DATA AND TECHNICAL LIMITATIONS IN GIS IMPLEMENTATION IN HEALTH MANAGEMENT: CASE OF MALAWI

MASTER OF SCIENCE IN INFORMATICS THESIS

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CHANCELLOR COLLEGE

JANUARY, 2018

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MASTER OF SCIENCE in INFORMATICS THESIS

By

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Thesis submitted to the Faculty of Science, in partial fulfillment of the requirements for the degree of Master of Science in Informatics

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January, 2018

DECLARATION

I, the undersigned hereby declare that the text of this thesis titled: **DATA AND TECHNICAL LIMITATIONS IN GIS IMPLEMENTATION IN HEALTH MANAGEMENT: CASE OF MALAWI** is my own original work which has not been submitted to any other institution for similar purposes. Where other people's work has been used acknowledgements have been made.

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Date

CERTIFICATE OF APPROVAL

We, the undersigned certify that this thesis represents the student's own work and effort and has been submitted with our approval. We recommend to the Postgraduate Studies and Research Committee and the Senate for acceptance of this thesis titled **DATA AND TECHNICAL LIMITATIONS IN GIS IMPLEMENTATION IN HEALTH MANAGEMENT: CASE OF MALAWI** submitted by GLORIA CHISAKASA in partial fulfillment of the requirements for the degree of Master of Science in Informatics.

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DEDICATION

This thesis is dedicated to my daughter, Josephine.

ACKNOWLEDGEMENTS

I would like to express great appreciation to University of Oslo and The Norwegian Centre for International Cooperation in Education through NORPART-2016/10134 Extending Health Informatics Capacity (ETHIC) project for the financial support rendered towards this thesis work.

I also acknowledge tireless efforts of Prof. Jens Kaasbøll and my supervisors, Dr. Kondwani Godwin Munthali and Mr. Patrick Chikumba. Their guidance, advice and support throughout the period of this thesis have been so helpful. I also thank the following institutions for authorisation and information given during the study; National Health Sciences Research Committee, Central Monitoring and Evaluation Department (CMED), Mchinji and Blantyre District Health Offices, DHIS2 Team and UNICEF.

Special thanks go to my daughter Josephine, my mum Christina, my siblings John, Felix, Juvie, Patrick, Priscilla and Jacqueline. This thesis robbed off the time they were to spend with me. I thank them for their prayers and understanding.

I also thank my friends and colleagues who encouraged and supported me during my study; in particular, Rev. Fr. Dr. Alfred Nsope, Dickson Chinguo, Elie Mapulanga, Timothy Chadza, Haleema Jika, Chrissie Chatsika and Noel Chavula.

ABSTRACT

Good decision making in health sector is very important. As part of strengthening their national health management information systems (HMIS), governments are applying Geographic Information Systems (GIS) to enhance decision making in health management. In Malawi, Ministry of Health and its partners are facilitating the use of GIS. Successful use of GIS is influenced by how it is implemented. This thesis explores data and technical limitations which should be addressed for the implementation of GIS in order to enhance data analysis, interpretation and visualisation in health management. The study was conducted using the case of implementation of District Health Management Information System GIS (DHIS2 GIS) in Malawi. Participant observations, documents and spatial data analysis, and interviews were used to collect data. Properties of boundary objects (modularity, accommodation, abstraction and standardization) and community of practice (CoP) were used to analyse the data and technical limitations. The study found that spatial data collected were not complete for the implementation of DHIS2 GIS; some health facilities and health districts, patient tracking, and population density data were missing. On technical limitations, the study found that: i) it is difficult to visualize data with similar patterns, ii) health facilities or catchment areas with 'no value' are not presented on the map, iii) creation of maps is affected by internet speed, and iv) the maps created in DHIS2 GIS cannot display health facilities and features such as roads and rivers when downloaded hence sharing maps offline is difficult. To mitigate some of these limitations, it is recommended that data sharing should be promoted amongst different institutions and HMIS officers should be equipped to be able to collect spatial data for new health facilities. DHIS2 GIS should be upgraded by migrating from DHIS2.21 to newer versions and implementing required functionalities e.g. charts and graphs on maps, DHIS2 Tracker and download tool.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANC	Antenatal Clinic
BO	Boundary Object
CD	Compact Disk
CHAM	Christian Association of Malawi
CMED	Central Monitoring and Evaluation Division
CoP	Community of Practice
DHIS	District Health Information System
DHO	District Health Office
GIS	Geographic Information Systems
GML	Geographical Markup Language
GPS	Global Positioning System
HSA	Health Surveillance Assistant
HMIS	Health Management Information System
IPT	Intermittent Preventive Treatment
ITN	Insecticide Treated Net
JICA	Japan International Cooperation Agency
KM	Knowledge Management
MoH	Ministry of Health
NHSRC	National Health Sciences Research Committee
NRU	Nutrition Rehabilitation Unit
NSO	National Statistical Office
OTP	Out-Patient Therapeutic Feeding Program
RUTF	Ready to Use Therapeutic Food
SFP	Supplementary Feeding Programme

QECH	Queen Elizabeth Central Hospital
UNICEF	United Nations Children's Fund
WHO	World Health Organisation

CHAPTER 1

INTRODUCTION

This thesis is about the implementation of Geographic Information Systems (GIS) in health management. The study was conducted in Malawi targeting the project of implementing District Health Information System - Geographic Information System 2 GIS (DHIS2 GIS) and it focused on data and technical limitations encountered during the implementation. This chapter introduces the topic of this study and provides a general overview of what is presented in the thesis. It contains the background, study context, Malawi health status and health programs used in the study, problem definition, research objectives, research question, and research justification.

1.1 Background

Good decision making in the health sector is very important. This can be achieved if reliable information is available and accessible by the decision makers. The absence of information can result in delay or failure to make right decisions. According to Tanser & LeSueur (2002), public health practice needs timely information on the cause of diseases and other events to implement appropriate actions. Health information is needed for either primary or secondary use. Primary use is when a medical practitioner (e.g. a doctor) is getting information to treat a patient while secondary use is when the information is collected for public health program planning, controlling, monitoring and evaluation. This research focuses on the secondary information.

In order to strengthen health information management in Malawi, several systems have been introduced. According to Chaulagai et al (2005), until 1999 the systems used were too many and uncoordinated. Due to several challenges which the MoH faced with those systems, it introduced Health Management Information System (HMIS). Considering that the health sector in Malawi has a lot of existing health programs, the MoH decided adopt District Health Information System (DHIS1) which would integrate data from various systems. Integrated system becomes more valuable and useful than fragmented and isolated systems. DHIS1 was a stand-alone and was installed in all districts and central hospitals across the country. In most cases, the DHIS1 database could only be accessed by HMIS officers because they were the only ones who were trained and it was their responsibility to share the data. Health programs had challenges to access data from DHIS1 in good time since data accessibility was dependent on HMIS officers' schedules. This led to the continuity of using parallel health program systems. To strengthen the integration of health programs and accessibility of data from all levels, the MoH migrated from DHIS1 to DHIS2.

DHIS2 is web-based, generic software which was first developed and adopted in the health sector in South Africa and later adopted in other developing countries (Nyella, 2007). Malawi adopted DHIS2 in 2012 and at the time of the study, Malawi was using DHIS2 version 21 (DHIS2.21). DHIS2 is open source software and each country customizes it according to its needs. DHIS2 is used for collection, validation, analysis, and presentation of aggregate or statistical health data and is meant to assist health management in making right decisions based on the information collected. The features of DHIS2 application are organized in modules which include DHIS2

Routine, used for the management of routine data; DHIS2 Tracking, used to manage community data; DHIS2 mHealth, for management of health data using mobile devices; and DHIS2 GIS, for spatial analysis and data display using maps.

In Malawi, health system has five management levels; national, zone, district, facility and community and currently, DHIS2 is used at national and district levels. At the community level community health workers, referred to as Health Surveillance Assistants (HSAs), collect data using paper forms and send them to their respective health facilities. At the facility level, focal persons compile the data also on paper forms and send to their respective District Health Offices (DHOs). At the district level, program coordinators with support of HMIS officers verify and capture the data into DHIS2. Then reports are extracted from the system and can be used by various stakeholders including health program managers and coordinators.

Since the introduction of DHIS2 in Malawi, reports have been presented in form of tables and charts. However, it has been observed that maps have been used in some cases in the MoH to assist in visualization which is difficult to achieve in tables and charts. According to Leland (2008), maps are best way of presenting some information because they can reveal significant data relationships that are difficult to comprehend otherwise. By layering information on top of a map in GIS, users can visually represent data in a way that can be easily understood by other users. Fisher & Myers (2011) also observed that presenting data in maps can provide more insight than a table of the same data, enabling quick assessment of trends and interrelationships.

In 2004, MoH with support from JICA and Surveys Department generated static maps for health facilities under Christian Association of Malawi (CHAM) and government in the country based on type and ownership. The maps were to assist the ministry know locations and strategic places where to put new health facilities. The maps were created and distributed on Compact Disks (CDs). In 2011, another set of static maps was generated as an update of the 2004 maps, which was also distributed on CDs. The MoH faced some challenges to update the maps on CDs because it required a lot of resources (such as finances, human, time, technology) to update and distribute the maps. Keeping the CDs was also a problem. By the time of this study, the researcher could not find even one of those CDs.

Therefore, MoH decided to introduce interactive GIS application which could easily be updated and shared by multiple programs. Since MoH is promoting usage of DHIS2, it decided to use DHIS2 GIS. It started collecting spatial data for public, CHAM and private health facilities from central hospitals down to health posts in 2013 with support from ICF International. In 2015 and 2016, UNICEF also collected spatial data for health facilities down to community level (village and outreach clinics) to be used in GIS applications. MoH through its section of Central Monitoring and Evaluation Division (CMED) is the implementer of DHIS2 GIS and it is assisted by its development partners such as UNICEF, HISP Malawi, JHPIEGO/SSDI, Baobab Health and University of Oslo.

Successful usage of GIS is influenced by how the GIS is implemented (Sieber, 2000). Literature shows that there are a number of limitations faced during GIS implementation and use for example, high cost of hardware and software, lack of qualified staff to implement and use GIS, acquisition of required data and lack of support from decision makers. The limitations can be categorized into organizational, data and technical (Sieber, 2000; Ibrahim & Kuta, 2015). This study focuses on data and technical issues.

In GIS, there are two categories of data: spatial data and non-spatial. Spatial data refers to data or information which identifies the geographical location of features and boundaries on earth whereas non spatial data is the data which cannot be related to a geographical location (Paudel et al., 2009). In this study, examples of spatial data used are administrative boundaries representing catchment areas and health facilities, while non-spatial data includes health indicators and data elements. Generally, GIS requires high quality data in forms of completeness, consistency, accuracy and timeliness. As regards to the objectives of this study, the researcher focuses on the completeness of spatial data. Issues concerning completeness of non-spatial data are not part of this study since DHIS2 has capability of checking such data during capturing.

Apart from looking at spatial data completeness, the study also explored issues around data visualization. Literature has discussed the power of GIS in areas of integration, analysis and visualization which can be related to the presentation of data. Therefore, in this study, the following four concepts to explore the limitations of data and technology are chosen: spatial data completeness, data visualization, GIS functionality, and GIS accessibility.

1.2 Study Context

The research was conducted in health sector in Malawi. Malawi is a landlocked country in southeast Africa and it borders with Tanzania to the northeast, Zambia to the northwest, and Mozambique to the east, south and west (see *Figure 1*). Administratively, Malawi is divided into three regions; North, South and Centre. The regions are further divided into 28 districts. The capital city of Malawi is Lilongwe. However, in health system the country is divided into 5 health zones which are further divided into 29 health districts. In this thesis, health districts have been used. Majority of activities in this research were done at the national level covering all districts but two districts were chosen to appreciate what happens at the district level. CMED and UNICEF which are based in Lilongwe health district (at national level) and Blantyre and Mchinji District Health Offices (DHOs) located in Blantyre and Mchinji health districts respectively (at district level) were chosen as study sites (see *Figure 1*).

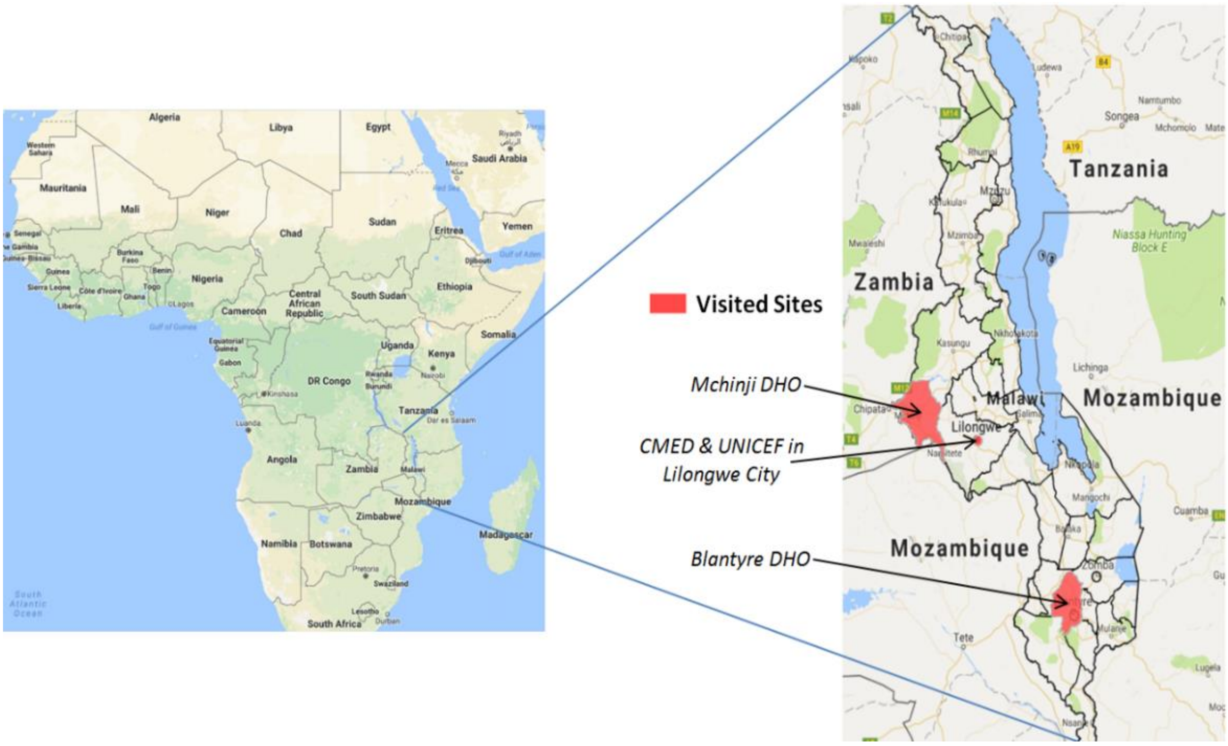

Figure 1: Map of Malawi and visited sites

CMED is a section in Department of Planning and Policy Development in the Ministry of Health (MoH) which is responsible for managing data, implementing systems and providing technical support at all levels and for all health programs. At district level, CMED has HMIS officers who manage data and provide technical support to DHIS2 users. At national level, it has health statisticians, health economists and M&E officers who are responsible for planning, monitoring and evaluation. It also coordinates activities of DHIS2 Team whose responsibility is to provide technical support to DHIS2 users at national and district levels.

UNICEF is MoH's development partner which advocates for the rights of children. As one of its roles, it promotes child health in communities. UNICEF recognised the lack of updated information on the location of health facilities, especially the village and outreach clinics (Jacobs, 2016). To overcome this, UNICEF collected coordinates of all health facilities which offer free health services to be used in GIS applications including DHIS2 GIS. It was a recommendation from UNICEF to use Mchinji health district as a study site. By the time data collection for this study started, UNICEF was in the process of collecting data for village and outreach clinics to be used for the implementation of DHIS2 GIS. Only data for Mchinji health district in central west zone was available. For comparison sake, Blantyre health district was chosen. It was convenient to collect data from Blantyre because it is where the researcher is based.

Malawi has the highest rates of stunting among under-five children in Africa with an estimation of 76,000 child deaths before the age of five (under-five mortality rate of 118/1000) (Ministry of Health, 2009). Malnutrition, Malaria and Anaemia are among the leading and underlying causes of the high mortality rate. The fertility rate is estimated at 5.7 (NSO & ICF Macro, 2011), which is mainly attributed to early marriages, early first pregnancies, relatively closely spaced births, and low contraceptive prevalence rates (Chaulagai et al., 2005). According to Chaulagai et al. (2005), statistics indicate that 70% of mortality among in patients is due to communicable and other preventable diseases. Currently, MoH is promoting preventive health care. It is with this background that the study chose to work with Malaria and Nutrition programs.

1.3 Health Programs

In Malawi, there are several health programs which use DHIS2 including Reproductive health, Family planning, Integrated disease surveillance and response, HIV/AIDs, Tuberculosis, Malaria, Nutrition, Non Communicable diseases, Palliative Care, and Environmental health. However, the study worked with Malaria and Nutrition health programs as mentioned in previous section.

1.3.1 Malaria Health Program

MoH through malaria program distributes free Insecticide Treated Nets (ITNs) to less privileged households throughout the country with priority to under-five children and pregnant women. Pregnant women receive ITNs when they visit health facilities for antenatal clinic and children receive ITNs at their first visit to a vaccination clinic. ITNs repel and kill anopheles mosquitoes. The MoH also distributes antimalarial drugs to high risk groups through a strategy called Intermittent Preventive Treatment (IPT). Through IPT, antimalarial treatment is given regularly, regardless of whether a person has malarial infection or not. IPT is mainly given during pregnancy, but can also be given to infants and children. When there is high prevalence of mosquitos, malaria health program also spreads mosquito repellent insecticides in mosquito breeding places of the targeted area. The insecticides can also be spread on surfaces; thus walls and ceilings of some residences when the program has enough funding. Although using mosquito repellent insecticides spreads is expensive than ITNs and IPT, its effectiveness is good because it covers a larger community. Despite the interventions discussed some people still fall sick and visit health facilities for treatment. Almost all health facilities provide malaria related health care.

