UNIVERSITY OF OSLO
Department of Informatics

Mapping Malaria Cases Using Geographic Information Systems: A Case Study From Mozambique

Master Thesis

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Dedicated to

My wife **Caldina** and our daughter **Xaron**.

ABSTRACT

This research is based on understanding the challenges related to the design, development and implementation of a GIS tool for mapping malaria in developing countries and Mozambique in particular. The research investigate the current practices and tools used for monitoring and controlling malaria in the current health information system. Assessing of potentialities and challenges of using GIS in monitoring and coordinating malaria control efforts, and devising strategies that can be used to address challenges associated with using GIS to monitor and control malaria were the specific objectives of the research. The research aimed at exploring GIS and interactively explore spatial data and non-spatial data (malaria routine data) to address malaria problems.

The research setting was the community health department within the Ministry of Health in Mozambique. The field work was conducted in one province, the Inhambane province, in order to answer the three research questions that guided the study, namely: How can GIS be used to improve the mapping of Malaria and decision-making in Mozambique?; What are the challenges associated with using GIS in mapping Malaria?; and What strategies can be used to overcome these challenges?

A case study research design and action research framework were used with a focus on the Ministry of Health and Community Health Department more specifically. The challenges experienced were studied using qualitative research methods that helped to inform both the data collection methods and analysis. To analyse the problems addressed in this thesis, I drew upon theories and concepts in two areas: Geographic Information System and Information Infrastructure. This thesis makes contributions to both theoretical and practical domains.

Keywords: Geographical information systems, malaria, mapping malaria, Mozambique.

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LIST OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
ANT	Actor Network Theory
BES	Bolentim Epidemioloógico Semanal
DDS	Direcção Distrital de Saúde
DPS	Direcção Provincial de Saúde
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System
GPS	Global Positioning System
HISP	Health Information System Programme
HIS	Health Information System
HIV	Human Immunodeficiency Virus
HMN	Health Metrics Network
ICT	Information Communication Technology
II	Information Infrastructure
ITN	Insecticide-Treated Net
IS	Information System
IT	Information Technology
MB	Módulo Básico
MDG	Millennium Development Goal
MoH	Ministry of Health
MISAU (MoH)	Ministerio de Saúde (Ministry of Health)
NGO	Non-Governmental Organization
NMCP	National Malaria Control Programme
RHINO	Routine Health Information Network
SIS	Sistema de Informação de Saúde
SISProg	Sistema de Informação de Saúde Program
TB	Tuberculosis
UCM	Universidade Católica de Moçambique
UEM	Eduardo Mondlane University
WHO	World Health Organisation

Chapter

1 INTRODUCTION

This chapter presents an introduction to the topic of mapping malaria using geographic information system. It presents the research domain; research questions; the main objectives of the research; the target audience of the research; the personal motivations and the organization of the thesis.

1.1 Introduction

This thesis will consider issues surrounding the use and development of open source geographical information system (GIS) as a possible solution for malaria research and control in developing countries with its focus in Mozambique. The base for this thesis is the field work done in one Mozambican province in cooperation with the Health Information System Program Mozambique (HISP Mozambique).

The essence of this thesis is to enable decision-making by using GIS solutions. The basis to do better decision is having reliable malaria data. Malaria is a serious vector-borne disease affecting a greater proportion of the world's population than any other vector-transmitted disease. This vector-borne disease is maintained under the influence of diverse ranges of interacting conditions, many of which are not well understood. These conditions are closely related to the habits and lifestyle of different communities; the behavior of the mosquitoes which transmit the disease; as well as climatic and other environmental attributes (Sweeney 1998).

The World Health Organization (WHO) estimates that each year 300-500 million cases of malaria occur and more than 1 million people die of malaria, especially in developing countries. Most deaths occur in young children below 5 years. For example, in Africa a child dies from malaria every 30 seconds (WHOa 2006).

The number of malaria cases increase every year. The increase in malaria prevalence is determined by several factors: mosquito resistance to insecticides, parasite resistance to drugs, changes in land-use patterns, and reductions in funding and manpower dedicated to control activities (Bretas 1996). Most of the determinants are heterogeneously distributed, changing over both space and time. Factors such as topography, temperature, rainfall, land use, population movements, and degree of deforestation have a profound influence on the temporal and spatial distribution of malaria vectors and malaria. The study of environmental determinants of malaria has been hampered by the difficulties related to collecting and analysing environmental data over large areas, and to the speed of change in the malaria epidemiological situation.

Geographic Information Systems (GIS), remote sensing, and Global Positioning System (GPS) are important tools for the study and control of malaria. Regarding the storage, collection, analysis and management of geographic data, Africa and in particular Mozambique is still facing problems, although there are some evidences in reversing the scenario. Large amounts of information are necessary for almost all aspects of malaria control programs.

GIS offer the capabilities to process quantities of data beyond the capacities of manual systems. Data are stored in a structured digital format, which permits rapid retrieval and use. In addition, data may be quickly compiled into documents, using techniques such as automatic mapping and direct report printouts.

1.2 Research issues addressed in this thesis

1.2.1 Research domain

The health status of any society or country is an important indicator of human development (Sheikh 2005). Most people rely on public healthcare services; therefore the condition of public healthcare largely determines this human development indicator. Yet public healthcare in most developing countries is in a state of shortage of resources in both material and personnel. This largely limits their capacity to improve the health status of the related population. A crucial task is to manage the provision of proper healthcare services to the related society based on the use of available resources while seeking more. To support this management, there is a need to develop a proper Health Information System (HIS), which will be a supporting tool for decision-making.

Wilson & Hedberg (2001) define a Health Information System (HIS) as "*a set of tools and procedures that a health program uses to collect, process, transmit, and use data for monitoring, evaluation and control*" (Wilson & Hedberg 2001, p.82). HIS is a functional part within the framework of a comprehensive healthcare system aimed at supporting the healthcare system, in order to improve the health of the population. The existence of an HIS in a community is fundamental. Therefore, HIS itself does not provide better health within the context of different levels of healthcare. Thus, there is a need for a tool that can help finding out regions or places where certain diseases demonstrate incidence and therefore define better strategies in order to fight against such diseases. In particular, for malaria, there is a need for a tool that can facilitate regions that are potential points of incidence of that disease.

Malaria accounts for a large percentage of Mozambique's disease burden. The mortality rate under-five in Mozambique is about 145/1000, and about 30% of the deaths are due to malaria, and the maternal mortality rate is estimated at 410/100,000 live births, with many of these deaths considered to result directly or indirectly from malaria infection (WHOa 2006).

The range of factors affecting transmission and distribution of vector-borne diseases, particularly malaria, include those related to temperature, humidity and precipitation. This highlights the need to collect, manage, display and analyze malaria data at the micro-level in order to understand the factors that result in the small scale, non-uniform transmission intensity. Thus, variation in both large (e.g. inter-annual climate variation) and small scale-variables (e.g. population movement, drug/insecticide resistance, etc.) result in a dynamic malaria situation that requires on-going research and management efforts to control it (Sharp et al. 2001).

1.2.2 Research otivations

Many developing countries are engaged in implementing geographical information systems for malaria research and control. Some countries reported include South Africa (Martin et al. 2002), India (Sipe & Dale 2003), and Kenya (Hightower et al. 1998, Omumbo et al. 1998), concentrating on developing systems that can help decision-making on malaria. Geographical information systems have allowed researchers to visualize distribution data on maps together with environmental parameters, such as rainfall and temperature (Coetzee et al. 2000).

However the situation in most developing countries, including some of the above mentioned, is still not satisfactory due to poor infrastructures with inadequate technical and financial support. Data on individual healthcare activities are irrelevant and of poor quality with the information produced not linking to a reference population (Lippeveld 2001). Moreover, the information is rarely used for evidence-based decision making. "[Most data] *remains unprocessed, or, if processed, unanalyzed, or, if analyzed, not read, or, if read, not used or acted upon* (Chambers 1994 cited in Lippeveld (2001)).

This situation therefore calls for more research to be done within the domain, hence motivation for doing this research. Personally, I am also motivated towards the practical contribution on the development of the GIS for Mozambique's healthcare system. The results of this research will therefore be very useful input to the improvement of the health management system, which is very important in management of the scarce available resources, so as to accomplish the Ministry's goal to provide sustainable and equitable high quality healthcare services to all Mozambicans.

More generally, I am interested in improving the social welfare of Mozambicans including myself. The courses taken in information systems development, which focused on social and technical perspectives of information systems development, helped me greatly in formulating more realistic strategies for this research in addition to my informatics background.

1.2.3 Research study

Malaria in Mozambique has varied entomological, epidemiological, and is endemic throughout the country, due to a multitude of factors such as climatic/environmental (favorable temperatures and rain patterns, abundant breeding sites) and socio-economical (poverty related improver housing/shelter, unaffordable preventive means) and ecological determinants and thus remains a major public health problem. The intensity of transmission may vary depending on the amount of rain and air temperature.

However, at present there is lack of good quality and updated information on the endemic levels in the country. Between 2002 and 2003 a country-wide malaria survey was carried out aiming to determine the prevalence and intensity of Plasmodium malaria infections, the prevalence and the severity of anemia in children under 10 years of age and in pregnant women across different ecological settings, in order to characterize the malaria transmission intensities and to estimate the disease burden in Mozambique. According to that survey, across the country approximately more than 2.6 million children less than ten years of age are infected with Plasmodium falciparum malaria parasites at any time and more than 3.8 million are anaemic. In addition, across the country more than 666,000 pregnant women are infected with Plasmodium falciparum malaria parasites at any time and more than 1.2 million are anaemic. Estimates of the disease burden caused by malaria are crucial for planning cost-effectively malaria control interventions, monitoring and advocacy (Mabunda 2006).

Although within the Ministry of Health (MoH) there are computer-based systems like MB (Módulo Básico) used for storing several epidemiological data like malaria, tuberculoses, cholera, HIV, leprosy, etc, these tools are not producing all required reports. Hence, the MoH and in particular the NMCP (National Malaria Control Program) tried to introduce HealthMapper, a surveillance and mapping application developed by WHO, but failed due to several impedances like lack of qualified human resources and data limitations.

Within the MoH there are constraints to have data according to its geographical distribution. That is, there is no easy ways of showing details for affected regions with cases of malaria. Therefore, the proposed study aims to address these issues as posed in the following research questions.

1.2.4 Research questions

The problems addressed in this research are expressed in the following questions:

1. How can GIS be used to improve the mapping of malaria and decision-making in Mozambique?

2. What are the challenges associated with using GIS in mapping malaria?

3. What strategies can be used to overcome these challenges?

1.2.5 Research objectives

The aim of this research is to broadly explore GIS and interactively explore spatial data and non-spatial data (routine malaria data) from Mozambique. The more specific objectives of the study include:

1. Investigating the current practices and tools used for monitoring and controlling malaria in Mozambique.

2. Assessing the potentialities and challenges of using GIS in monitoring and coordinating malaria control efforts.

3. Devising strategies that can be used to address challenges associated with using GIS to monitor and control malaria.

1.3 Target audience of this research

The results of this research are expected to be useful to a number of target groups including public health specialists, malaria researchers, information officers, health workers and administrators.

The intended audiences of this research work are GIS developers and researchers, who are involved in designing, implementing and maintaining geographic information systems. These groups mainly consist of computer professionals and GIS students and experts.

1.4 Organization of the thesis

This thesis is organized in seven chapters. This chapter (chapter one) deals with the introduction to the study and presented the research domain; research questions; the main objectives of the research; the target audience of the researc;, the personal motivations and the structure of the thesis.

Chapter two presents the research settings which include description of visited sites. Chapter three includes literature review and the theoretical framework for the thesis. Chapter three also reviews researches and studies carried out in the past; and present the theoretical base for analysis and discussion in chapter seven.

Chapter four describes the research method approach adopted and the different methods used in the research. The research findings are presented in chapter five and in chapter seven, discussion and conclusions of this thesis are drawn.

Chapter 2

RESEARCH SETTINGS

The purpose of this chapter is to provide an introduction to the settings comprising the present research. The study presented in this thesis is based on empirical research performed in Mozambique during the period of May to December 2008. More directly, the study was carried out within the Department of Community Health in the MoH and in one province, the Inhambane province. The chapter is organized in two broad sections. The first section provides an overall understanding of the background of Mozambique. This is, further divided into three subsections where the geography, demographic and social and economic contexts are described. The second section describes the Mozambique's healthcare which include background information of the health sector; disease surveillance systems; major health problems; Mozambique's health status; health system and finally health information system.

2.1 Geography, demographic, social and economic context of Mozambique

2.1.1 Geography of Mozambique

Mozambique stretches for 2,470 km along Africa's southeast coast and 784,090 sq km of extension. Tanzania is to the north; Malawi, Zambia, and Zimbabwe to the west; Indian Ocean to the east; and South Africa and Swaziland to the south (Figure 2.1). The country is generally a low-lying plateau broken up by 25 sizable rivers that flow into the Indian Ocean. The country is drained by five principal rivers and several smaller ones with the largest and most important the Zambezi, which provides access to Central Africa. The country has three lakes, Lake Niassa or Malawi, Lake Chiuta and Lake Shirwa, all in the north. The major cities are Maputo, Beira, Nampula, Tete, Quelimane, Chimoio, Pemba, Inhambane, Xai-Xai and Lichinga.

Figure 2.1: Map of Mozambique

Mozambique is divided into ten provinces and one capital city (Maputo) with provincial status. The provinces are subdivided into 129 districts. The districts are further divided in 405 Administratives Posts and then into Localities, the lowest geographical level of the central state administration. Since 1998, 43 Municipalities have been created in Mozambique.

One province was selected in order to conduct the fieldwork, the Inhambane provinces. Inhambane is located on the coast in the southern part of the country. It has an area of 68,615 sqr km. The provincial capital is also called Inhambane. Districts in Inhambane province include Funhalouro, Govuro, Homoine, Jangamo, Inharrime, Inhassoro, Mabote, Massinga, Morrumbene, Panda, Vilankulo, and Zavala (Figure 2.2).

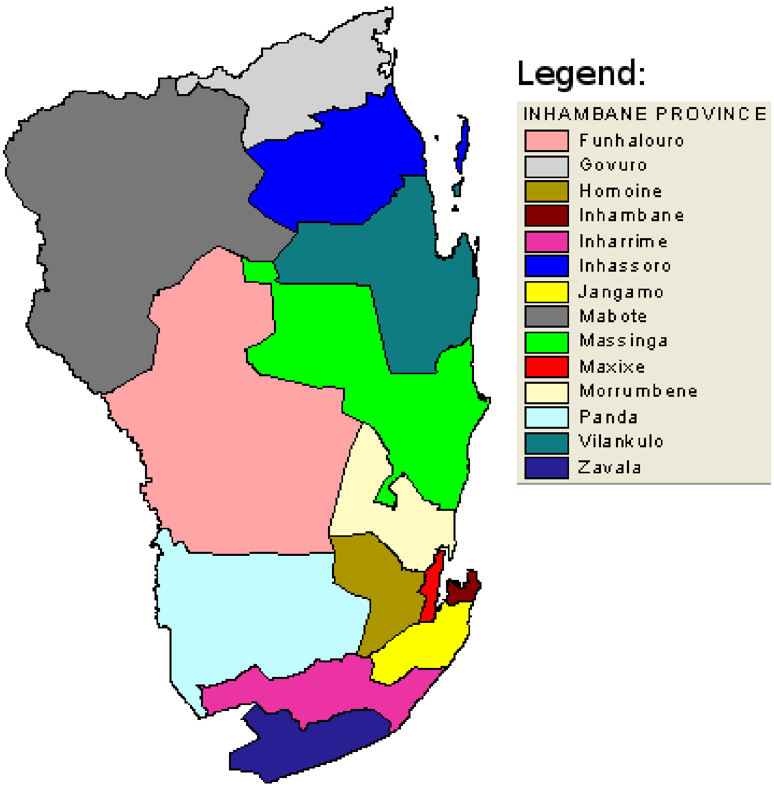


Figure 2.2: Inhambane province and its districts

Cities of Inhambane province are Inhambane (provincial capital) and Maxixe (largest population and economical capital). Four districts were visited: Jangamo, Maxixe, Inharrime and Massinga.

2.1.2 Demographics

The 2007 Mozambican census reported a population of 20.5 million, with 9.8 million males and 10.7 million females. The estimates for this country explicitly take into account the effects of excess mortality due to HIV/AIDS (the 2003 estimates of HIV/AIDS adult prevalence rate is 12.2%; HIV/AIDS - people living with HIV/AIDS: 1.3 million and HIV/AIDS - deaths: 110,000); this can result in lower life expectancy, higher infant mortality, higher death rates, lower population growth rates, and changes in the distribution of population by age and sex than would otherwise be expected. The age structure is as follow: 0-14 years: 44.5% (male 4,762,335/female 4,711,422); 15-64 years: 52.7% (male 5,472,184/female 5,736,154); 65 years and over: 2.8% (male 251,026/female 351,580).

Almost 73% of the population lives in rural areas and 70% lives below the poverty line; 23% are women of reproductive age and 46% are under 15 years of age. The crude birth rate is 45.2 per 1000 population, the death rate 18.6 per 1000, life expectancy is 46 (44.5 for men and 47.5 for women), and the population growth rate is 2.7% (data referring to the period 1996-2000).

2.1.3 Social and economic context of Mozambique

Since the signing of the 1992 Peace Agreement, Mozambique has been viewed as one of Africa's most successful stories of post-war reconstruction and economic recovery. The country held its third peaceful and democratic legislative and presidential elections in December 2004, reaffirming its commitment to political stability, democratic governance and national reconciliation.

The Government has engaged in an ambitious economic, social and political reform agenda, and has made efforts to consolidate macro-economic stability, as a result of which the country is experiencing strong economic growth, averaging eight percent between 1996 and 2006, and has made significant progress in reducing poverty.

In spite of these achievements, many development challenges remain. Mozambique remains one of the poorest countries in the world and was ranked 172nd out of 177 in the 2007/08 Human Development Index. The national Millennium Development Goal (MDG) progress report produced in 2005 indicated that of 11 MDG targets for which data were available, only five have the potential of being met without a considerable acceleration of efforts – those relating to poverty, under-five mortality, maternal mortality, malaria and the establishment of an open trading and financial system.

The single greatest threat to development in Mozambique is HIV and AIDS and the epidemic is threatening to undermine all of the results achieved by the Government over the last decade. Based on the prevalence of HIV among pregnant women attending antenatal care, the national HIV prevalence rate for 15-49 year-olds increased from 14% in 2001 to 16% in 2007 (UNM 2009).

Estimates indicate that AIDS may reduce the economic growth per capita by between 0.3 and 1.0 per cent each year. The reduction of poverty rates will be slower on account of weaker economic growth, a reduction in the accumulation of human capital and an increase in household dependency rates.

The Government has invested heavily in public sector reform, capacity development and an ambitious decentralisation programme, with the objective of improving efficiency, enhancing transparency and devolving responsibility from the heavily centralised state ministries to the provinces and districts. The limited operational and managerial capacity of some sectors remains a concern, however, particularly at the sub-national levels and in relation to the recruitment and retention of qualified human resources, a problem that is being exacerbated by the AIDS pandemic.

If Mozambique is to attain the MDGs, it requires an urgent halt and reversal of the incidence of HIV and malaria, improvements in the efficiency of service delivery to the poor, employment creation, increases in state revenue, reductions in foreign aid dependency, and effective preparedness for recurrent natural disasters. Particular focus will need to be placed on reaching the most disadvantaged communities in order to reduce the prevailing disparities, increase participation in development processes and ensure that the development gains are experienced by all Mozambicans.

Despite considerable economic and social gains in recent years, Mozambique is still one of the poorest countries in the world with a per capita income of US$240. Between 1996 and 2003 GDP grew by an average of 8% a year and the number of people living in absolute poverty fell from 69% to 54%. Rural poverty fell from 71% to 55%. There were also improvements in social well-being: infant mortality fell from 149 to 101 per thousand and access to clean water rose sharply, as did primary school enrolment and completion rates.

There is, however, another side to these figures. Most of the growth rate is due to the effect of mega projects that have little impact on the lives of ordinary people, illiteracy rates remain high, even more so for women, and the substantial increase in agricultural production is due more to increased area and labour than to increased productivity. Donor contributions still account for half the government's budget. In addition, many of the improvements only signify a recovery to the infrastructure, production and service levels that existed prior to the long period of conflicts in Mozambique. The legacy of the conflicts also persists. Although there is little probability of a renewed outbreak of war, its scars and divisions remain. In many areas there is still much latent tension that occasionally boils over into physical confrontation, especially because the two sides in the conflict are now also the country's two main political parties. Finally, despite constitutional guarantees of equality, women still suffer from male domination and exploitation.

In the late eighties, following major constitutional and economic policy changes, the country shifted from a one-party to a multi-party system, and from a centrally planned to a market economy. This period also saw a rapid rise in civil society organisations (CSO) and activities. Originally the result of donor pull rather than internal push, civil society is becoming stronger and more influential with every year that passes. In recent years its voice has been heard on many issues; economic policy, poverty, debt, corruption, gender and conflict.

2.2 Mozambique's healthcare

2.2.1 Health Sector

The Ministry of Health policy is to provide and preserve the health of Mozambicans population, to promote the delivery of good quality and sustainable services that are accessible to all Mozambicans with equity and efficiency. Consequently, the Health Sector Strategic Plan (HSSP) 2001-2005 lays emphasis on health care provision, capacity building of individuals and communities and health advocacy.

During the destabilization war, the public systems and structures were consistently destroyed with health and educational institutions being affected most. The war ended in 1992 and reconstruction started in 1994 with funding from World Bank and Africa Development Bank among other partners.

Health care services in Mozambique are provided by five levels of health systems:

1. Traditional Medicine and Community Health Workers: Though operating at the community level, is to some extent linked to formal service at peripheral level.

2. Health Post/Facility (HPs) and Health centre (HCs): This is a formal, but most peripheral level of the Health system in the country. This is a basic facility in often managed by one health worker who has elementary or basic health training. The facility offers curative and immunization services during normal official working hours.

3. Rural and General Hospital (RHs and GHs): This level provides essential preventive care, medical, surgical, maternity services and laboratory services. A medical officer manages the facility and an epidemiological surveillance (vigilante epidemiological) officer is usually located at the facility.

4. Provincial Hospital (PHs): This level receives referrals from the rural and general hospitals. The provincial hospitals are quite well equipped tertiary health care institutions. They provide comprehensive care just like district hospitals but in addition provide learning facilities for medical training institutions.

5. Central and specialised Hospitals (CHs): These are located in Maputo, Beira and Nampula. They serve as referral centres for the population within their catchment areas.

2.2.2 Disease surveillance system

In 1979, the MoH created the epidemiological surveillance system with a long list of diseases to be reported by all health facilities. In 1985, the system was revised with the establishment of two sub-systems known as BES (Boletim Epidemiológico Semanal) and BEM-PS (Boletim Posto Sentinela).

The BES is the weekly epidemiological report by all health facilities. It includes epidemic prone diseases and diseases of national importance such as measles, neonatal tetanus, AFP, whooping cough, diarrhoea, cholera, dysentery, rabies, plague, Meningococcal, meningitis and malaria.

The BEM-PS is a sentinel surveillance of a limited number of diseases by central (3) and provincial hospitals (7) reporting monthly. To reinforce the surveillance system the reporting of monthly summary of data on hospitalisations in rural hospitals and HCs was started in 1990. In 2001, the country conducted the first assessment of the surveillance system and in 2005 the non-communicable diseases (Hypertension, cardiovascular, accidents, diabetes, mellitus, trauma, asthma, and cancer), were introduced in the sentinel reporting system or better known as the BEM-PS.

