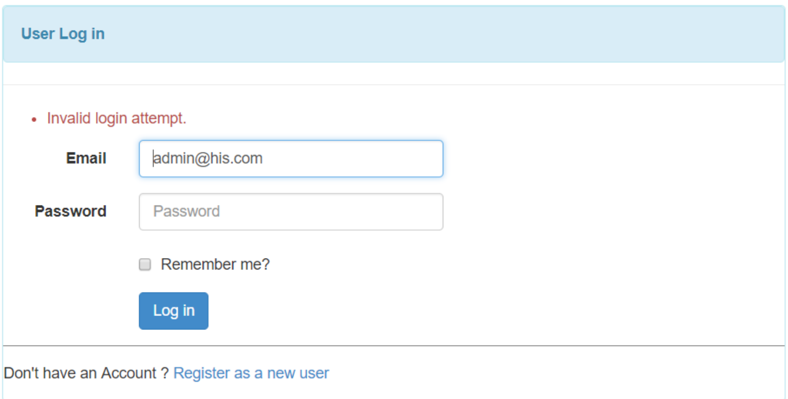
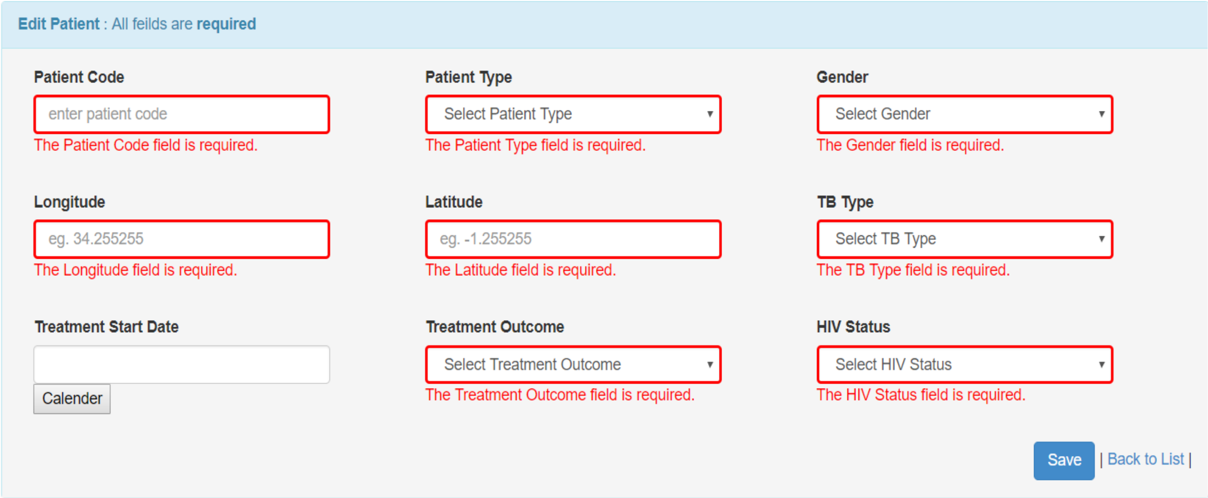


Figure 4.14 Trying to save a blank patient form.



4.11. Development

This project is implemented using the MVC architectural pattern. It has been widely adopted for web applications. The ASP.NET MVC framework will guide both the server side and client side development. MVC stands for Model View Controller. MODEL represents the application data and behaviour in terms of the problem definition of the domain. The model is independent of the user interface. VIEW represents the HTML mark-up displayed to the end user. CONTROLLER is fully responsible for handling all the Hypertext Transfer Protocol (HTTP) requests. This provides an efficient and better way of separation of concerns and a more maintainable application. Moreover, routes are used to select the right controller to handle the issued requests. The actions in the controllers a responsible for handling user requests.

Note: Sample code snippets are available in appendix A

4.12. Sample User interface designs

Figure 4. User login

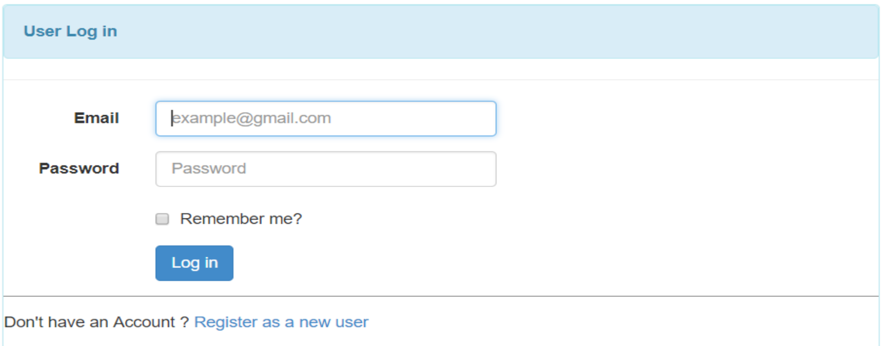


Figure 4.15 The landing page.