1.3.2 Nutrition Health Program

Nutrition health program targets children aged 6 months to 12 years, pregnant women and lactating women up to 6 months after delivery. Children and women are screened during routine clinic visits (antenatal, postnatal and under-five). Moderate acute malnourished patients with no complications and good appetite are referred to Supplementary Feeding Programme (SFP). Under SFP, patients are supplied with Corn Soya Blend every two weeks. Severe acute malnourished patients with appetite are referred to Out-Patient Therapeutic Feeding Program (OTP). SFP services are offered at community level.

Under OTP, patients are given the Ready to Use Therapeutic Food (RUTF) which is locally known as *chiponde*. Moderate malnourished patients who are HIV positive are also referred to OTP. Severe acute malnourished patients who refuse to eat RUTF or have difficulty taking the RUTF (patients with complications) are further referred to Nutrition Rehabilitation Unit (NRU). OTP services are offered by almost all facilities at facility level. NRU is intensive care unit and patients are treated as in-patients. NRU are offered in specialised health facilities. For example, in Blantyre health district, only 4 out of 35 reporting health facilities provide NRU services and by the time of data collection only 2 were operational. Patients discharged from NRU are referred to OTP and from OTP to SFP. From SFP, patients are linked to community outreach. In communities, there are care groups of 10 members who look after the patients. The care groups report to HSAs if there is any case to refer to SFP or discharge.

1.4 Problem Statement

Since the introduction of DHIS in Malawi, reports have been presented in form of text, tables and charts. As explained in the background, MoH has recognized the need of using maps to enhance analysis, integration and visualisation of data which is difficult in some cases when text, table and charts are used. For example, some health indicators have spatial dimension such as population distribution which cannot easily be visualized in tables and graphs but maps. To accomplish this, the MoH has initiated the implementation of DHIS2 GIS which enables spatial analysis, integration and visualisation of data through maps. However, literature has demonstrated that there are data and technical limitations that affect implementation and usage of GIS that can differ from one application domain or context to the other. The limitations include inadequate data, high cost of data collection and failure of some functionalities to meet user needs (Somers, 2009; Bernhardsen, 1999; Graeff & Loui, 2008; Taleai et al., 2009).

Although a number of studies have been conducted in Malawi (Nyirenda et al., 2005; Chikumba, 2010; Msiska,2009; Awali & Chikumba, 2014; Maliwichi & Chikumba, 2014; Munthali, 2014), in common, the studies targeted the use of GIS and not exactly the implementation process. In addition, these studies focused on application of GIS for specific programs. This study has focused on implementation of DHIS2 GIS which supports multiple health programs. In this context, a single system (i.e. DHIS2 GIS) is expected to accommodate requirements from multiple health programs with understanding that each health program has its own unique requirements.

1.5 Research Objectives and Question

The main objective of this research was to explore the data and technical limitations for the implementation of GIS in health management to enhance data analysis, integration and visualisation using the case of DHIS2 GIS in Malawi.

In order to achieve the main objective, the following specific objectives were identified;

a. Analyse user requirements for the implementation of GIS in health management
b. Assess spatial data completeness
c. Assess DHIS2 GIS functionalities against the user requirements
d. Propose strategies for implementing DHIS2 GIS to mitigate data and technical limitations

This research aimed to answer the following question:

What data and technical limitations need to be addressed for the successful implementation of GIS in health management?

1.6 Justification of the Study

Ministry of Health in Malawi initiated the implementation of DHIS2 GIS to improve analysis, integration and visualisation of data, but literature shows that there are several limitations which are encountered during GIS implementation and use. Being the first time to implement DHIS2 GIS, it was important to explore limitations which would affect the implementation and how they would be resolved to ensure that the DHIS2 GIS meets the users' requirements. Limitations explored and addressed in this study assisted in successful implementation of DHIS2 GIS as the health program managers, coordinators and other stakeholders have been assisted to analyse, integrate and visualise data which was not possible previously. Hence, decision making in health sector has been promoted. The research has also added the literature on GIS implementation in health management.

CHAPTER 2

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

This chapter covers the literature reviewed in relation to the topic under study. The Chapter also discusses the theoretical frame work used to guide the study.

2.1 GIS Definition

Researchers have defined GIS in several ways. Wiggins (2002) defines GIS as a structural approach to collecting, archiving, analysing, manipulating, and displaying data having one or more spatial components, using a combination of personnel, equipment, computer software, and organizational procedures. Vik & Andresen (2005) define GIS as a computer-based information system that enables capturing, modelling, manipulation, retrieval, analysis, and presentation of spatially-referenced data. Raju (2003) says GIS is a computer-based system that provides input, data management, manipulation and analysis, and output capabilities to handle geo-referenced data. In summary, all these definitions agree that GIS is an information system that manages geographic information.

GIS is also termed as a technology because it can be used in explaining events, predicting outcomes, and planning strategies (Vik & Andresen, 2005; Saugene et al., 2012; Wiggins, 2002; Baulos, 2004; Tanser, 2006). GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. According to Vik & Andresen (2005),

GIS is powerful because it also integrates spatial information with higher end statistical and analytical processes to derive spatial patterns not readily apparent to the observer. GIS can be used to combine data and generate information required for decision making.

Researchers have debated whether GIS is just another information system or it has unique characteristics that separate it from other systems. GIS is similar to any information system, but with all information linked to a spatial reference (Foote & Lynch, 2015). Data in GIS has three components: location or space, attribute and time (Gregory & Ell, 2007; Peuquet, 2002). According to Gregory & Ell (2007), location identifies where the feature or an object is, attribute defines what the feature or an object is, and time defines trend for change of pattern over a certain period. In addition, GIS has map, database and spatial analysis views which are distinct but overlapping (Maguire, 1991). According to Maguire (1991), map view focuses on cartographic presentation of data, a database view for storage of the data and spatial analysis view for modelling, interpretation and analysis of data.

In this study, focus is on the three ‘powers’ of GIS: data integration, visualisation and analysis. Data integration means combining data from different sources, e.g. programs or datasets, such that users have a unified view of the combined data (Pődör, 2010). For example, Kraak (1999) cites that GIS integrates data from different kinds of sources, such as remote sensing, statistical databases, and recycled paper maps. The

main purpose of integrating data is to enable sharing of existing data. In GIS, integration involves combining data from different layers. A layer is a geographic dataset containing groups of point, line, or polygon (area) features representing a particular class of real-world entities such as buildings, streets, rivers or boundaries.
In DHIS2 GIS, there are four types of layers: boundary, facility, thematic and event layers (DHIS2 Documentation Team, 2017). According to DHIS2 Documentation Team, 2017, boundary layer displays boundaries of catchment area required. Boundaries are presented as polygons. Facility layer displays symbols that represent health facilities and this layer only presents data that is stored as points. The thematic layers in DHIS2 GIS are used for analysis of required themes or characteristics basing on health facilities, districts or zones. Users define the combination of indicators or data elements, period, organisation level and catchment area. Colours are used to present the different patterns of results on the map. The link between values and colours on the map is defined on the legend.

GIS has the capability to process integrated data to be useful to decision makers and other stakeholders. This spatial analysis is the process of turning raw data into useful information. With the ability of GIS to integrate data from different sources, complex spatial queries are performed which are not possible with other systems. Through the three components of spatial data discussed earlier, questions in relation to ‘what’, ‘when’ and ‘where’ are answered (Kraak, 1999; Peuquet, 2002) . Spatial data analysis can be inductive, deductive and normative (Pratt, 2003). Inductive analysis examines the data to discern patterns that might support new theories or derive principles. Deductive analysis focuses on testing the known theories or principles against data. Normative analysis aims at developing or prescribing best solutions.

The results of spatial analysis are presented through maps and one consideration is visualisation. In GIS, data visualisation is interactive (Egenhofer & Kuhn, 1999) because spatial data stored in layers has visual representation of a feature and a link from the feature to its attributes in the database. When a query is executed, features and their characteristics are represented by shape and colour of symbols on the map (Huisman & de By, 2009). Successful visualisation depends on how well the map reader recognizes these shapes and symbols and the accuracy of estimating the distances on the map (Reveiu & Dardala, 2011). Commonly, data visualisation is affected by the map's scale. Huisman & de By (2009) define the scale of a map as the ratio between the scale on the map and the corresponding distance in reality. Small-scale is used for visualisation of few details on a large area and large-scale is for much detail on a small area. GIS has the inbuilt feature which enables increasing and reducing the scale (i.e. zooming).

2.2 Health Management

Management in general can be defined as use of human, physical, and financial resources to achieve the set goals and objectives of an organization (Hissom, 2009; Rahman, 2012). In health, management is complex and broad. It involves care of health facilities, coordination of preventive and promotive health programs, organising and controlling health teams and controlling of resources (Engelbrecht et al., 2002; Hintea et al., 2009). Health managers lead and provide direction in health management either at supervisory, middle-management or senior-management levels and they perform managerial roles of planning, organising, staffing, directing, controlling and decision making (Thompson et al., 2012). Hintea et al. (2009) categorises the roles of a health manager into informational, interpersonal and decisional. Informational role involves monitoring work related information, disseminating information within the health program and transmitting information to other programs and stakeholders. Interpersonal role involves representing the health program, leading the subordinates and acting as a liaison for the program. Decisional role involves identifying new ideas to improve how the program operates, resolving disputes and allocating resources. To carry out these roles, health managers need to have adequate and reliable information.

Information is an important resource in health management. Feldman & March (1981) argue that the value of information depends in a well-defined way on the information's relevance to the decision to be made. Health managers may make good decisions when the information is well managed. Management of health information involves health information collection, analysis, interpretation, utilization and dissemination. Health information systems have been introduced to assist management of the health information.

Health information system is a system that integrates health data collection, processing, reporting, and use for improving health service effectiveness and efficiency through better management at all levels (WHO, 2004). A health information system specially designed to assist in the management and planning of health programmes is a health management information system (HMIS). Use of HMIS improves effectiveness and efficiency (Chikumba, 2017; Jha et al., 2009; Chaudrey et al., 2006). For instance, the study conducted by Chaudrey et al. (2006) found that HMIS enhanced surveillance and monitoring for disease conditions. The health sector has various managers who require information from different HMIS.

Most times these managers need to share information. When health data from different systems is integrated, it becomes more convenient and more useful to the managers. For example, analysis of epidemiological data for TB program can be improved and useful when data from finance, human resource and HIV/AIDS is available because it will give a more complete picture of the situation. In absence of integration, finance, human resource, HIV/AIDS and TB data would otherwise be from four different systems. Technology has been used to integrate data from different systems (Chikumba, 2017; Rajanna & Kapila, 2011). Chikumba (2017) emphasises on the role of technology in strengthening HMIS and recently, GIS is one of the technologies which most health organisations are adopting.

2.3 GIS in Health in Developing Countries

The use of GIS has been instrumental to solve public health issues because the health professionals have been assisted to understand and treat health conditions in different geographic areas thereby assisting the health personnel to work more effectively and efficiently (Fradelos et al, 2014). Vik & Andresen (2005) highlight the ability of GIS to enable the user to visualize and explore health data interactively. Health data which is in tables can be combined with map data. The user can then query the data by either selecting rows from the table, and get the result highlighted on the map. Alternatively, the user can select an area on the map, do a query about it, and get the results listed in a table.

GIS is applied in all three dimensions of decision-making in health sector: operational control, management control, and strategic planning (Hilton et al., 2005). In operational control, GIS improves the practice of health care by assisting in management of people, assets, and services using spatial information to ensure the delivery of the health care service while assuring that specific tasks are carried out effectively and efficiently. In management control, GIS assists to manage the whole health delivery system, and is specifically used in planning for the needs and provision of health services, health promotion, disease prevention, and health inequalities while assuring that resources are obtained and used effectively and efficiently. Application of GIS in strategic planning involves analysing spatial distribution of diseases and their epidemiological patterns to devise means of early disease detection.

According to Montana (2006) and Saugene et al. (2012), GIS has been used to predict outbreaks and spread of diseases. GIS can also display and analyze statistics on health services and social programs such as immunization compliance and maternal/high-risk infant programs. Munthali (2014) adds that time series maps can show whether or not health indicators in an area have improved, remained constant, or deteriorated for a given time period.

GIS has also been applied in health programs in developing countries. For example, in Laos, GIS was used to explore the impact of intervention coverage and how people adhere to the intervention in malaria control (Shirayama et al., 2009). In Cameroon, Kenya and Tanzania, GIS was used to assess availability of HIV-related health services (Montana et al., 2006). In Latin America and Caribbean, GIS was used to address disparities in access to family planning services and commodities (USAID, 2008).

GIS has also been applied in analysis of patterns and prediction of disease outbreaks. In South Africa, GIS was used to assess changes in infant mortality patterns between 1992 and 2007, and to identify factors associated with infant mortality risk (Sartorius et al., 2010). In Cuba, GIS was used to predict increased breeding of Aedes aegypti a species of mosquito which transmits various arboviruses, such as those causing yellow fever and dengue diseases (Ortiz et al., 2015).

Some studies have been conducted on GIS application in management of health programs (Tanser & LeSueur, 2002; Nyirenda et al., 2005; Msiska, 2009), accessibility of health facilities (Yao et al., 2013; Awali & Chikumba, 2014; Maliwichi & Chikumba, 2014), drug logistics (Chikumba, 2014) and human resource deployment (Munthali, 2014).

2.4 GIS Implementation in Developing Countries

The successful usage of GIS is influenced by how the GIS are implemented. Sommers (2009), points out that GIS should be implemented following structured process that ensures to meet users' needs. Sommers proposes five basic phases for GIS implementation; planning, requirements analysis, design, acquisition and development, and operation and maintenance.

Planning phase defines scope and role of GIS in the organization which determines the resources and approach required in the implementation. Resources include time, finance and human. Sommers (2009) emphasizes that implementers should ensure that GIS fits in the overall goals of an organization.

Requirements analysis phase determines users' specific requirements. This phase involves analysis of how current spatial data is handled and how will the GIS be used. Purpose, process step, data involved, inputs and outputs of work processes are examined to understand how GIS will fit in.

Designing phase defines what type of spatial data is required and how will the data meet user and organizational needs. GIS specific software, hardware and supporting systems software are also identified. Resources identified in planning phase are detailed in this phase. For instance, on finance, cost/benefit analysis is done basing on budget, GIS design and funding sources. On human resource, tasks are attached to personnel including management basing on individual skills.

Acquisition and development phase identifies system components for GIS implementation during design phase thus hardware, software and spatial data are acquired and put together to create a unique system. If spatial data is collected in raw form (hard copies), it is digitized so that it can be used. Operations and maintenance is last phase which involves putting the system into operation. Data and system are maintained and updated to ensure that it is meeting user and organisational requirements.

In this study, GIS implementation involved the requirements analysis, designing, data acquisition and testing of DHIS2 GIS. Maintenance was done depending on feedback from testing and it is ongoing. Planning phase had already been done before this study started. GIS implementation is expensive and complex (Sieber, 2000). Literature shows that there are four major limitations which GIS implementation faces in developing countries: lack of qualified staff, data limitation, high cost of hardware and software, and lack of support from decision-makers.

Lack of qualified staff - GIS is relatively new technology and there are few skilled and trained personnel in developing countries that can install and use GIS. In most cases, GIS projects are initiated by expatriate employees (Hall et al., 1997). It becomes expensive to maintain the expatriate employees and Msiska (2009) noted that when expatriate employees leave, technical support for GIS projects is compromised hence the projects come to an end.

Data limitation - Sommers (2009) identifies data as the most important component of GIS. However, getting the required data set has proved to be a big limitation. According to Somers (2009), Taleai et al. (2009) and Bernhardsen (1999), data collection and updating is expensive; most organisations spend huge part of implementation budget on collecting data and updating it. Taleai et al. (2009) adds that lack of proper legislation framework affects collection, maintenance, sharing and use of spatial data in national organisations.

High cost of hardware and software- GIS requires hardware of high specifications for data capturing, processing and system installation which is expensive. Most organizations in developing countries fail to secure right equipment due to financial constraints (Taleai et al., 2009). Hall et al. (1997) also argue that financial constraints cause organisations in developing countries to have difficulties in acquiring software and settling software license fees. However, Tanser & LeSueur (2002) argue that these hardware and software issues have become less of a problem. Hardware and software has become cheaper and now most GIS work adequately on standard desktop computers. Some organisations which had problems with software licensing are switching to open source GIS (e.g. QGIS).

Lack of support from decision makers -Msiska (2009) found that there is little or no knowledge of GIS and its possible applications in health sector in Malawi. This is also a scenario in other fields as Ibrahim & Kuta (2015) also points that many decision and policy makers do not understand what GIS does and what it can do. Therefore, policy formulations and financial support become a challenge which affects implementation of GIS.

2.5 Conceptual Framework

This research was guided by theories of Community of Practice (CoP) and Boundary Object (BO).

2.5.1 Community of Practice (CoP)

CoP as a social theory was originally developed by Jean Lave and Etienne Wenger in 1991. At first it was applied the understanding of how learning occurs outside classroom. The learning is through practicing and participation and Jean Lave and Etienne Wenger termed this '*situated learning*'. Later on, the theory was extended and applied in Knowledge Management (KM) in business context (Hildreth & Kimble, 2004). Recently, researchers have applied CoP in various studies to understand interactions and practices of people in communities (Portoghese et al., 2014; Kanjo, 2012; Ranmuthugala et al., 2011). Similarly, in this study, CoP is used to understand interactions between health programs and departments.