2.2.3 Major health problems

The major cause of morbidity and mortality in the country is malaria, HIV/Aids, tuberculosis, respiratory infections, diarrhoea, measles and meningitis. The country is vulnerable to disasters due to cyclones, floods and other times drought. There have been frequent outbreaks of cholera, dysentery, meningococcal and meningitis. Sporadic outbreaks of plague have occurred in the country. Surveillance reports indicate that non-communicable diseases, particularly cardiovascular diseases, diabetes and injuries are on the rise.

2.2.4 Mozambique's health status

The epidemiological framework in Mozambique is dominated by communicable diseases, infections diseases and parasites, namely malaria, diarrhea, respiratory infections, tuberculosis and HIV/AIDS. HIV/AIDS is an increasingly serious problem, affecting the economically active population; 42% of the population have HIV/AIDs while tuberculosis and malaria are also major problems. There are currently an estimated 1.5 million people living with HIV or AIDS in the country, constituting a prevalence rate of 13.6 percent (721,803 male and 920,130 female).

With an estimated prevalence of HIV infection among adults ages 15 to 49 of 12.5 percent (UNAIDS 2008), Mozambique ranks among the 10 most affected countries in the world. An estimated 500 people are infected every day. Of adults living with

HIV/AIDS, an estimated 57 percent are women. Indeed the national rate of HIV prevalence masks considerable regional differences, with adult prevalence rates being estimated at 13.2 percent for the south, 16.5 percent for the centre and 5.7 percent for the north of the country (CHG 2008).

Apart of HIV/AIDS, malaria accounts for a large percentage of Mozambique's disease burden. Under-five mortality rate in Mozambique is about 145/1000, with malaria accounting for 60% of child paediatric hospital admissions and 30% of hospital deaths due to malaria. The maternal mortality rate is estimated at 410/100,000 live births, with many of these deaths considered to result directly or indirectly from malaria infection. The true scale of the economic losses attributable to malaria in-country is unknown, but it severely limits productivity and reduces school attendance.

According to the situational analysis carried out in Mozambique in 2000, malaria is the major cause of health problems, being responsible for 40% of all outpatients. Up to 60% of paediatric inpatients are due to severe malaria. The estimated prevalence rates in the 2 to 9 year age group varies from 40 to 80%, with 90% of children under five infected by malaria parasites in some areas (WHO 2008). Most of the cases are severely affecting children and pregnant women. Apart from the humanitarian concern, malaria constitutes a barrier to economic development. Currently available public health measures are failing to bring the disease under control. It is therefore essential to develop new and improved technologies and drugs to begin to achieve the Millennium Development Goal (MDG) of halting and reversing the incidence of malaria and reducing child and maternal mortality by 2010.

Mozambique is prone to natural disasters such as drought, cyclones and floods, and these can contribute to dramatic increases in malaria transmission. Access to health care in Mozambique is very low and an estimated 50% of the population lives further than 20 kilometers from the nearest health facility, a situation which shows that a large part of the population lacks access to health services. Malaria is also a major problem affecting pregnant women in rural areas. Approximately 20% of pregnant women are infected by the parasite, first time pregnancies are the most affected, with a 31%

prevalence rate. Anaemia, very often associated with malaria, is a serious problem and 68% of pregnant women have a haematocrit below 33% (MoH 2006).

Mozambique has very high rates of infant, child, maternal and adult mortality. The maternal mortality rate (MMR) prevailing in the country is considered among the highest in the world, with its total of 107.84 deaths/1,000 live births and 110.67 deaths/1,000 live births for male and 104.97 deaths/1,000 live births for female (2008 est). Mozambique accounts for a high degree of risk for infectious diseases like bacterial and protozonal diarrhea, hepatitis A, and typhoid fever as of vector-borne diseases like malaria and plague. These epidemics are more likely to occur in unstable environments, particularly in urban areas, and are caused by overpopulation in cities and towns by people who migrated searching for security during the 16 years of civil war.

The Mozambican birth rate is approximately 38.21 births/1,000 population, while the death rate is approximately 20.29 deaths/1,000 population (2008 est.). 70% of the pupulation is below poverty line. The low literacy rate, 47.8% of total population and 63.5% for male and 32.7% for female (2003 est.), regional inequalities in access and consumption of healthcare services and unfavorable environments to good health such as limited supply of safe drinking water all aggravate the health situation in Mozambique (MoH 2001). The HIV and AIDS epidemic in Mozambique has a woman's face: the prevalence among women in the 15-24 age group is 2.5 times higher than that among men. In addition to the human cost of HIV and AIDS, the epidemic is also threatening to seriously weaken institutional capacity and decrease economic productivity through the loss of manpower.

2.2.5 Health system

The health system in Mozambique is provided by the "Ministério de Saúde" (MISAU), Ministry of Health through hospitals, health centres and health posts. The Health budget is a priority for Mozambique, it will cut from other areas before cutting from health. MISAU has 2 areas of expenses:

- Current (medicines and salaries), and

- Investment

Donors sometimes give funds for specific programs. This can either be by Mozambique providing a specific project and then finding a donor or the project proposed by MISAU is part of strategy of donor. Sometimes donors fund part of a project and ask the government to fund another part; this sometimes limits some projects. For example donors will help with building a hospital, but not recurrent costs.

The public sector is complemented by services being provided by the Private sector (mainly in large cities) and NGOs. There are 3 levels of organisation of health, national, provincial and then finally at the district level. The lowest level of care is provided by Health Posts (total of 638, 27,674 people per Health Post). Between the Central Hospitals and the Health Posts there are the following types of health dispensing units: Health Centres, Rural Hospitals, Provincial or General Hospitals. These different centres provide different services and have different types of personnel present. These vary between centres and between cities.

At both hospitals and some health centres the first port of call is the Banco de Socorso (literally Bank of Help). This serves as the equivalent to the emergency room, but unfortunately due to the workload of the health centres and hospitals it is not always used for this purpose. Resources are not equally allocated throughout the country. The divisions are primarily between urban and rural populations and between the poor and rich (Chao & Kostermans 2002).

The challenges that Mozambique faces with regard to health are:

- 30-50% of the population have access to basic preventive and curative health services, which means that they live within 10kms of a health facility.
- High level of communicable diseases (13% of adults living with HIV/AIDS, 18,108 cases of Malaria per 100,000 (UNDP 2002))
- Lack of staff (599 “Superior Health Personnel” (INE 2002) in the whole country, including 400 Mozambican doctors)
- General lack of resources from paper and desks to medical equipment and medicines.

It is also important to note that Traditional Doctors or Curandeiros, play an important role in providing health care to both rural and urban populations. As many people do not have access to modern medicine, Curandeiros are their only source of care.

In MISAU's 2005-2010 Strategic Plan has as its aim to achieve for all Mozambicans health levels close to those of the rest of sub-Saharan Africa with access to basic health services and good quality through a health system that responds to its citizen's expectations. The mission to improve the health services is guided by the following principles:

- Efficiency and equity;
- Flexibility and diversification;
- Partnership and community participation;
- Transparency and accountability'
- Integration and coordination.

Mozambique's law on Non Communicable Diseases states that care for people suffering from chronic conditions should receive all the aspects of their care for free.

2.2.6 Health information system in Mozambique

The health information system (called SIS – Sistema de Informação de Saúde) in Mozambique was created in 1976. In the meantime, the system has been trying to accompany the developments of a system of information at regional and global level. However, due to limitations this is still far from being considered a good system.

In 1979, the MoH established a mechanism of data collection at every health facility of the national health system, based on annual inquiry records that led to the first national panorama of the country's situation. In 1985, a system of notification of communicable diseases through sentinel sites was introduced. In 1997, a system of obligatory notification was introduced for a list of communicable diseases on a weekly basis for every health facility.

The SIS that was under the Planning and Cooperation Department of the MoH, is now placed at the National Health Institute where the Disease Surveillance Unit is operating within the Health Information Department.

The SIS in Mozambique is facing serious problems with lack of information. To overcome the lack of information, Demographic and Health Surveys and the MoH have been doing some studies on morbidity. The first study was conducted in 2003 and the next is planned for 2009/10. In the last 5 years were conducted researches about

- prevalence of malaria parasitemia in pregnant women (2001);
- prevalence of malaria parasitemia in children from 2 - 9 years (2001),
- prevalence of deficiency of vitamin A in women of childbearing age (2002),
- prevalence of anemia in women of childbearing age (2002);
- prevalence of lack of iodine in school children (2004);
- prevalence of goiter in children from 6 to 12 months (2004);
- prevalence of HIV/AIDS (2004),

In 2001, the MoH conducted a study on the main causes of death in Maputo, Beira Chimoio and Nampula cities, with WHO support. In 1989-90, the registration and data collection processes were updated, and guidelines and tools on Health Information Systems for district and provincial levels were produced. In 2003, the Government of Mozambique, based on the Health Sector Strategic Plan (PESS), approved the "Health Information System Development Programme". In 2007, the National Institute of Statistics (INE) in collaboration with the MoH and the Civil Registration Office planned a study on the causes of death in the country.

Routine Health Information System

Like in many African countries, this system still faces some organizational difficulties, lack of quality data, poor analysis, the problem of transmission and the problem of timely use of information by producers. Several efforts have been made to overcome these barriers as the following shows.

In 1979, the MoH established a mechanism for collecting data from all health units (health facilities) (U.S.) of the NHS (Sistema Nacional de Saúde) based on survey sheets type annual survey. Based on this mechanism it was possible to obtain the first national picture of the situation of the country. The first organized system, structured, standardized data collection system emerged in 1982. The initiative of structuring the system essentially involved the standardization of methods of recording and the inclusion of epidemiological indicators.

The information system for health established in 1982 still had limitations and malfunctions so that the Ministry of Health (MOH), recognizing that an information system correct, complete, timely, useful and usable was essential for effective and efficient management of health services. In 1989, the MoH decided for the first review and reformulation of the system in order to make it more relevant to the degree of development of the NHS and more useful and appropriate to decision-making at different levels and organization of health services.

Indeed, in 1989-90 the MoH updated the registration process, collecting data following several principles such as simplify the forms and registration books and eliminate duplication of data; reduce the amount of data to be recorded and collected; define the minimum necessary information so that each level and sector can respond to their functions; gradually reduce in correspondence to each level the amount of data sent to the higher levels and streamline the flow so that one sector at each level (district, provincial and central) has the overall responsibility to control the arrival of the monthly statistical summaries.

Since then, various sub-systems have been created leading to a duplication of information collection, dispersion of data, lack of credibility given to the mother's data system (DIS) and poor production of statistical reports. In an attempt to solve this problem the restructuring and reorientation of the SIS for the purpose of restoring the reliability, increase comprehensiveness of the information system and start the integration of different systems into a single system, were created and approved in 2006.

Epidemiological surveillance deserves a special mention for keeping the ability to record data about notifiable diseases. The notification of transmissible diseases began in 1989 by the use of BE-PS (Boletim Epidemiológico dos Postos Sentinelas) including notification of diseases of differential diagnosis done by central and provincial hospitals. In 1997, the system of compulsory notification of a weekly list of diseases in all health facilities in the country, was introduced.

Information flow

The flow of information defined in the standards of the SIS allows, among others, to achieve the following objectives: (i) monitor the arrival of the summaries; (ii) ensure the quality of data and information; and (iii) provide timely data and information needed at different levels and sectors.

Thus the reception and transmission of data are concentrated at each level in a single sector, that is, NEP (Nucleo de Estatisticas e Planificacao) in District Health Directorate (DDS), the Provincial Department of Planning and Cooperation (DPPC) in the Provincial Health Directorate (DPS), and the Department of Information System at the central level (Figure 2.3).

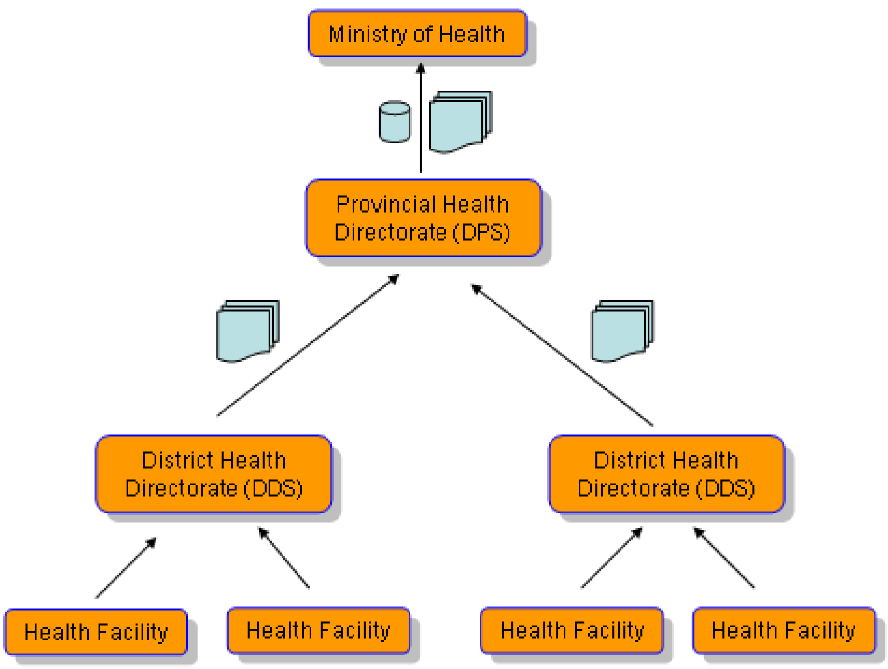


Figure 2.3: Information Flow in Mozambique Health System

These sectors not only have an overview of services and programs of health within their area of health but also have the flow under control and ensure the validation of information.

Use of computer applications to support the SIS

Since 1992 / 1993 the MOH has been using computer applications to support information system. The first system was called SIS-Prog. The SIS-Prog was developed in the early 90s using the technology then available. Today this application is inadequate to meet the current needs in terms of information for health, taking into account not only large technological developments occurring in recent years but also to obtain other types of systematic and integrated information.

Given this limitation, it was developed another system called SIMP was developed, and then the SIS-MB (Módulo Basico SIS) with the vision to provide a robust application, simple and compatible with subsequent developments within the shortest possible time, for the whole country. Some of the most important characteristics of the new system are data entry for the monthly forms; listing and printing aggregated data (for different levels and periods). All aggregate data are printed on the original format of the chips; export and import of data between computers in different levels (district/province/central) and different periods; input data of the population; and backup of data on hard disk, floppy, ZIP disk, Memory 'Flash', etc ...).

2.3 Summary

This chapter provided a description of the settings of the research including details of the demographic and socio-economic context. Also, a background of the Mozambique's healthcare which include health sector, health status, health system and health information system were developed.

Chapter

3 LITERATURE REVIEW

This chapter provides a review of relevant literature and presents the theoretical background relevant to this thesis. The research topics and theories reviewed here will be reflected in the empirical study and furthermore in the discussions and analysis, and interpretation of the findings of this study. For that, the following sections are presented: section 3.1 presents a discussion on HIS including HIS in developing countries. Section 3.2 presents a discussion of GIS. This discussion includes a discussion of GIS in developing countries, and GIS application to health information systems. Still in this section, particularly in subsections 3.2.2 and 3.2.4, discussions on advantages and limitations of GIS in public health are presented. Finally, section 3.3 discusses the Information Infrastructure theory and an argument for it to be suitable to conceptualize GIS as an Information Infrastructure, is drawn.

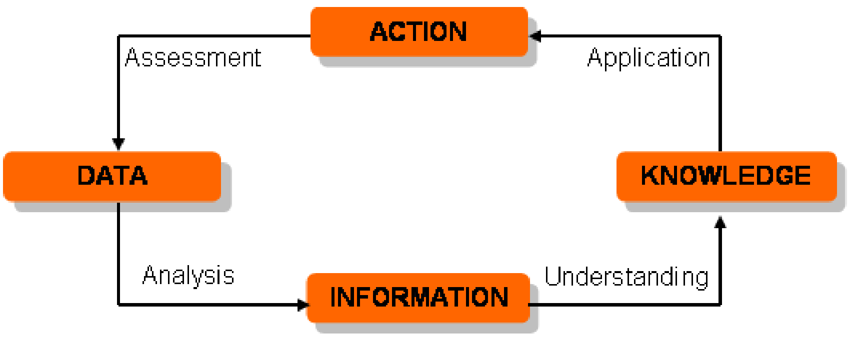
3.1 Health Information System

An Information System (IS) can be defined as "*a powerful collection of interrelated components that work together to achieve some objective*" (Sommerville 2001, p.21). An information system is developed and maintained to support, manage and define processes of collection, aggregation, use and flow of information and it involves three main components: people, technology and the systems environment. An Information system also comprises human and technical components. This idea is supported by Heeks when he defines information systems as "*...systems of human technical components that accept, store, output and transmit information. They may be based on any combination of human endeavours, paper-based and IT*" (Heeks 1998, p.5).

Introduction of IS in developing countries, as argued by Braa & Nermunkh (1997), is more complex as compared to that in developed countries due to its actions and dynamics which are primarily based on technology and use of computers. Therefore, the focus when approaching an IS should be on the people within the context and processes of technological learning, and not primarily on the technological elements of the IS (Braa & Hedberg 2000).

A generic label for different types of ISs used in health care can be viewed as Health Information System (HIS). Lippeveld (2001) sees HIS as "*an integrated effort to collect, process, report and use health information and knowledge to influence policy-making programme action and research*" (Lippeveld 2001). An HIS may include computer equipment, procedures and personnel designed, constructed, operated, and maintained to collect, record, process, retrieve and display information specific to the health domain. In the definition of Lippeveld (2001) it remains clear that health information is much more than the collection of data. Data have no value in themselves – value and relevance come only when they are analysed, transformed into meaningful information, and used (Figure 3.1).

Figure 3.1: The data for action cycle



An HIS is not a static entity but a process through which health-related data are gathered, shared, analysed, and used for decision-making – information is transformed into knowledge for action. Only after data have been compiled, managed and analysed do they produce information (Figure 3.2).

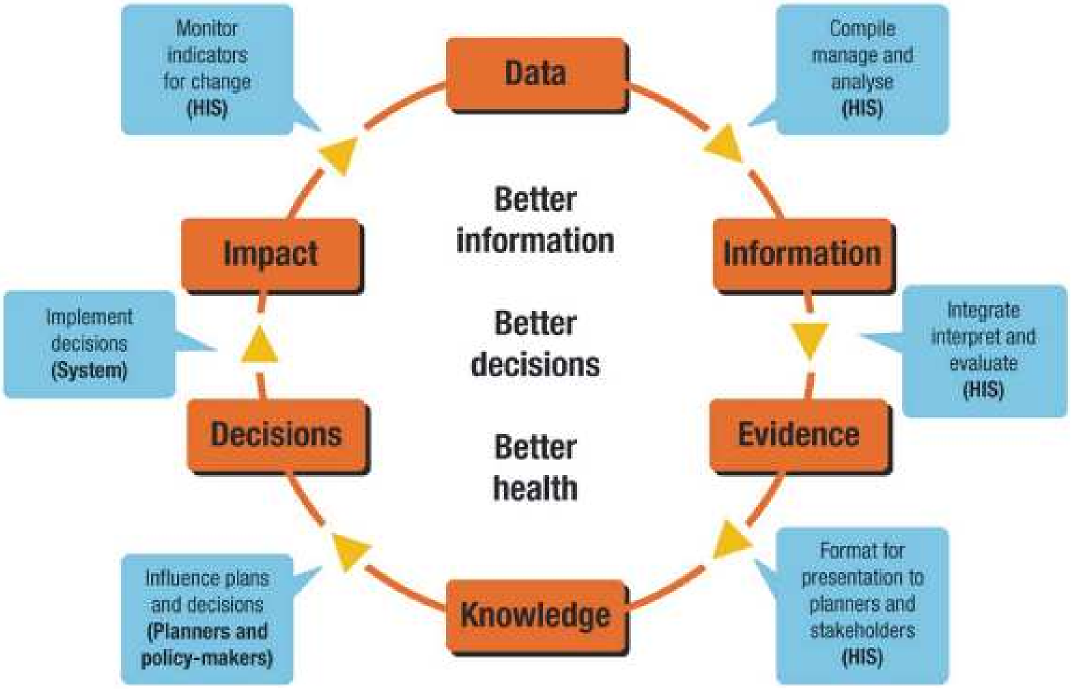


Figure 3.2: Transforming data into information and evidence
Source: (HMN 2008)

Heywood et al. (1994) argue that when looking at HIS it is important to look at it as a tool for improving health care, and not as a solution itself. Doing so, an HIS will improve the health care by improving health services and effectiveness and efficiency through better management at all levels of health service (Lippeveld & Sauerborn 2000). As RHINO puts it, "*The ultimate objective of a health information system is to produce information for taking action in the health sector. Performance of such a system should therefore be measured not only on the basis of the quality of data produced, but also on evidence of the continued use of these data for improving health systems operations and health status*" RHINO (2003). This principle applies at all levels - at the level of patient care, at the health facility, and at the community, district, national and global levels.

3.1.1 HIS in developing countries

In the label *Health Information System*, the word "system" implies a connected whole of organized process. AbouZahr & Boerma (2005) argue that, in practice, "*most country health information systems lack such cohesion, having developed in a piecemeal way, fashioned by administrative, economic, legal or donor pressures and are invari-*

ably highly complex". According to them, one way of simplifying the issue is to describe the dimensions of demand: who needs the data and what for? of supply: the tools and methods available to generate the needed information; and of level: the level of the system at which data are generated and used.

Various researchers have identified several problems associated with HIS in developing countries, including inappropriate procedures of data collection, analysis and information use (Lippeveld & Sauerborn 2000, Lippeveld 2001). A range of data collection methods is available including health facility data, administrative returns, household survey, censuses, vital registration, national health accounts and health research. The vital issue is on matching the data item or indicator with the most appropriate and cost-effective tool for generating it. This matching is essential function of the health information system and it is not always straightforward as discrepancies can arise when different data collection methods are used for the same indicator. For instance, indicators such as "Reported malaria cases" or "clinical confirmed malaria cases" can be generated both using clinical laboratories reporting system and the weekly epidemiological bulletin (BES) from the Department of Epidemiology within the Mozambique's National Directorate of Health.

In general, it has been recognized that there is a proliferation of health programs and their associated information systems which contributes to a wastage of resources as the same data gets collected repeatedly in parallel information systems. These parallel systems often arise because of the focus of support to particular diseases or services that are of their interest rather than on the district-based HIS. This multiplicity contributes to inappropriate reporting systems, limited feedback routines, and overall both poor quality of data and poor use of data being collected. In addition, it contributes to fragmentation of the HIS characterized by redundances and inconsistencies in data collection procedures and poor quality HIS.

Problems of poor reporting mechanisms, weak data management at both district and provincial levels, poor feedback and nearly non-existent use of information to support local action have been repeatedly identified by various researchers (Braa & Blobel

2003, Chilundo et al. 2004, Mosse 2005). Generally, attempts are being made by national, state and local governments to introduce various reforms in the health sector, including decentralization, integration of different health programs, strengthening of management practices, and the introduction of information and communication technologies to support the HIS (Lippeveld 2001). However, the existing procedures of data collection, processing and reporting, and a weak information culture constraint the effective deployment of technology.

Many developing countries lack necessary infrastructure and skills to effectively operate the technology. For example, nn Mozambique, while the spread of computers and Internet to the provincial capitals and major districts is gradually becoming visible, its effective use is slowed down by the lack of Information Technology (IT) skilled people and poor infrastructure including electricity, roads, and transportation (Mosse 2005). Similarly, in Tanzania, although the level of IT adoption has been described to be increasing since the eighties, the value obtained from its implementation in the health sector has been constrained by a variety of factors, including lack of transport and communication infrastructure, and human resources (Kimaro & Splettstoesser 2000, Lungo 2003).