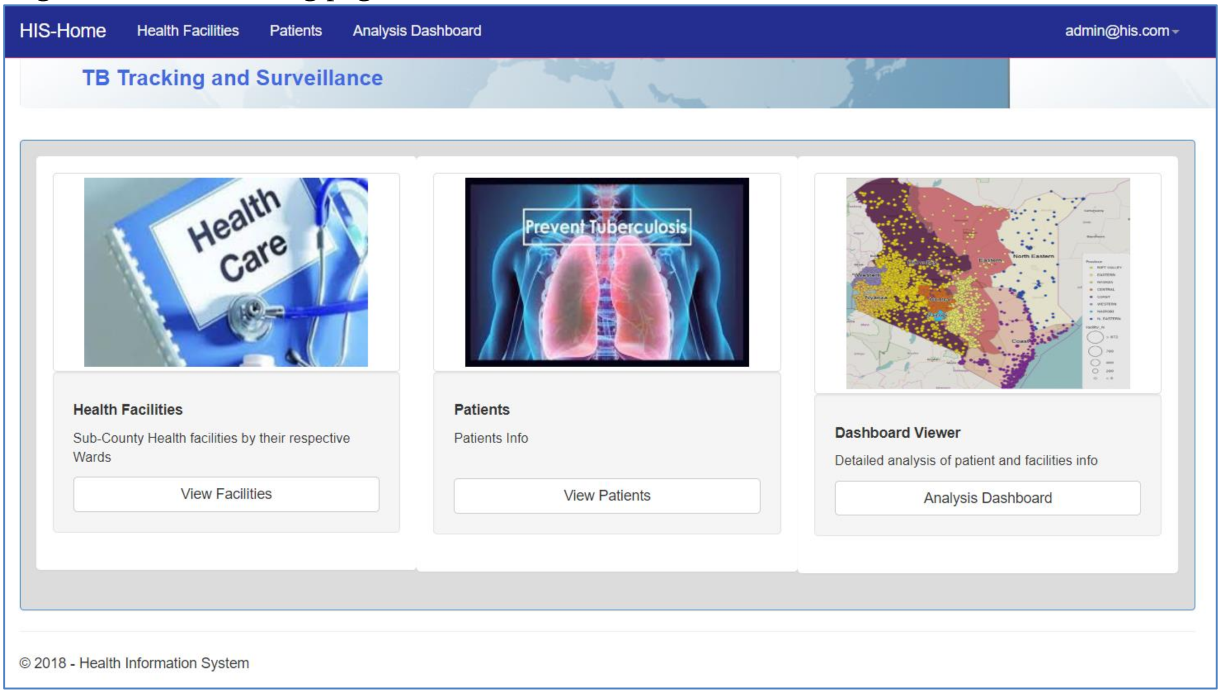
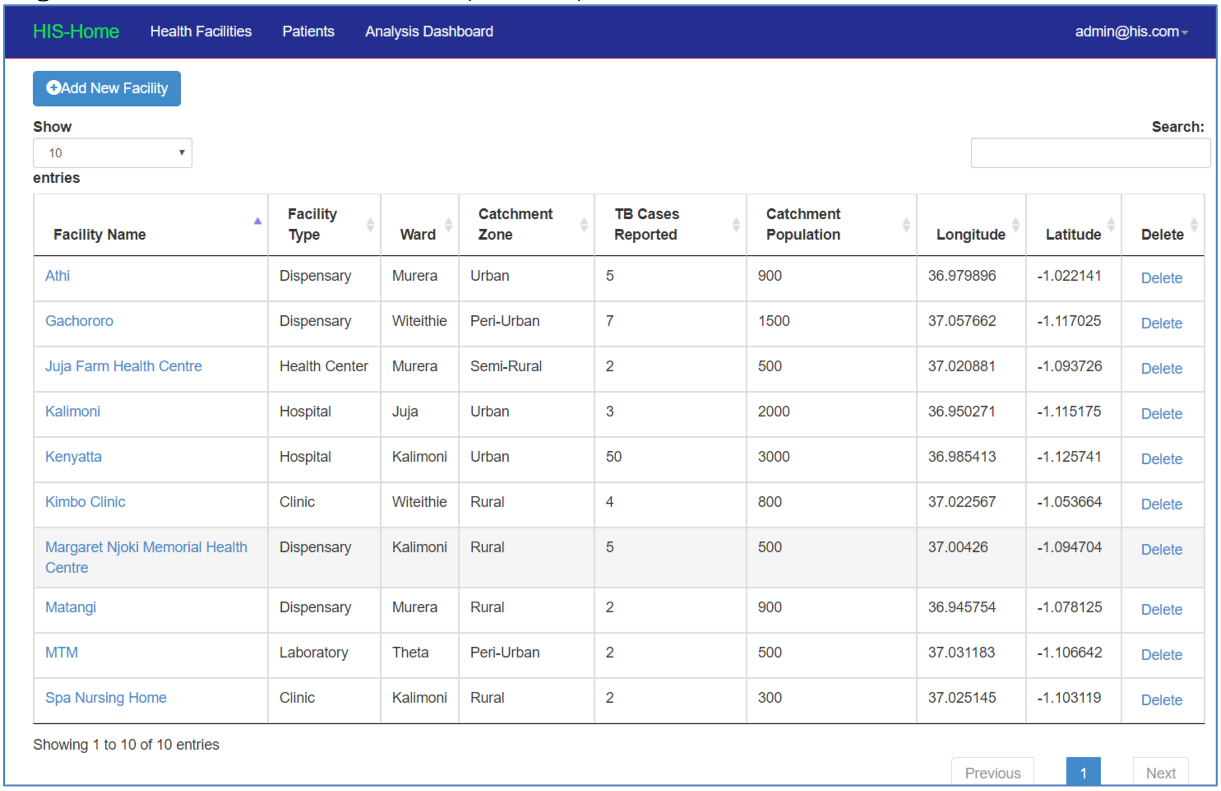