The CoP is a group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly (Kanjo, 2012; Hildreth & Kimble, 2004). The main objective of a CoP is the learning which is an outcome of member's interactions which are bounded by rules and procedures. A CoP is characterized by three elements; domain, community and practice (Kanjo, 2012) and it is the combination of these three elements that constitutes a CoP. As a domain, every CoP has an identity which is defined by a shared domain of interest and membership. CoPs have shared competence which distinguishes their members from other people. As the community, members of a CoP need to engage in joint activities and discussions in which they utilize their ideas and build relationships that enable them to learn from each other. In case of practice, the members of a CoP are practitioners who develop a shared repertoire of resources: experiences, stories, tools, and ways of addressing recurring problems which results to a shared practice.

According to Worall (2009), CoPs vary in size, boundaries, visibility, structure, and topics. They also intersect under a variety of conditions. When two or more CoPs are interacting, data and knowledge are shared across the communities (Huvila et al., 2014). Boundary connectors are used to enable the interaction and sharing across CoPs and they are in forms of boundary objects, boundary interactions and boundary spanners (brokers) (Huang & Huang, 2013; Kanjo, 2012). Interaction and brokering are more of participation involving mainly a human being. In this case one member belongs to two or more CoPs and he/she is responsible for transferring, exchanging, coordinating, negotiating, translating and aligning elements of one CoP into another. Since the boundaries hoard both domain-specific and common knowledge, it is very important to make sure that what is passed on needs to be effectively managed otherwise knowledge can be misrepresented across boundaries. Since, in this study, the interest is on spatial data and DHIS2 GIS as artefacts, the theory of boundary object is used.

2.5.2 Boundary Objects

The boundary object theory was originally developed by Susan Leigh Star and James R. Griesemer in 1989 in their study on information practices at the Berkeley Museum of Vertebrate Zoology (Huang & Huang, 2013; Worrall, 2009; Fong et al., 2007). Boundary object theory has been applied and used to study the interactions that take place and objects that people create and use in the context of crossing the boundaries of different social worlds such as communities of practice (Puri,2007; Huvila et al., 2014).

Bowker and Star define boundary objects as *"objects that both inhabit several communities of practice and satisfy the informational requirements of each of them"* (Bowker & Star, 1999 p. 297). They further argue that boundary objects should be plastic enough to adapt to local needs of parties employing them and robust enough to maintain a common identity across sites, i.e. weakly structured in common use and strongly structured in individual use (Bowker & Star, 1999). Boundary objects are useful in studying how CoPs formalize, communicate, and define who and what remains part of their discursive community as opposed to expelled as irrelevant or threatening to their self-defined social world (Fischer, 2007). A boundary object, when identified by multiple communities, serves as a common point of reference to facilitate conversation around contested issues thereby enhancing mutual understanding in the process.

Boundary object theory explains the relationships between CoPs and the role boundary objects play in facilitating interactions, translations, and coherence across the CoPs (Worrall, 2009). According to Star & Griesemer (1989) translation is the task of reconciling the meanings of objects, methods, and concepts across multiple CoPs. The translation allows members from different CoPs to work together. The degree of consistency between different translations and CoPs is referred to as coherence (Star & Griesemer, 1989). Boundary objects play a critical role in developing and maintaining coherence across intersecting CoPs (Worrall, 2009). The coherence of sets of translations depends on the extent to which efforts from multiple CoPs can coexist, and that an indeterminate number of coherent sets of translations are possible.

In order for the object to be a boundary object it requires to satisfy certain properties. Wenger (1998) suggested four properties: *modularity* - actors in the CoPs use only those subsets of the provided information which is needed for their tasks, *abstraction* - removing details that are not relevant to the stakeholders whilst still maintaining the common identity across the CoPs, *accommodation* - information is generic enough to assist different activities and *standardization* - the object is interpretable by diverse stakeholders.

2.5.3 Conceptualization of CoPs and BOs in the Research

Any management, like health management, requires collaboration among actors from different groups, departments and organisations (Jensen & Kushniruk, 2014). In the Malawi health system, there are various groups of people who interact within their respective groups and between groups to promote health to the communities. In most cases, members from the group share a concern, interact regularly, learn from each other and are bounded by some rules and procedures. As in this study of DHIS2 GIS implementation in Malawi, these groups include CMED and health program managers at the national level, and HMIS officers and health program coordinators at the district level. These groups interact in many ways such as reports, meetings, workshops, trainings, emails, memos, telephones, face-to-face, and DHIS2 GIS. Generally, the interaction between district and national levels is within, for example, health programs (coordinators and managers). Technical personnel also interact (HMIS officers and CMED).

With the introduction of DHIS2 GIS, the interaction between national and district levels can be diagonal. For instance, CMED at the national level is able to access data of health programs from DHIS2 without involvement of HMIS officers. This demonstrates that there is an interaction between health program coordinators and CMED through DHIS2. As Kanjo & Kaasbøll (2011) argue that management levels in health system can be treated as communities of practice (CoPs), in this thesis, district and national levels are treated as the CoPs and even health programs and CMED as a division can also be taken as individual CoPs. When these CoPs are interacting, boundaries exist and data is transferred to accomplish their common goal of managing health data. To share the data across these CoPs, connectors are required and in this case, DHIS2 GIS is treated as one of them as illustrated in *Figure 2.*

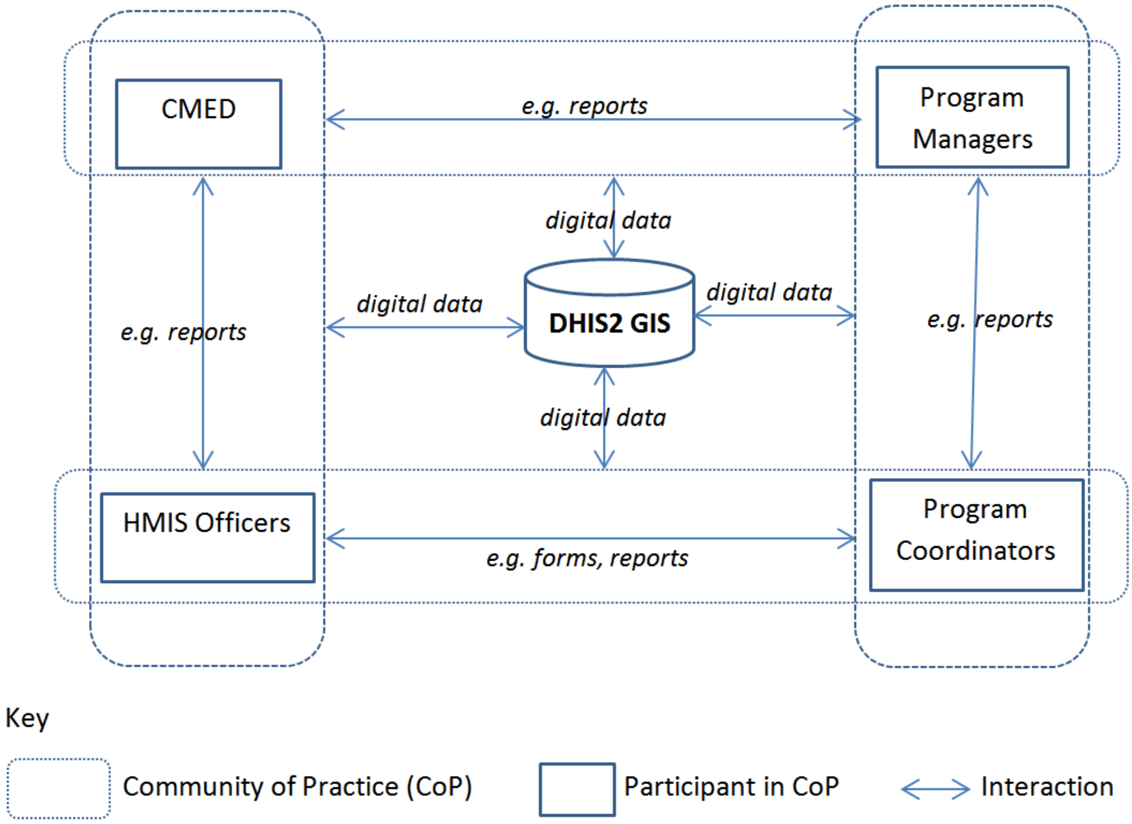

Figure 2 : CoPs in health management in Malawi

When building a boundary object (i.e. DHIS2 GIS and spatial data in this case), it has three attributes: its content (the scope of knowledge inscribed in it), the technology that goes into its construction, and the practices which go into the utilization of the knowledge (Puri, 2007). DHIS2 GIS is viewed as a socio-technical entity and it cannot be introduced without studying its social context. Its implementation in the health management requires interactions between people and technology, through sharing of spatial data and maps which have social and technical attributes (i.e. content, technology and practices).

CHAPTER 3

RESEARCH METHODOLOGY

This chapter contains research approach, data collection and analysis techniques which were used in this study. It also presents the deployment process of DHIS2 GIS and ethical considerations.

3.1 Research Approach

The research adopted qualitative design method. Qualitative research seeks to understand a given research problem or topic from the perspectives of the local population it involves. It is especially effective in obtaining culturally specific information about the values, opinions, behaviours, and social contexts of particular populations (Mack et al., 2005). Qualitative research can be a survey, experiment, case study or action research (Singh, 2006). This research was an experiment in a field context (field experiment). An experiment can also be done by pooling standard subjects e.g. students in a laboratory (laboratory experiment). Field experiment approach attempts to investigate the conditions or processes under the natural environment (Gerber & Green, 2015; List, 2014). Field experiment was chosen because the researcher wanted to understand social, natural settings and practices before, during and after deployment of DHIS2 GIS whilst the participants carried out their normal duties. Therefore, the researcher interacted with the participants at their work places.

A field experiment can be artefactual, framed and natural (List, 2014; Dufwenbwerg & Harrison, 2008). This research followed framed field experiment involving the nature of subject, the nature of commodity, the nature of information, and the nature of task. The non-standard subjects pool comprising of officials from CMED and UNICEF, health program coordinators, HMIS officers and DHIS Team members was used basing on subjects' knowledge and experience in DHIS2. These subjects have specific roles in DHIS2 (see *Table 1)*. Therefore, their knowledge and experience was fundamental in the implementation of DHIS2 GIS. DHIS2 GIS is the commodity being evaluated in this study and it was presented through demonstration to subjects at their respective working places. The subjects provided comments and suggestions.

3.2 Data Collection

In this study, documents and spatial data analysis, interviews and participant observation were used and participant observation was the main method. Data collection was conducted from March 2016 to January 2017.

3.2.1 Document and Spatial Data Analysis

The researcher analysed documents which are used at MoH to guide implementation of DHIS2 GIS. Documents analysed were national bulletins, Health Information System – National Policy and Strategy (Ministry of Health and Population, 2003), Malawi National Health Information System Policy (Ministry of Health, 2015) and Malawi Health Sector Strategic Plan (Ministry of Health, 2013). These documents were analysed to understand the procedure which the ministry was following for the implementation of DHIS2 GIS. Other documents which were analysed are: National Nutrition Guidelines for Malawi (Ministry of Health, 2007), Malawi National

Nutrition Policy and Strategic Plan (Ministry of Health, 2009) and Guidelines for Community Management of Acute Malnutrition (Ministry of Health, 2012). These documents were analysed to understand the health indicators required for nutrition program. Facility report monthly forms for Nutrition and Malaria programs were also analysed to understand what type of data is captured into DHIS2 for the programs.

Besides analysing the documents, the researcher also analysed spatial data of health facilities collected by MoH and UNICEF and that of administrative districts from National Statistical Office (NSO). Spatial data is the key component of every GIS application (Maguire, 1991; Raju, 2003) and it was important to check if the data was adequate and complete before starting the DHIS2 GIS set up.

3.2.2 Interview

Face-to-face semi-structured interview was another method of collecting data in this research. Interviews were conducted to understand user requirements and to establish if functionalities in DHIS2 GIS are meeting the user needs. Interview guide was developed before the interviews (*Appendix 1*). All conducted interviews were recorded to avoid missing vital information. Health program coordinators for Nutrition and Malaria programs in Mchinji and Blantyre health districts were interviewed on the flow of data concerning their respective programs and how it is captured into DHIS2, which indicators their programs use, how they present their reports and challenges they encounter when accessing the data from DHIS2. HMIS officers were interviewed on how they capture data into DHIS2, the technical support they provide to other users, their expertise in GIS and challenges they encounter when using DHIS2. DHIS2 Team was interviewed on its role in DHIS2 and its expertise in GIS. CMED officials were interviewed on background of GIS in health management in Malawi and GIS implementation strategy. Since other development partners for MoH are also interested to start using DHIS2, representatives from UNICEF were also interviewed to understand their user requirements in DHIS2 GIS.

All informants were interviewed individually and on average each interview took one hour. Some interviews were conducted before setup of DHIS2 GIS and some after. All interviews conducted after DHIS2 GIS set up were preceded with demonstration on how DHIS2 GIS works. Below is the table which shows the number of informants who were interviewed, their roles and at what stage they were interviewed.

Table 1: Interviewed informants

Informants	**Number**	**Role**	**Before / after DHIS2 GIS set up**
CMED Officials	2	Managing health data and implementing health systems	Before and after
DHIS2 Team	2	Providing DHIS2 technical support at national and district level	Before and after
UNICEF Officials	2	Managing health programs at national and level	Before and after
Health Program Coordinators	4	Managing health programs at district level	After
HMIS Officers	4	Managing health data and providing DHIS2 technical support at district level	Before and after

3.2.3 Participant Observation

The researcher participated in a number of meetings and workshops and was involved in deployment of DHIS2 GIS. This was important so that participants' actual practices be observed in their natural settings. Data collected during observations assisted to understand what was collected during documents and spatial data analysis, and interviews

The researcher attended three meetings and two workshops (*Table 2*) whilst collecting data for the study. At the first meeting development partners and DHIS Team deliberated on DHIS2 server migration and general GIS user needs for development partners in DHIS2. At the second meeting, participants discussed the procedure to be followed when implementing DHIS2 GIS. At the third meeting, DHIS2 Team and development partners discussed on observations during data preprocessing and way forward on DHIS2 GIS implementation.

Table 2: Meetings and workshops attended during data collection

No.	Date	Meeting / Workshop	Issues discussed	Participants
1	13/06/2016	Meeting	• Progress of DHIS2 GIS • DHIS2 server migration • DHIS2 GIS implementation at MoH	Development partners and DHIS2 team
2	14/07/2016	Meeting	• DHIS2 GIS set up procedure	Development partners and DHIS2 team
3	03/08/2016	Workshop	• Sharing experiences on GIS implementation	CMED and Development partners
4	28/09/2016	Meeting	• Observations during spatial data preprocessing • Way forward on GIS implementation at MoH	Development partners and DHIS2 team
5	28/11/2016 to 02/12/2016	Workshop	• Training on how to set up and customize DHIS2 in Tanzania	DHIS2 implementers

At the first workshop, DHIS2 team reported to CMED and development partners on the progress of the DHIS2 GIS implementation. At the second workshop conducted in

Dar es Salaam, Tanzania, participants from 15 developing countries were trained on how to set up and customize DHIS2.

3.3 Deployment of DHIS2 GIS

Deployment of DHIS2 GIS involved user needs analysis, spatial data preparation, DHIS2 GIS setup and DHIS2 GIS evaluation. The whole process was done by the researcher with support from DHIS2 team members and the process took almost 6 months.

3.3.1 User Needs Analysis

User needs analysis is one key issue which affects system implementation success or failure. Defining user needs is fundamental in implementation of every system (Attarzadeh & Ow, 2008). In this research, gathering user needs for DHIS2 GIS was done through interviews as explained in *Section 3.2.2*. CMED, UNICEF, HMIS officers and DHIS2 team were interviewed to provide their specific needs. The user needs were determined through Sommerville's framework. Collected user needs were afterwards analysed and the analysis mainly involved understanding the capacities and limitations of the intended GIS users, their problems, and of course the desires for the future (Sommerville, 1998). Sommerville (1998) proposed seven stages to be used during user needs analysis: document what is known, organise user needs analysis, perform stakeholder analysis, perform analysis of users in context, identify user needs, document and validate user needs and translate to specification, and consider implications for evaluation. User needs analysis assisted in determination of the system requirements for the DHIS2 GIS in Malawi.

3.3.2 Spatial Data Preparation

Spatial data preparation was in three stages: spatial data acquisition, spatial data pre-processing and spatial data verification.

3.3.2.1 Spatial Data Acquisition

Spatial data which was needed for DHIS2 GIS implementation was country, zone and district administrative boundaries and coordinates for health facilities. Administrative boundaries, except zones, were generated by National Statistical Office (NSO) in 2008 in shapefile format. The district boundaries were to model health districts. Spatial data for health facilities was in Excel format and was collected from CMED and UNICEF (*Appendix 5*). CMED collected the spatial data in 2013 during its service provision assessment survey whilst UNICEF collected the data in two phases: first phase was from May to September 2015 covering 9 health districts and second phase was from July to October 2016 covering the remaining 20 health districts. The spatial data was not ready to be used in DHIS2 GIS because they were in formats not compatible for DHIS2 GIS. DHIS2 GIS only allows importation of data in Geography Markup Language (GML) format. Hence preprocessing was required.