Realizing the potential of ICTs to improve the efficiency of the existing poor quality HIS, many developing countries are in the process of making significant investments in hardware, software and capacity building efforts around their HIS (Lippeveld & Sauerborn 2000). However, effective implementation of these systems still remains a challenge due to various existing social, economic, political and organizational conditions. For example, the costs of purchase of computers and their maintenance (printer, cartridges, paper, technical support) are often prohibitive (Lippeveld 2001). There is typically the problem of limited number of skilled personnel, high human capital costs of installing, training, operating and maintaining ICTs which is estimated to be ten times that of the acquisition cost of the computer itself (Heeks & Kenny 2002).

The challenges of implementing HIS in developing countries described above are also very evident, and arguably magnified, in the case of GIS technology for both social and technical reasons. The next section provides a description of GIS technology. The description also include a discussion of GIS in developing countries, application of GIS to HIS, advantages, and limitations of GIS.

3.2 Geographic Information Systems

"*Almost everything that happens, happens somewhere. Knowing where something happens is of critical importance*" (Longley et al. 2005, p.4). Geographic information systems are a special class of information systems that keep track not only of events, activities, and things, but also of a location of these events, activities, and things.

Because location is so important, it is an issue in many of the problems society must solve. These problems that involve an aspect of location are termed *geographic problems* (Longley et al. 2005). An example of such geographic problems is a situation where a health care manager decides where to locate new clinics and hospitals.

The phrase *geographic information systems* was first used in the 1960s to refer to a computerized system for asking questions of maps showing current and potential land use in Canada (Richards et al. 1999). Since that time, a number of definitions have been proposed, with variations that depend on the perspective of the author, the specific application, the software available at a given time, and the level of complexity appropriate for the intended audience. One reason why it can be difficult to agree on a single definition for GIS is that various kinds of GIS exist, each made for different purposes and for different types of decision-making. A variety of names have been applied to different types of GIS to distinguish their functions and roles.

For instance, from a community health planning perspective, the Federal Geographic Data Committee (FGDC) definition provides a useful starting point:

> *"A computer system for the input, storage, maintenance, management, retrieval, analysis, synthesis, and output of geographic or location-based information. In the most restrictive usage, GIS refers only to hardware and software. In common usage, it includes hardware, software, and data. When*

organizations refer to their GIS, this latter usage is usually what they mean. For some, GIS also implies the people and procedures involved in GIS operation". (FGDC 1997).

However, Johnson & Johnson (2001) argue that

"*a typical geographic information system (GIS) comprises an organized collection of computer hardware, software, geographic data and personnel, designed to efficiently capture, store, update, analyze and display all forms of geographically referenced information*".

Geographic information systems are very complex systems ranging from automating the production of maps to data analysis. Despite its complexity, a GIS does have its well-defined component parts (Figure 3.3).

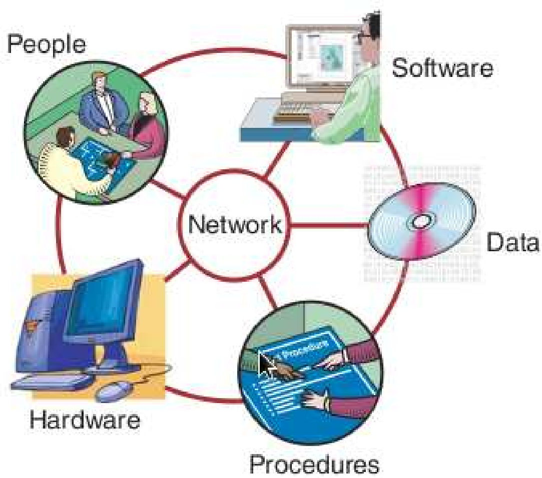


Figure 3.3: The six component parts of a GIS

The inclusion of *people* and *procedures* as part of both definitions is essential for GIS applications in a public health context, given the need to link the science and methods of epidemiology to GIS maps. A GIS is useless without the *people* who design, program, and maintain it, supply it with data, and interpret its results. Without trained staff (*people*), one scenario is that the GIS software will not be used at all (given the time and staff constraints that exist in many public health agencies and organizations). Alternatively, without trained staff and standardized *procedures*, the technology may be used to develop maps that are invalid or misleading.

Another fundamental element is the *network*, without which no rapid communication or sharing of digital information could occur, except between a small group of people crowded around a computer monitor. Examples of a network is the Internet which plays an important role serving as channel for data and information sharing.

The other piece of the GIS anatomy is the user's *hardware*, the device that the user interacts with directly in carrying out GIS operations, by typing, pointing, clicking which returns information by displaying it on the device's screen. One other piece of the GIS anatomy is the *software* that runs locally in the user's machine. GIS software can range from a simple package designed for a PC to a major industrial-strength workhorse designed to serve an entire enterprize of networked computers (Longley et al. 2005).

The last piece of the anatomy is the data or database, which consists of a digital representation of selected aspects of some specific area of the Earth's surface or near-surface, built to serve some problems. The data includes spatial and non-spatial databases.

3.2.1 Geographical Information Systems Applied to Health Information Systems

Sauerborn & Karan (2000) argue that GIS can enhance health information systems in four important areas:

- *Data communication.* Maps display existing data in a format which is easily comprehensible to decision-makers, health practitioners, and media alike.
- *Data analysis.* Spacial analysis can only be done using GIS.
- *Decision support.* The intuitive grasp of maps and the ability to display both health information system indicators and the results of data analysis make geographic information systems a valuable tool for decision support.
- *Links to other sectors.* Maps are a generic platform for displaying information from all sectors: education, economic development, infrastructure, finances, agriculture, and so on. Thus they provide an opportunity to share data from different

sectors and further exchange and communication.

GIS and epidemiology

Information technology has provided the means for integrating and analyzing diverse data sources in a spacial-temporal context. This approach supports the development of predictive models and timely intervention of diseases. Epidemiologic surveillance is advancing rapidly, both in terms of international collaboration through integrated global health networks and through the development of sophisticated monitoring technologies (Kopp et al. 2002). GIS plays a vital tool in strengthening the whole process of epidemiological surveillance information management and analysis. For example, Kopp et al. (2002) argue that GIS is being used in a variety of research efforts:

- Geographical distribution and gradients in disease prevalence and incidence.
- Geospatial and longitudinal disease trends.
- Identification of differential populations at-risk based on risk factor profiles.
- Differentiating and delineating risk factors within a population.
- Population health assessment.
- Intervention planning; assessment of various intervention strategies and their effectiveness.
- Anticipating epidemics.
- Real-time monitoring of diseases, locally and globally.

GIS provides excellent means for visualizing and analyzing epidemiological data, revealing trends, dependencies and inter-relationships (Johnson & Johnson 2001) that would be more difficult to discover in tabular formats. Epidemiologic surveillance contains information on the incidence and prevalence of diseases, relevant demographic data, physical environmental profiles, geo-referenced acute and chronic disease patterns within a defined population or defined geographic area that, together with a variety of ecological and socio-economic factors, might account for these trends (Johnson & Johnson 2001).

These data sets can be joined together into a whole and into a common data set for efficient multivariate analysis, trend analysis, and the search for causes.

Public health resources, specific diseases and other health events can be mapped in relation to their surrounding environment and existing health and social infrastructures. Such information when mapped together creates a powerful tool for monitoring and management of diseases and public health programmes.

The underlying factors likely to lead to increased incidence of diseases, including adverse environmental, demography, behavioural and socio-economic conditions (Johnson & Johnson 2001) and other important indicators need to be monitored regularly. By tracking the sources of diseases and the movement of contagions, health agencies can respond more effectively to the outbreaks of epidemics by identifying populations at risk.

Nevertheless, epidemiologists need to be able to understand and critically evaluate maps prepared using GIS technology, data and spatial statistical methods. But, to avoid drawing false conclusions from maps, users of GIS technology need to understand and apply epidemiologic principles and methods in formulating study questions, testing hypotheses about cause-and-effect relationships, and critically evaluating how data quality, confounding factors, and bias may influence the interpretation of results (Richards et al. 1999).

GIS and vector-borne diseases

GIS provides the basic architecture and analytic tools to perform spatial-temporal modeling of climate, environment, disease transmission, and other factors helpful in understanding the spread of vector borne diseases like malaria.

Kopp et al. (2002) argues that GIS combined with remote sensing can significantly improve the management of vector-borne disease events by providing:

- predictive capabilities based on climate and environmental models;
- remediation measures through rapid and efficient allocation of resources; and

- preventive methods by providing the ability to evaluate scenarios.

GIS in public health

In public health GIS has been used since 90's age. For example, GIS has continued to be used in public health for epidemiological studies. Studying epidemiology has become relatively simply. When GIS is applied in public health, it can help agencies respond more effectively to outbreaks of disease by identifying at-risk population and targeting intervention.

Public health users of GIS also include tracking child immunizations, conducting health policy research, and establishing service areas and districts. Using GIS for demographic analysis to estimate the demand for various types of services can benefit individual physicians. Physician specialists are more effectively marketed by locating offices near pools of potential patients. This type of analysis can be extended for use by managed health care providers.

GIS is being used by public health administrators and professionals, including policy makers, statisticians, epidemiologists, regional and district medical officers. In general, according to Johnson & Johnson (2001), some of its applications in public health are:

- Find out geographical distribution and variation of diseases
- Analyse spatial and temporal trends
- Identify gaps in immunizations
- Map populations at risk and stratify risk factors
- Document health care needs of a community and assess resource allocations
- Forecast epidemics
- Plan and target interventions
- Monitor diseases and interventions over time
- Manage patient care environments, materials, supplies and human resources

- Monitor the utilisation of health centres
- Route health workers, equipment and supplies to service locations
- Publish health information using maps on the Internet
- Locate the nearest health facility.

3.2.2 Advantages of GIS in public health

GIS has several advantages over conventional methods used in health planning, management and research. These advantages are discussed in the following lines:

Data management: GIS can be used to capture, store, handle and geographically integrate large amounts of information from different sources, programmes and sectors; including epidemiological surveillance, census, environment and others (Johnson & Johnson 2001). Surveillance of diseases requires continuous and systematic collection and analysis of data. A GIS can eliminate the duplication of effort involved in data collection across an organization, and hence substantially reduce the cost involved in it. GIS serves as a common platform for convergence of multi-disease surveillance activities. Each data record has to be geo-referenced to a desired level of accuracy. Once the basic structure is ready, it is easy to convert it to surveillance system for any other disease, by replacing data of one disease with data of another disease (Srivastava & Nagpal 2000).

Visualisation: GIS offers powerful tools to present spatial information to the level of individual occurrence, and conduct predictive modelling (Johnson & Johnson 2001). It determines geographical distribution and variation of diseases, and their prevalence and incidence. For example, in studying the surveillance of poliomyelitis in Mozambique, it is important to find out which type of polio is occurring in which parts of the country, as this has important implications for the disease eradication strategy employed. GIS can help in generating thematic maps - ranged colour maps or proportional symbol maps to denote the intensity of a disease or a vector (Johnson & Johnson 2001). In comparison with tables and charts, maps developed using GIS can be extremely effective tool to help community decision makers visualize and understand a public health problem

(Johnson & Johnson 2001, Richards et al. 1999). In addition, action is more likely when the decision maker can see on a map that a problem is occurring in his/her "backyard". GIS also enables detailed maps to be generated with relative speed and ease. It allows policy makers to easily understand and visualize the problems in relation to the resources, and effectively target resources to those communities in need.

Data integration: GIS permits dynamic link between databases and maps so that data updates are automatically reflected on the maps. GIS provides access to additional information from a wide variety of sources. For example, local public health departments can use global positioning systems (GPS) to obtain locations of point features on a map, such as wells or septic tanks, precisely. GIS can process aerial or satellite images to allow information such as temperature, soil types and land use to be easily integrated, and spatial correlations between potential risk factors and the occurrence of diseases to be determined (Johnson & Johnson 2001). GIS also could be used to link data for an individual with contextual information aggregated at a variety of geographic levels, for example, census data. This ability to link datasets can help public health practitioners plan more cost-effective interventions.

Overlay analysis: GIS can overlay different pieces of information. This helps in decision making and medical research through multicriteria modelling (Johnson & Johnson 2001). For example, in understanding the association between prevalence of certain diseases and specific geographic features.

Buffer analysis: GIS can create buffer zones around selected features. For example, a radius of 10 km around a hospital to depict its catchment area or 1 km around a pollution site or 5 m on both sides of sewerage to indicate the spread of hazardous material (Johnson & Johnson 2001). The user can specify the size of the buffer and then combine this information with disease incidence data to determine how many cases fall within the buffer. Buffer or proximity analysis can be used to map the impact zones of vector breeding sites, where control activity needs to be strengthened (Srivastava & Nagpal 2000).

Network analysis: GIS provides the ability to quickly access the geodemographic dynamics of an organisation's existing service area in contrast to the likely demand for services at a new location. It can identify catchment areas of health centres and also locate suitable sites for a new health facility. Health services delivered at home (e.g. polio vaccination) can be scheduled in a more efficient manner by analyzing transportation factors and street patterns, and by recommending the most efficient route (Johnson & Johnson 2001). GIS provides accurate and timely information about where health services are located and instructions and maps on how to get there.

Statistical analysis: GIS can carry out specific calculations, for example, proportion of population falling within a certain radius of a health centre or dam (Johnson & Johnson 2001). It can also calculate distances and areas, for example, distance of a community to a health centre, and area covered by a particular health programme.

Query: GIS allows interactive queries for extracting information contained within the map, table or graph. It can answer queries of location, condition, trends, spatial patterns and modelling (Johnson & Johnson 2001).

Extrapolation: GIS provides a range of extrapolation techniques. For example, vector distribution in inaccessible and unsampled areas can be mapped using GIS.

Web GIS: One of the recent advancements in GIS technology is web-based GIS. Health data is stored in a central server which can be accessed from various terminals connected to the server through internet or intranet. Statistical and epidemiological methods need to be developed to protect individual confidentiality while accessing data (Richards et al. 1999). Internet based GIS technology eliminates the traditional method of flow of information, and the information is instantly available across the globe. Dynamic maps published on the web allow patients to locate the most convenient services to their home or work easily.

3.2.3 GIS in developing countries

There are many actual and potential applications for GIS in developing countries ranging from resource inventory and monitoring through land use planning, land evaluation, biological control and health studies, irrigation and drainage, social and economic planning, disaster avoidance, management of conservation areas and parks to tourism (Burrough 1992). The use of GIS in developing countries and developed countries are the same, although there are some differences. These differences are concerned with poverty which in turn are related to limitations of availability of financial resources. The major constraints are probably the cost and the education constraints, but also infrastructure and data constraints make the application of a GIS a very time consuming process. The aforementioned constraints and others are discussed in detail in the following subsection.

3.2.4 Limitations of GIS

Some of the limitations of GIS from a public health perspective are as follows:

Data limitations: Current, accurate, low-cost maps are essential for epidemiologic users. Without an up-to-date district map, for example, a public health practitioner investigating a disease outbreak may have to spend considerable extra time and effort to digitalize the locations of cases or may not be able to map all case reports.

Lack of qualified staff: Practitioners, planners, and researchers, and especially local public health department staff, need training and user support in GIS, data, and epidemiologic methods in order to use GIS appropriately and effectively (Richards et al. 1999). The cost of training programs offered by commercial GIS vendors can be a financial burden for a small local public health agency. In addition, the time required for training can be a severe challenge for organizations in which demands on personnel are already high (Richards et al. 1999).

Financial implications of hardware and software: GIS software continues to evolve rapidly. Every software has its strengths and weaknesses. Current prices for some GIS products remain a potential barrier (running as much as $10,000 or more). In addition, costs for maintenance and upgrades can be substantial.

Lack of Web models and methods for Web-enabled GIS: The technology to prepare and display maps on the web is still in the very stages of development.

Models and methods for web-enabled GIS need to be developed for public health applications. As Foresman points out, full GIS capability on the web is a considerable technical challenge because GIS software has only recently started to be developed using web-accessible programming languages, and the size of GIS map images and data files can be large and significantly slow access and display functions over the web (Foresman 1999).

Lack of software to perform spatial analysis: Spatial statistical software programs also need to be developed for use with these web-enabled GIS applications; as Foresman writes, "*The next logical step is to actually provide the Web tools to perform spatial statistical analysis over the web*." (Foresman 1999). In general, this issue deals with the problem that most GIS software does not adequately handle spatial statistics. In fact, as Sipe & Dale (2003) put it, the discipline of spatial statistics is in the early development stage and is not well understood by most GIS users.

Decision-makers do not understand its application: GIS vendors have done a very good job of selling their applications to decision-makers. Sipe & Dale (2003) argue that the focus of the selling tends to get caught up in technical "jargon" and not in the fact that a GIS can quickly make maps, and that maps are much easier to understand than tables. In addition, because many do not understand what GIS does and what it could do, getting financial support continues to be a problem. This was a problem identified in the early days of GIS and it remains a problem today.

Lack of software/controlled by outsiders: The most used GIS software typically originates from the United States or Europe. In some cases this results in problems getting copies of the software as well as getting support for the software (Sipe & Dale 2003), particularly if the problem cannot be solved via telephone or email.

The list of problems and limitations of using GIS is not intended to discourage the use of GIS for malaria research and control, but it is an effort to focus attention and effort on overcoming these problems. Some of these problems and limitations will be addressed in the Chapter 7, the Analysis and Discussion chapter. The next section discusses how

Information Infrastructure theory provides us with a set of concepts to analyze GIS development. In addition, I conceptualize GIS as Information Infrastructure including its justification.

3.3 Information Infrastructure

Information Infrastructure (II) theory is a body of research that is increasingly being drawn upon by researchers to analyze complex, inter-connected and networked systems that are characteristics of contemporary processes around globalization. Hanseth & Monteiro (1998) use the term Information Infrastructure to explain that II are something bigger than traditional ISs, groupware, and stand-alone applications. IIs have six main characteristics: *heterogeneity*, *socio-technical* nature, *enabling*, *shared*, *open* and *evolving* (Hanseth & Monteiro 1998).

The II perspective emphasizes that the social and technical are not separable and are instead constituted and constitutive of one another. IIs are thus not built to support one application for a pre-defined set of users, but to provide an *enabling* environment in which a variety of application and user communities can increase, and the infrastructure can evolve to support changing needs (Ginger 2005).

IIs are *heterogeneous* in a way that they include components of different kinds, technological and non-technological as well as human, social, and organizational aspects (for example, people, institutions, software, hardware etc). The absence of limits for number of users, stakeholders, and vendors involved in different nodes in the network and other technological components, application areas, network operators, make the infrastructure to be *open* and contributes to its heterogeneity. There are technically no limitations in terms of who can participate and contribute to its design and development. Infrastructures are *shared* in the sense that, it is the one and the same single object used by different actors in the community. The same single object can be used by all of them without reducing the value of the infrastructure. E-mail can be taken as example of this feature.

One aspect of infrastructures is their supporting and *enabling* functions for a wide range of activities, not especially tailored to one. The various components of an II are interconnected through gateways. The development of a new one cannot be done from scratch and also cannot be achieved instantly. It depends on the already existing old infrastructure; the *installed base*. Building large infrastructures takes time. New requirements come that need to be adapted. A whole infrastructure can not be changed instantly: the new has to be connected to the old. Hence, the old, the *installed base*, influences how the new is designed. Infrastructures develop through extending and improving the *installed base* (Hanseth 1996). Hanseth & Monteiro (1998) explain the role of the installed base in building an II as installed base implies that infrastructures are considered as always already existing; they are never developed or created from scratch. That is, new infrastructures are always designed as extensions and improvements of existing ones. In this way, the new components have to fit into the old, the installed base.

The concept of *installed base* have been adopted as guiding principles to understand the challenge of using GIS for malaria mapping, in this thesis. The installed base comprises the existing systems, work processes, users and organization procedures that govern the overall process of change. Consequently, the present installed base carries the heritage of, and is affected by, the former installed base.

The focus on II theory is particularly on the concept of installed base, and how the development of the GIS is influenced by the existing systems, work procedures and routines. The GIS tool for mapping malaria is meant to support decision-making by incorporating spatial analysis of data that are part of the existing HIS. In this way, the new system is also involved in the process of improving new ways of working. In the next section, I first argue that GIS for health are better conceptualized as II, and then develop specific implications for my theoretical analysis.

3.3.1 Conceptualizing GIS as II

Analyzing GIS implementation in health needs to consider GIS as a part of larger heterogeneous socio-technical network encompassing humans, technological components and institutions. The design of a GIS, that is of the new system, must respect the already existing HIS, reporting procedures, systems, technologies and users, that is, must respect the existing installed base. Specifically, the linkage between the GIS and the existing IS needs to be understood where the GIS application should represent an open shared, evolving and heterogeneous installed base. When developing this new GIS, it will need to be integrated into the existing one by either introducing new components or improving one part of an infrastructure.

In the context of health sector, GIS is a *heterogeneous* network as it is constituted of technical (hardware, software, data) social (health staff, politics, economics, organizations, management, donors and other artifacts) and their interconnections. For example, a number of organizations and participants including the Ministry of Health, and international agencies such as WHO, World Bank, and so on, deal with spatial and demographic data in their everyday work. A GIS for health application is *shared* in the sense that it supports information sharing amongst a large community of different users or organizations with different needs. For example, information can be shared by different users for health program management, disease surveillance, and international health planning (such as WHO), etc.

A GIS system is *open*, since it is not limited to the number of users, application nodes in the network and other technological components for particular user groups. For example, the same data can be used for spatial analysis in different sectors and departments within health sector and in other public areas like education. A GIS application is flexible, since it can be used for information analysis for different purposes, supporting decision-making and resources planning, and evolving over time, that is, allowing new functionalities to be added or deleted as required.

Hanseth & Monteiro (1998) have emphasized that there is no clear definition for II and there are different kinds of infrastructures (global such as Internet, sectors and corporate). Thus, GIS is better conceptualized as II rather than a traditional IS. In summary, I argue that a GIS application for health, particularly when applied to mapping diseases, represents the characteristics of an II.

Chapter

4 RESEARCH METHODS

4.1 Introduction

The purpose of this chapter is to present the philosophical assumptions underpinning this research, as well as to introduce the research approach and the empirical techniques applied. The chapter defines the scope and limitations of the research design, and situates the research amongst existing research traditions in information systems.

The philosophical assumptions underlying the thesis is based on interpretive research approach which emphasizes the role of action. The research strategy adopted was to conduct one case study. The fieldwork was conducted at the sites described in Chapter 2 during the period from May to December 2008. The main data collection techniques used in the research study were semi-structured interviews, participant observations, documentation and software analysis.

This chapter is divided into four sections. In the first, the research strategy is presented. It describes the research approach followed in the case study research. The next section is about the research methods and covers the data collection techniques along with reasons for selecting the methods. Section 4.4 is about data analysis techniques. Finally, section 4.5 presents a brief summary of the chapter.

4.2 Research approach

There are various ways of classifying research approaches. One of these ways is that which distinguishes between quantitative and qualitative and the selection of the approach to be used depends solely on what the researcher wants to find out (Myers 1997).

The quantitative research methods were originally developed in the natural sciences to study natural phenomena and these involve numerical representation and statistical analysis of observations for the purpose of describing and explaining the phenomena that those observations reflect (Myers 1997). Examples of quantitative methods include surveys, laboratory experiments, formal methods (e.g. econometrics) and numerical methods such as mathematical modeling (ibid).

Therefore, qualitative research methods were developed in the social sciences to enable researchers to study social and cultural phenomena, and are particularly useful in determining how and why specific outcomes occur. Qualitative research involves the use of qualitative data, such as interviews, documents, and participant observation data, to understand and explain social phenomena (Myers 1997). Examples of qualitative methods are action research, case study research and ethnography. Qualitative data sources include observation and participant observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions (Myers 2009).

Bearing in mind that the objective of this study is to assess the HIS in Mozambique in order to address the issue of malaria, this research adopted a qualitative research approach. This approach allowed me to understand both social and technical aspects of the HIS especially as the socio-technical relation is not linear but rather difficult to demarcate and complex.