Figure 4.16 List of health facilities (test data).



Facility Name	Facility Type	Ward	Catchment Zone	TB Cases Reported	Catchment Population	Longitude	Latitude	Delete
Athi	Dispensary	Murera	Urban	5	900	36.979896	-1.022141	Delete
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Margaret Njoki Memorial Health Centre	Dispensary	Kalimoni	Rural	5	500	37.00426	-1.094704	Delete
Matangi	Dispensary	Murera	Rural	2	900	36.945754	-1.078125	Delete
MTM	Laboratory	Theta	Peri-Urban	2	500	37.031183	-1.106642	Delete
Spa Nursing Home	Clinic	Kalimoni	Rural	2	300	37.025145	-1.103119	Delete

Figure 4.17 Patient details form.

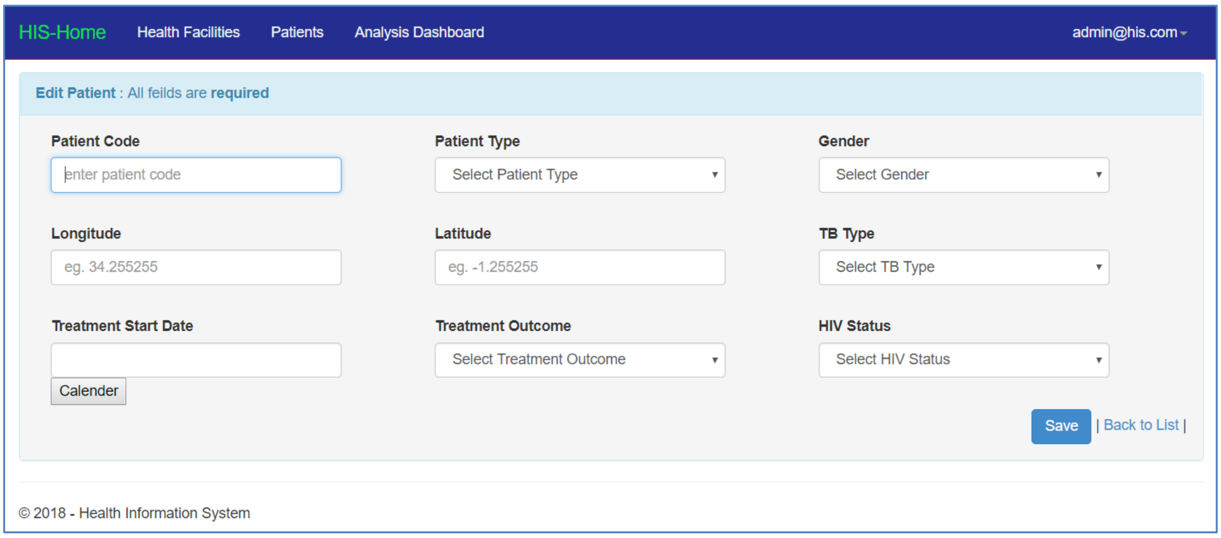


Figure 4.18 The main analysis dashboard.