3.3.2.2 Spatial data preprocessing

From user needs analysis, it was also noted that the users would need to analyse data at zone level and there was no spatial data for zone boundaries. Using ArcGIS 10.2 software, the zone boundaries were created by dissolving administrative district boundaries. In GIS, to '*dissolve*' is to aggregate features based on specified attributes. For example, central-west zone consists of Mchinji, Lilongwe, Dedza and Ntcheu districts. Therefore, to generate central-west zone boundary, the district features were aggregated using the attribute of '*zone*'. Spatial data for health facilities in Excel format was first converted into shapefiles using ArcGIS 10.2 software. Afterwards, all spatial data for health facilities, country, districts and zones were converted from shapefiles to GML also using ArcGIS 10.2 software.

3.3.2.3 Spatial Data Verification

Next step was to check if the names of all health facilities in DHIS2 were in the GML files and if all health facilities were attached to their appropriate groupset (e.g. facility type). Health facilities are referred to as organization units in DHIS2. Verification of names was done because importation of coordinates in DHIS2 uses the name of organization unit as an identifier. Health facilities were all checked if they were assigned to the right facility types (e.g. central hospital, district hospital, health centre). When creating maps in DHIS2 GIS, there is a need to define the group set of facilities otherwise the affected facilities will not be included on the map.

It was observed that some health facility names had spelling errors, some facilities were not assigned to any facility type and others were not in DHIS2. There were also some duplicates mainly for village and outreach clinics. Communication was sent to concerned HMIS officers and DHIS2 team for confirmation on the observations of which most of them responded and appropriate actions were taken during the setup of DHIS2 GIS.

3.3.3 DHIS2 GIS Setup

In responding to the observations during verification process, various actions were executed. All health facilities were assigned to their respective facility types and duplicates were resolved by renaming the affected organization units. All misspelled health facilities were corrected. Coordinates were later imported into DHIS2 using created GML files. The setup also involved creation of 8,632 village and outreach clinics in DHIS2. Setting up of DHIS2 GIS took almost three months.

3.3.4 DHIS2 GIS Evaluation

The evaluation was another critical stage in the DHIS2 GIS implementation. DECIDE framework suggested by Sharp et al. (2007) was applied to evaluate DHIS2 GIS. The framework provides a checklist of six items which assisted in evaluating the DHIS2 GIS.

Determine the goals – Main goal of the evaluation of DHIS2 GIS was to get feedback from the expected system users to check if the system performs according to user requirements.

Explore the questions – Questions to be answered through the evaluation process were drafted prior to interacting with the participants.

Choose the evaluation approach and methods – Two approaches were identified: use of emails and visits to users' work places. Instructions for creating maps were documented and sent through email to HMIS officers across the country for them to verify if all the health facilities in their respective catchment areas were displaying on the maps. DHIS2 GIS demonstrations were also conducted to some system users (health program coordinators, M&E officers and HMIS officers) at Blantyre DHO, Mchinji DHO, UNICEF and CMED. Demonstrations focused on map creation and data visualisation from different tools such as tables, charts and maps. Participants were giving comments and suggestions during demonstrations.

Identify the practical issues – Practical issues such as users, schedule, facilities and financial resources were identified for evaluation. At Blantyre DHO, UNICEF and CMED, each participant had individual demonstration followed by the interview whilst at Mchinji DHO, demonstration was done to all participants at same time but it was followed by individual interviews to get their feedback. The scenario at Mchinji was due to electric power blackout and there was one laptop which was being used for demonstration. All HMIS officers who participated during the demonstrations were given opportunity to try functionalities in DHIS2 GIS. HMIS officers from the rest of health districts were involved during evaluation to check DHIS2 GIS accessibility as it is a web-based system.

Decide how to deal with the ethical issues – Ethical issues were also considered as discussed in *Section 3.5*.

Evaluate, analyse, interpret and present the data – The data collected during evaluation was analysed, interpreted and presented as part of this thesis.

3.4 Data Analysis

This research used content analysis method to analyse data collected. Content analysis involves extracting major themes from the verbal or behavioral collected data and categorizing them for the purposes of classification, summarizing and tabulation (Hancook, 1998; Hsieh & Shannon, 2005). In this study, data recorded during interviews was first transcribed into text soon after the interviews to ensure that the interviews captured the information required. In the events where some data was missed, emails were sent to participants and they responded accordingly. Major themes and categories were identified from transcribed data and data collected through observations and document analysis. Thereafter, the findings were drawn based on the themes and categories.

3.5 Ethical Considerations

Ethical issues relevant to the research were taken into account. Ethical clearance to conduct a research in health sector was obtained from the National Health Sciences Research Committee (*Appendix 2*). In addition authorisation from CMED was obtained to use data in DHIS2 (*Appendix 3*) and to visit selected DHOs and health program coordinators (*Appendix 4*). In addition, informed consent was obtained verbally from all interviewees before taking part. This research did not collect patient data. Confidentiality and anonymity were also observed. All participants in this study remain anonymous in all written reports and related publications.

CHAPTER 4

RESULTS AND DISCUSSIONS

This chapter presents research findings and discussions based on research aim, objectives and literature.

4.1 User Requirements

The first specific objective of the research was to identify user requirements. Therefore, it was important to identify the users of DHIS2 GIS, their roles and their requirements. Currently, DHIS2 is used at national and district levels. Hence this section focuses on these levels.

4.1.1 Users Roles and Requirements at District Level

At district level, the main users are health program coordinators and HMIS officers. There are some stakeholders who would also require data from DHIS2 GIS such as NGOs and other managers in the district. The main role of health program coordinators in DHIS2 is to manage health data at district level. These coordinators receive aggregated data from all health facilities in the district for their specific programs. They verify the data by ensuring that it has no anomalies. The aggregated data is prone to mathematical errors because aggregation at health facility is manual. After verification they enter the data in DHIS2. However, it was observed that due to other official engagements, health program coordinators mostly delegate data entry to HMIS officers. Health program coordinators produce reports in form of tables and charts from DHIS2 for use when providing health care services to communities. They also share the reports with managers and other stakeholders when a need arises.

Health program coordinators indicated that they would require DHIS2 GIS to assist them have a visual presentation of locations where the health facilities are in their districts. This would assist them when they are planning for supervisory visits which they conduct because they would know how to use minimum resources in terms of fuel, time and other logistics. One health program coordinator added that the information for personnel who are working in the health facilities should also be displayed on the maps.

> *"The map should also show us number of trained staff and their contact details. We should be able to just click a facility and get their information."*– said Health program coordinator

The spatial data collected by UNICEF included the details of the in-charge for every health facility. However, it was observed that the details are not captured in DHIS2 although the provision is there. A study conducted by Munthali (2014), found that, with relevant data available, applying GIS can help in allocation of human resource in health sector.

Health program coordinators want DHIS2 GIS to assist them in supply management logistics, for example in Nutrition Program. They indicated that they do not receive supplies consistently in the health facilities due to challenges with funding. However, some facilities have more supplies in stock than others. They have to check which facilities have run out of supplies and which ones have more stock so that they can transfer the supplies to ensure continuation of treatment to all patients.

> *"We experience some cases whereby children who were about to be discharged from SFP, are admitted into OTP because their dosage was interrupted due to shortage of stock and yet other facilities had more stock. Tracking down the supplies is the challenge. I have to call all facilities to check how much they have in stock. I wish I could see a red flag for the facility which is run out of supplies and a green flag for a facility which has more supplies."*– said Health program coordinator

In nutrition program, it was reported that once a month coordinators with their teams visit communities to assess how village committees are working with communities. Sometimes they find guardians with ill children but the guardians do not take the children to the health facilities due to timidity or negligence. Some of the children are the ones who were treated of malnutrition and got discharged. Health program coordinators want DHIS2 GIS to assist them tracking these children so that the children should receive treatment through mobile clinics.

> "*We go flat out in the communities once every month. Sometimes we find mothers with ill children who do not bring the children to the facilities because they are afraid of their friends to laugh at them, some are just at ease. Some of these children are the ones we already treated and discharged. We want assistance if these children can be tracked and linked to mobile clinics"*– said Health program coordinator

HMIS officers provide data management services and technical support to program health coordinators and other stakeholders. They ensure that data in their respective health districts is entered into DHIS2. For health program coordinators to access DHIS2, they need to have user accounts in DHIS2. It is the responsibility of HMIS officers to create those accounts and ensure that they have assigned the required roles to all users in their respective health districts. Assignment of roles assists to control activities that users can do on data in DHIS2 such as entering, viewing and updating.

Data in DHIS2 is entered per service which the facility offers and HMIS officers are responsible for linking data entry forms to health facilities where they are needed. It was observed that some health services are offered at specific health facilities. For example, in Mchinji health district, NRU services under nutrition health program are offered at Mchinji District Hospital, Kochilira Rural Hospital and Kapiri Community Hospital (3 out of 17 health facilities). Therefore, HMIS officers in Mchinji health district have linked NRU data entry forms to the three facilities only.

When MoH has opened a new facility, HMIS officers create the facility in DHIS2 and also deactivate non-functional facilities with authorisation from CMED. Since DHIS2 is web-based which can only be accessed through the internet, HMIS officers are responsible to ensure that internet connectivity is available and computers are also working. When the program health coordinators are stuck whilst using DHIS2, they seek support from HMIS officers which may include in-house training on how to use DHIS2.

4.1.2 User Roles and Requirements at National Level

At national level, main DHIS2 GIS users are health program managers and CMED. As at district level, there are some stakeholders who would also require data from DHIS2 such as development partners. Health program managers use data in DHIS2 for planning and monitoring services. It was observed that health program managers aim at providing adequate health services across the country. Like health program coordinators, managers need DHIS2 GIS to assist them have a visual presentation of locations where the health facilities are across the country with associated program indicators in various services. They can also compare health districts on performance and other management related issues. For instance, visual presentation would assist to determine the areas where to put new health facilities (e.g. village and outreach clinics) so that they can reach all communities.

> "*We are supposed to have village clinics at every 5kms. We want this GIS to assist us view how our facilities are distributed so that we can know where to put new facilities*" –health program manager

It was also noted that knowledge of population distribution assists health program managers to plan well when they are providing health care services.

> "*The map should include population distribution. If the map can show population by age e.g. under-five the better. We need to reach everybody*." – Added the program manager

For these health managers to effectively use DHIS2 GIS, they need support from CMED. CMED manages data and technologies including DHIS2 and provides necessary technical support at all levels. CMED has health statisticians, health economists and M&E officers who act as technical advisors to health program managers. It is the responsibility of CMED to implement new tools in DHIS2 which would be of help to manage health data. For instance, when a health program has introduced new service and it wants to start capturing data into DHIS2, it consults CMED. CMED comes up with the methodology to incorporate capturing of required data. This may involve creation of new indicators, data elements, categories and data entry forms in DHIS2. CMED also implements new technologies to address the requirements of health programs. It also ensures that users are able to use the system by providing accessibility, user documentation and training. When health program managers and other stakeholders need health data at national level in the country, CMED produces reports using data from DHIS2. CMED implemented DHIS2 GIS to enable extraction of reports in form of maps. Technical support of DHIS2 is provided through DHIS2 Team which comprises members from CMED, NGOs and development partners.

4.2 Spatial Data Limitations

As indicated in Chapter 2, spatial data is the most important component of GIS. According to Somers (2009) and Bernhardsen (1999), organisations spend the largest portion of their GIS budgets (between 60% and 80%) on spatial data collection and updating. Spatial data is integrated with non-spatial data to produce the maps in GIS. Langaas & Tveite (1995) point out that spatial data has to be complete as it is a measure of quality of GIS and Veregin (1999) adds that spatial data should be complete if GIS is to be meaningful to all users. Veregin (1999) argues that every GIS database has spatial data limitations such as data incompleteness and it would be unfair to suggest that producers of spatial data are unware of the limitations. According to Langaas & Tveite (1995), spatial data completeness is an indication of whether or not actual data available is able to meet current and future user needs specified during user requirements analysis. In this basis, spatial data completeness for DHIS2 GIS implementation was analysed to achieve the second specific objective of the research.

As presented in Chapter 3, spatial data used in this study for administrative boundaries was generated by NSO and for health facilities generated by MoH and UNICEF. It was observed that MoH involved clinicians and nurses in data collection while UNICEF involved HSAs with expertise from Department of Surveys. This entails that internal human resources can be used to collect spatial data. The personnel just need proper training so that data is collected accurately. However, there are some cases where technical expertise is required to generate some spatial data like boundaries. Hence spatial data was acquired from other stakeholders (NSO in this case).

The spatial data collected proved to be not complete for DHIS2 GIS set up. Some spatial data is missing (e.g. health districts, health facilities, patient tracking data and population density).

4.2.1 Absence of Health Districts data

Administratively, Mzimba is one district whilst in health system it is divided into two: Mzimba South and Mzimba North health districts. The Mzimba administrative boundary data could not be used in DHIS2 GIS. In this context, presenting reports for the two health districts, Mzimba North and Mzimba South is not possible through maps from DHIS2 GIS. However, it is possible to use tables and charts in the generation of reports for the same health districts as in *Figure 3*. Similarly, administratively, the country is divided into three regions but in health system, it is divided into five zones. Therefore, analysis at zone level was not possible until when zone boundaries were created as discussed in *Section 3.3.2*.

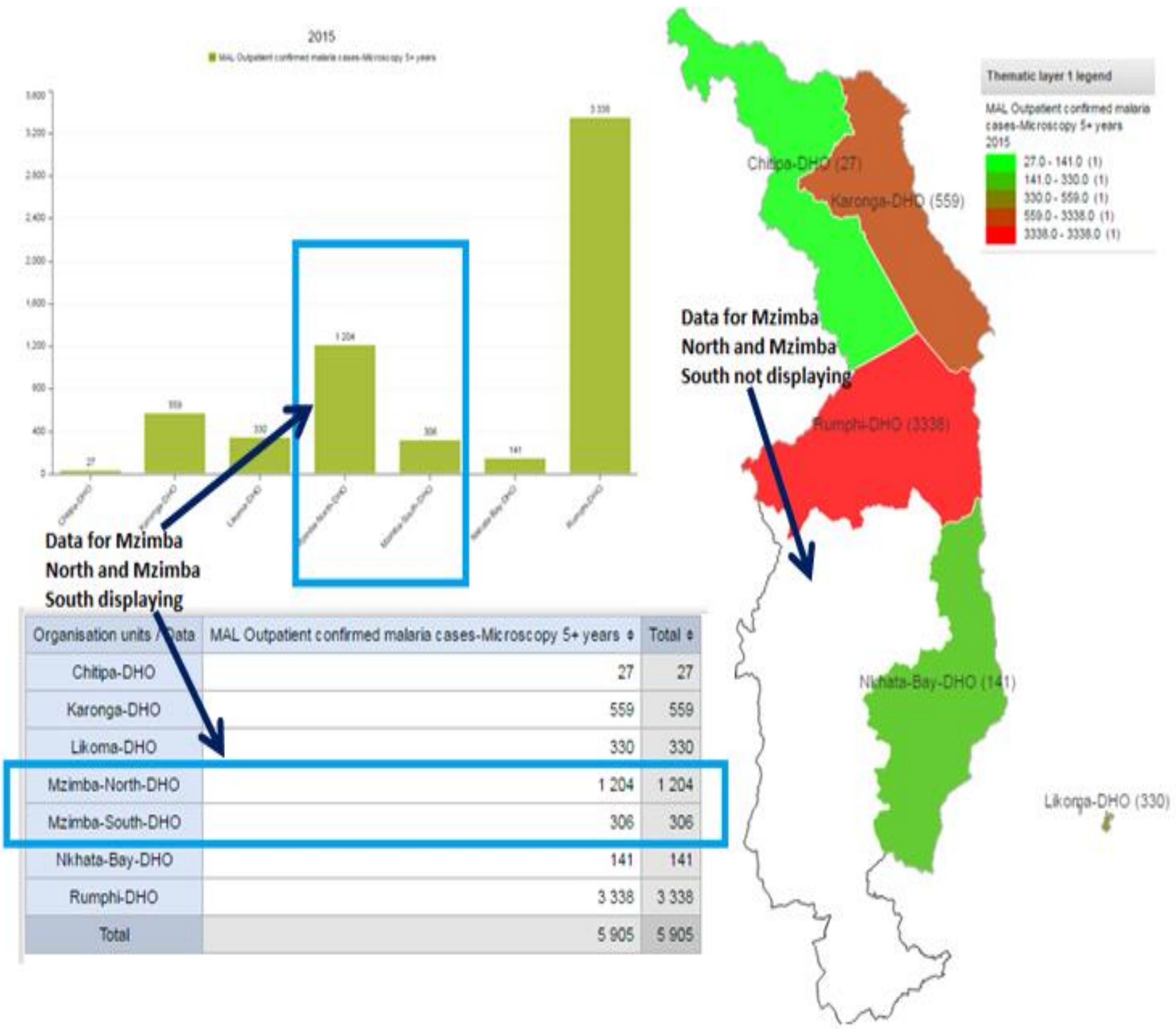

Figure 3: Malaria outpatient confirmed cases - Microscopy 5+ Years in 2015 extracted from DHIS2

4.2.2 Central Hospitals Data

Spatial data for central hospitals is also not complete. There are five central hospitals in Malawi: Mzuzu, Kamuzu, Queen Elizabeth, Zomba Central Hospitals and Zomba Mental Hospital. Data collected shows that reporting of data at central hospitals is done at departments and wards. Organisational hierarchy in DHIS2 (see *Figure 4*) shows some departments and wards for Queen Elizabeth Central Hospital where data reporting is done. In order to conduct spatial analysis for Queen Elizabeth Central Hospital, coordinates for reporting departments (e.g. qech clinical services, qech dental) and wards (e.g. qech OPD ANC normal, qech OPD family planning) are required. However, it was observed that coordinates at Queen Elizabeth Central Hospital were collected at one point (i.e. 35.021000 for longitude and 15.802140 for latitude). This implies that spatial analysis for Queen Elizabeth Central Hospital in DHIS2 GIS is difficult. This is also the case with the rest of the central hospitals.