The following subsections discuss the case study approach followed in this study and the action research approach together with an outline of its five phases in order to build theory, knowledge, and practical action by engaging with the HIS in practice.

4.2.1 Case study

In this study, a case study approach was used to study how GIS can be used as a health care tool to map malaria. Case study research is an approach for bringing an understanding of a complex phenomenon such as the design and development of an information system or a GIS within a multi-level setting of the health sector.

A case study approach emphasizes the need for a detailed contextual analysis of a limited number of events or conditions and their relationships. Although there are numerous definitions (Myers 1997), Yin (2002) defines the a case study research as "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, espacially when the boundaries between phenomenon and context are not clearly evident*" (Yin 2002, p.23).

Myers (1997) argue that case study research can be positivist, interpretive, or critical (Figure 4.1), depending upon the underlying philosophical assumptions of the researcher.

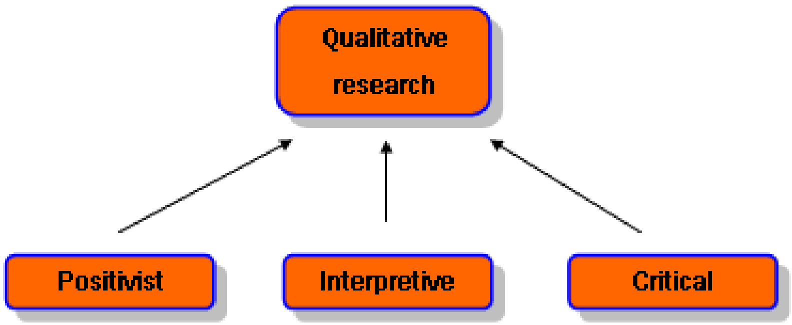


Figure 4.1: Underlying philosophical assumptions

The philosophical assumptions underlying the thesis are based on interpretive research. Interpretive studies generally attempt to understand phenomena through the meanings that people assign to them (Myers 1997) and interpretive methods of research in IS are "aimed at producing an understanding of the context of the information system, and the process whereby the information system influences and is influenced by the context" (Walsham 1993, p. 4-5).

The case study method was chosen in this research because of the focus on the analysis of the social and cultural influences on the development and adoption of the technology within the Mozambique health sector. I had opportunity to visit health districts in one of the HISP research sites, the Inhambane province, where I made detailed observations of the work setting, and conducted interviews with different actors involved in the health sector. This helped me to develop a deeper understanding of the problems related to the current HIS, and helped to guide the prototyping process of the GIS tool for the Department of Community Health. The main focus was on studying the existing malaria problems including the current malaria data collection methods and reporting mechanisms.

The study also followed the framework of action research approach, which is briefly described in the next section.

4.2.2 Action research

Greenwood & Levin defined action research as "*social research carried out by a team encompassing a professional action researcher and members of an organization or community seeking to improve their situation. Action research promotes broad participation in research process and supports action leading to a more just or satisfying situation for stakeholders*" (Greenwood & Levin 1998, p.4).

Action research is grounded in practical action, aimed at solving an immediate problem situation while carefully informing theory. In order to be identified as action research, there are three elements that must be present, namely research, action and participation. By research it is proposed that action research is one of the most powerful ways to generate new knowledge. Participation promotes democracy, which means that it enables the communities or organizations to mobilize their diverse and complex internal resources to the fullest. Action research is a participatory process in that trained social researchers function as facilitators and together they establish the action research agenda, generate the knowledge necessary to transform the situation and put the result to work. Action research is participatory in that it aims to alter the initial situation of the group or organization in the direction of a more self-managing, liberated state, where the practitioners function as democratic reformers. Hence, action is a sensible way to generate and test new knowledge.

Different researchers have used a research methodology based on action research in a global research and development project called the Health Information System Program (HISP)[1]. For instance, Braa & Hedberg (2002) employed action research in order to involve the wider social system in the design and development of information systems; Braa et al. (2004) based their study on *networks* on action research: "*. . . action research interventions need to be conceptualized and approached as but one element in larger "network" of action in order to meet the grave challenges of making localized action scale (i.e. spread) and be sustainable (i.e. persist over time, also after the researcher leave)*." (Braa et al. 2004).

The fundamental contention of the action researcher is that complex social processes can be studied by experiments, i.e. introducing changes into these processes and observing the effects of these changes (Baskerville 1999). The method is particularly useful in developing context-based, process-oriented descriptions and explanations of the phenomena (Galimoto 2007).

Action research is also the process in which a group of people aim to influence or change the focus of their research through the improvement of a practice, the improvement of the understanding of the practice by its practitioners and the improvement of the situation in which the practice takes place (Baskerville 1999).

According to Baskerville & Wood-Harper (1996), action research consists of five phases comprising: diagnosing, action planning, action taking, evaluating, and specifying learning, in a cyclical process (Figure 4.2).

This can be described as an *ideal* exemplar of the original formulation of action research (ibid) to study important organizational and social problems together with the people who experience them. These phases were used for this study, for the assessment

[1]HISP is a large-scale action research initiative that operates as a global network within the health care sector in a number of developing countries like Mozambique

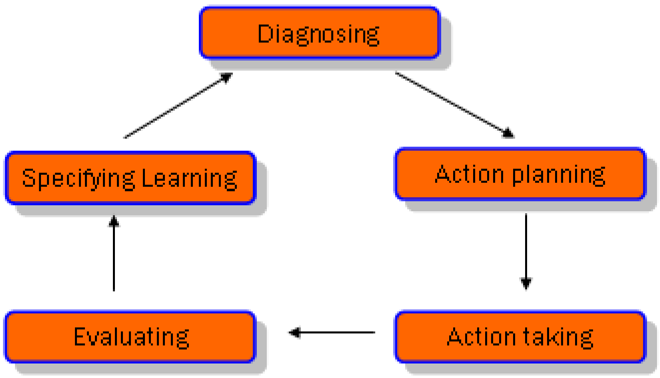


Figure 4.2: The action research cycle

and the assumed intervention process to solve the identified problem.

Diagnosing

Diagnosing corresponds to the identification of the primary problems that are the underlying causes of the organization's desire for change (Baskerville & Wood-Harper 1996). In this study, I assessed the HIS and diagnosed the practical problems experienced by the users. In order to reach the goals of the research, I analyzed the technical and organizational issues at different levels which are the national, province and district levels.

Together with the MoH, I visited the Inhambane province to carry out the analysis. The data source was extracted in the Department of Community Health in form of spreadsheets from the spreadsheet application called MB. This data extraction occurred at both national and province levels. As a way to understand the needs of users and Community Health Department decision-makers I also investigated the spread of computer facilities over the MoH at the national and province health directorate.

Action plan

An action plan specifies organizational actions that should relieve or improve the primary problems. This refers to the process of analysing and identifying information and user needs for project implementation. More to the point, specific mechanisms on the particular activities, resources required from the CHD, resources provided by HISP-Mozambique and the time frame for action were clearly defined.

Action taking

This phase included assessing the different HIS within the MoH, assessing the spatial and non-spatial data and also the development of the GIS system. The main source of the non-spatial data was the MB system and spatial data was gathered in different sources which include the INE, and MISAU.

Evaluation

At this stage, researchers and practitioners undertake the evaluation of the outcomes (Baskerville & Wood-Harper 1996) including determining the extent to which the theorized effects of the action were carried out (Saugene 2005). Basically, in this phase outputs of the GIS prototype were analysed.

Specifying learning

This last phase corresponds to thesis writing and helps to consolidate the findings and its documentation. It is hoped that this document can be used in further research. In addition to the conceptual learning, there is also practical learning that has taken place. The development of the application, giving presentations to the health officials, doing some training, gaining feedback etc, can all be seen as steps of learning and their articulation. This helps to enable learning for both sides, and contributes to some improvements on the ground.

4.3 Research methods

The choice of research method influences the way in which the researcher collects data. The empirical data collection aimed at obtaining a holistic overview picture and understanding of the HIS.

The collection of data and other information is essential to action research as it is the prime output of observation, and the prime input to reflection, as well as for planning future meetings (Saugene 2005). Given that the system was designed around an existing set of work processes that involved structured interactions between numerous personnel – both within and between organizations, ethnographic methods were used.

Ethnographic methods include observation, interviews, document analysis, surveys or questionnaires, and participation in meetings (Ellis et al. 2002).

These methods, each contributed to the formation of a rich, comprehensive picture of the social structure, and revealed both opportunities and constraints on system design. These qualitative methods proved to be appropriate in this situation.

This study mainly obtained empirical data from interviews. To ensure reliability and validity of the data, document and software analysis, and participant observation were also used to complement the interviews.

4.3.1 Interviews

Interviews offer researchers the chance to explore topics in-depth and to gain appreciation of the context of the phenomena (Damitew & Gebreyesus 2005).

During the period reserved for data collection, I interviewed various professionals working at the various levels and open-ended semi-structured interviews were used. The choice of this technique is because it gives more freedom to both interviewer and interviewee to ask and give further elaborations and provides a better way to obtain a more authentic understanding of people's experiences (Silverman 2000).

Non-structured interviews in the form of conversations with the available people were conducted at the Province Health Directorate at Inhambane province. This was done as a way to understand the health related dilemmas as well as to know the existing strengths and information related problems facing the sector, for example the present problem of high maternal mortality rate due to malaria. These interviews were also important to gain more knowledge about health related concepts, for example about health indicators and coverage.

At the district level I also conducted non-structured interviews with health workers dealing with the immunization data and malaria programmes. Two non-structured interviews were also conducted with officials working in the National Malaria Control

Programme (NMCP) in the MoH which has the main responsibility with issues related to malaria nationally. The Department of Epidemiology in the MoH being an active stakeholder on malaria and other diseases issues in the country, I also interviewed some of the professionals in order to understand issues related with data flow as well as where it comes from, how it is stored and how it is further used.

The interviews were conducted at the interviewees' respective workplaces such as their offices, the wards, or the consultation rooms. The interviews lasted for a period ranging from 20 minutes to 2 hours. The interviews proved to be a powerful way to get the necessary information and also gave freedom to those who knew the situation to explain it using their terms.

All these interviews provided information on how the system works and/or is at least supposed to work. The interviews were in Portuguese and were later translated to English by the researcher for the purpose of thesis writing.

One problem encountered in some districts was that when the health workers were approached for interviews related to data issues they associated it only with the HMIS or as if I was doing inspection. To overcome this, I had to explain in detail, before starting the interview, what I wanted to find out from them and I also had to use a lot of probing during the interviews to get the information I required.

4.3.2 Observations

According to Myers (1999), observations are important in qualitative research as they allow the researcher to see what the people are doing as well as what they say they are doing.

In an effort to obtain a better understanding of what was discovered from other sources, participant observation was used whenever possible. More specifically, I attended meetings and visited health facilities in order to see how they collected the data and where and how they stored the data after collection. Doing so, I particularly increased my understanding and informed this research mainly on issues related to data analysis and data/information use.

4.3.3 Document and software analysis

Documents are very important source of qualitative data. In this research, documents and software analysis were used for data collection and interpretation process. Atkinson & Coffey (2004) argue that "*If we wish to understand how organizations work and how people work in them, then we cannot afford to ignore their various activities as readers and writers. Moreover if we wish to understand how the organizations function, then we also need to take account of the role of recording, filling, archiving and retrieving information.*" (Atkinson & Coffey 2004, p.46).

Different perspectives like comparisons between the situation analyzed through the software and what was recorded in the documents, and what people said about the situation, were used and helped to develop a relatively broader understanding of the larger cultural and social-technical context in which the study was situated.

This led to study various documents such as registers; training reports; district implementation plans; general programme reports; supervision checklists and reports, reporting forms including monthly and annual reports and other national official documents. The review of registers provided information on data that was collected at facility level during patient/facility encounter. In general, the analysis of the aforementioned documents helped to understand the problem of existing systems that influence the existing data and information flow.

I analyzed the MB system that is used at the Ministry of Health and at the Province Health Directorate at Inhambane. In addition I analyzed the DHIS in order to find out how the data that already exist could be used with GIS application.

Other secondary sources of data were used. These consisted of relevant literature on HIS and GIS implementation in developing countries including PhD and Masters theses and other journal publications of Mozambican researchers, and also official MISAU documents which included books and electronic articles. Other valuable sources of information were official websites of some government institutions like National Institute of Statistics (INE) from where I obtained demographic data for Mozambique.

4.3.4 Fieldwork documentation

During the interviews and observations, data was collected mainly through note taking. Recording was not used, as participants were not comfortable with it; however, pictures of various types of documents were taken.

At the end of the day, I organized the field notes taken, making comparison between what was reported and what I analyzed from the documents. During this process I also examined any documents (or pictures of documents) obtained and this enabled a comprehensive reflection on all the data obtained and identification of areas for clarification and further investigation. This also helped in gradually getting more familiar with some basic important health concepts as well as in understanding the related problems like discrepancies between the reported data at province level and the collected data at the district and health facility levels.

The fieldwork notes and the resumes that I was doing at the end of the day helped me in designing the input for the next day fieldwork or for planning the next stage of the research.

4.3.5 System prototyping

Prototypes are 'instruments' used within the software development process, and different kinds of prototypes are employed to achieve different goals (Ginger 2005). The advantage with prototyping is that the resulting system is more easily used and maintained compared to system development using other kinds of methods. User needs and problems are detected earlier and the design is potentially of higher quality and requires less effort to be used (Sommerville 2001).

Bearing in mind that the objective was to provide a GIS system to be used by decision-makers in the Department of Health Community, system prototyping was chosen as a way to minimize system complexity. However, the prototyping of the GIS software involved different cycles which include user requirements specification and analysis; study of the existing databases and database design and population of the database with data taken from the MB system used by the Ministry of Health. Because of the nature of the project the spatial and non-spatial systems were modified, changed and customized according to the Department of Community Health's socio-technical conditions.

4.4 Data analysis techniques

The process of data analysis started during the empirical data collection and was performed continuously as the study proceeded. The focus was on understanding the current HIS, its characteristics and the existing working practices and how these influenced the GIS development and implementation.

The software analysis helped to develop a deeper understanding of how the work practices were shaped and its influences on the introduction of the GIS application to support HIS. By the time I was writing the findings from this research, the reading of available literature helped to further develop a theoretical basis to understand the current HIS and information flow and the relationship between the work practices and the GIS system introduction.

The analysis of data gathered at the health facility level and district level were discussed with various staff, particularly in the CHD in the province and Ministry of health. These discussions were with health managers and other health staff mainly dealing with malaria issues. This process of discussion helped to develop coherence in my interpretations, and a stronger background understanding of the organizational context. In addition, a process of cultivation can be seen to characterize the analytical work, where inputs were coming from various sources including reviews of literature, and informal conversations with other researchers.

In trying to make sense of the whole, a triangulation method was used to understand the system by analyzing the information obtained from interviews, document analysis and observations.

4.5 Summary

This chapter presented detailed explanation of the research approach undertaken as well as an accounting of the research methods which were divided into interviews, observations, documents and software analysis, fieldwork documentation and system prototyping. Finally I presented the data analysis techniques used to get a holistic picture of the data collected.

Chapter

5 RESEARCH FINDINGS

5.1 Introduction

This chapter presents the main findings of the empirical study. The study was conducted mainly in Inhambane Province. The findings are based on the qualitative methods and research techniques described in Chapter 4.

Chapter 2 described the research sites where the research was conducted, as well as the background information of Mozambique. In the field work sites I was able to contact health workers dealing mainly with malaria data. The research techniques and qualitative methods were applied in different circumstances being the main purpose for the collection of data.

This chapter is divided into four sections. The next section describes the information flow at different levels, namely health facility, district, province and national levels. Section 5.3 discusses the tools used by health workers to collect and present malaria data. Section 5.4 presents the main problems related with malaria information. The last section describes briefly the main findings of the chapter.

5.2 Information and data flow

In Mozambique, each province has an organization structure with different directorates, including the province and district health directorates. The province health directorate is composed of several district health directorates which are composed of several health facilities which provide health services to the population. At each district there is a district health management team that is responsible for health management.

Primarily, the data are gathered at the health facilities and registered in different forms and the flow of these data is as shown in Figure 5.1.

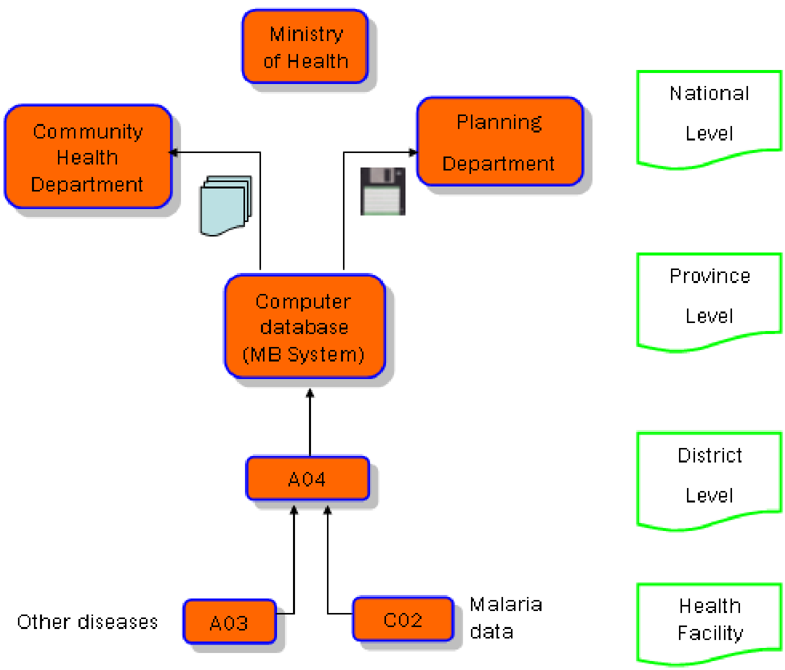


Figure 5.1: Malaria information and data flow

On a weekly basis two paper forms, the A01 and A02 registers, are collected in two paper forms, A03 and C02. These paper forms are sent to the district level. Then, the data are aggregated at the district level into a district paper form (A04) which does not discriminate information from various facilities. This district form is sent to the province level on a monthly basis where the data are entered in a computer database called MB (Módulo Básico). On a quarterly basis the data is sent to the national level using a floppy disk (by the Planning Department staff) or in a paper format (by the Department of Community Health staff).

In general, as can be appreciated in Figure 5.2, malaria data flows through four reporting channels, namely (a) the weekly epidemiological bulletin (BES) from the Department of Epidemiology within the National Directorate of Health; (b) the specific

Malaria Programme reporting system; (c) the monthly summary for inpatients from district hospitals as part of the main health information system from the Department of Health Information within the National Directorate of Planning and Cooperation, and (d) the clinical laboratories reporting system. This multiplicity of channels contributes to duplication of effort, consumes time and contributes to low validity, incorrectness and incompleteness of data.

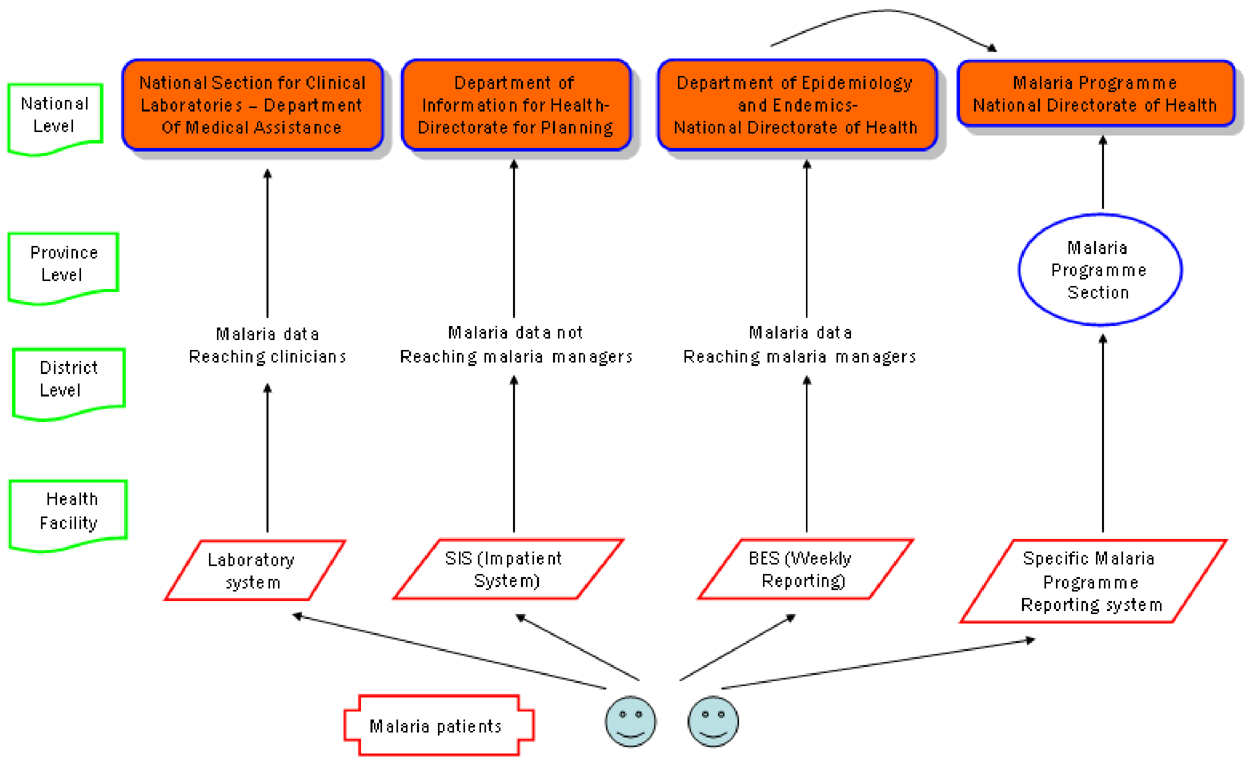


Figure 5.2: Several malaria case reporting channels in Mozambique
Adapted from Chilundo et al. (2004).

The empirical findings presented here follow the information cycle model proposed by (Rohde et al. 2008) (Figure 5.3). These findings are related to the following five topics:

- Data collection;
- Data processing;
- Data presentation;
- Data interpretation; and
- Information use.

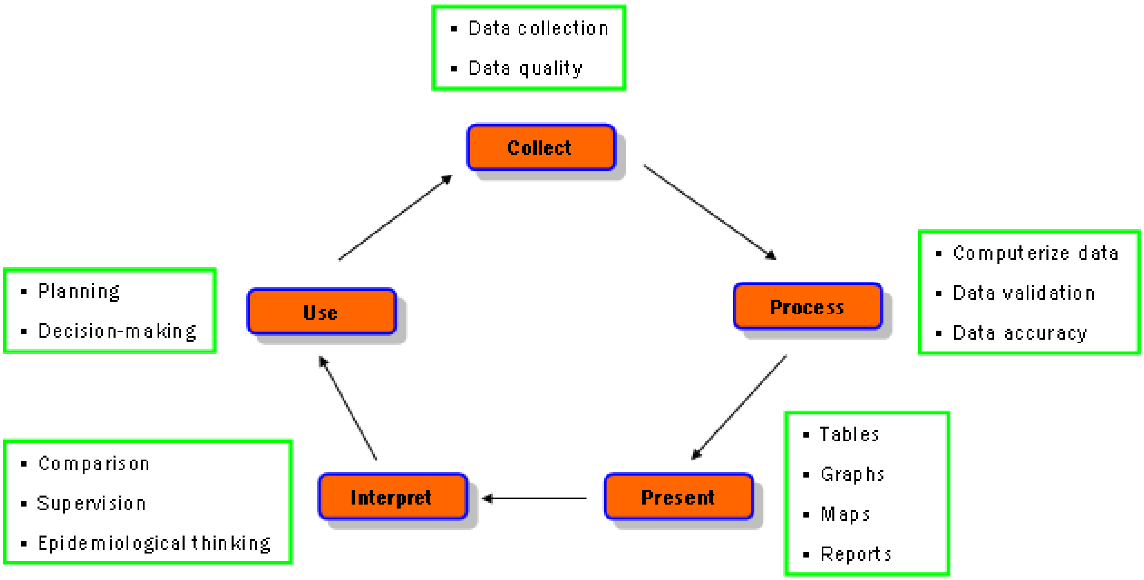


Figure 5.3: The information cycle
Adapted from Rohde et al. (2008).