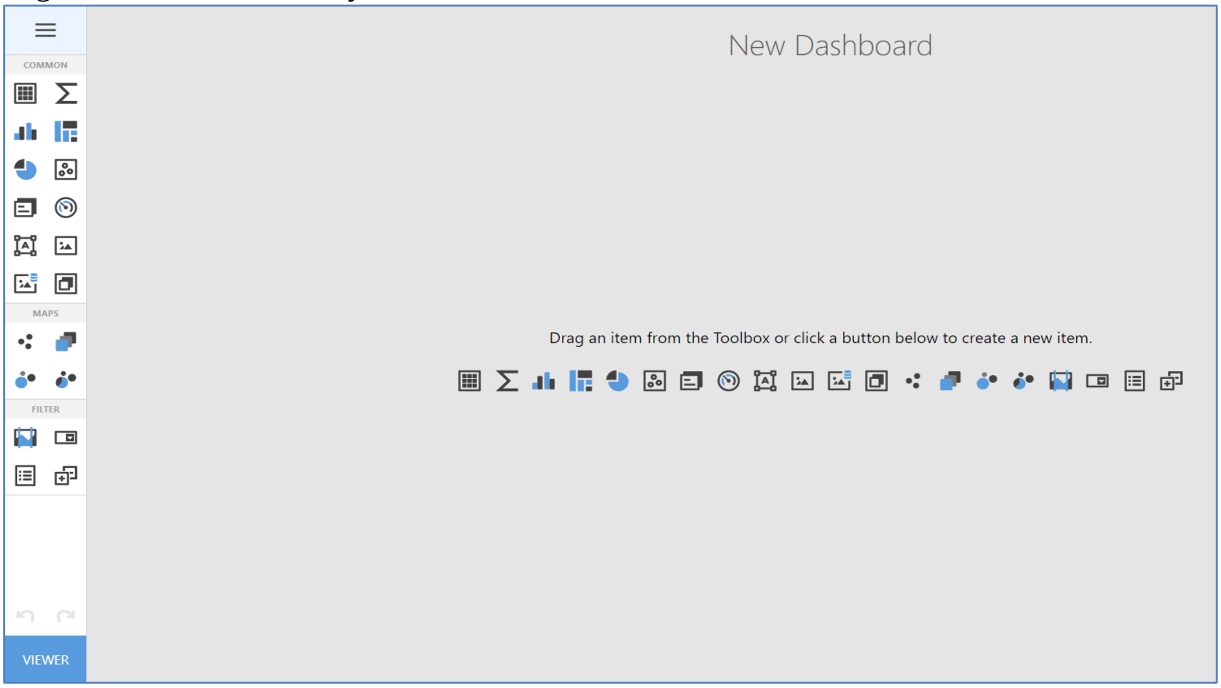


Figure 4.19 Spatial distribution of patients within Juja Sub-County wards (test data).