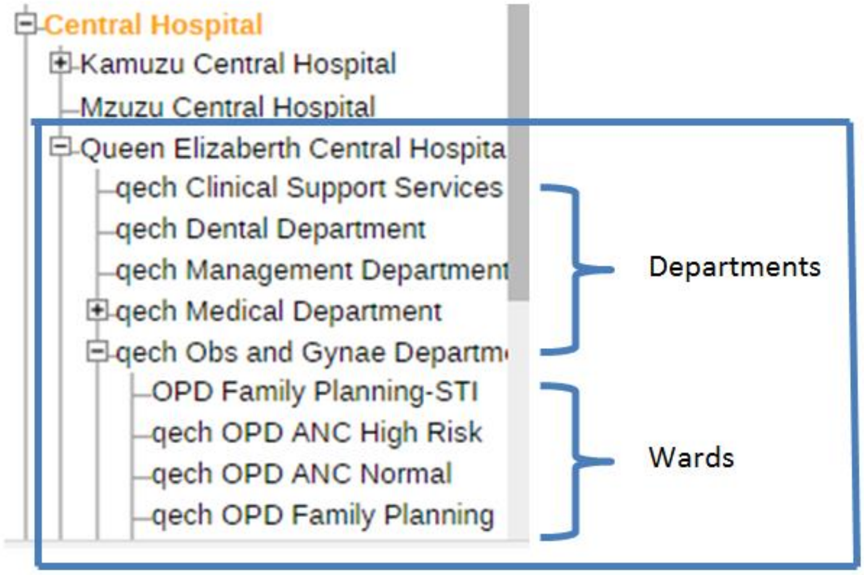

Figure 4 : Organisational hierarchy extracted from DHIS2

One of the functionalities of DHIS2 GIS is to analyse data per catchment area (thus health zones or health districts). It was observed that it is difficult to present catchment area for central hospitals. Unlike other hospitals which offer health services to a particular catchment area, the departments at central hospitals provide specialised health services and when patients require those services, they can be referred from any health district in the country. The five central hospitals can have patients from any health district. In case of other hospitals, catchment area is clearly defined. For example, Mchinji district hospital caters for Mchinji health district and in normal practice; it cannot offer services to patients from other health districts. Since catchment area for central hospitals is not demarcated, it is difficult to analyse data against catchment area.

4.2.3 Health Facilities Coordinates

According to section 4.1, users need to have visual presentation of health facilities and analyse data, for example, comparing on performance and other management related issues for health facilities. For this to be possible, spatial data for all health facilities is required. The study noted that spatial data for most health facilities is available and the health facilities can be presented on the map. Hence spatial analysis for the health facilities using DHIS2 GIS is possible as it can be seen on *Figure 5*.

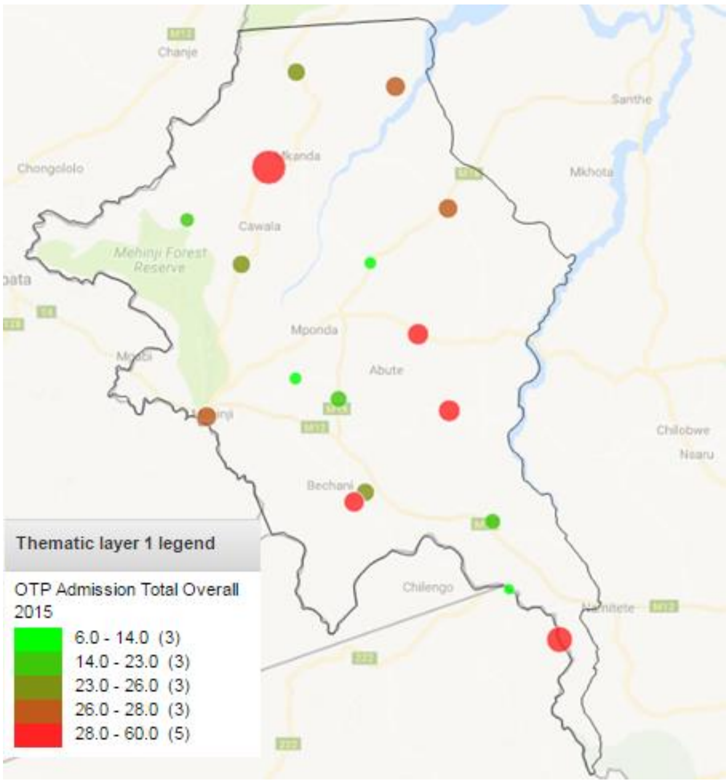

Figure 5: Map of Mchinji health district showing comparison of total OTP admissions at facility level in 2015

It was observed that spatial dataset collected by MoH has data for health facilities from central hospitals down to health posts including private clinics. This data was collected in 2013 and it was complemented by the data collected by UNICEF from 2015 to 2016 which included village and outreach clinics. UNICEF captured some health facilities which were not captured by MoH; for example, Kachindamoto Health

Centre and Kalimanjira Health Centre in Dedza and Ntcheu Health Districts respectively. These health centres were opened after MoH collected the spatial data.
It can be observed that there was spatial data sharing which is commendable. Spatial data sharing saves resources, time and effort when trying to acquire new datasets. Rajabifard et al. (2006) argue that when organisations share spatial data, duplication of expenses associated with the generation and maintenance of data is avoided.

As presented earlier, UNICEF only collected spatial data for government institutions. This means that there is no spatial data for private clinics which were opened after collection of spatial data by MoH in 2013. These private clinics have been created in DHIS2 and data is being captured. For instance, Chigumula Clinic in Blantyre Health District was created in DHIS2 on 14 October, 2014 and the data in DHIS2 shows that this health facility distributed 140 Insecticide Treated Nets (ITNs) for malaria prevention in 2015 as shown in *Figure 6.* This information cannot be presented using DHIS2 GIS because there is no spatial data for this health facility. This is the scenario with all private clinics which were opened after spatial data collection by MoH. This also applies to government health facilities which have opened after UNICEF collected the spatial data.

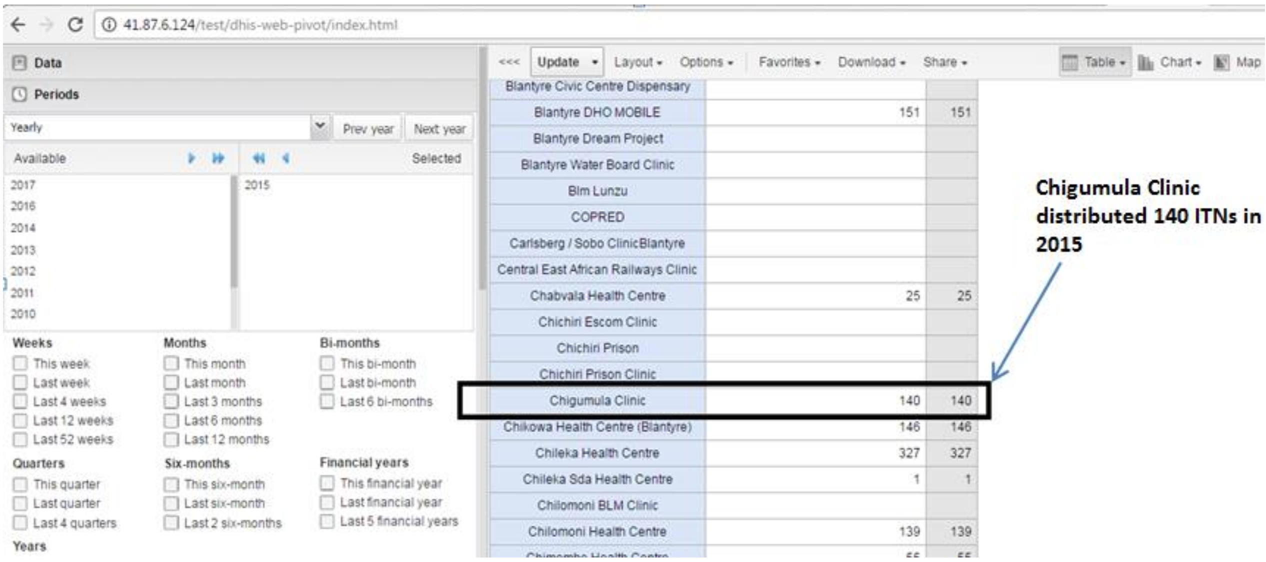

Figure 6: Distribution of ITNs for Chigumula Clinic in 2015 extracted from DHIS2

4.2.4 Patient Tracking Data

Some health services are provided to patients for a long period. The patients are based in their homes but are required to visit a health facility at defined intervals or as advised by medical personnel. In some cases, the patients miss appointments. Tracking chronic patients helps management of their diseases (Chiauzzi et al., 2015) so that treatment should not be missed. In a study by Chiauzzi et al. (2015), tracking patients proved promising in cases such as post-surgery recovery in cardiac patients, pulmonary rehabilitation and activity counselling in diabetic patients. Tracking of patients brings peace of mind to guardians of the patients when they see that professional care givers are monitoring the patients (Landau et al., 2009). However, tracking patients at their communities should be dealt with caution as it jeopardises the patient’s ethics. Landau et al. (2009) indicates that tracking patients is contrary to human dignity and freedom since their privacy is invaded.

In this study, the need for tracking patients was observed. DHIS2 has a capability of tracking patients through the use of '*Tracker*' facility. Event layer can be used to display geographical locations of events registered in DHIS2 Tracker. Although DHIS2 is for storage of aggregated data, it has set of identifiers which enable capturing of individuals' data and tracking of the individuals over time. DHIS2 has an extension called DHIS2 Tracker which supports management, data collection, and analysis of transactional or disaggregated data. Among other activities, DHIS2 Tracker enrolls patient's data into longitudinal and chronic programs, scheduled visits, sets up automated SMS reminders and tracks missed appointments. When these events are registered in DHIS2, it can be presented on map through event layer provided that events have associated coordinates. Drilling down to event of a patient (thus isolating patient's data) from the aggregated data displayed in thematic layers is possible through event layer. For instance, *Figure 10* and *Figure 5* show comparison of total cases admitted into Out-Patient Therapeutic Feeding Program (OTP) under nutrition health program in 2015 at district level and facility level respectively. With event layer, it is possible to drill further from facility leveland present details of one patient. However, DHIS2 Tracker is not implemented in DHIS2 in Malawi. As a result, patient tracking using DHIS2 GIS is difficult.

4.2.5 Population Density Data

Population distribution is one key factor which assists in health planning (De Winter, 1992). According to De Winter (1992), the number of people depending on a health facility would determine the accessibility of health services. Knowledge of population would assist management to deploy enough resources such as health workers. For example, when 1 midwife is allocated to 1000 people, it shows that maternal services are less accessible than when 1 midwife is allocated to 100 people. Similarly, when a health facility is serving 10,000 people, it shows that health services are less accessible than when it is serving 1,000 people. Generally, it can be argued that the greater the number of people depending on a health facility or health worker, the less accessibility to the services.

Population distribution should also be combined with distance to the health facilities when defining accessibility. De Winter (1992) argued that accessibility of health services is also measured by need of health services within a certain distance. Literature shows that in some cases, patients fail to access some health services due to long distance to health facilities (Maliwichi & Chikumba, 2014; Hanlon et al., 2012; De Winter, 1992). If population alone is considered, areas with less population are likely to have few facilities and patients will have challenges to access health services as they have to walk long distances. To balance the population and distance, it is important to consider the population per unit area.

In this study, data collected through interviews show that there is need to use DHIS2 GIS when planning for health services delivery. For instance, when deciding new locations to open health facilities. Currently, the available spatial data does not include population distribution. DHIS2 GIS has the capability of using population density spatial data from google map engine. According to Hanlon et al. (2012), providing health services to areas with low population requires more resources. Visual presentation would assist the managers to decide how to accomplish health services provision even to low population density. For instance, establishing outreach clinics would be more appropriate for area with low population density than health centres.

The visualisation of population density would also assist when deploying health workers. World Health Organisation (WHO) defines ‘number of health workers per 10 000 population’ and ‘number and distribution of health facilities per 10 000 population’ as recommended core indicators on health service delivery and work force respectively (WHO, 2010). Currently, it is possible to visualize a certain kilometer radius (e.g. 5 kilometer radius) around the health facility using DHIS2 GIS (*Figure 7*). However, it is difficult to determine how many people are served by those health facilities within the specified area. Therefore, it would be difficult to assess if the core indicators recommended by WHO are achieved.

The map with population density can only be presented in DHIS2 versions 2.24 and above. As mentioned earlier in *Section 1.1*, MoH is using DHIS2 version 2.21, therefore, it is not possible to incorporate population density spatial data until when the DHIS2 version 2.21 is upgraded to at least 2.24.

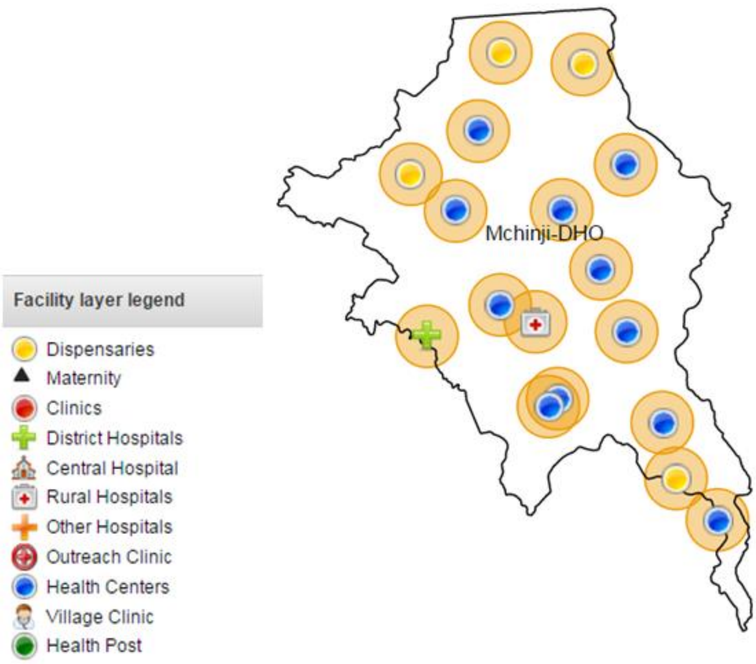

Figure 7: Map of Mchinji health district showing health facilities with Buffer zones of 5Kms extracted from DHIS2 GIS

4.3 Technical Limitations

Inaccuracies caused by technical limitations in GIS can have significant consequences (Graeff & Loui, 2008). For instance, US San Francisco submarine collided with an underwater mountain because its navigation map could not show the mountain which could be seen on other maps. Graeff & Loui (2008) suggests that technical limitations may be due to inaccuracies introduced when preprocessing spatial data and incompatibilities of data sets stored in different formats which can be mitigated by consistency checks and use of technical standards. Basing on this, this section discusses the technical limitations which were observed by assessing DHIS2 GIS functionalities against the user requirements.

4.3.1 'Zero value' and 'No value' Representation

In a conversation zero (0) and blank ( ) may be treated the same. However, scientifically they are different and hence, in DHIS2 the two are different. Zero means there is a 'zero' as the value whilst blank means there is 'no value'. For example, *Figure 8* shows a table and a chart illustrating the number of Insecticide Treated Nets (ITNs) which were distributed in 2016 at Antenatal Clinics (ANC) in Mchinji Health District. The same data is also presented in the map as shown in *Figure 9*.