5.2.1 Data collection

The primary source of malaria cases is patients presenting at health facilities with symptoms indicative of malaria. These are recorded in a tally sheet or register book. However, most of the peripheral consultations do not have appropriate register books. For instance, in one health facility register books being used in screening consultations were overwritten by hand leading to reading constraints and thus contributing to errors in collated data.

Data source

The data sources are all the data registered in a daily routine at the health facilities. All malaria data being reported from health facilities are primarily gathered from tally sheets and register books in consultation rooms, infirmaries and laboratories. In the National Health System, infirmaries and laboratories are physically located within ordinary health facilities such as health centres, district, provincial and central hospitals, which are part of the established network. The tally sheets and registers represent the largest manual database of the health information system in Mozambique. There is a lot of registered data and not all of it can be processed. With data collection, the data are selected and the Ministry of Health has to decide and select which data to process.

5.2.2 Processing phase

Having collected data, it is necessary to convert it into information through agregation and tabulation. Data need to be aggregated and tabulated in a way that aids future analysis so that it can be reported both vertically (sent up to higher levels) and horizontally (shared with all staff at the districts levels or health facilities levels) and fed into a computer to be communicated.

Aggregation (also known as collation) is the gathering together of data from various sources. Aggregation usually means gathering of data or reports from all health facilities. At the health facility level the data is aggregated into one report and sent to district level using the A03 data form. The same occurs at district and province levels. At the district level, the District Núcleo de Estatística (NED) aggregates the reported data manually from all health facilities into the A04 data reporting form and then reports to the province level. This report presents an overview of the district activities. The advantage of aggregation at the district level is that it allows calculating the district indicators, providing useful information for planning, also draws the epidemiological profile of most common diseases of the district.

At the province level the data is entered in a computer-based information system and processed to produce desired reports. The reports and the stored data is sent to the national level on a monthly basis. The computerized data is processed and used to generate reports for national level use by the Department of Community Health.

Data validity

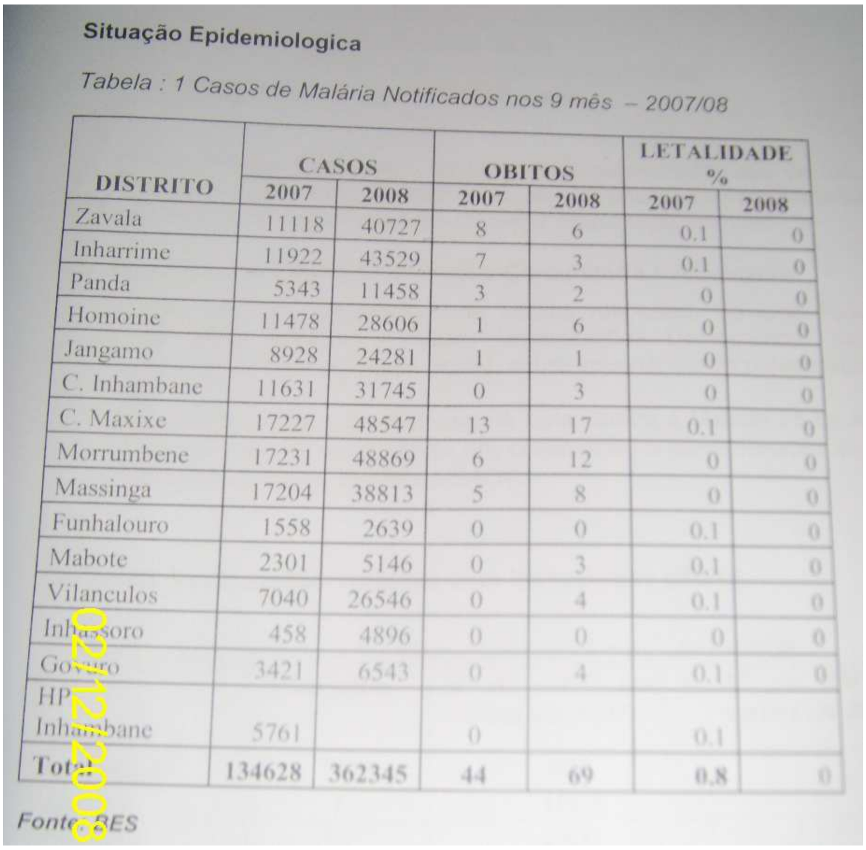
At the health facility there is no evidence of use of validation rules. While at the district level, the NED verifies and validates the consistency of values on the summary to be sent to province against those received from health facilities. The health workers do check the validity of the data contained in the forms in terms of consistency, e.g. number of discharges greater than number of births in the maternity.

The MB system allows health staff at the province level to formulate some validation rules. For instance, there is a validation rule in the MB system to check whether the health facility that is currently reporting, has the ability to report the kind of data that it is reporting. The MB system also provides full information about the reporting process, who should report and what type of report should be provided.

5.2.3 Data presentation

Tables

At the distrital level several tables are generated using MS Word. In order to generate these tables, the data is extracted from the BES system and exported to MS Excel and later on processed to produce desired tables. Figure 5.4 shows a table comparing malaria cases of the third quarter of 2007 and 2008.



Situação Epidemiologica

Tabela : 1 Casos de Malária Notificados nos 9 mês – 2007/08

DISTRITO	CASOS		OBITOS		LETALIDADE %	
	2007	2008	2007	2008	2007	2008
Zavala	11118	40727	8	6	0.1	0
Inharrime	11922	43529	7	3	0.1	0
Panda	5343	11458	3	2	0	0
Homoine	11478	28606	1	6	0	0
Jangamo	8928	24281	1	1	0	0
C. Inhambane	11631	31745	0	3	0	0
C. Maxixe	17227	48547	13	17	0.1	0
Morrumbene	17231	48869	6	12	0	0
Massinga	17204	38813	5	8	0	0
Funhalouro	1558	2639	0	0	0.1	0
Mabote	2301	5146	0	3	0.1	0
Vilanculos	7040	26546	0	4	0.1	0
Inhassoro	458	4896	0	0	0	0
Govuro	3421	6543	0	4	0.1	0
HP Inhambane	5761		0		0.1	
Total	134628	362345	44	69	0.8	0

Fonte: BES

Figure 5.4: A table showing malaria cases of the third quarter of 2007 and 2008

Graphs

Graphs are generated using MS Excel and the data is exported from the BES system. There is no another tool other than MS Excel being used to produce the graphs. Figure

5.5 shows a graph of comparison os malaria cases of the first quarter of 2007 and 2008 in Inharrime district.

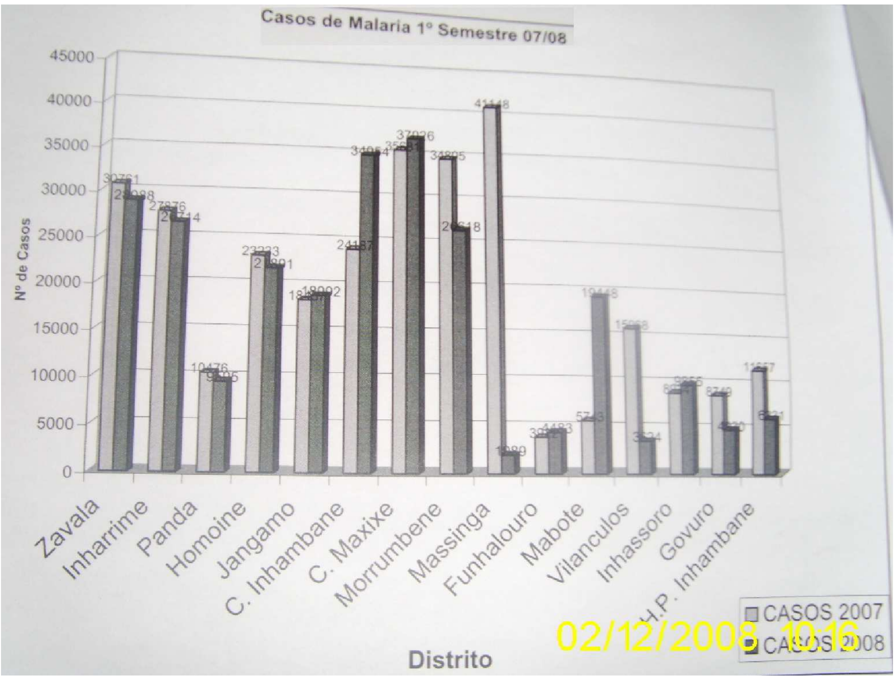


Figure 5.5: A graph showing malaria cases of the first quarter of 2007 and 2008

In certain districts, the health workers design hand written graphs because of lack of skill or because of the lack of a computer. For instance, Figure 5.6 shows a monthly resume graph of distribution of vaccines of the EPI in Massinga District.

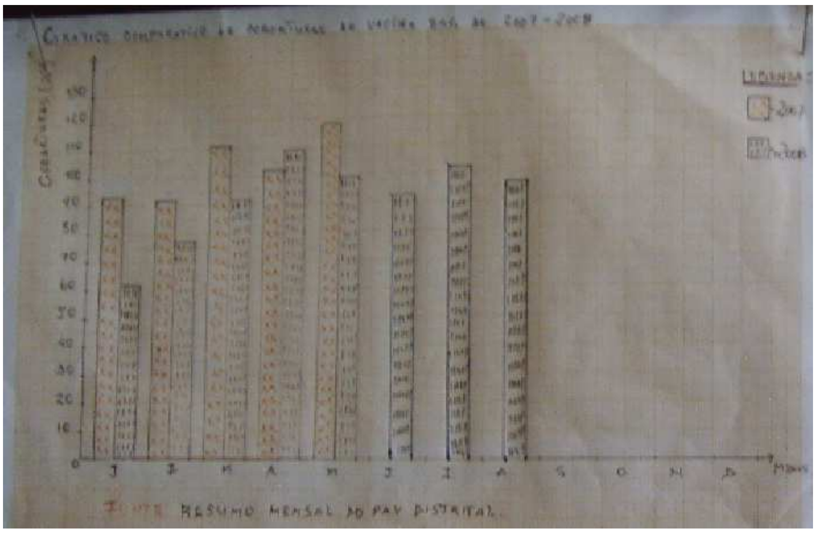


Figure 5.6: A graph showing hand written graph

Maps

At the province level there are official maps showing details about boundaries of the province and all districts. There is nothing showing demographic information. At the district level there are also official maps showing boundaries of the district (Figure 5.7).

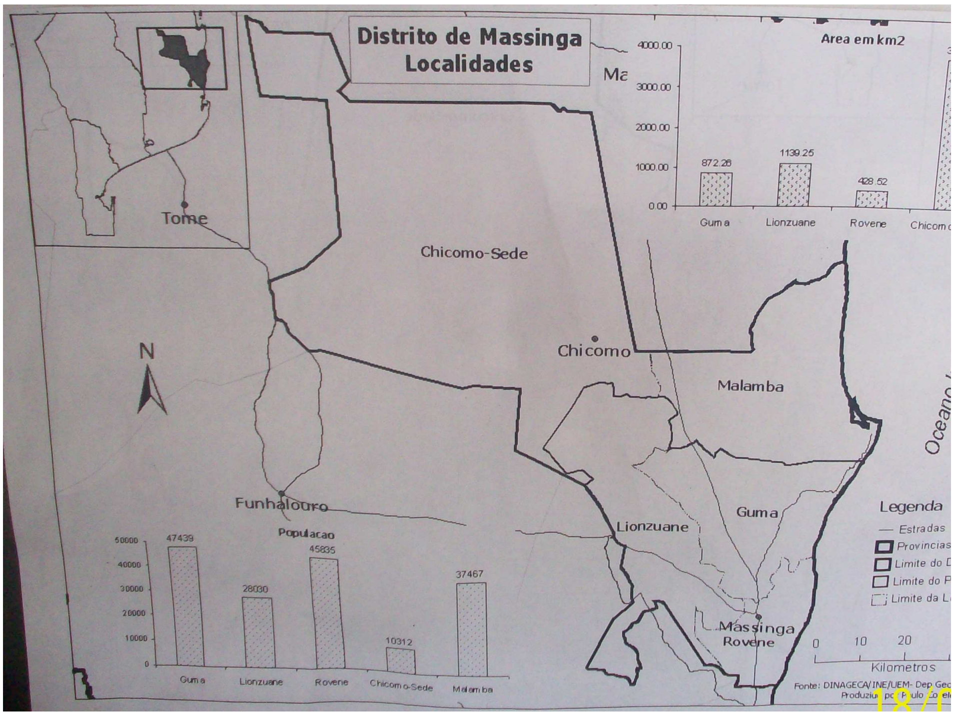


Figure 5.7: A machine designed map

At this level there are also hand designed maps showing boundaries and health facility locations (Figure 5.8(a)). These maps, according to one informant at Massinga district, are designed locally and updated periodically. In some districts the maps also show demographic information, location of health facility and health centres (Figure 5.8(b)).

Health managers use these maps for channeling human resources and to know where the health facilities are located. Health manages calculate the distances among the health facilities and the health centre. For instance,

> “*With this map it is easy to see where the health facility is located and with that we can know the distance to reach it.* ” (Medical Chief, Massinga, December 2008).

(a) Map showing location of health facilities

(b) Map showing location of health facilities and demographic data

Figure 5.8: Different hand designed maps

Reports

Reports are written using the MS Word text processor. These reports mostly contain tables and graphs reflecting events during a certain period of time. At the district level these reports are written monthly if there is a special need or quarterly. The quarterly reports are mandatory.

Reports are written at all levels. At the health facility level, reports are written to verify the status of implementation of related programs. At the district level they are written weekly and not only for local consumption, but also to be sent to province health directorate. These reports reflect information about all activities and the health status of the district. Also, they provide information about case, not only malaria cases, but also about other diseases.

At the district level, the reports are also written monthly to resume all activities according to the reports from the districts. Since the districts send weekly forms containing disease cases and reports, the DPS also uses this information to write their own reports. The reports are later sent to the national level. At the national level reports are written to satisfy certain specific needs like a reply to a request from a particular program sponsor.

5.2.4 Data interpretation

Comparison

The health workers and data manager at the district and province level regularly interpret the data by doing two types of comparisons:

- Data of one health facility or service with another to detect similarities and differences;
- Data of the same area or service analyzed over time to detect oscillations and tendencies;

Table 5.1 shows reported cases in Jangamo District. The report says,

> "*....The analysis of cases reported during a quarter in comparison with previous years, in the attached table as data source of BES conditions with its development, it is pointed out that malaria, diarrhea reduced significantly in previous years.*" Quarterly Report 2007, District of Jangamo.

Table 5.1: Epidemiological situation of Jangamo district

Disease	**Notified cases**			**Deaths**		
Source: BES	07	06	05	07	06	05
Malaria	5.290	12.332	9.087	2	0	2
Diarrhea	75	228	348	0	0	
Cholera	0	0	0	0	0	

Source: District Health Directorate, Jangamo.

Health workers interpret tables with reported cases of diseases to establish a priority scale between disease cases, programs and service results or personnel performance. Health workers use comparison to determine the best performing health facility, district or province in a specific program or service, at the end of the year.

Epidemiological thinking

Epidemiological thinking is the process of answering questions about the population covered by health facilities. "The key issue of epidemiological thinking is that it always relate data to known population" (Heywood and Rohde, 2002). From the research I can conclude that epidemiological thinking occurs at district, province and national levels. Documents that I had opportunity to read at district, province and national levels show that demographic information and malaria cases are both used to explain situational cases.

5.2.5 Information use

Once the data is collected it needs to be used otherwise all the efforts done will have no meaning. After collecting the data, there is a need to generate information which can be used for decision-making. The idealized relationship between data, information, and decision-making is that, "the collected data are transformed into information. Processing and analyzing information with problem solving in mind leads to knowledge. The interpretation of this knowledge, then, is guided by subjective judgement, rather than by objective, scientific rigour" (Sauerborn 2000, p.34).

The focus in this section is to elucidate the use and non-use of information because this is a major problem found in health information systems both in my own experience and in the published literatures. The study results show that health information is used in the following ways:

- to control epidemics;
- to plan and manage the health delivery services in the health facilities, including allocating the budget, allocating drugs, and consumables;
- to monitor and evaluate health facility performance;
- to monitor and evaluate the health information system performance.

The next paragraphs presents some examples demonstrating the use of health data in the Mozambican health information system (SIS).

One of interviewees at Massinga district said

> "*We are using the information for management purposes. For example if we want to allocate a new clinical officer to a health facility, we can select a unit and see the available staff list to see if there is a lack of a clinical*

> *officer or not*" (Responsible for Health Community, Massinga, December 2008).

Other informant at Jangamo district said

> "*Sometimes we use the received data from the health facilities to schedule meeting with the population to fight against new trends of outbreaks of malaria.*" (Medical chief, Jangamo, December 2008).

At Jangamo district, one informant said

> "*Looking at the numbers reported from nearby health facilities, we discovered that few children were vaccinated. Most of parents do not have habits of bringing their children to the Health centre to get vaccinated. So we decided that we will send the Mobile Brigade to schools.*" (Medical chief, Jangamo, March 2008).

However, there is a significant under-use of the health data found in this study. For example, the distribution of nets is one of the most crucial issues in all public health services when it comes to provision of health services. At Inharrime district, one informant said:

> "*We are not receiving enough nets to distribute to all pregnant women. We are using the demographic information to calculate the expected coverage of pregnant women. But, since not all the health facilities are receiving the nets, we are failing in delivering better health services.*" (District Medical Officer, Inharrime, December 2008).

Information system resources

Sometimes, the problem of under-use and non-use of information can be attributed to the accessibility of the health data and computer resources. This study attempted to investigate the accessibility of health data related to computing resources. One of the rationales for using computers in health information systems is to improve the accessibility for health data.

In the case study in Maxixe, despite the availability of computers, one informant replied "no", when asked if they use the computer for data processing. The same informant said,

> "*The two computers we have in our computer laboratory are only for writing reports purposes. They are also being used to write general documents as for generating tables and graphs for local use. Although we have the BES system installed in both computers, we don't use for data processing purpose because most of us do not have skill.*" (District Medical Officer, Maxixe District, December 2008).

The MoH distributed computers for HIS data to all districts medical offices. Despite this, health data are transcribed and reported using the official registers that are paper-based. As reported by on informant at Massinga district, this system is hard to handle,

> "*It is easy to use this system when reporting the collected data but it becomes very difficult to deal with the system when it comes to searching for a particular information in this piled forms. If we could use computers, I know that this task could be easy.*" (Medical chief, Massinga, December 2008).

While asked whether it is easy to retrieve health data, health facilities workers, in Cumbana, replied "yes", but at the district and provincial levels, they responded to "not easy".

> "*Look at these papers, all of them are forms from all the 12 districts. We received them last week. It is very difficult for me, because of the volume, to read and input all the data in the system.*" (Responsible for Epidemiology, province health directorate Inhambane, December 2008).

Also at the province level things get harder to do when it comes to generating local reports.

> "*To send data to the Ministry is very easy, we just export the data to a diskette and send the diskettes. However to retrieve data for local use is very difficult because you must search in the piled reports from all districts. The computer database is of less help if you want to create a report. Most of the cases, we export the data to Excel in order to generate specific tables*

and graphs." (Responsible for Epidemiology, Inhambane Province Health Directorate, December 2008).

The figure below (Figure 5.9) shows that Doctors, Nurses, Technical staff, and other health workers collect data by filling in a number of forms and register books. The Department of Statistics collect these filled forms and stores them. To get statistics, these data are copied again to other forms in a weekly, monthly, quarterly, or annual report. The report is edited in Microsoft Word and Excel or in other computer programs and distributed to the Ministry of Health (MISAU), and donors. The reports are also used for internal control purposes.

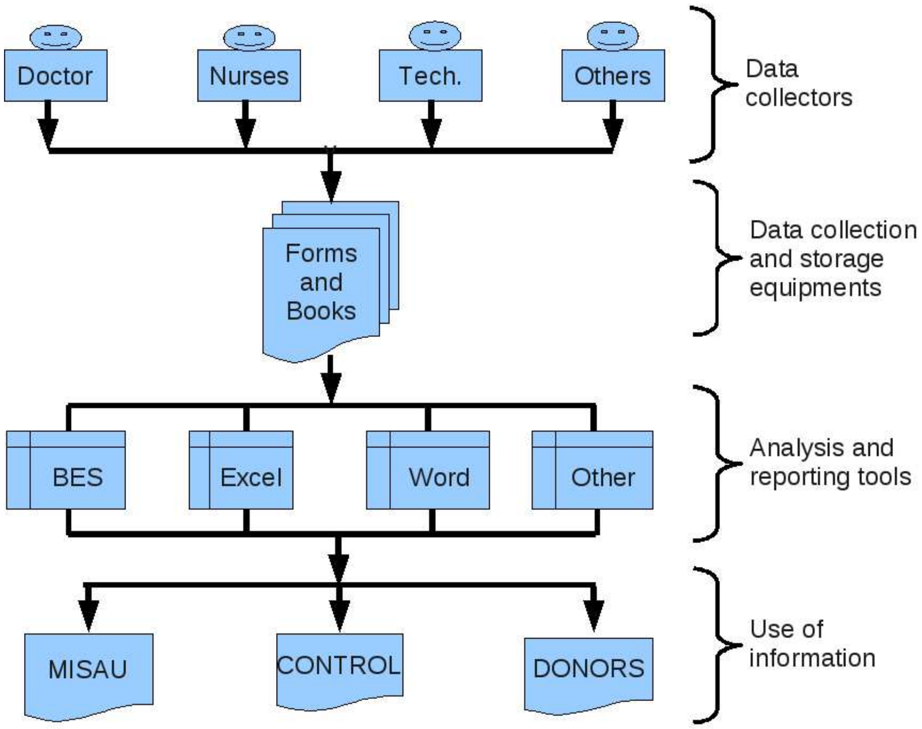


Figure 5.9: Health data processing at different levels

Supervision and feedback

Regular supervision is an important part of an effective health information system. During the fieldwork I was not able to identify any occasions on which the district or province office had provided written feedback to reporting facilities. Even at the district level, written feedbacks from the province level are not there.

The Department of Information in the Mozambique Ministry of Health conducts supervision in pre-defined periods of time. The Department of Information is the highest organ responsible for supervision in the Ministry of Health and within it there are other authorities responsible for supervision of specific diseases like the National Malaria Control Programme (PNCM) which deals with malaria issues. At the province level, the Provincial Health Directorate is responsible for supervision task. Each level has specific objectives while conducting the supervision. For instance, the Provincial Health Directorate has its objective of

- verify, monthly, the entire registration process of patients to the reporting data in the data BES;
- verify compliance with the standards for epidemiological surveillance in notifying health facilities;
- analyze the quality of information sent from health facilities to district and from district to Provincial Health Directorate.

It is not only the MoH that conducts supervision but also other international actors like donors and operational agencies. The main objective of the national actors (Mozambique MoH) and international actors is to check the implementation status of several programs running at different levels (province, district and facility levels). With the lack of specialized personnel, the Department of Information and other nominated level for supervision fail in conducting supervision.

According to interviewers at study sites, supervision visits are routine practices for data quality assessment for the outpatient services but not related to data consistency between the reported data and the facility reports. Generally, when supervisors of the health sector are doing supervision, they concentrate more on a particular situation. For instance, for the Expanded Program on Immunization, supervisors concentrated more on the consistency checks between data in the facility reports and the number of vaccines received during the same period (Mavimbe et al. 2005).