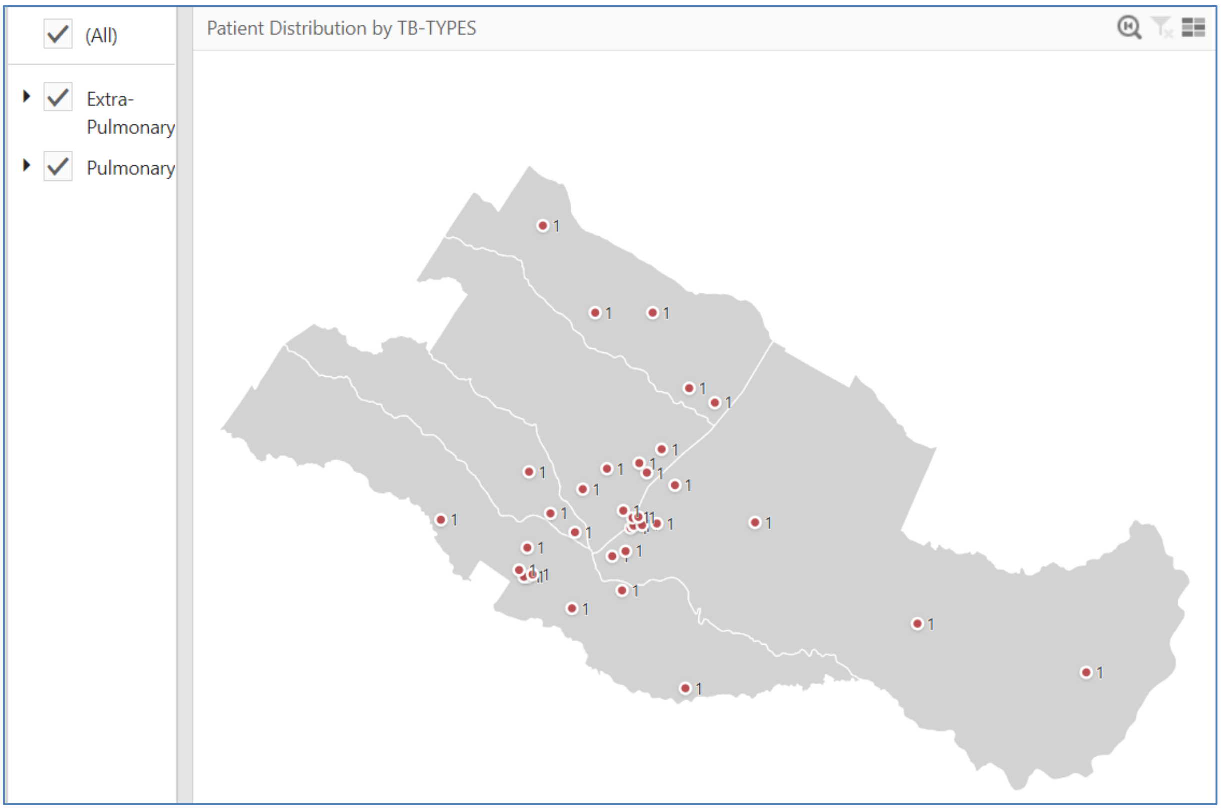


Figure 4.20 Spatial distribution of different health facilities (test data).

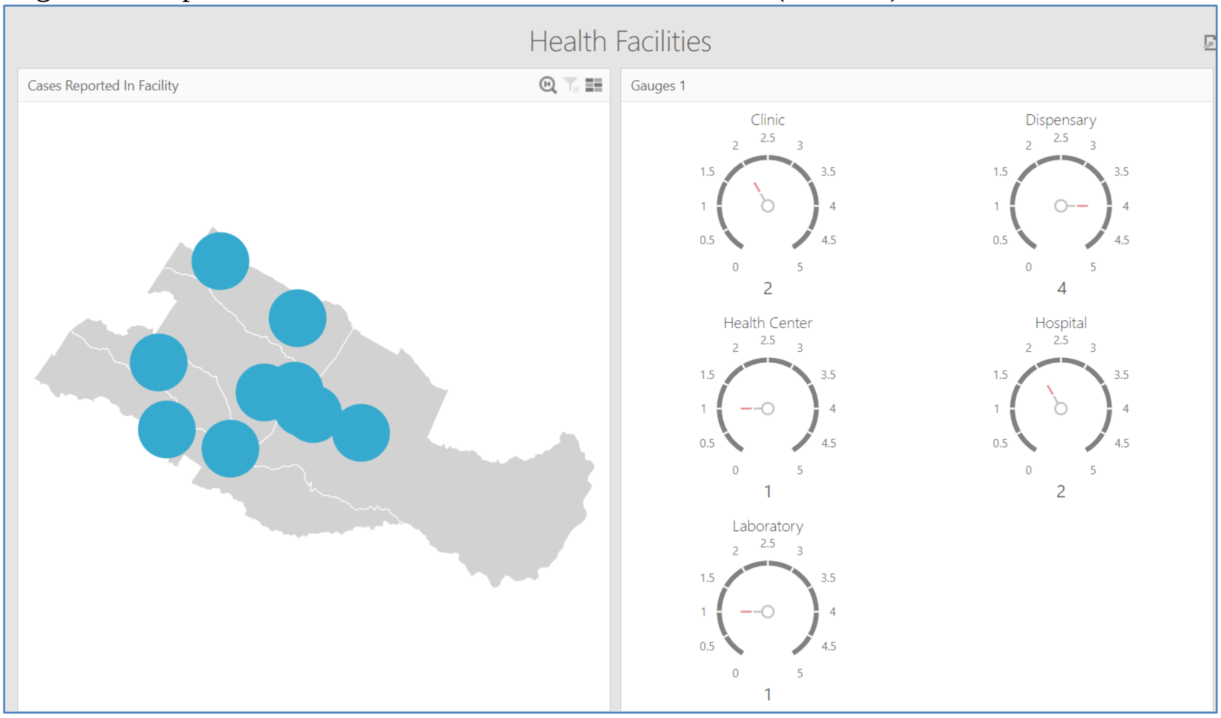
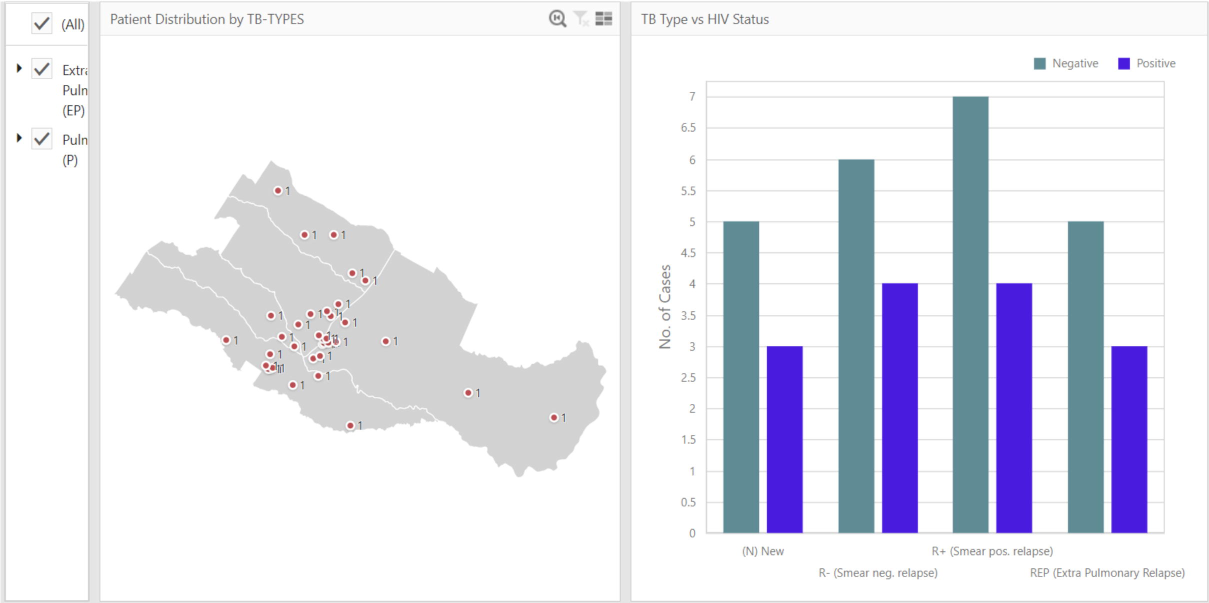