Organisation units / Data	ANC Recieved ITN None	Total
Chimwamkango Dispensary	134	134
Chioshya Health Centre	2	2
Chipumi Health Centre	98	98
Guilleme St Michaels Health Centre	104	104
Gumba Dispensary		
Kaigwazanga Health Centre	0	0
Kapanga Health Centre	4	4
Kapiri Health Centre	4	4
Kazyozyo Dispensary		
Kochilira Rural Hospital	0	0
Ludzi St Josephs Health Centre	0	0
Mchinji District Hospital	26	26
Mikundi Health Centre	109	109
Mkanda Health Centre	64	64
Namizana Dispensary		
Nkhwazi Health Centre	0	0
Tembwe Health Centre	0	0
Total	545	545

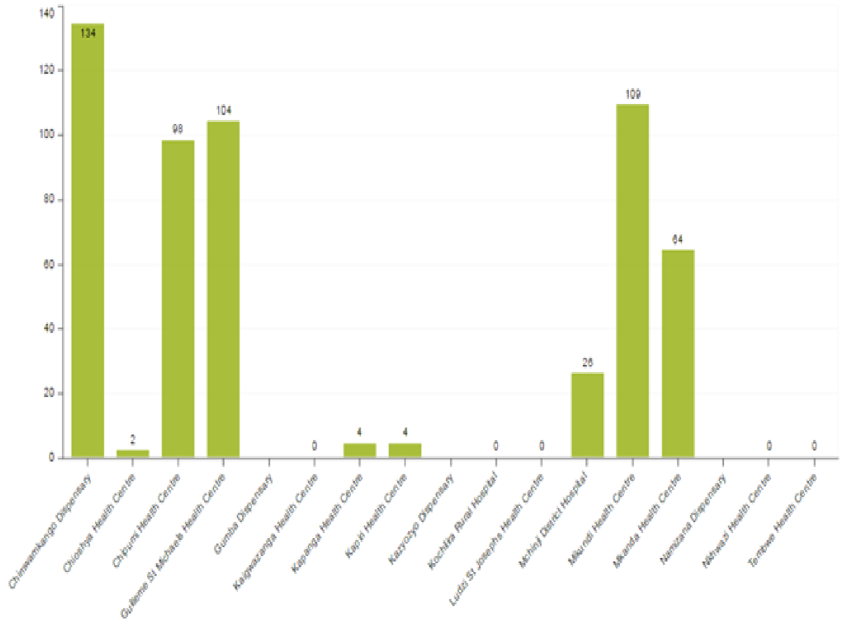

Figure 8: Table and chart showing distribution of ITNs in 2016 at ANC in Mchinji Health District extracted from DHIS2

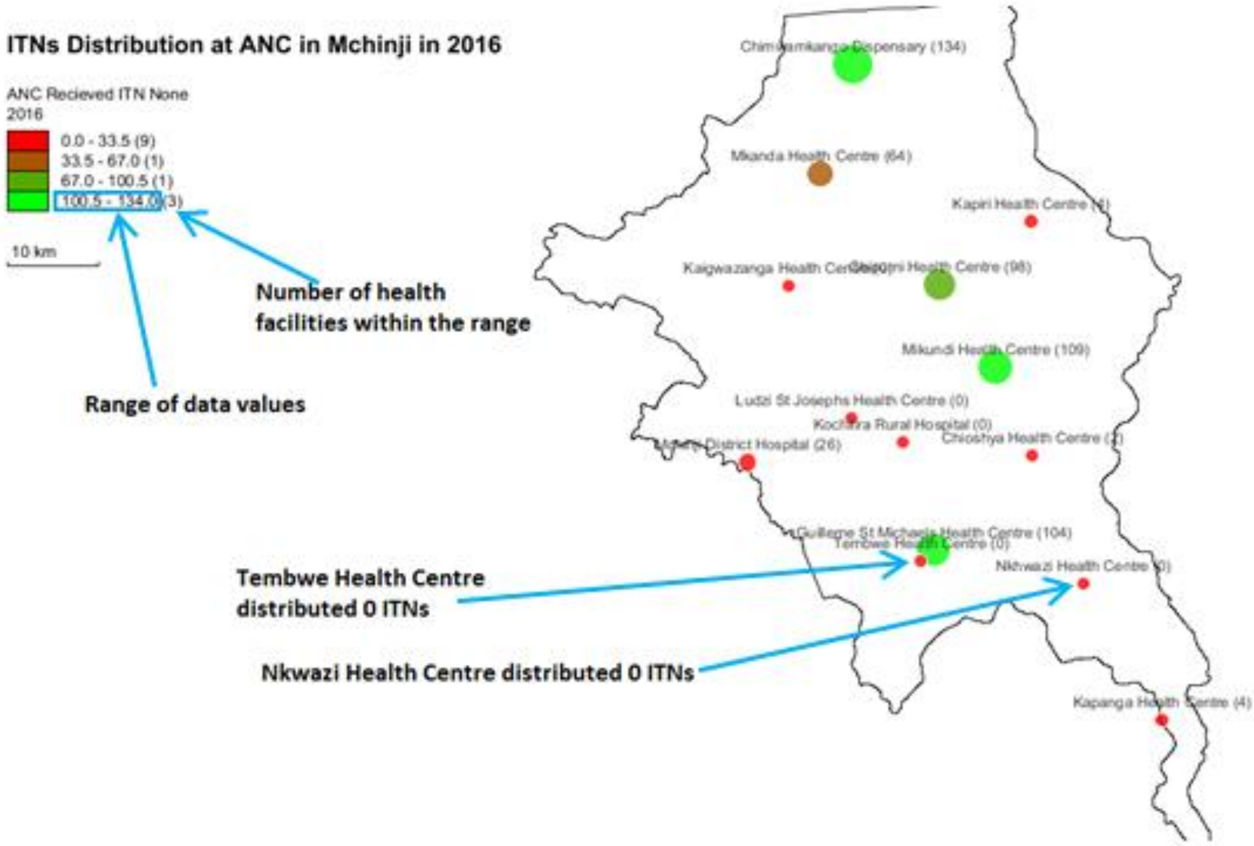

Figure 9: Map showing distribution of ITNs in 2016 at ANC in Mchinji Health District extracted from DHIS2 GIS

On the table and the chart *(Figure 8)*, Gumba, Kazyozyo and Namizana Dispensaries have no data value whilst Kaigwaza, Kochilira, Ludzi St. Joseph, Nkwazi and Tembwe Health Centres have zero (0) as their value. This means that Gumba, Kazyozyo and Namizana Dispensaries did not report on ITNs distribution in 2016 whilst Kaigwaza, Kochilira, Ludzi St. Joseph, Nkwazi and Tembwe Health Centres reported that they did not distribute ITNs in 2016. The difference is very important to health program coordinators and managers as they are analysing the data.

With reference to *Figure 9*, the findings in this study show that the 'no value' is not presented in DHIS2 GIS. The total number of health facilities in Mchinji is 17 but the map is only showing 14 health facilities. The health facilities not being visualised are those which did not report, Gumba, Kazyozyo and Namizana Dispensaries. In this case, it is only Nutrition Health Program Coordinator for Mchinji Health District who would know that the 3 health facilities exist; otherwise, other DHIS2 GIS users would not. Through tables and charts, other DHIS2 GIS users would know that 3 health facilities exist but they did not report as in *Figure 8*.

Similarly, in *Figure 10*, it can be seen that no colour has been used to represent Chiradzulu Health District because no data was presented on cases of patients who were admitted into Out-Patient Therapeutic Feeding Program (OTP) under nutrition health program in 2015. In the same *Figure 10*, it should be noted that there are Mzimba North and Mzimba South Health Districts which are also not represented by colour. Mzimba North and Mzimba South presented the data but the data cannot be presented on the map because there is no spatial data for Mzimba North and Mzimba South boundaries in DHIS2 GIS. In this case it is misleading. Since, for example, a health manager at national level will not be able to differentiate cases of Chiradzulu, Mzimba South and Mzimba North Health Districts. Health facilities and districts with 'no value' should be displayed for analysis. It should be up to the user extracting the data to filter according to areas of interest.

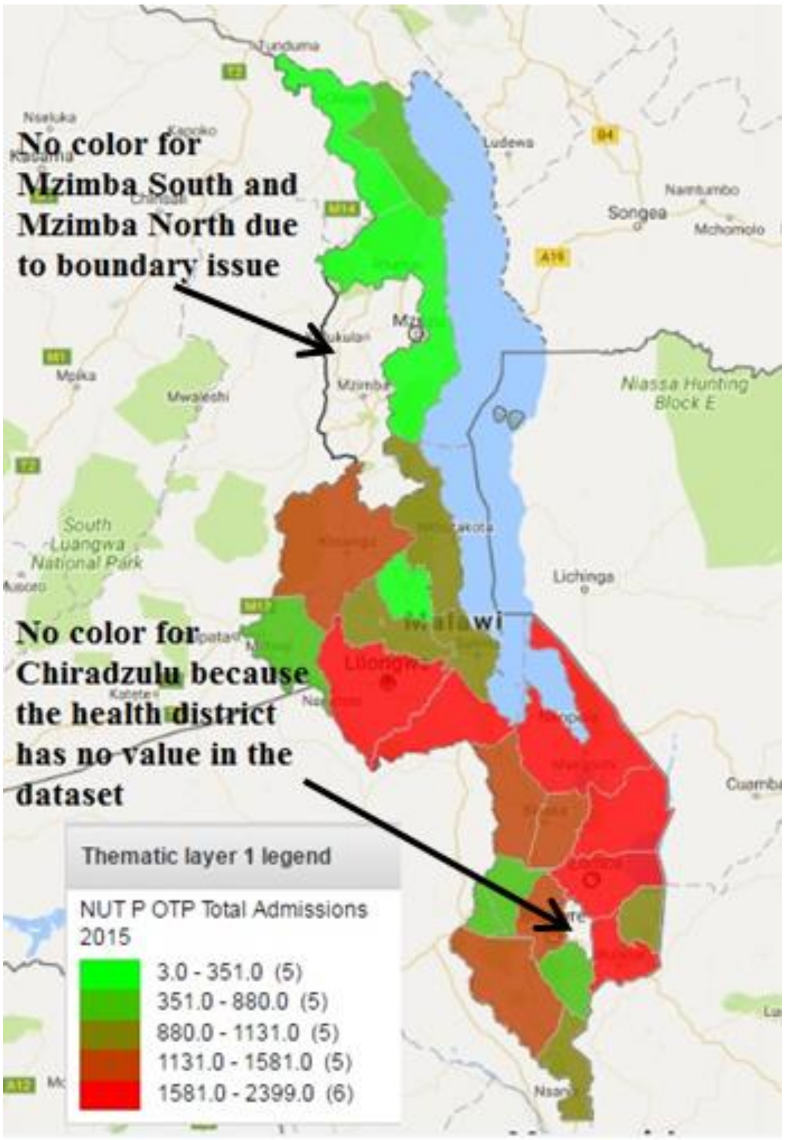

Figure 10: Map of Malawi showing comparison of total OTP admissions at district level in 2015 extracted from DHIS2 GIS

4.3.2 Accessibility

Accessibility of information resource in information systems has a link with the subsequent use (Culnan, 1983). According to Culnan (1983), in online systems such as DHIS2 GIS, accessibility encompasses physical access to the hardware component (i.e. the server hosting the system) and access to the actual information on the server. In both dimensions, DHIS2 is accessible by multiple users.

DHIS2 users (e.g. Health program coordinators, HMIS officers) have computers in their offices and access DHIS2 through the internet. The study finds that data from health facilities in the health district is captured at district health offices (DHOs) since most health facilities are not equipped with resources including computers, internet, and electricity, to enable accessibility of DHIS2. Although the DHOs have the resources, it was observed that sometimes the DHIS2 is not accessible. The responses received when evaluating DHIS2 GIS accessibility showed that some HMIS officers took time to give feedback because they had electricity and internet connection disruptions. Inaccessibility of DHIS2 GIS due to electricity disruption was also practically observed during the visit to Mchinji Health District. It was also observed that internet speed affects accessibility of some data through DHIS2 GIS.

Speed of internet affects activities which can be done in DHIS2 GIS. When internet speed is slow, some data cannot be displayed. For example, it was noted that creation of maps for large catchment areas such as a zone was not possible with slow internet whilst at the same speed it was possible to create maps for health districts. Similarly, creation of maps with more features requires high speed internet. In some cases, it was difficult to create maps with village and outreach clinics even at district level due to slow speed of internet. For example *Figure 11* shows an error message which was returned whilst creating map of village and outreach clinics for Blantyre health district. When internet speed is high, maps with more features can be created as in *Appendix 6*.

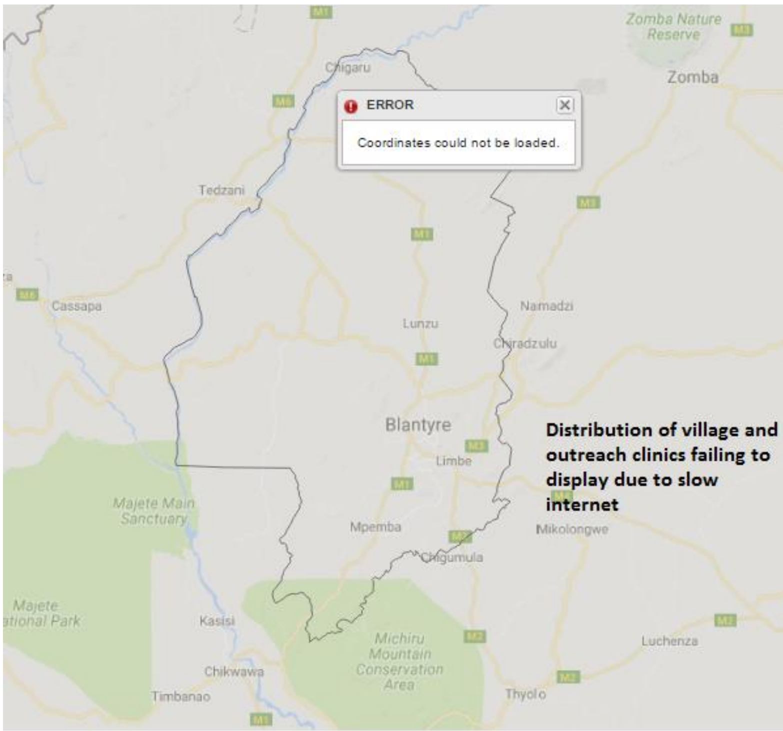

Figure 11: Error due to slow speed of internet

When users have access to DHIS2, they also need access to the actual data on the server. In DHIS2, users are assigned user roles which are collection of data sets and authorities. The data sets are forms and reports which a user is allowed to access whilst authorities are the rights of action a user can perform on the data sets. Users are also attached to organization units (health facilities) which they are allowed to capture, view and maintain data. Since data is entered at district level, program coordinators and HMIS officers are attached at district level and they get access to enter and maintain data in health facilities in their respective districts. For instance, health program coordinators for nutrition program are attached to user role of ‘nutrition’ with a data set comprising the forms which are used to capture data for nutrition program e.g. NRU monthly report form, OTP monthly report and SFP monthly form, and authorities such as add, update and delete data value. They also have authority to see some modules in DHIS2 like data visualizer, GIS and reports. The health program coordinators for Blantyre and Mchinji are attached to Blantyre-DHO and Mchinji-DHO respectively for entering, updating and deleting data. In this case, nutrition health program coordinator for Blantyre has access to add, update and delete nutrition data for health facilities in Blantyre Health District only in DHIS2. Similarly, a malaria health program coordinator for Mchinji has access to add, update and delete malaria data for health facilities in Mchinji Health District only. Both coordinators have access to view data for other health districts through modules which are defined in 'nutrition' user role. Users who do not enter data in DHIS2 e.g. health program managers, are assigned 'data viewer' role which comprises some forms and reports but with authority to see modules only. Health program managers are at national level hence they are given access to view data for all health districts through the specified modules. The user only views and analyses data in modules he/she has authority to see.

4.3.3 Map Sharing

Among other activities in an organisation or a community, members share reports. Cummings (2001) argues that sharing of reports assist members to develop a common understanding of the activities or business. Members are able to give their views or seek clarification when the report is shared. DHIS2 allow users to share reports in different forms such as tables, charts and maps. The user sharing the report specifies who should have access to the report. Users are grouped according to their roles in DHIS2 and the sharing of reports can be within these groups. Some reports are shared to everyone in DHIS2 and in some cases, they are even shared to external users of DHIS2 e.g. development partners.

In DHIS2 GIS, maps can be shared as favourites, pictures or PDF documents. The user creates the map and saves it as favourites. The map can be restored at any other time from favourites menu and shared with other users as an interpretation or the map is put on the dashboard. The users have to be online to access the shared map. The user can also save a map as a picture or PDF file using the download tool (as in *Figure 12*). In this scenario, the map is accessible whilst offline and can be shared through CDs or email.

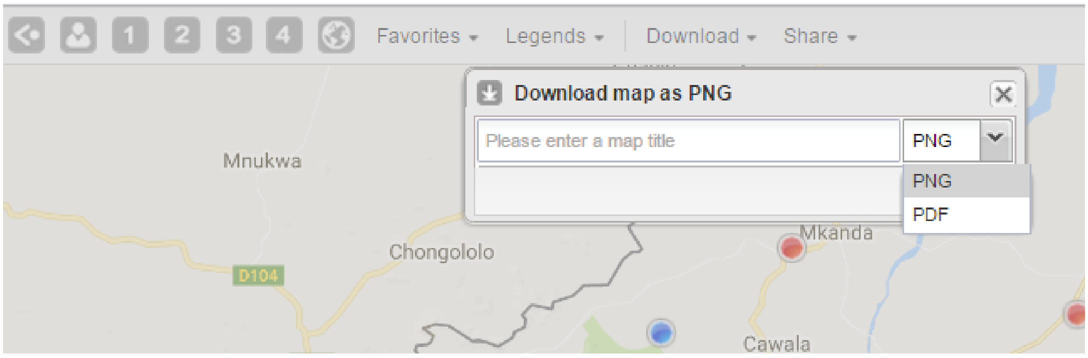

Figure 12 : Download tool in DHIS2 GIS

Findings in this study show that maps saved as favourites can be restored and shared without problems and the users are able to give feedback. Whilst maps saved as pictures and PDF files cannot display health facilities under the facility layer. Features from Google layers which may be needed for analysis are also lost e.g. rivers, roads, buildings and mountains etc. as illustrated in *Figure 13* and *Figure 14*. When health facilities and the mentioned features are not presented, the map loses its meaning hence such map cannot be used as a communication tool amongst users thereby defeating the purpose of DHIS2 GIS as a boundary object.