In some cases, data are primarily used to criticize or to reprimand local staff for not achieving targets, and not motivate and support their actions (Fumo 2003) and this is not seen as a form of feedback. Health workers also seek for positive comments in order to improve their work and consequently the health services. According to MoH (2001), “from a technical point of view, supervision has been implemented inefficiently. Monitoring, retro-information and incorporating supervision into management systems as a way of resolving problems have all been poor” (MoH 2001, p.27).

Although there is no evidence of written feedback at the district and health facility levels, there is a certain kind of feedback. For instance, health workers understand that medicines from Province Health Directorate are a result of reporting routine rather than province duty.

From the district level to the health facility level there is also a certain level of feedback. The health workers at the health facility level are required to report every week. As explained by one informant

> *“Sometimes we receive feedback from our district. For example, sometimes when we are having problems, like running out of stock for a particular medicine, we write a report and they send the medicines even if it was not scheduled. So we think that they react to our needs”.* Medical Chief, Cumbana health facility, December 2008.

Decision-making

During the research, interviewees at different levels recognized that relevant decisions can only be taken based on data coming from different existing information systems. Managers interviewed argued that decision makers need to have accurate data, in a presentable form and timely in order to make correct decision.

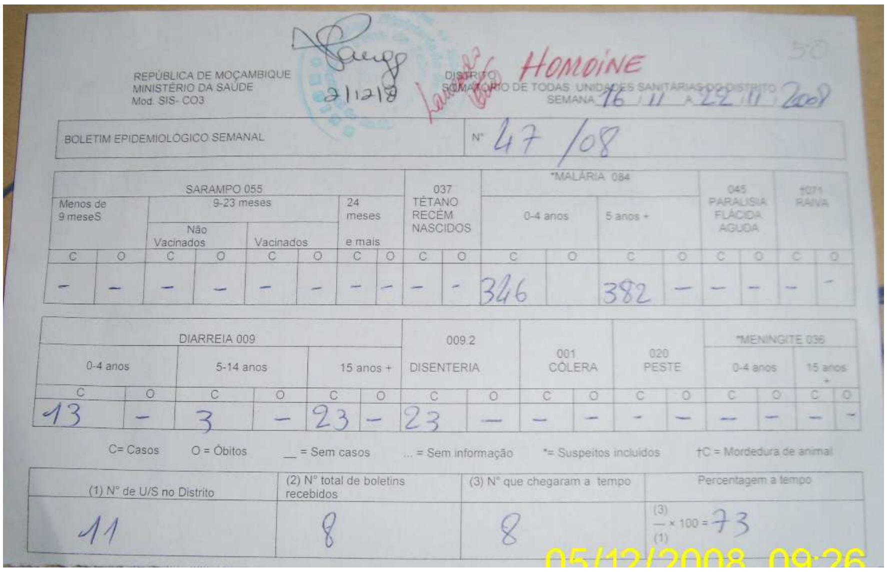
The MoH motivate managers at all levels to use the information collected at different levels for decision-making process. However, managers face difficulties when using collected data because of its incorrectness and incompleteness. The National Health System has set a deadline for sending data and reports to the upper levels, but this is not followed in many situations, according to managers at Province Health Directorate in Inhambane and at the District Health Directorate in Maxixe, Jangamo, Morrombene and Massinga. The interviewees in those sites argued that it is very difficult to make decision without information coming from other levels. This leads to conclude that the data collected are several times not used for decision-making process.

The problem of delays in delivering the data and reports to the Provincial Directorate of Health brings several problems when it comes to producing reports to be sent to Ministry of Health. Interviewees at the Provincial Directorate of Health in Inhambane argued that sometimes it becomes very difficult to write reports. And sometimes they use data that is not updated.

5.3 Tools used

5.3.1 Data collection tools

At health facility level the data is collected using the paper forms A01, A02 and A03, and then kept on paper based archive folders. Resume of the aforementioned forms is written in the A04 form called BES.



REPÚBLICA DE MOÇAMBIQUE
MINISTÉRIO DA SAÚDE
Mod. SIS- CO3

DISTRITO Homoine
SOMATÓRIO DE TODAS UNIDADES SANITÁRIAS DO DISTRITO
SEMANA 16/11 A 22/11/2008

BOLETIM EPIDEMIOLÓGICO SEMANAL N° 47/08

SARAMPO 055 Menos de 9 meseS		SARAMPO 055 9-23 meses Não Vacinados		SARAMPO 055 9-23 meses Vacinados		SARAMPO 055 24 meses e mais		037 TÉTANO RECÉM NASCIDOS		*MALÁRIA 084 0-4 anos		*MALÁRIA 084 5 anos +		045 PARALISIA FLÁCIDA AGUDA		†071 RAIVA	
C	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O
–	–	–	–	–	–	–	–	–	–	346		382	–	–	–	–	–

DIARREIA 009 0-4 anos		DIARREIA 009 5-14 anos		DIARREIA 009 15 anos +		009.2 DISENTERIA		001 CÓLERA		020 PESTE		*MENINGITE 036 0-4 anos		*MENINGITE 036 15 anos +	
C	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O
13	–	3	–	23	–	23	–	–	–	–	–	–	–	–	–

C= Casos O = Óbitos __ = Sem casos ... = Sem informação *= Suspeitos incluidos †C = Mordedura de animal

(1) N° de U/S no Distrito	(2) N° total de boletins recebidos	(3) N° que chegaram a tempo	Percentagem a tempo
11	8	8	(3)/(1) × 100 = 73

05/12/2008 09:26

Figure 5.10: A sample of BES paper based weekly resume

At the province level, since health workers use computer based health information system called MB (Módulo Básico), the data is entered in the database and the copies from the districts are kept on paper based archive folders. At the national level, the data is also stored in the MB system. The province health directorate sends the data in storage devices such as flash drives. Reporting tools being used at all levels are MS Word and MS Excel.

5.3.2 Processing phase

The Mozambican HIS uses two basic systems for storing and manipulation of routine data, and not only for malaria cases but also for TB, diarrhea, etc. These systems are BES and MB. These systems were designed as result of

- the need to prevent the duplication of effort necessitated by the manual system,
- the need for improved data quality by reducing data entry errors and
- the need for increased speed of availability of results.

The BES and MB systems were designed with the purpose of providing a user-friendly input to output system (Figure 5.11). These systems require a certain level of skilled personnel which do not exist at the health facility and district levels.

That is why, these system are mostly being used at the province and national levels. Several workshops and short courses have been carried out in order to skill health workers. In deed, for instance, when I was carrying out the field work I visited the province health directorate and I was looking to meet someone dealing with malaria data, I was informed that the person was doing a job at Inharrime district. The person was engaged in a course for local staff in data collection and storage.

5.4 Limitations

In Mozambique, the general problem in the health sector is that primary health care services are not accessible to everyone. Some factors that contribute to this problem include the lack of funds, human resources and infrastructure, difficult communication and access to the remote areas. For example, some nurses who run the health centres and posts do not have adequate educational background and some of the health facilities have been closed because of the lack of skilled people (Macueve 2003). "The existing

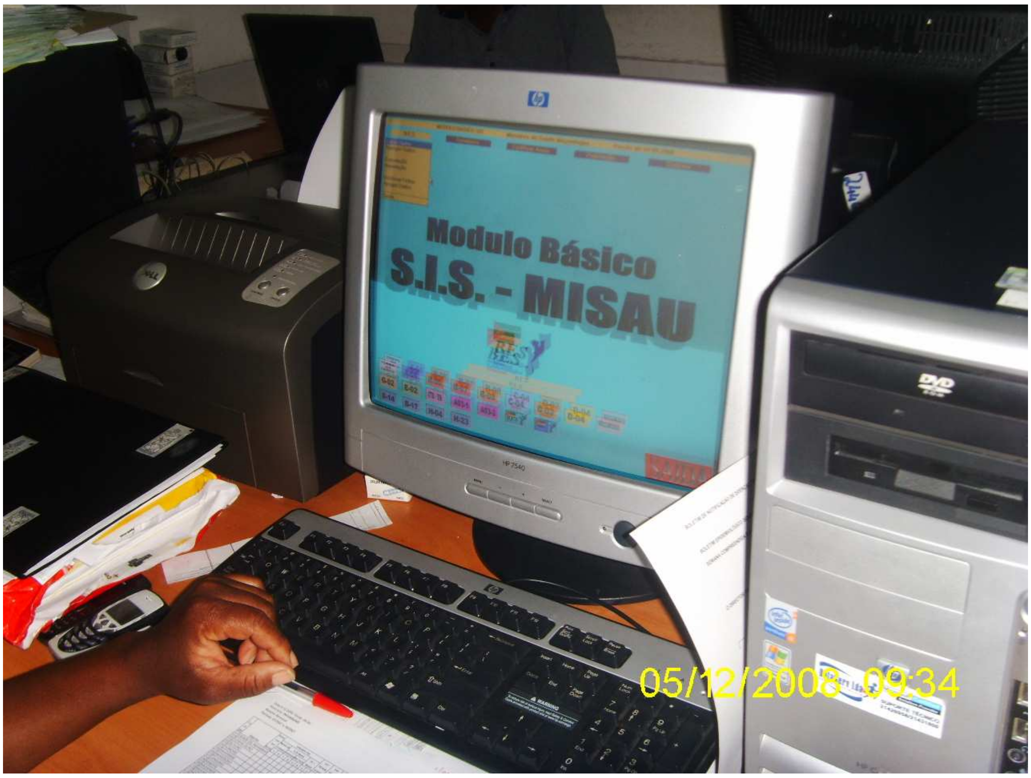


Figure 5.11: A sample of computer based MB system used at the Province and National levels

limited number of health workers struggle to provide care to the patients using poor resources and capabilities. So, filling data, analysing data is not a priority, since it is not directly related to the cure. The priority is to heal the patients." (Macueve 2003, p. 38).

5.4.1 Data problems

Malaria cases are based either on clinical (clinical malaria, suspected or relative) or laboratory (confirmed or objective) diagnosis and this system does not differentiate between the two types of malaria data cases. The value of clinical reporting is limited because clinical cases can easily be misdiagnosed as malaria due to various mimic symptoms such as meningitis, typhoid fever, influenza, hepatitis, etc. Another problem with this system is that the primary data collecting form does not identify the service or the individual who has completed it, making quality control difficult. As a consequence, I observed in some health centres that cases were not being reported and later deliberately "invented" to cover the missing data. In another example, in one health centre, clinicians had not reported data in two consecutive weeks (from 10th to 21st

November 2008). However, this gap could not be identified by the chief of statistics, leading to less cases being reported.

During the data collection process, different types of errors occur. Most of these errors occur at the health facility level, but are only detected at district level. From the research, I found that the typical and most important errors made by health workers in data collection are:

Gap between reported data and the real data: Real data means the data that are in the books and forms at health facilities or the right data confirmed by supervisors. Reported data are the data that appear in periodic reports produced by health workers at different levels. When both types of data are compared, the supervisors of SIS usually detect that these data do not match meaning that there are several problems at the health facility level where the data is collected. Usually supervisors compare the reported data and the real data present in the books and forms from health facilities.

Table 5.2 presents the problem. This table shows the reported data, the real data and the discrepancies between the two. As one can see these numbers are different which means the Province Health Directorate reports incorrect data.

Table 5.2: Gap between reported and real data in the districts

District	**Malaria Cases**		
	Reported	Real	Discrepancy
Inharrime	43.529	44.468	939
Jangamo	24.281	24.681	400
Maxixe	48.547	50.360	1.813
Massinga	38.813	39.056	243

Source: Malaria Control Province Report for Inhambane province, 2008

The report refers that the source of data is the BES system. But, when comparing these data it is easy to see that, although the source is the same, there are mismatches. By understanding the words of one epidemiologist working at the Provincial Health Directorate, the results presented in above tables become understandable.

> "*I usually participate in the supervision here in Inhambane province and I think that people at health facilities sometimes give a likely looking number in their reports to give us, at province level, the image that they are working hard ... and the supervisions prove the opposite.*"
> Epidemiologist, Province Health Directorate, Inhambane, 2008

Other stakeholders at Province and National levels argue that this is an intentional error used by health workers to give the impression of huge workload.

Calculation Errors: The data reported in the books and forms have calculation errors. At the health facility level after the data is filled in the books and forms, the health workers do manual calculations using calculator and then the output is written in a report form to be sent to the district. In most cases, the health workers do mistakes when calculating and inputting the data in the form.

Missing data: In most of the cases there are missing data. Many health facilities delay in delivering the data even though the health workers write reports. Usually when a certain health facility do not send the data and the data is received later in another form by adding the actual results with the delayed, they normally write at the back of the report some information about the data added. Table 5.3 shows a case of missing data in a report written at province health directorate. As one can see in the report no data is reported for malaria cases in 2008 and no death cases due to absence of malaria cases reported. This sounds strange since the report was written in the third quarter of 2008.

Table 5.3: Missing data

District	**Malaria cases**		**Deaths**	
	2007	2008	2007	2008
Maxixe	17227	48547	13	17
HP-Inhambane	5761		0	

Source: Malaria Control Province Report for Inhambane province, 2008

In addition to these problems, there are extreme delays in sending the completed form from the health facilities to the district. In this case, the subsequent week's form usually provided the missing week's data aggregated with the current data with some comments on the reverse of the form. Such untimely reporting contributed to the poor quality of data.

Aggregation also brings other problems. In terms of disadvantages, data aggregation can turn aggregated data into non-useful data because it hides important details. For example, when at district level, data from all health facilities are aggregated, all detailed information about health facilities becomes lost. The managers of District and Province Directorates' of Health only realize this problem when the Ministry of Health sends, for example, a stock of medicines. They have problems in delivering the medicines to the districts and health facilities because the information is aggregated. For example, if the district of Jangamo needs 500 nets and Inhassoro 200 nets, the Province Health Directorate will aggregate the information into 700. In turn, the MoH will provide 700 nets to the Province Health Directorate without knowing exactly which district needs the nets.

5.4.2 Human resources

Many countries lack the human resources needed to deliver essential health interventions for a number of reasons, including limited production capacity, migration of health workers within and across countries, poor mix of skills and demographic imbalances (Gupta & Poz 2009). Mozambique has been identified as having a critical shortage of skilled medical, nursing and midwifery personnel (WHOb 2006). This shortage of skilled staff influence negatively in delivering proper health services to desired population.

At the health facility level this lack of skilled personnel influences negatively in delivering the health services, and to the information cycle at large. Many districts do shifts of their personnel in order to help their health facilities:

> "*Sometimes we receive information from health facilities under our jurisdiction asking for help in personnel staff. For example, at Rio das Pedras and Cangela we had to send some of our local personnel staff to support the staff that they have because of new outbreaks of malaria in those health*

facilities". (Responsible for Health Community, Massinga, December 2008).

Although the Province Health Directorate do have scheduled plans for improving the skills of its personnel, there still are problems. There is also the problem of lack of staff. For instance, when I visited Maxixe district and I was about to see the person responsible for epidemiology, I was told that I had to wait because the health worker was busy with patients. I had to wait almost two hours to see the worker.

The problems of shortage of human resources can be felt in all levels of the Mozambican's health information system. At the province level, there are problems with skilled personnel to deal with malaria data. The available personnel have to deal with huge amount of data and at the same time see patients. This increases the possibility of errors in data handling. The data reported is not even checked for its accuracy and no validation is done. Yet the upper levels believe that the data received can be useful for something, although they acknowledge all these problems.

At the national level the problems of lack of skilled staff can also be recognized. For instance, in the Department of epidemiology one can find a doctor doing double job, handling malaria data and collecting data at the hospital while this first task could be left to a statistician.

5.4.3 Sumary of the problems

Problems found in the fieldwork sites suggest that:

1. Lack of understanding of use for which data is collected.
2. Inability to distinguish between data that are needed for service delivery and data needed for programme management and monitoring.
3. Inability of lower administrative levels to generate summaries of raw data collected due to:
    - Lack of skilled personnel
    - Lack of data processing facilities (calculators, computers, etc.)
    - Lack of staff with computer skills

  - Lack of an Epidemiologist Statistician

4. Lack of storage facilities for raw data at lower administrative levels (at the health facility level).

5. Data retrieval issues; inability to generate any information because of computer breakdown (at the health facility level).

6. Technical expertise/capability of data providers at data source is not consistent with the level of complexity needed for data collection tools.

7. Sometimes decisions are made without evidence.

8. Poor use of information for decision-making

9. Data not sent timely.

10. Lack of motivation (poor salaries, lack of feedback), and skills for data entry and analysis.

11. Poor quality of data.

5.5 Summary

The main findings of the empirical research can be summarized as follow:

- Data are collected methodically by health facility level and systematically sent up to district and province levels.
- Data quality is poor due to:
  - Excessive amounts of data being collected;
  - Lack of clear definition of data elements;
  - Aggregation at district level in such a way that health facility detail is lost;
  - Lack of feedback from higher levels.
- Graphs are widely used and displayed but most of them are meaningless;
- Feedback exist but not at all levels;

- District Health Information Software and other related software are not used at district level by health workers;
- Work condition aspects affect the performance of health workers;
- Supervision is not routinely done and when done they focus on few elements;
- Decisions do not occur at all levels and if they are taken they are not based on updated information.

Chapter 6

GIS PROTOTYPE DEVELOPMENT

This chapter explains the process of building the GIS prototyping system. This explanation includes building the non-spatial and spatial databases and how they were linked.

6.1 Maps and malaria

The research findings chapter, particularly in data presentation phase subsection, presented the findings about the use of maps at the district level. The health workers at the district level use maps to present demographic information and location of health facilities. These maps are designed locally and they are used mainly for management of resources. The health workers also use these maps to calculate the distance between districts, community centres and health facilities. These maps can also be used to map malaria cases for a particular health facility with a specific number of population. The features in these maps are limited but still provide some information needed by the health workers.

The ideal map linked to malaria should show among other features, malaria cases related to population in a specific area. This idea of having malaria data reflected on a map is greatly helpful, not only because it can facilitate the understanding of a specific scenario, but also because it facilitates the health management and decision-making. Health workers at different districts visited, lack maps showing malaria data and other information fundamental for management of malaria. For instance, with a map showing malaria data and population data and other features like roads, position of health facilities and health centres, it is possible for a health worker to know where there is a need to take more action. Possible decisions include allocation of net, spraying, and vaccination.

The idea of having population data together with land features is seen by the health workers to be good, and that is why the health workers keep drawing these maps. According to the problems managed by the decision makers and the opportunity the GIS brings to the malaria field, maps can easily be used to address the problems faced by the decision makers to analyze the outputs and address malaria problems. The next section describes the process of defining the necessary requirements, according to the Department of Community Health, needed for malaria management and decision-making.

6.2 Prototyping process

6.2.1 Requirements

The project objective was to support decision makers at the Department of Community Health and Epidemiology Department by providing the following analysis, which could be used for decision making:

- Representation of health indicators (malaria) by geographical areas.
- Comparison of health indicator (malaria) over time and across geographical areas.
- Access to health facilities by combining the population data with its location.
- Coverage of health indicator and combine with its geographical area.
- Any other application that is identified to be important.

Table 6.1 shows some of the malaria indicators.

Table 6.1: Malaria indicators

Indicator	**Definition**
Reported malaria cases	Total number of reported malaria cases
Reported malaria deaths	Total number of reported malaria deaths
Laboratory confirmed malaria cases	This term denotes all patients with signs and/or symptoms of malaria and laboratory-confirmed diagnosis who received antimalarial treatment.
Probable or clinically diagnosed malaria cases	This term denotes patients who are supected to have malaria based on clinical signs and symptoms and who receive treatment for malaria.
Confirmed malaria deaths	This term denotes deaths among patients with laboratory-confirmed diagnosis of sever malaria.
Household net possession	households with mosquito nets (or ITNs): the percentage of households that possess one or more nets, treated on not.
Household ITN possession	Households with mosquito nets (or ITNs): the percentage of households that possess one or more nets, treated or not.
Net use among children under five years of age	Under-5s using mosquito nets (or ITNS): the percentage of children under 5 years of age who slept under nets (or ITNs) the night before the survey.
ITN use among children under five years of age	Under-5s using mosquito nets (or ITNs): the percentage of children under 5 years of age who slept under nets (or ITNs) the night before the survey.
Net use among pregnant women	Pregnant women using nets/ITNs: the percentage of women reportedly pregnant at the time of the survey who slept under a net /ITN the night before the survey.
No. of nets sold or distributed	Number of nets sold or distributed
No. of nets (re-)treated	Number of nets (re-) treated
No. of households/units sprayed	Number of households/units sprayed indoor residual spraying efforts

6.2.2 Gathering data

Two types of data are needed to develop the prototype. These are non-spatial and spatial data. The non-spatial components include various elements ranging from malaria cases to demographic data, as described below:

- Routine malaria data from the Department of Epidemiology in the Ministry of Health and from Province Health Directorate at Inhambane province.

- Semi permanent data relating to infrastructures of health facilities and population.

- Data on health indicators from demographic health surveys.

The gathering of spatial components also included various elements which are described as follows:

- National level boundaries;

- Province and district level boundaries;

- Location of various health facilities;

- Road maps;

- Physical features like rivers, lakes, and mountains;

- Any other map data that is available in digital for.

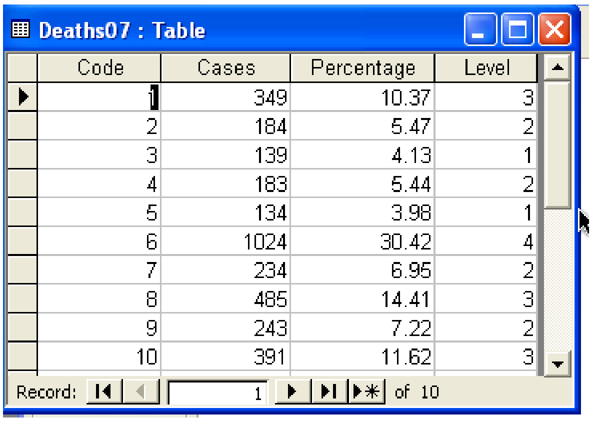
The MB system, the key non-spatial data source for the project was studied prior to data gathering. This software integrates an export feature that outputs files in different formats including .xls (MS Excell format). The system was implemented in all provinces and at the national level. In addition to the routine health data, the MB software includes epidemiological data. While the process of studying the MB software was going on, other activities such as customizing the GIS application was taking place in parallel. Unfortunately it was not possible to install MB software due to accessibility constraints. In addition to malaria data, demographic data were gathered in the National Statistics Institute's (INE) website. The demographic information was gathered in different forms.

6.2.3 Preparation of the non-spatial data

The non-spatial data comprising malaria data and demographic data were gathered in two different locations. The first was gathered in PNCM. In this location it was only possible to collect malaria data from 2001 and 2007. But from 2001 to 2005 the data was not complete. The other source of malaria data was the MB system from the Inhambane Province Health Directorate. In this location it was possible to collect malaria data regarding the first 9 months of 2008. The remaining malaria data was not possible to collect due to the fact that the system was still not updated. The data was exported from the MB system in form of MS Excel files.

These malaria data were then cleaned and prepared in an MsAccess database where different tables were created. For example, a table composed of four fields was created. These four fields contained attribute values of the Code (attribute of the province), Cases (number of deaths due to malaria), Percentage (of coverage) and level (1, 2, 3 and 4, referring to ranges 0 – 5%, 5 – 10%, 10 – 15% and above 15%, respectively) (Figure 6.1).

Figure 6.1: Attributes values of a MsAccess table



Deaths07 : Table

Code	Cases	Percentage	Level
1	349	10.37	3
2	184	5.47	2
3	139	4.13	1
4	183	5.44	2
5	134	3.98	1
6	1024	30.42	4
7	234	6.95	2
8	485	14.41	3
9	243	7.22	2
10	391	11.62	3

Record: 1 of 10

Other tables were created including for tables demographic data. For the demographic data there was no need for data cleaning. These data were also populated in the same MsAccess database. This data was arranged in three columns, namely district ID, District and Population. The District column refers to the district name and population refers to number of people living in that specific district according to the census carried out in 2007.