Figure 4.21 Graphical representation of patients' spatial distribution and a graph showing the relationship between TB Types and HIV&AIDS



CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Summary

The first objective was to develop a disease geo-database from the existing TB patient registry records. The research was able to gather non-spatial data and other patients demographic data from TB registers. The data gathered was used to develop the geo-database. The research therefore successfully achieved the objective

The second objective was to find outpatient data gaps in the TB patients records. Despite TB registers capturing location-specific information on the reported cases, the distribution of cases was not spatially defined. Therefore, the spatial distribution of all the patients who are diagnosed and treated at the health facilities is not known. The research identified this gap and was able to attach specific coordinates to the patients and health facilities. The spatial distribution of patients was thereby easily identified.

The third objective was to design a spatially referenced TB database on a Web platform with a reporting system for TB surveillance and tracking. From the outcomes obtained as a result of achieving the above two objectives, a spatially referenced TB database was developed and the intended users were able to interact with all patient data and other related information on a web platform.

The fourth objective was to create thematic maps to facilitate visualization of TB cases and aid in monitoring health facilities. The system was able to generate maps and patients could easily be traced on a map.

5.2. Conclusion

In some areas, health facilities are not easily accessible. This has forced the people to travel for long distances in order to access the required health services. Spatial distribution of health facilities is not equitably distributed, there are areas with a high number of health facilities. Some areas has low number of health facilities.

Densely populated areas are more vulnerable to this infectious disease than others. These areas are the hotspots and regular monitoring and surveillance. High population density is one of the notable factors contributing to the increase in distribution of TB in the study area making these areas more vulnerable. This is according to responses given by key informants through interviews and questionnaires.

Spatial distribution of all health facilities should match the corresponding population density. Further, more resources should be provided to equip major health facilities to minimize the number of referral cases to already congested national hospitals.

Lack of technical know-how: Majority of data clerks and records officers lack the knowledge to analyze and interpret health data. This means no further probing is done once patient data is recorded in the TB books. Training is therefore paramount.

5.3. Constraints

The project has encountered a lot of challenges

High confidentiality of health data: Patient-related data is treated with utmost confidentiality. Accessing patient records and other related health facility information took enormous time trying to obtain authorization letters.

Bureaucracy in some public institutions was highly frustrating the research.

Limited resources: Due to limited resources, the project would not cover all health facilities within Juja sub-county. As a result, only the sampled health facilities were considered.