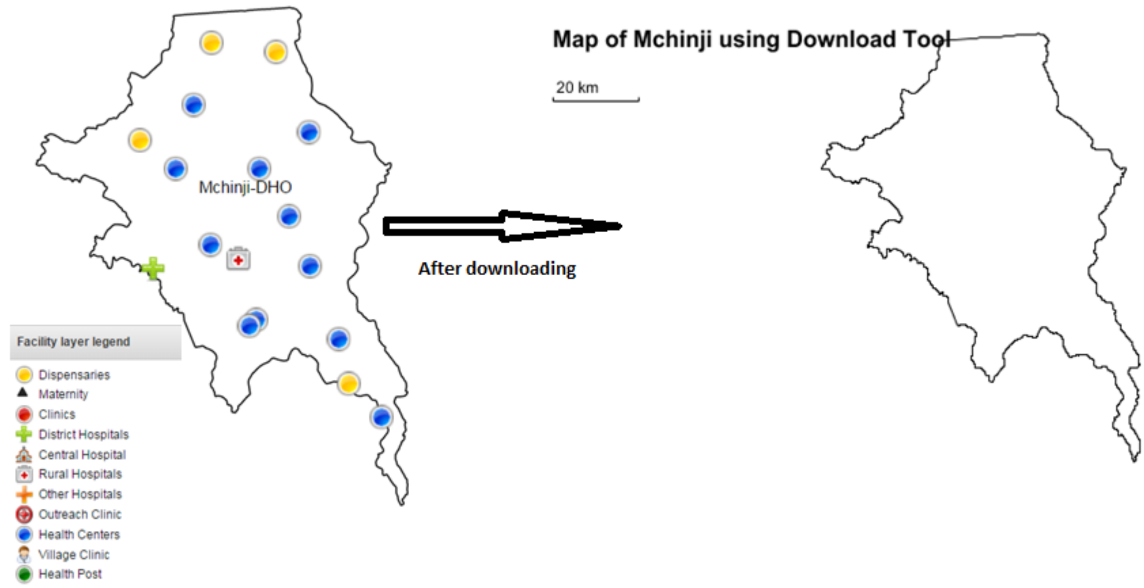

Figure 13: Map of Mchinji health district (with facility layer) when saved using Download Tool in DHIS2 GIS

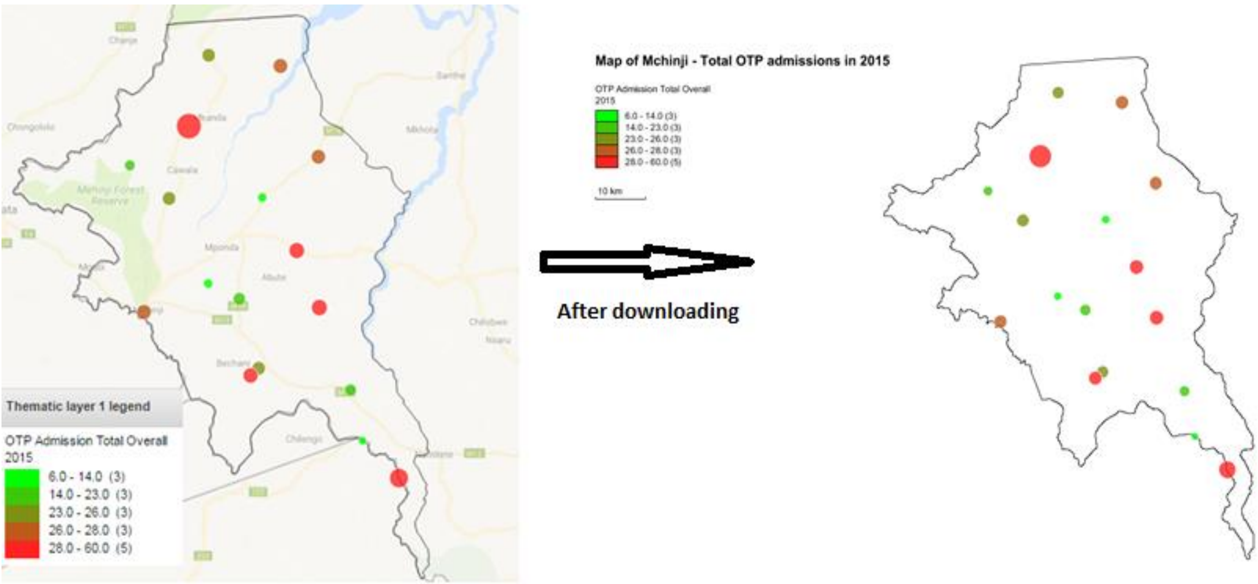

Figure 14: Map of Mchinji health district (with thematic and google layers) when saved using Download Tool in DHIS2 GIS

4.3.4 Visualisation of Similar Data Patterns

As presented in Chapter 2, data in GIS is presented through layers and one map can have a stack of different layers. In this scenario, the layers overlap each other. In some cases, the objects or features on two layers can have the same pattern and it is difficult to visualise and analyse the data on map. There are cases when a comparison of indicators or data elements is needed for same health program, service, facility or catchment area. For example, when it is required to analyze the total number of admissions against the total number of beds available in health facilities, the data can be presented using two thematic layers (see *Figure 15*); however, it is difficult to visualize. On *Figure 15*, thematic layer labelled ‘A’ presents number of admissions per health facility in Mchinji Health District in 2016 and thematic layer labelled ‘B’ presents number of beds for the same health facility in the same year. The two layers overlap to produce map labelled ‘A+B’.

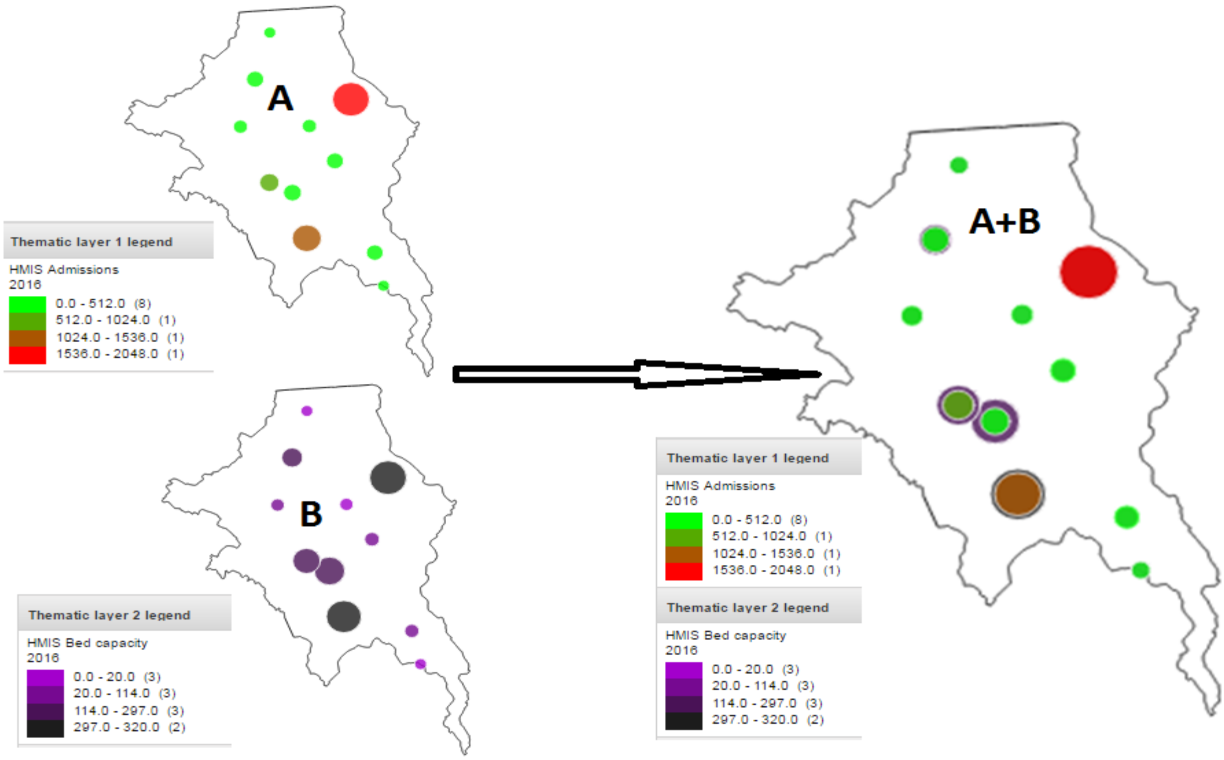

Figure 15: Comparison of total number of admissions against beds in Mchinji Health District in 2016

In cases where comparison of more indicators or data elements is required, GIS allows the inclusion of graphs on maps to enhance visualization and analysis of data. Graphs assist in presenting data and relationships of the features on the map and they are complementary to maps since graphs convey the data which is already on the map but it is not visible. Using the graphs is easier to visualize the distribution, trends, and patterns in the data that otherwise would be difficult to see. A sample of a map with graphs is on *Figure 16* in which the graphs were added on the map to present trend of HIV prevalence for 4 years (Msiska, 2009). The map has 4 thematic layers which have been stacked and the trend for each year is presented on separate thematic layer. This map was produced using ArcGIS software. DHIS2 GIS has no functionality to enable the inclusion of graphs on the map hence comparison of indicators or data elements for same health program, service, facility or catchment area is difficult to visualise.

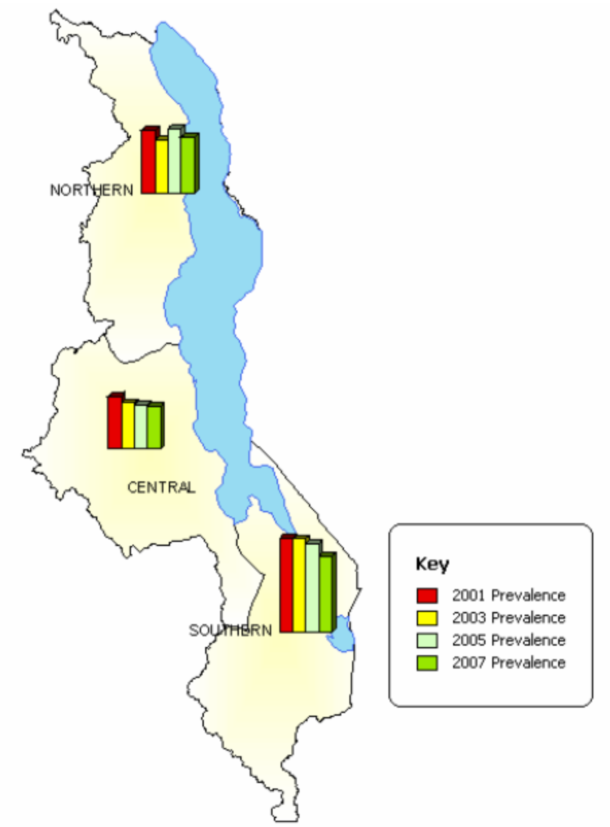

Figure 16: Regional HIV Prevalence Trends 2001 - 2007 (Source: Msiska, 2009 pp 55)

4.3.5 Measuring Distance between Facilities

Users also need to know distances from one health facility to another in DHIS2 GIS. There is a '*measure distance tool'* which is used for measuring straight distances between two points. To measure the distance, a user selects the '*measure distance tool'* and clicks at the starting point for measuring then also clicks at the ending point. The DHIS2 GIS reads and displays the distance between the two points. When measuring distance between two health facilities, it was observed that the moment a health facility is clicked, infrastructural data for that particular facility pops up. For example in *Figure 17*, distance was measured between Mlambe hospital and Lirangwe health centre which was 12.74kms. As observed in the map, starting and ending points are slightly away from the actual positions of the health facilities. Reason being that when a point is on actual position of Mlambe hospital, for example, the measure tool is disabled and instead a pop up window of the infrastructure data appear as in *Figure 17*. It was further observed that this issue has been addressed in DHIS2.26.

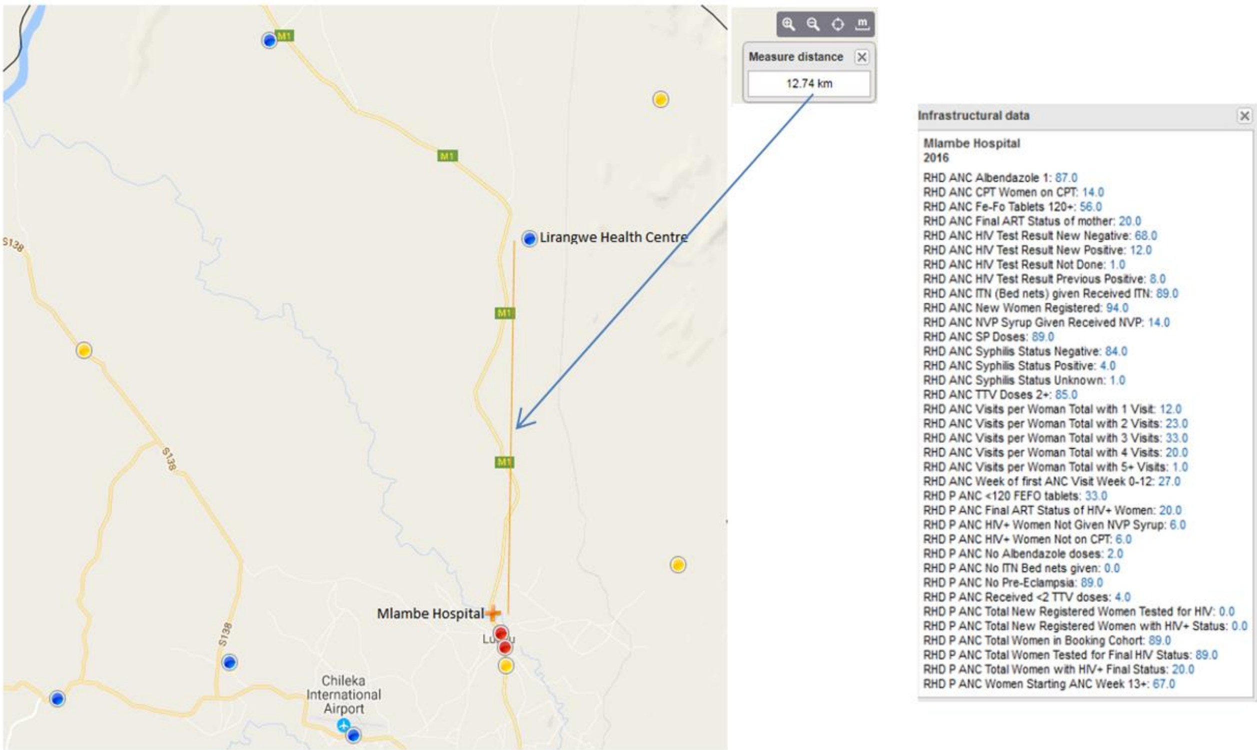

Figure 17 : Measuring distance between two health facilities

4.4 Articulating the Limitations from Boundary Object Perceptive

With reference to Chapter 2, this section defines DHIS2 GIS as the boundary object which connects different health programs and departments as CoPs, and enhances the communication among the participants in these CoPs. The findings have shown that DHIS2 GIS is a shared system. In this thesis, three objects within DHIS2 GIS are treated as boundary objects: GIS as technology, spatial data, and maps generated from the system. The limitations are in line with these boundary objects. On the other hand, this thesis focuses on three powers of GIS (analysis, integration and visualisation) which the limitations are also related to.

Various health programs, departments and other stakeholders are using DHIS2 GIS. A user in one health program can enter data in the system and users from other health programs and departments are able to use that data. In this case, DHIS2 GIS is taken as a boundary object for communication as it is interfacing the users from various CoPs. The findings have also shown that DHIS2 GIS houses data for different health programs and the users from each health program are able to get a subset of the data as per their needs. Hence, DHIS2 GIS is a boundary object. In fact, this is in line with Pawlowski & Raven (2000) who argued that shared information systems are boundary objects.

In order for the DHIS2 GIS to be the suitable boundary object, it should have properties such as those being suggested by Wenger (1998): abstraction, modularity, accommodation, and standardization. It has been observed that the limitations presented in this thesis affect these properties which may lead to difficulties in analysis, integration and visualisation in DHIS2 GIS. Therefore, the rest of this section aligns the limitations with the properties of boundary objects and expected effect on the three powers of GIS.

4.4.1 Abstraction

This property emphasises that the boundary object should contain only details relevant to the stakeholders. In the case of DHIS2 GIS, it should contain only data relevant to the health programs and services. All details of spatial data which are not relevant to the health programs and services in DHIS2 GIS have not been captured. The spatial data for health facilities and health districts are the ones available in DHIS2 GIS for all programs to use. It is possible to integrate these spatial data with data elements and indicators in DHIS2 GIS to support the analysis and visualisation.

However, there are still some limitations with the system due to lack of some boundary object properties such as modularity, accommodation and standardization.

4.4.2 Modularity

The DHIS2 GIS allows users in the health programs and services to extract subsets of data needed for their individual tasks. For example, they can analyse and visualize data in DHIS2 GIS per health facilities they wish and per health districts and levels of their choice. The observation is that some groups of users fail to meet their needs in some circumstances due to the missing of required spatial data. The findings have demonstrated the failure of departments and wards in central hospitals to be part of GIS and even absence of Mzimba South and North Health Districts. Missing of spatial data for some health facilities also contribute to the lack of modularity in DHIS2 GIS. Apart from the spatial data, the lack of important DHIS2 GIS functionalities can also affect the modularity by hindering some users to get the information they want. Examples include the failing to visualize the similar data patterns and 'no value' health facilities or catchment area.

4.4.3 Standardisation

This is another important property in DHIS2 GIS as the boundary object which enhances the common interpretation among users of the system. One issue is on the health facilities; there is a standard way of naming them by adding the facility type to facility names. In the case of duplications, its parent facility name is embedded in the facility names. Another issue is on the management levels: nation, zone, district, facility and community. In DHIS2 GIS, the organisation units are organized in the hierarchy following these levels. Hence, it is easy to analyse, integrate and visualize data in the GIS. Limitations associated with this property are related to the technology in terms of visualisation; for example, difficult to differentiate ‘no value’ and no boundary spatial data.

4.4.4 Accommodation

The majority of limitations are towards the lack of DHIS2 GIS to accommodate some groups of users. The DHIS2 GIS is expected to support all users to carry out their different activities. However, this is difficult because some spatial data is missing (e.g. health facilities, health districts and population density); the system fails to accommodate some functions (e.g. patient tracking and map download); and users fail to access the system when they need it. These three mentioned issues are related to each other. On one hand, it is possible to have all needed data but the system fails to manipulate it for meeting certain user needs. On the other hand, the system can be perfect but there is no data to process. In addition, the system is perfect and data is available but the system is not accessible. The accessibility in DHIS2 GIS limits its accommodation in two dimensions; registered users fail to access and unregistered users fail to get information from registered users. As mentioned earlier, only registered users are able to access resources of DHIS2 GIS and their accessibility is affected generally by the infrastructure as discussed above. However, other people who are not registered users want to get the access to maps generated from DHIS2 GIS but they fail because, for example, of difficulty in map downloading for sharing.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions of the study and recommendations the study proposes to mitigate the data and technical limitations explored.