In resume, the identification attributes of the non-spatial data were modified to correspond to the spatial attributes. The following steps were taken:

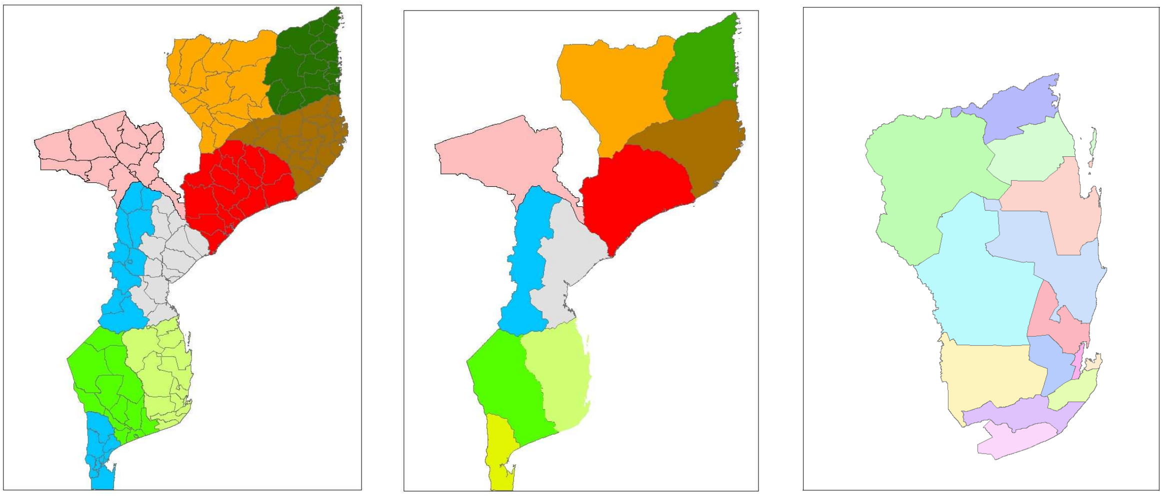
- collect the non-spatial databases;
- create the attribute tables of the MsAccess database;

- adjust the attributes to correspond to the spatial attributes.

6.2.4 Preparation of the spatial data

Different maps with different scales were collected from different sources. These maps are of scale 1:50 000 and 1:25 000. To effectively analyse the maps, it was necessary to divide them into three sets: two at the national level and other at the province level (Figure 6.2).

Figure 6.2: Different sets of maps used for analyzing the data



The maps of the national level consisted of provincial boundaries and the other of district boundaries of the whole Mozambique. In all these maps a common field was identified. This common field was identified to enable the linking between the spatial and non-spatial databases. Although, cleaning of the maps was not necessary since the lowest level was district which could be easily identified, there was a need to generate new shape files as a way to get a certain specific maps. For example, a new shape file of Inhambane province with its health facilities was created.

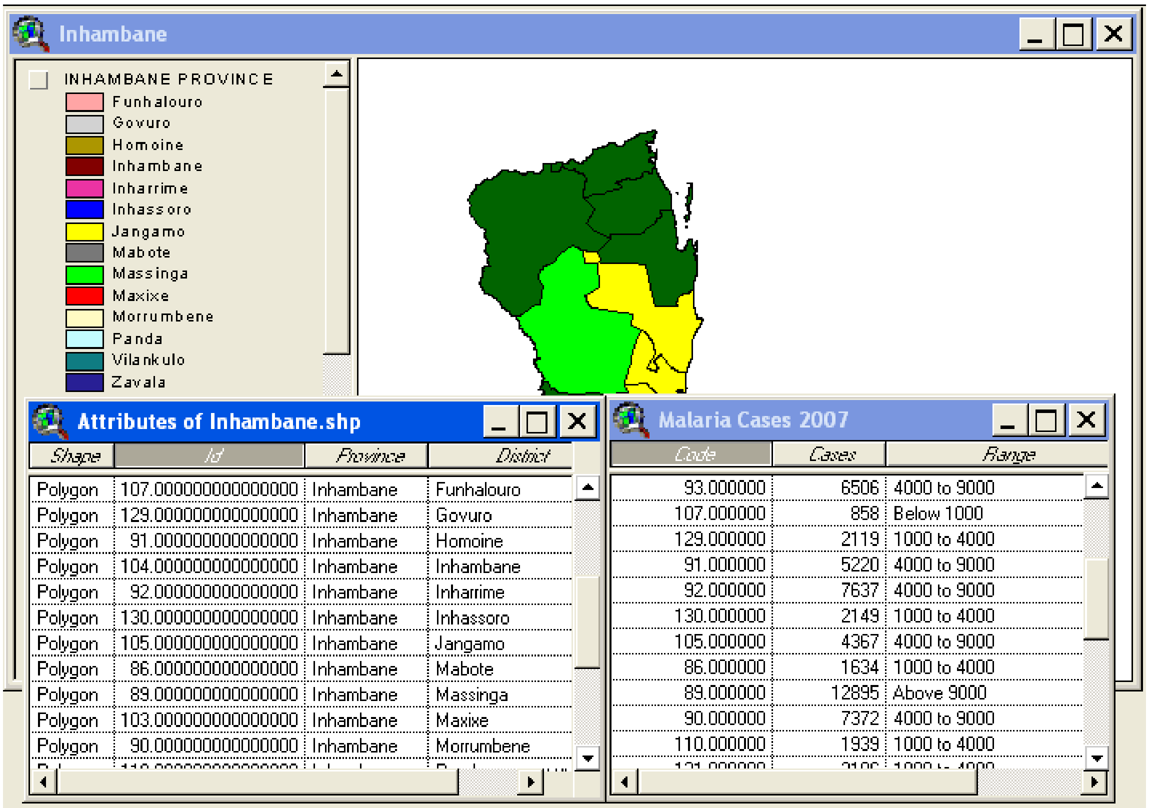
6.2.5 Linking the data

The spatial data had predefined attributes in conjunction with the descriptive information which constitute the raw material to the prototype's functionality. To fit it with the non-saptial data there was a need to design an MsAccess database of the non-spatial data. The following steps were used to produce a linkage between the two data.

1. The MsAccess has to have the same structure of the database of the shape files. A common column field was identified in the spatial database and included in the MsAccess

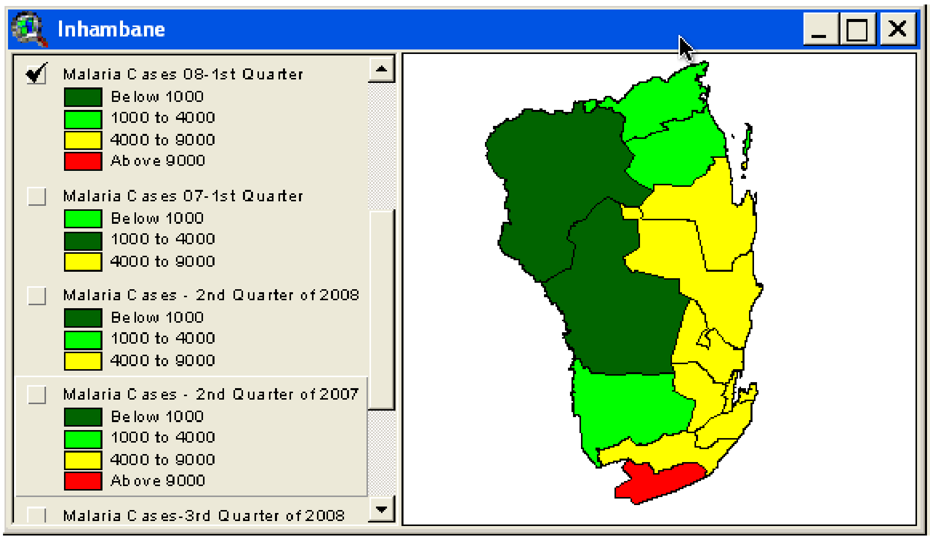
2. In Arcview, a connection with the database in MsAccess is established in order to gain access to the created table. With the join tool in Arcview, the attributes table of the shape file with the MsAccess table are linked through the common field as seen on Figure 6.3.

Figure 6.3: Linking shape file to a MsAccess table



3. After the linking step, the shape file is classified according to a specific field on the MsAccess table. A classified map is shown in Figure 6.4.

Figure 6.4: Chassified shape file



6.3 The potential of GIS prototype

This section aims to provide examples of possible spatial analysis of the GIS prototype. With the GIS prototype it is possible to perform geographical analysis based on different needs. Specifically for malaria, the spatial analysis for health information system data can be categorized as follows:

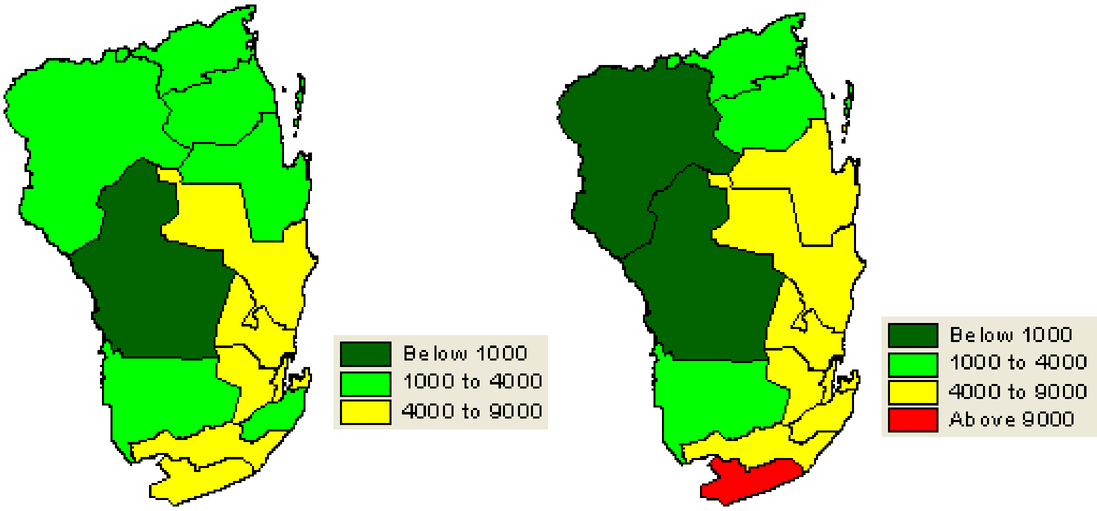
6.3.1 Comparative analysis of raw data

It is possible to display the routine raw data for selected range of time periods across different health facilities. For example, while Figure 6.5(a) shows the number of malaria cases for the first quarter of 2007, Figure 6.5(b) shows malaria cases in Inhambane province for the first quarter of 2008.

6.3.2 Coverage of health indicators

The analysis of both performance indicators and health indicators across health facilities over a period of time can be presented. For example, the performance of indicator "Number of nets distributed" for the third quarter of 2007 can be presented in a map (Figure 6.6).

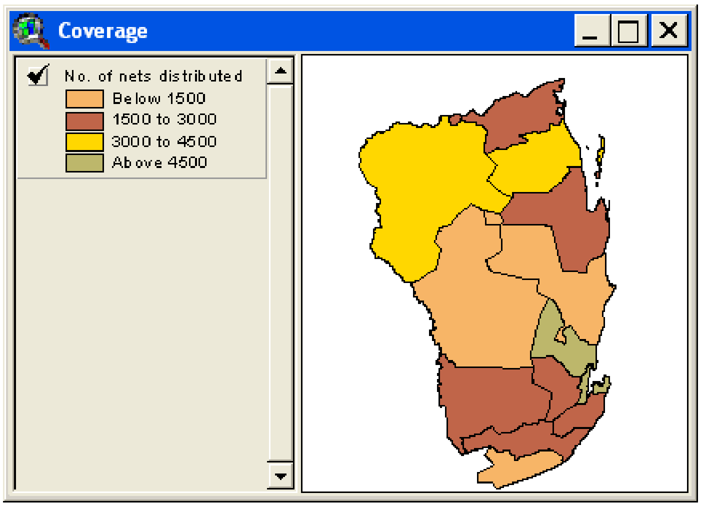
Figure 6.5: Comparative analysis of raw data



(a) Malaria cases for the first quarter of 2007

(b) Malaria cases for the first quarter of 2008

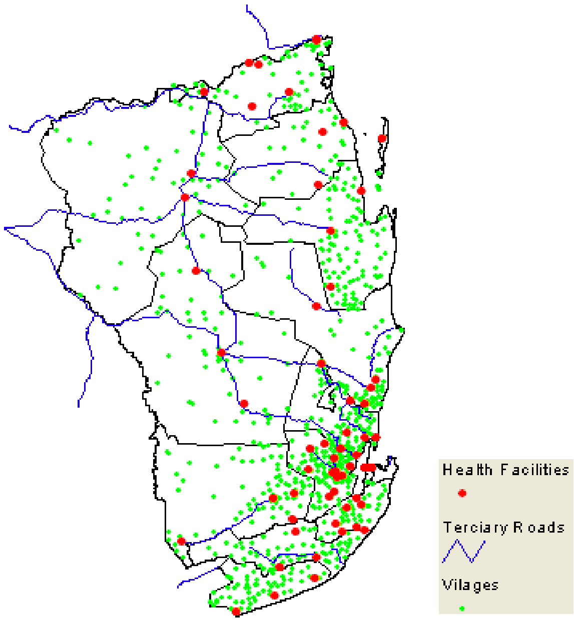
Figure 6.6: Number of nets distributed in Inhambane province for the third quarter of 2007



6.3.3 Health information infrastructure

Through the use of GIS, information on specific health infrastructure can be easily compared across different health facilities. For example, Figure 6.7 shows a map of Inhambane province with its health facilities, road infrastructure, etc. It is possible to see that some districts have fewer health facilities than others and it can become easy for the decision makers to know approximately where to locate a new health facility. This decision can help reduce the distance that patients have to travel to get to the nearest health facility.

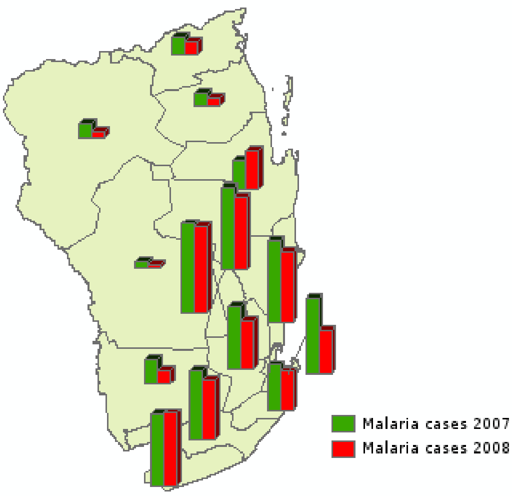
Figure 6.7: Inhambane province with some of its health information infrastructures



6.3.4 Comparative health data analysis using charts

Health workers do comparisons through the use of charts in order to find specific trends. Through the use of GIS it is possible to display different health data across health facilities, health districts and across different time periods (Figure 6.8). With this way of representation it is possible to visualize the deaths coverage, malaria cases, etc.

Figure 6.8: Comparative malaria cases of the first quarter of 2007 and 2008



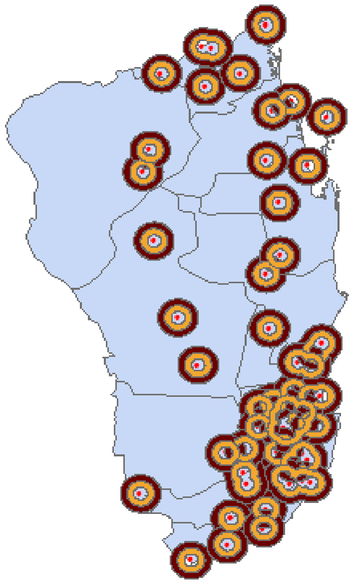
6.3.5 Location analysis

In the health sector location is a very important element. Knowing the location of a hospital makes it easy for decision makers to address certain health related problems. A map showing location and access to different health facilities can be displayed easily with zoom feature. Like in Figure 6.7 it is possible to the location of health facilities. The possibility to incorporate other features such as roads makes it easy to know how to access a health facility and even the distance between two health facilities.

6.3.6 Buffer analysis

Buffer Analysis is one of the most important functions of spatial analysis in GIS. Its basic idea is to create a zonal area of a certain distance around its boundary, namely buffer zones and to identify the impact range and service range to surrounding environment (proximity). It is possible to use the buffer feature to analyse the coverage of health facilities with respect to population catchment area. For example, Figure 6.9 shows health facility coverage using 5 to 10 kms buffer in Inhambane province.

Figure 6.9: Inhambane province-Health facility coverage using 5 to 10 km buffer



Health workers empirically use this feature in their daily analysis of catchment. As referred in section 5.2.3, health workers in some districts also use maps to visualize the catchment area of the health facilities. With this buffer feature it is generically possible to specify the size of the buffer and then combine this information with malaria incidence to determine how many cases fall within the buffer.

6.4 Strengths and weakness

To establish what the prototype's strengths are, it is necessary to think about how much useful it might be for the potential users. So far, the Ministry of Health in Mozambique has no tools that help to carry out spatial analysis of malaria health data, although attempts have been done on the ground. For example, the National Malaria Control Programme introduced HealthMap, a free GIS tool provided by the World Health Organization but failed due to lack of skilled personnel.

With this prototype, the Ministry of Health and the Province Health Directorates in particular, may rely on this as a tool that allows them to plot on the maps and display health related information such as health facilities and malaria data plus some other information like geographical features and population obtained from national surveys just to mention a few. Thus, the decision making process is easier to carry out when all information needed is graphically displayed and linked.

As a prototype the tool is in constant development stage, therefore it is not right to establish the lacking of any kind of functionality as a weakness. However, the prototyping process is time-consuming. Besides, it needs a considerable number of embedded attribute values that are not updated and that constitute a huge disadvantage from the point of view of what now exists and what is within the shape files. Another constraint is that the non-spatial data is not updated regularly. For example, malaria data used in this prototype was gathered in December but data for October and November was still not available.

6.5 Summary

This chapter discussed the GIS prototyping process. This process had taken various steps, namely definition of requirements, data gathering, and preparation of the non-spatial and spatial data. The results of the prototype were highlighted in section 6.3.

Relevant strengths and weaknesses were presented in section 6.4 where it was pointed out that the lack of updated data is the main constraint for the GIS prototype.

Chapter

7

DISCUSSION AND CONCLUSIONS

This chapter discusses the key empirical findings presented in Chapter 5. The chapter also responds to the research questions and objectives as presented in Chapter 1. It, therefore, address the following three research questions:

1. How can GIS be used to improve the mapping of Malaria and decision-making in Mozambique?
2. What are the challenges associated with using GIS in mapping Malaria?
3. What strategies can be used to overcome these challenges?

For the remaining part of this chapter I will address the above stated questions in connection with the research findings (Chapter 5) and available literature. In doing this, the discussion is guided by GIS literature presented in Chapter 3.

7.1 Use of GIS to improve mapping of malaria and decision-making

Maps produced by GIS can be used to undertake spatial analysis for disease control, health care planning and management and to investigate the epidemiology of malaria. Johnson & Johnson (2001) argue that GIS can be used by public health administrators and professionals, policy makers including epidemiologists in the following area:

- Find out geographical distribution and variation of disease;
- Analyse spatial and temporal trends;

- Map populations at risk and stratify risk factor;
- Plan and target interventions;
- Monitor disease and interventions over time;
- Route health workers, equipment and supplies to service locations;
- Locate the nearest health facility.

Maps produced using the GIS prototype and shown in Chapter 6 appear to be feasible to use GIS as a tool for mapping malaria. Relying on maps produced using GIS, health workers may easily make decision and take action rapidly. But, maps indicating the locality of disease in local areas are difficult to interpret. Indeed, they may be misinterpreted by a health practitioner who is not aware that, in small areas, there are naturally marked geographic variations, even when the true disease rate do not vary.

Melnick and Fleming stress that "Ironically, the power of the GIS tool may also be its biggest pitfall. The consequence [of integrating] complex data into a visually easy to understand picture ... is a setup for misunderstanding and misuse" (Melnick & Fleming 1999). Indeed, maps may lead a decision-maker to draw false conclusions. The cartographer's paradox is that "to avoid hiding critical information in a fog of detail, the map must offer a selective, incomplete view of reality" (Monmonier 1996).

To avoid drawing false conclusions, public health practitioners need to be alert for "lies" that can range from "little white lies" (suppressing details selectively to help the user see what needs to be seen) to more serious distortions in which the visual image suggests conclusions that would not be supported by careful epidemiologic analysis (Richards et al. 1999). For example, when some geographic units of analysis have small denominators, disease rates computed for these areas may appear extremely high if any cases have occurred in these areas. When the rates for these geographic locations are displayed on a map, readers may incorrectly conclude that these are "hot spots", high priority locations for targeted interventions. More appropriately, these areas should be labeled to indicate that rates are statistically unstable due to small numbers and therefore not shown.

Although much can be mentioned about how GIS can be useful for mapping malaria, there are important challenges that need to be analysed and from them strategies must arise and discussed appropriately. The next section analyses such challenges.

7.2 Challenges in using GIS for malaria in Mozambique

This section addresses the second question which focuses on challenges associated with using GIS for mapping malaria.

The challenges in using GIS for malaria research can be organized in three areas. The first relates to data concerns. Without adequate data, GIS is not very useful. Specific problem areas include: accurate data on the disease and how it is reported; and demographic data. These areas are part of the non-spatial data for a GIS application without which it is not possible to deploy. The spatial data is also an important area and without it GIS itself is nothing. The spatial data includes maps, and other Earth surface features such as rivers, lakes, etc.

The second area relates to technology – specifically computer hardware, GIS software and training. The third area concerns methods – assuming the previous data and technological problems have been resolved.

7.2.1 Data challenges

This subsection is divided in two parts. The first is related to malaria data and the second to spatial data. The malaria data problems are deeply related to collection and reporting mechanisms. In depth, these disease reporting problems include:

- Repeat visits of a patient to the same health facility resulting in a duplicate case reporting;
- Out-of-date information or non-reporting of data due to technical problems or because the local clinic does not see the value in sending data to the higher levels

for processing;

- People diagnosed with malaria but not verified with blood test
- People not visiting a health facility even though they may have malaria.

The aforementioned data problems contribute heavily to several other problems. For instance, it becomes very difficult to decide how many nets a particular donor programme can provide for distribution to a specific area considered of high risk if the number of malaria cases are reported incorrectly. Also, the available data brings other problems related to false alarms of outbreak.

There are many problems discussed in the research findings chapter. These problems include the use of different channels for data reporting. The use of these multiple channel makes the process of malaria reporting complex. In this sense, there is a need for a national dialog on the improvement and standardization of the quality and quantity of malaria data needed to be collected.

In addition to the constraint of data quality, a lack of suitable GIS data sets is a major impediment to implementation of GIS. The access to spatial data (which are fundamental to any GIS application) constitutes a huge advantage.

The spatial data problems relates to availability and quality of data. The effectiveness of GIS depends, firstly, on availability of useful dada, since the power of GIS application relies on the scope and quality of data used, and lastly on the degree of relevance of the input data. In developing countries like Mozambique, the availability of spatial information is poor or non existent. In many cases, the spatial data is in the form of unscaled sketches. Particularly in Mozambique, the existing maps are out dated or classified as restricted information and access by public departments is very difficult if not impossible. Much of the spatial data that exist in Mozambique resulted from data collection efforts done by many organizations and they occurred in a decentralized and uncoordinated manner.