5.4. Recommendations.

1. Development of an up-to-date geo-database. This is what will enable spatial distribution of hospitals, TB patients be easily visualized and analyzed.
1. Employ GIS tools for spatial mapping of TB and other infectious diseases in all wards across the sub-county and Kenya at large.
2. Introduce compulsory free screening for TB to all patients visiting health facilities. Patients locations should be geo-coded so as to improve on the accuracy of the results. This will aid in the timely detection of possible TB cases within the sub-county.

3. Training of health records information officers and other key stakeholders to have basic but key data analytical skills. This will greatly contribute to the understanding and interpretation of patient data. This would be a great milestone in making an informed decision by health stakeholders, thereby contributing to enhanced TB control efforts.

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APPENDICES

Appendix A: *Sample Code Snippets*

Facilities Controller

```
public class FacilitiesController : Controller
    {
        private ApplicationDbContext _context;

        public FacilitiesController() => _context = new ApplicationDbContext();

        protected override void Dispose(bool disposing) => _context.Dispose();


        // GET: Facilities
        public ActionResult Index()
        {
            var facilities = _context.Facilities
                .Include(f => f.FacilityType)
                .Include(f => f.Ward)
                .Include(f => f.CatchmentZoneSpatialCharacteristic)
                .ToList();

            return View(facilities);
        }

        public ActionResult New()
        {

            var facilityTypes = _context.FacilityTypes.ToList();
            var wards = _context.Wards.ToList();

            var viewModel = new FacilityFormViewModel
            {
                Facility = new Facility(),
                FacilityTypes = facilityTypes,
                Wards = wards,

            };
            return View("FacilityForm", viewModel);

        }
```

Facility Form

```
@using (Html.BeginForm("Save", "Facilities"))
       {
           @*<p class="alert alert-info">All fields are <strong>required</strong></p>*@
           <div class="row">
               <div class="col-md-4">

                   @Html.LabelFor(m => m.Facility.Name)
                   @Html.TextBoxFor(m => m.Facility.Name, new { @class = "form-control", autofocus = "autofocus", placeholder = "  enter facility name..." })
                   @Html.ValidationMessageFor(m => m.Facility.Name)
                   @ViewBag.ErrorMessage

```

```
                </div>
                <div class="col-md-4">
                    @Html.LabelFor(m => m.Facility.Code)
                    @Html.TextBoxFor(m => m.Facility.Code, "{0:#.#}", new { @class = "form-control" })
                    @Html.ValidationMessageFor(m => m.Facility.Code)
                </div>
                <div class="col-md-4">


                    @Html.LabelFor(m => m.Facility.FacilityTypeId)
                    @Html.DropDownListFor(m => m.Facility.FacilityTypeId, new SelectList(Model.FacilityTypes, "Id", "Name"), "Select Facility Type", new { @class = "form-control" })
                    @Html.ValidationMessageFor(m => m.Facility.FacilityTypeId)
                </div>
            </div>
            <p> </p>
            <div class="row">

                <div class="col-md-4">
                    @Html.LabelFor(m => m.Facility.WardId)
                    @Html.DropDownListFor(m => m.Facility.WardId, new SelectList(Model.Wards, "Id", "Name"), "Select Ward", new { @class = "form-control" })
                    @Html.ValidationMessageFor(m => m.Facility.WardId)

                </div>
                <div class="col-md-4">
                    @Html.LabelFor(m => m.Facility.Longitude)
                    @Html.TextBoxFor(m => m.Facility.Longitude, "{0:#.######}", new { @class = "form-control", placeholder = "eg. 34.255255" })
                    @Html.ValidationMessageFor(m => m.Facility.Longitude)

                </div>
                <div class="col-md-4">
                    @Html.LabelFor(m => m.Facility.Latitude)
                    @Html.TextBoxFor(m => m.Facility.Latitude, "{0:#.######}", new { @class = "form-control", placeholder = "eg. -1.255255" })
                    @Html.ValidationMessageFor(m => m.Facility.Latitude)

                </div>
            </div>
```

Patients Model

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;
using System.ComponentModel.DataAnnotations;
using RichardLawley.EF.AttributeConfig;

namespace HIS.Models
{
    public class Patient
    {
        public int Id { get; set; }

        [DisplayFormat(ApplyFormatInEditMode = true, DataFormatString = "{0:#.#}")]
        [Display(Name ="Patient Code")]
        [Required]
        [RegularExpression("^[0-]{1,12}$", ErrorMessage = "* Numeric codes only")]
```