5.1 Conclusions

This study aimed at exploring the data and technical limitations in the implementation of GIS in health management. The MoH wanted GIS to strengthen its HMIS through the enhancement in data visualisation, integration and analysis. The MoH with advice from CMED opted for DHIS2 GIS as the system to support various health programs at different levels. The research question focused on data and technical limitations needed to be addressed for the GIS implementation in health management in Malawi. In this research, the interest was on the spatial data and DHIS2 GIS as the technology. Since it was expected to support various health programs and services, the DHIS2 GIS was treated as a Boundary Object and the properties of Boundary Object were applied to understand the data and technical limitations.

In developing countries, major limitations in GIS implementation are lack of qualified staff, data limitation, high cost of technology, and lack of support from the management. This study focused on areas of data and technology. The study reveals that limitations on spatial data still exist with much focus on the spatial data completeness. The study has shown that identified limitations are related to the missing spatial data for health facilities, health districts, patient tracking and population density. Spatial data sharing has been observed to be improving.

In terms of the GIS technology, it has been observed that the main issue is on its functionalities. For example, measuring distance between facilities, patient tracking and map downloading, visualizing the similar data patterns and ‘no value’ health facilities or catchment areas, and creating maps when internet speed is slow cannot be done.The main concern is how to make sure that necessary functionalities are available and accessible.

5.2 Recommendations

In order to minimise the identified data and technical limitations, this thesis has suggested two strategies: spatial data completeness and technology upgrade.

- **Spatial data completeness** can be achieved through data sharing by different institutions and equipping HMIS Officers with skills and Global Positioning System (GPS) gadgets so that they should be able to collect spatial data for new health facilities in their respective health districts. In this case, the datasets will be complete and up to date. Spatial data sharing should be promoted to minimize costs involved in data updating.
- With respect to **technology upgrade**, the issue is to migrate to the latest version of DHIS2 GIS and implementation of functionalities to accommodate new user requirements, for example, customising DHIS2 Tracker module, embedding the graphs and charts on maps and fixing the download tool.

By having the complete spatial data and upgrading the technology, the usability and shareability of DHIS2 GIS can be achieved. It is possible for every health program and service to use the system.However, the infrastructure should be stable in order to access DHIS2 GIS with minimum hassles.As illustrated in *Figure 18*, by making spatial data to be complete and upgrading DHIS2 GIS, it is possible to enhance the accommodation, abstraction, modularity and standardization of the system as the boundary object and then it will be able to handle required analysis, integration and visualisation.

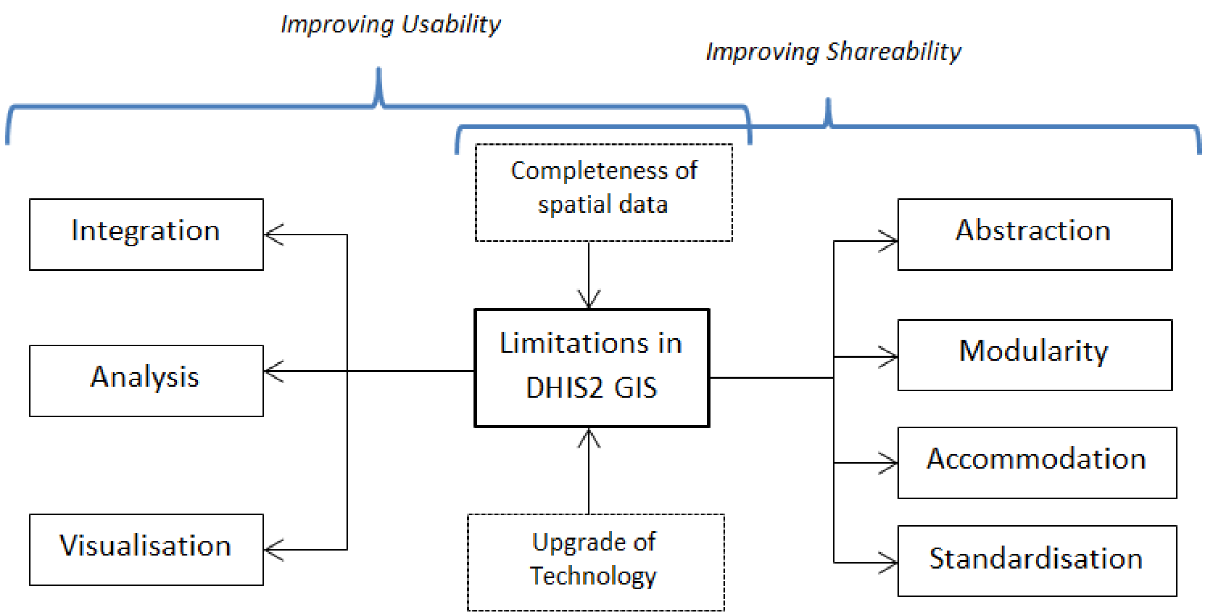

Figure 18: Proposed strategies for minimizing the limitations

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APPENDICES

Appendix 1: Interview guide for the research

The study is planned to collect data through semi-structured interviews with four groups; (1) Health program managers (Coordinators and UNICEF), (2) CMED officials, (3) HMIS officers, and (4) DHIS Technical Team. Each group has its guiding questions as summarised in the following sections.

Interviews with CMED officials
CMED officials will be interviewed on GIS implementation background and strategy.

- What does your work involve?
- What prompted the MoH to decide on using GIS? - Background
- Are there any policies to guide GIS implementation?
- GIS implementation is a process, so far what has the MoH done?
- Does the MoH have enough capacity to do the implementation? Any areas you may require assistance?

Interviews with Health Program Managers
Health programs managers will be interviewed on user needs

- What does your work involve?
- Where do you get the data from and how?
- How do you capture data into DHIS?, Does your program have any forms which are used?
- Which are the indicators your program use in DHIS?
- Do you share data with other program managers? How?
- How do you normally present your data and information in your reports?
- What challenges do you encounter when accessing the data and information from DHIS?
- When you report the problems to ICT Team, how long does it take for you to get assisted?
- Is there any other data that you would feel would have been captured that is essential to your work?
- How effective are the reports from DHIS towards your decision making?
- Do you think that introduction of maps will enhance your decision making?

Interviews with HMIS Officers
HMIS officers will be interviewed on data management and the technical support they provide at district health offices.

- What does your work involve?
- Where do you get the data from?
- How do you collect and capture the data into the system?
- How do you extract data from DHIS?
- Is there any data you wish to be captured? If yes, what type of data and why is it not captured?
- What technical skills do you have for your work?

- What challenges do you encounter on your day-to-day work?
- Do you know anything on GIS? To what extent?

Interviews with DHIS Technical Team

DHIS Technical Team members will be interviewed on the technical support they provide at national level.

- What type of technical support do you provide to DHIS users?
- What frequent problems do you have from the users or the DHIS system?
- What skills do you have for your technical support provision?
- Have you ever attended a special training for DHIS support?
- Are you conversant with GIS? Explain
- What challenges do you encounter on your day-to-day work?

Appendix 2: Ethical clearance letter from National Health Sciences Research Committee

Telephone: + 265 789 400
Facsimile: + 265 789 431
e-mail mohdoccentre@gmail.com
All Communications should be addressed to:
The Secretary for Health

In reply please quote No. MED/4/36c
MINISTRY OF HEALTH
P.O. BOX 30377
LILONGWE 3
MALAWI

9th February 2016

Gloria Chisakasa
Chancellor College

Dear Sir/Madam,

Re: Protocol #16/2/1544: Application of GIS in Health Management in Malawi-Case of DHIS2

Thank you for the above titled proposal that you submitted to the National Health Sciences Research Committee (NHSRC) for review. Please be advised that the NHSRC has **reviewed** and **approved** your application to conduct the above titled study.

- **APPROVAL NUMBER** : **NHSRC # 16/2/1544**
  The above details should be used on all correspondence, consent forms and documents as appropriate.
- **APPROVAL DATE** : **09/2/2016**
- **EXPIRATION DATE** :This approval expires on **09/2/2017**
  After this date, this project may only continue upon renewal. For purposes of renewal, a progress report on a standard form obtainable from the NHSRC secretariat should be submitted one month before the expiration date for continuing review.
- **SERIOUS ADVERSE EVENT REPORTING** :All serious problems having to do with subject safety must be reported to the National Health Sciences Research Committee within 10 working days using standard forms obtainable from the NHSRC Secretariat.
- **MODIFICATIONS**: Prior NHSRC approval using standard forms obtainable from the NHSRC Secretariat is required before implementing any changes in the Protocol (including changes in the consent documents). You may not use any other consent documents besides those approved by the NHSRC.
- **TERMINATION OF STUDY**: On termination of a study, a report has to be submitted to the NHSRC using standard forms obtainable from the NHSRC Secretariat.
- **QUESTIONS**: Please contact the NHSRC on Telephone No. (01) 789314, 0888344443 or by e-mail on mohdoccentre@gmail.com
- **Other:**
  Please be reminded to send in copies of your final research results for our records as well as for the Health Research Database.

Kind regards from the NHSRC Secretariat.

SECRETARY FOR HEALTH
2016 -02- 09
P.O. BOX 30377, CAPITAL CITY, LILONGWE 3

....
FOR CHAIRMAN, NATIONAL HEALTH SCIENCES RESEARCH COMMITTEE

PROMOTING THE ETHICAL CONDUCT OF RESEARCH
Executive Committee: *Dr.B.Chilima (Chairman), Dr B. Ngwira (Vice Chairperson)*
Registered with the USA Office for Human Research Protections (OHRP) as an International IRB
(IRB Number IRB00003905 FWA00005976)

Appendix 3: Authorisation letter to use data in DHIS2

Telephone: + 265 1 789 400
Facsimile: + 265 1 789 431

All Communications should be addressed to:
The Secretary for Health

In reply please quote No. ………………

MINISTRY OF HEALTH
P.O. BOX 30377
LILONGWE 3
MALAWI

Ref. No. HMIS/ 14 **4 February 2016**

TO: University of Malawi
The Malawi Polytechnic
Private Bag 303
Chichiri
Blantyre 3

Dear Ms. Chisakasa,

RE: APPLICATION TO USE DATA FROM DHIS 2 FOR ACADEMIC RESEARCH

I refer to your letter dated 30 November 2015 in which you requested for access to use data from DHIS 2 for academic research titled "Application of GIS in Health Management in Malawi – Case of DHIS 2".

I am pleased to report that the Ministry will allow you access to the data in order to conduct your research. When you are ready to access the data please present your Ethical Clearance approval letter. Alongside this letter please also fill in and submit a data request form which will be made available from the Central Monitoring and Evaluation Division upon request.

I wish you success with your research.

Sincerely,

Rhino Mchenga
For:SECRETARY FOR HEALTH

Appendix 4: Authorisation letter to visit DHOs

<u>REF. No. HMIS/ 14</u> 31st October, 2016

FROM : THE SECRETARY FOR HEALTH, P.O BOX 30377,
LILONGWE 3;

TO : THE PROGRAMME MANAGER, MALARIA;
: THE PROGRAMME MANAGER, NUTRITION;
: THE PROGRAMME MANAGER, FAMILY PLANNING;
: THE DISTRICT HEALTH OFFICER, MCHINJI;
: THE DISTRICT HEALTH OFFICER, BLANTYRE.

IMPLEMENTATION OF DHIS2

The Department of Computing and Information Technology at The Polytechnic, University of Malawi is facilitating the implementation of DHIS2 GIS, with support from University of Oslo, Norway. The first step of setting up the DHIS2 GIS was done in September, 2016.

In order to get feedback from end-users of the system to make improvements, the lead partners Mr Patrick A. Chikumba, and Ms Gloria Chisakasa from the University of Malawi would like to visit your department/district to have discussions with the HMIS and IT Officers. The visits will be conducted from November 2016 to January 2017. We therefore request the support of the HMIS or IT officers, when the partners visit your office.

Please contact Mr Chikumba on 0885 123 533 or patrick_chikumba@yahoo.com for any further clarification that may be required.

Isaac Dambula
For:**SECRETARY FOR HEALTH**

Appendix 5: Sample of spatial data collected for Blantyre health district facilities

	SPAID	DHSCC	FIPSCC	SPAYEAR	SPAFACID	SPA_Facility_Name	ADM1CODE	ADM1NAME	SPAREGCO	SPAREGNA	SPATYPEC	SPATYPEN	SPAMANGC	SPAMANGN	SOURCE	LATNUM	LONGNUM	DATUM
2	MWSPA201300010745	MW	MI	2013	10745	Queen Elizabeth Central Hos	20	Blantyre	3	South	1	Central Hospit	1	Government/public	GPS	-15.802140	35.021000	WGS84
3	MWSPA201300010746	MW	MI	2013	10746	Blantyre City Assembly Clinic	20	Blantyre	3	South	8	Clinic	1	Government/public	GPS	-15.803330	35.038950	WGS84
4	MWSPA201300010747	MW	MI	2013	10747	Bangwe Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.823820	35.080460	WGS84
5	MWSPA201300010748	MW	MI	2013	10748	Chabvala Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.833720	34.834610	WGS84
6	MWSPA201300010749	MW	MI	2013	10749	Chikowa Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.671330	34.871720	WGS84
7	MWSPA201300010750	MW	MI	2013	10750	Chileka Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.685750	34.970140	WGS84
8	MWSPA201300010751	MW	MI	2013	10751	Chilomoni Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.771280	34.981560	WGS84
9	MWSPA201300010752	MW	MI	2013	10752	Chimembe Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.777330	34.885480	WGS84
10	MWSPA201300010753	MW	MI	2013	10753	Dziwe Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.563690	34.880380	WGS84
11	MWSPA201300010754	MW	MI	2013	10754	Limbe Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.816880	35.051760	WGS84
12	MWSPA201300010755	MW	MI	2013	10755	Lirangwe Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.529630	35.029730	WGS84
13	MWSPA201300010756	MW	MI	2013	10756	Lundu Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.421850	35.012940	WGS84
14	MWSPA201300010757	MW	MI	2013	10757	Madziabango Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.967800	34.908250	WGS84
15	MWSPA201300010758	MW	MI	2013	10758	Makata Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.629960	35.079640	WGS84
16	MWSPA201300010759	MW	MI	2013	10759	Mdeka Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.467690	34.942360	WGS84
17	MWSPA201300010760	MW	MI	2013	10760	Mpemba Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.873850	34.952300	WGS84
18	MWSPA201300010761	MW	MI	2013	10761	Namikoko Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.486510	35.073790	WGS84
19	MWSPA201300010762	MW	MI	2013	10762	Ndirande Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.778100	35.039460	WGS84
20	MWSPA201300010763	MW	MI	2013	10763	South Lunzu Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.726780	35.054710	WGS84
21	MWSPA201300010765	MW	MI	2013	10765	Sanjika Clinic	20	Blantyre	3	South	8	Clinic	1	Government/public	GPS	-15.792670	34.972880	WGS84
22	MWSPA201300010767	MW	MI	2013	10767	Zingwangwa Health Centre	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.821400	35.011970	WGS84
23	MWSPA201300010768	MW	MI	2013	10768	Blantyre Adventist Hospital	20	Blantyre	3	South	4	Other Hospita	2	Christian Health Associati	GPS	-15.782400	35.003100	WGS84
24	MWSPA201300010769	MW	MI	2013	10769	Mlambe Hospital	20	Blantyre	3	South	4	Other Hospita	2	Christian Health Associati	GPS	-15.644660	35.017330	WGS84
25	MWSPA201300010770	MW	MI	2013	10770	Chileka SDA Health Centre	20	Blantyre	3	South	5	Health Centre	2	Christian Health Associati	GPS	-15.659860	34.929040	WGS84
26	MWSPA201300010771	MW	MI	2013	10771	Malabada Health Centre	20	Blantyre	3	South	5	Health Centre	2	Christian Health Associati	GPS	-15.767590	35.044460	WGS84
27	MWSPA201300010772	MW	MI	2013	10772	St Vincent Health Centre	20	Blantyre	3	South	5	Health Centre	2	Christian Health Associati	GPS	-15.914210	34.949840	WGS84
28	MWSPA201300010773	MW	MI	2013	10773	Soche Maternity	20	Blantyre	3	South	5	Health Centre	1	Government/public	GPS	-15.857260	35.027610	WGS84
29	MWSPA201300010774	MW	MI	2013	10774	Soche SDA Dispensary	20	Blantyre	3	South	8	Clinic	2	Christian Health Associati	GPS	-15.809180	35.019770	WGS84
30	MWSPA201300010776	MW	MI	2013	10776	Dr Chilemba Surgery	20	Blantyre	3	South	8	Clinic	3	Private for profit	GPS	-15.786400	35.000800	WGS84
31	MWSPA201300010777	MW	MI	2013	10777	Dr Dzinyemba Private Clinic	20	Blantyre	3	South	8	Clinic	3	Private for profit	GPS	-15.786090	35.006630	WGS84
32	MWSPA201300010779	MW	MI	2013	10779	Dr S. Kampondeni	20	Blantyre	3	South	4	Other Hospita	3	Private for profit	GPS	-15.816410	35.066290	WGS84

Appendix 6: Map showing village and outreach clinics for Mchinji, Lilongwe and Dedza health districts with 5Kms buffer zones extracted from DHIS2 GIS