```
        public int Code { get; set; }

        public Gender Gender { get; set; }
        [Display(Name ="Gender")]
        public byte GenderId { get; set; }

        public TBType TBType { get; set; }
        [Display(Name ="TB Type")]
        public byte TBTypeId { get; set; }

        public PatientType PatientType { get; set; }
        [Display(Name ="Patient Type")]
        public byte PatientTypeId { get; set; }

        public TreatmentOutcome TreatmentOutcome { get; set; }
        [Display(Name ="Treatment Outcome")]
        public byte TreatmentOutcomeId { get; set; }

        public HIVStatus HIVStatus { get; set; }
        [Display(Name ="HIV Status")]
        public byte HIVStatusId { get; set; }

        [Display(Name ="Treatment Start Date")]
        [DataType(DataType.Date)]
       // [DisplayFormat(ApplyFormatInEditMode = true, DataFormatString = "{0:dd-MM-yyyy}")]  public DateTime? TreatmentStartDate { get; set; }

        [DisplayFormat(ApplyFormatInEditMode = true, DataFormatString = "{0:#.#}")]

        [Required]
        [RegularExpression(@"^-?[0-9]\d*(\.\d+)?$", ErrorMessage = "invalid")]
        [DecimalPrecision(8,6)]
        public decimal Longitude { get; set; }

        [DisplayFormat(ApplyFormatInEditMode = true, DataFormatString = "{0:#.#}")]
        [Required]
        //[RegularExpression(@"^-?[0-9]\d+(\.\d+)?$", ErrorMessage = "invalid")]
        [DecimalPrecision(8, 6)]
        public decimal Latitude { get; set; }
```

Appendix B: *Health Facility Asessment Questionnaire*

PART 1: Facility Statistics

1	Facility code				
2	Facility Type				
3	No of CHW attached to facility				
4	Community units attached to facility				
5	Is this facility a	**Diagnostic& treatment center**		**Treatment center only**	Other
7	Sub location name				
9	Location name				

2. List all essential **diagnostic/treatment equipments** this facility has for TB;

no	diagnostic/treatment equipment
1	
2	
3	
4	
5	

3. Is there personnel **trained to handle TB** in this facility [yes]___ [No]___
4. If **yes** in question 3 above how many are they: [Male]___

   [Female]____
5. From question 4 above, fill the details of these personnel in the table below;

no	Personnel name	Personnel position in facility	Level/ type of training (Cert, diploma, workshop e.t.c)
1.			
2.			
3.			
4.			
5.			

6. Does the facility have **health records data officer**? [yes]___ [No]___
7. If **yes** in question 6 above how many are they: [Male]___

   [Female]____
8. From question 7 above, list the qualifications and type of training for each in the table below

no	Health records officer name	qualification	Type/Level of training (Cert, diploma, workshop e.t.c)
1.			
2.			
3.			
4.			
5.			

9. What kind of health recording system is used this facility
   1. [Manual]__ 2. [Digital]___ 3. [both]____

10. If the answer is **digital** in question 9 above, list all the data recording equipment and any special software used in the table below;

no	Equipment (s) names	Programme used e.g. (Msword, Excel, SPSS) e.t.c	name any special Software (s) used
1.			
2.			
3.			
4.			

5.			

11. Does the facility have the standard tools for data recording for TB; [yes]___ [No]___
12. If yes in question 11 above, list the tools used in the following;

no	Activity	Name of tool/ method used
1	data recording	
2	data interpretation & analysis	
3	data storage	
4	data reporting & communication	
5	Data retrieval	

13. What challenges does this facility face in medical data recording and storage?

a. ____

b. ____

c. ____

d. ____

e. ____

14. Is there any form of data analysis done on already collected data for TB?

[yes]___ [No]___

15. If YES in question 14 above, list the type or kind of analysis that is carried out on these data,

a. ____

b. ____

c. ____

d. ____

e. ____

16. What is the catchment area and population of this facility

Catchment population	**Catchment area (Km^2)**	**Catchment pop density (derived)**

17. Fill In the table below for TB cases reported at this facility (use TB Collection sheet)

Year	**No of TB cases**		
	diagnosed	Fully treated	Mortality
Year 2015			
Year 2016			
Year 2017			
Totals			

Appendix C: *TB Data Collection Sheet*

TB Data Collection Sheet no: (_____of _____)

Health Facility Name: ____________________________________

Facility treatment types for TB A.__________________ (diagnostic & treatment) B._______________________ (treatment only)

No	Patient code	Sex	Age yrs	Patient Physical address		Patient classification	Mode of diagnosis	Date treatment started		Week of treatment	Date cured or recurrent	TB Classification *(fill as appropriate)*		HIV Status	MDR TB *(Yes/no)*
				village	Sub-location(ward)			Month	Year	_of 8 months		Pulmonary	Extrapulmonary		
1															
2															
3															
4															
5															
6															
7															
8															
9															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															

Any additional Notes: ____