These data constrains are magnified in contexts such as the health sector, which traditionally have not used maps in their everyday work. In the health sector data are often non-existent, and when existing are often hard to find due to poor data sharing culture and a lack of institutional commitment to provide data (Ginger 2005) and lack of institutional co-ordination (Saugene 2005). Saugene discusses the lack of data sharing culture arguing that "one of the fundamental problems is the lack of awareness of value of spatial data" (Saugene 2005, p. 159). However, the main reason is the bureaucratic apathy towards such requests displayed by the concerned holding institutions that restrict access to maps. Thus, the existing maps present problems of scale, inconsistency and incompleteness.

7.2.2 Technology problems

Three problems related to technology problems will be discussed in this part. The first is concerned with computer hardware. Tanser & Sueur (2002) argue that computer hardware is becoming increasingly cheaper and more powerful, so that even complex analysis of GIS and image can be carried out on a desktop computer. However, some problems still exist such as having to keep up with new operating systems (Windows XP vs Windows Vista, etc) (Sipe & Dale 2003). In the research sites it was found that there is a lack of computers. Even at highest level, the MoH, one can experience these problems.

The second problem is about GIS software. The main problem with software is cost. The cost for site licences for most of GIS mainstream packages is far too expensive for most health departments. Whilst there is an increasing amount of free software, the commercially available comprehensive packages remain expensive. Thus, while a copy of the software is manageable, what is unmanageable are multiple copies of the software (Sipe & Dale 2003). Something has been done in the Ministry of Health, but such effort were reduced to almost nothing because of the above reasons. A software also requires hardware compatibility. Without such compatibility it is impossible to install such software.

The third issue is about training on use of the software. Regarding this there are two relevant levels of training. The first relates to how to use a basic GIS package. The second relates to how to use GIS software to better understand and manage malaria. In many ways the first issue is easy to resolve. These ways include the on-line training material available on the Internet; many books provide GIS training, and also many Aid Organizations provide GIS training. But unfortunately, professionals seeking training in GIS rarely find specific courses or workshops on the application of GIS in public health issues particularly for malaria. The problem that often occurs is a lack of coordination in this training. For instance, in many cases people are sent off to get training but then do not find a corresponding technological environment in terms of software and hardware when they return. Or the person that gets the training is not the one that really needs to know how to use the software. The other training issue is how to use GIS specifically for malaria control. Sipe & Dale (2003) argue that there is little training material in this regard. Thus, there are serious educational needs for both researchers and practitioners in the health fields who are using GIS in their work and who are struggling to find the educational resources to meet their needs. It is important to remark that, just knowing GIS does not mean that one can use it effectively to deal with malaria research and control (Sipe & Dale 2003).

7.2.3 Methodology

The last issue relates to methodology problems. The methodology problem is linked to spatial statistical analysis - how can spatial analysis help in understanding malaria? This is closely related to the training problems noted above. There are two aspects that need to be addressed in this issue. The first is of not having appropriate software. The second is that even with appropriate software, how does one use it, interpret the results and use this information in a management context?

Most GIS software do not deal with spatial statistics and those wanting to perform this type of analysis must use another piece of software or with an add-on module such as ESRI's Geostatistical Analyst. Even that requires extra time and skill which somehow might not exist. Looking at the literature, one might reach a point whereby concludes that there is little guidance on how to use spatial statistics.

This is a general problem and not limited to public health or malaria. Being able to generate maps that show malaria incidence by month or year is clearly a step forward. However, interpreting what it means is another matter altogether. Spatial statistical analysis also requires training. And because it is a very complex area, most of GIS software do not include built in such features. Even though, there is a need for inclusion.

7.3 Strategies to overcome obstacles

This section addresses the third research question in which I discuss some possible strategies to overcome the obstacles discussed above. Unfortunately, some of these obstacles have no quick and easy solutions – they require concentrated efforts, time and money.

7.3.1 Addressing data related problems

Malaria data

In the research findings chapter, particularly in the data collection and data processing subsections, it was shown how the current sources of malaria data, mainly register books, contribute to a large extent to the poor quality and sub-notification of data reported and thus decisions made are based on an incomplete and often incorrect picture. This situation is aggravated by the existing four reporting channels, presented in Figure 5.3, that are very fragmented with little or no communication between them.

The discrepancies of inpatients data in district reporting systems between data in paper format and digital data at province level is also a course os concerns. This suggests that data entering errors and incorrect checks and verifications contribute to incorrect picture. There is also important data that are not gathered but are necessary for the targets and indicators established in the national malaria strategic framework, including data by age groups, gender and the status of pregnant women. All these are important for accurate and reliable estimates of trend in incidence and mortality.

To overcome the above mentioned concerns, it is recommended that all malaria case reporting systems should be integrated into one standardized system in terms of using the same data collection forms and tools. One approach could be the diagram presented in Figure 7.1, where malaria data would be reported weekly from health facilities to district and from district to province levels and reported monthly from the province to the national levels (Chilundo et al. 2004).

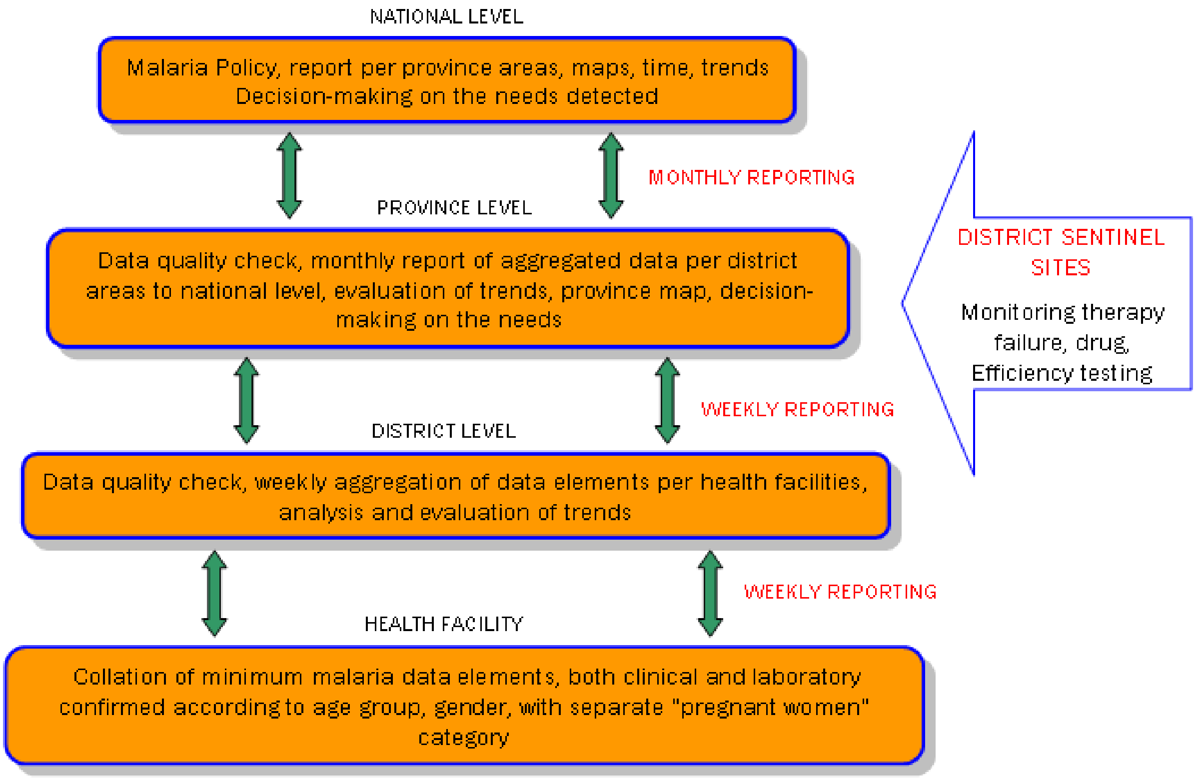


Figure 7.1: Proposed diagram for malaria reporting from health facilities to the national level and vice-versa

Adapted from: Chilundo et al. (2004).

Collection, analysis and reporting of malaria data for action is very important. The current weekly BES reporting system is very important and should be retained but the quality of the data should be verified through regular supportive supervision and training of the staff. Supervisory visits by surveillance focal persons to all levels were found to be irregular and few. This should be reviewed to ensure that whoever goes to the facility can also asses the performance of the staff and advise accordingly.

Spatial data

Sipe & Dale (2003) propose setting up a pilot program as one way of approaching spatial data problems. They argue that a pilot program would have several benefits including: showing decision makers what is possible; working out problems on a small scale before launching a program nationwide; determining costs for collecting data or converting it from analog format.

As much of the spatial data problems are related with existence of duplication of data collection efforts, it is crucial to start by covering all government departments and define a set of data standards. Departments such as the forestry, mining, and/or natural resources departments are more advanced and have good GIS datasets and may be willing to collaborate and share data. These include setting up a major programme (possibly funded by an international body) to take up this challenge.

For the health sector, in particular there is a need to establish a national geo-referenced health facility database. Priorities include, for example, the digitalization of 1:250 000 and 1:50 000 cartographic maps.

7.3.2 Addressing technology related problems

A proposal to solve the hardware issue is to conduct a survey about available computers and their capabilities in terms of requirements based on a chosen GIS application. Regarding existence of skilled personnel, it is known that in developing countries there is still a high level of illiteracy and only a few of them know how to work with computers. Although the number of computer training institutes is rapidly increasing, the number of people that have mastered computer skills is very low.

The way in which this problem is dealt with varies. Two ways have been used. One way is through sending local selected staff abroad to attend GIS courses. Other way is to import skilled personnel to conduct training in the work setting of the local staff. Both methods have the problem that they are very expensive, because it is either necessary to import skilled people who need to be paid much higher wages or pay the seminar trips to developed countries.

As internet facilities become more and more available for developing countries, there is a third way to solve this problem: online seminars. Software companies like ESRI offer many basic modules for free and also further education is priced reasonably at about US$50–300. One further problem about the workforce is that people who are educated enough often emigrate to developed countries, because they can get higher salaries there. Paying high salaries in developing countries is a big problem because there are not enough financial resources. This is a problem which can not be solved easily. When selecting the workforce attention must be paid that the workers will stay long enough with the team before investing big sums of money.

The main technological issue involves acquisition of multiple copies of GIS software. There are a couple of proposed solutions to this problem. First is to get HealthMap introduced into the country. It is freely available, is relatively easy to use and is bundled with relevant data. There have also been training packages developed using HealthMap specifically geared to those working in malaria control.

A second proposed solution is to use a combination of commercial software and public domain software together – like ArcGIS and ArcExplorer (Sipe & Dale 2003). Both of these software packages are produced by ESRI and they are compatible in terms of data formats and the "look and feel" of the program. The main office can take the data collected by the field offices, create maps and perform sophisticated analyses and then send them back to the field offices where they can be displayed and examined.

With a developed routine for analysis, the feedback could be rapid and useful in focusing attention and resources on emerging problems. An added advantage of this strategy is that field personnel get to start using a very simple mapping package that operates in much the same way as the full-featured ArcView. Once funds are available to upgrade to ArcView, there are fewer problems with learning how to use new software and with incompatible file formats.

7.3.3 Addressing methodology related problems

It may take some time before the methodological issues discussed above are resolved. In the meantime, what can be done? Before a great deal of effort is spent on collecting data and setting up a GIS, some thought should be given as to what is to be accomplished. As noted by Yeh (1991) the technical considerations often tend to receive more attention with less effort or thought given as to what analysis needs to be done. Another common problem is to focus too much on data collection. Often just mapping malaria incidence/prevalence is not sufficient. There is a need for more in-depth analysis that often requires different expertise (not that of a GIS technician) (Sipe & Dale 2003).

It is critical to have someone who is trained (or has skills) in GIS/spatial analysis and malaria. Having expertise in just one of these areas is not enough. There should be an overall strategy to using GIS. While the strategy might begin with data collection and acquisition of GIS software, it must also include the types of analysis that need to be done and how those analyses might be interpreted. Hence, the implementation can start in central/head offices like in the Provincial Health Directorate because it is where there are computer resources and a certain level of expertise.

7.4 Research contributions

This thesis has made both theoretical and practical contributions. These are presented in the subsections below.

7.4.1 Theoretical contributions

This research makes a useful contribution to the research domain of HIS in developing countries, by providing an example of how to use concepts and theories from the broad available literature in order to understand and address the challenges of introducing and implementing GIS. While there is a quite a lot of literature centralizing on the analysis of the spatial component of GIS, on how this can constitute a big barrier when introducing GIS in developing countries, this study's analysis and discussion highlights the need to consider both spatial and non-spatial components in order to build a linkage between them and get GIS to work as a solution on the issue of using GIS as a monitoring and controlling tool for malaria.

7.4.2 Practical contributions

Pertaining to practical contributions, this study has provided a multi-stage process on how spatial and non-spatial data can be developed and linked. While this process was developed with a focus on empirical findings from, and application, within the health sector in Mozambique, it gives insights on how a similar approach can be applied in other sectors other that health. The process demonstrated here can also be applied in other developing countries, with some adjustments.

This study has also discussed various strategies that can be employed to address currently existing limitations pertaining to data quality, available technical capacity, and methodologies employed in implementing new GIS solutions. Here again, despite particulary focusing on the health sector, the suggested strategies can be applied to other application areas wanting to implement GIS solutions.
In addition to this, the prototype system developed as part of this study has the potential to be adopted and applied to other diseases and areas of health that will benefit from being able to display and analyse spatial relationships based on accurate and reliable data (Martin et al. 2002).

7.5 Concluding remarks

Despite the fact that this study was based on small sample locations in one part of the country and may therefore not be representative of the whole country, it provides an idea of the reality in peripheral health care settings and shows how numbers of malaria cases are being used at all management levels. Based on available data it was explained and shown how the current sources of malaria data contribute to a large extent towards poor quality and sub-notification of reported data and thus leading to an unrealistic picture on malaria.

As the data is of crucial importance, there is a need to strengthen data collection mechanisms in order to ensure that the data collected is accurate and reliable. This applies both to non-spatial and spatial data. For example, with up-to-date and correct data the GIS prototype developed as part of this study could provide accurate, timely and relevant information for decision-making and research.

GIS is far more than a mapping tool. It can be seen as an analytic system that brings together information on disease incidence, health services availability and access, demographic characteristics, and environmental factors in a geographic context. Hence, there are many different ways through which GIS can be used – from simple mapping malaria incidence/prevalence all the way to sophisticated risk models (Sipe & Dale 2003).

For example, maps produced using the GIS solution developed here may play an important role in formulating malaria insecticide and drug policies. The maps can also be used to provide appropriate information for tourists, plan infrastructural development, evaluate changes in malaria transmission over time, and allocate resources to control malaria. Even further, such maps can provide a decision support platform for provincial malaria control initiatives. This can be achieved through the use of spatial analysises that focus on the management of scarce resources and the improvement of efficacy of control. In turn, this can help decrease the burden of malaria in Mozambique.

7.6 Limitations

There are two major limitations to this study. The first limitation concerns the availability of updated spatial and non-spatial data. Presently only a part of the existing health resources (e.g. health facilities) have been geo-referenced. Because much of spatial analysis required by Ministry of Health requires spatial data, this limited the development of the prototype and in providing exhaustive analysis as part of this research. For example, while the maps used in the prototype provides information on the location of health facilities, it was found at the research sites that there are more health facilities than the ones in the maps.

In addition to this, due to the incompleteness of malaria data, it was not possible to perform accurate data analysis. For instance, the malaria data used was collected in December 2008, but only data from January 2008 to September 2008 was available. This shows that the months of October and November the data was unavailable.

The second limitation is on the non use of environmental factors. Factors such as climatic changes were not used. The use of such information can provide more fruitful insights and in-depth understanding of the spread of malaria. As Sweeney argues "Malaria is maintained under the influence of diverse ranges of interacting conditions, many of which are not well understood. These conditions are closely related to ... the bihaviour of the mosquitoes which transmit the disease; as well as climatic and other environmental attributes" (Sweeney 1998, p. 315). Therefore, it would be useful to associate malaria data with climate indicators (rainfall, relative humidity, maximum temperature, and minimum temperature) in order to generate more accurate and reliable maps.

The result of this combination would be a better understanding of the environmental factors which underpin the distribution of malaria vectors as well as a deeper appreciation of the contribution such factors to malaria epidemiology (Sweeney 1998). In addition, it would provide useful insights into likely distribution of malaria vectors in future.

7.7 Suggestions for further research

From the limitations presented above, I would suggest using GIS to asses the prevalence of Malaria in relation to climatic conditions.

As expounded in this thesis, this study attempts to illustrate the process for the adoption and use of GIS in Mozambique for mapping malaria. However, the fact that the case study represents a unique situation to the Mozambican context may make the lessons learnt here not fully transferable to other developing countries. It is therefore necessary to replicate this study in another developing country. This would help isolate findings that are only applicable to Mozambique and highlight those that are applicable across countries. Highlighting issues that apply across countries would help to generalize the findings here for an even wider and varied application area.

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Annex A: Interview guide

A.1 Questions for Inhambane province

1. Identificação
    - Nome
    - Email
    - Telefone
    - Sexo
    - Habilitações Literárias
    - Função que exerce ou cargo
2. Divisão Administrativa
    - Área
    - Localização
    - Limites (Norte, Sul, Este e Oeste)
    - Postos administrativos
    - Distrito
3. Situação Geográfia
    - Planaltos
    - Rios
    - Vales
4. População e Infra-estruturas
    - População
    - Serviços disponíveis
    - Sistema educacional
    - Perfil sócio-económico

- Sistema de transporte
- Vias de acesso
- Sistemas de comunicação (Telefone, rádios comunitárias, etc.)

5. Perfil da saúde

- Serviços das unidades sanitárias
- Principais doenças
- Maior causa de mortes
- Problemas crónicos

6. Infra-estruturas e pessoal de saúde

- Número de unidades hospitalares e sua distribuição
- Número de pessoal (medicos, técnicos, enfermeiros, agents, serventes e outros) distribuídos pelas diferentes unidades sanitárias
- Serviços de saúde existentes
- Principais problemas (Transporte, medicamentos, alimentação, pessoal, ambulância, edifícios)

7. Pragramas ligados a malaria

- Pulverização
- Distribuição de redes mosquiteiras
- Vacinação
- Outros

8. Recolha de dados

- Quem recolhe os dados
- Locais de recolha de dados
- Formas de registo de dados
- Tipos de registos ou ferramentas de recolha
- Periodicidade

- Armazenamento dos dados

9. Apresentação de dados ou informação

    - Tabelas
    - Gráficos
    - Mapas
    - Outros

10. Fluxo de informação sobre saúde

    - Tratamento dos dados
    - Forma em que os dados existem
    - Análise da informação
    - Meios para o armazenamento de dados
    - Meios usados na produção da informação
    - Relatórios? Seminários?
    - Quem produz a informação? Periodicidade?
    - Qualidade da informação produzida
    - Acesso a informação produzida
    - Feedback da informação
    - Contribuição da população
    - Maiores problemas no envio de informação para o nível seguinte
    - Informação do sector tradicional? privado? ONG's?

11. Recursos computacionais

    - Quantos computadores existem
    - Principais actividades
    - Principais softwares
    - Acesso a internet
    - Disponibilidade dos computadores

- Principais problemas

12. Tomada de decisão

    - Nível de decísao
    - Nivel de execução
    - Envolvimento de gestores

A.2 Questions for the Ministry of Health

1. Identificação

    - Nome
    - Email
    - Telefone
    - Sexo
    - Habilitações Literárias
    - Função que exerce ou cargo

2. Estrutura da organização

    - Estrutura do Ministério
    - Recursos computacionais
    - Sistemas de Informação computacionais: nome, plataforma, lingua, saida de dados
    - Nível de decísao
    - Fluxo de informação

3. Recolha de dados

    - Quem recolhe os dados
    - Formas de registo de dados
    - Ferramentas de recolha de dados

- Periodicidade
- Armazenamento dos dados
- Volume de dados
- Tipos de dados necessitados pelos gestores

4. Proveniência de dados

    - Nacional (Ministério). Departamento
    - DPS (Direcção Provincia de Saúde)
    - DDS (Direcção Distrital de Saúde)
    - Unidade Sanitária
    - Formas de recolha (Disquete, Memória Flash, Disco (CDs), outro)

5. Armazenamento de dados

    - Formas de armazenamento de dados
    - Formatos de armazenamento
    - Uso de pacotes informáticos (SISprog, SIMP, MB, outro)

6. Qualidade dos dados de Saúde que recebe

    - Correctos
    - Completos
    - Confiáveis/Fiáveis
    - A tempo e hora

7. Apresentação de dados ou informação

    - Tabelas
    - Gráficos
    - Mapas
    - Relatórios
    - Outros

8. Analise dos dados
    - Que tipo de informação é produzida?
    - Tipo de análises
    - Ferramentas usadas
    - Nivel de análise
    - Indicadores em uso
    - Uso dos princípios epidemiológicos
    - Envolvimento dos gestores
9. Disseminação
    - Tipos de tabelas construídas
    - Tipos de gráficos construídos
    - Tipo de retroalimentação? Conteúdo?
    - Responsáveis pela retroalimentação
10. Uso da informação
    - Evidências do uso de informação na tomada de decisões
    - Uso de informação nas reuniões
    - Planificação usa informação? Evidências
    - Uso de informação nas supervisões
11. Uso de mapas
    - Tipos de mapas (Digitais, papel)
    - Fins de uso
    - Já ouviu falar de programas de tratamento de mapas (EPI Info, ArcView, ArcMap, HealthMap, ArcGIS, ArcExplorer, AutoCAD)

Annex B: List of some of the data collection and aggregation forms

Form name	Category	Purpose	Level of use	Periodicity
A01	Expanded Immunuzaton Program	Registration data for BCG, Polio, DTP and measles	Health facility	Daily
A02	Expanded Immunization Program	Registration data of Tetanus	Health facility	Daily
A03	Expanded Immunization Program	Resume of PAV	Health facility	Monthly
A04	Expanded Immunization Program	Resume of PAV	District	Monthly
A11	Expanded Immunization Program	Stock control of vaccines	Health facility	Monthly
A12	Expanded Immunization Program	Control of temperature variations	Health facility	Daily
B01	Mother and child health	Registry book for maternal	Health facility	Daily
B02	Mother and child health	Registration of consultancies for Ante-Natl and Post-Partum care	Health facility	Daily
B03	Mother and child health	Registration of consultancies for 0-4 years and 0-35 months children and nutritional control	Health facility	Daily

B04	Mother and child health		Health facility	Monthly
C01	Outpatient services	Registry book for outpatients	Health facility	Daily
C04	Outpatient services		Health facility	Monthly
C05	Outpatient services		District	Monthly
C02	Notification of cases		Health facility	Weekly
C03	Notification of cases	Epidemiological bulletin	Health facility, district, province	Weekly
A05	Immunization		District	Daily
B06	Mother and child health	Resume	District	Daily
B07	Mother and child health	Resume	District	Monthly
B08	Mother and child health			
B05	Mother and child health	Stock control of anti-conceptive methods	Health facility	Monthly
...	...	...	...	...

Annex C: List of contacted people during the research

1. Mr. Guidion – MISAU, PNCM, Data manager.
2. Dr. Delino Nhalungo – CIS, Manhiça, Responsavel do GIS ArcMap e Demografia.
3. Dr. Sergio – DPS, Inhambane, Coordinator of Malaria, TB, DTS programmes.
4. Dr. Nelsom – DPS, Responsable of NMCP in Inhambane
5. Mr. Bernardino – DPS, NMCP.
6. Mr. Paulo – DPS, Responsable for Health Community, Inhambane.
7. Ms. Otilia – DPS, Responsable for Epidemiology.
8. Mr. Cofe – Responsable for Health Community, Massinga
9. Mr. Reginaldo Pacule –Responsable for Health Community, Inharrime.
10. Mr. Custódio – Chief Nurse of Nursing, Jangamo.
11. Ms. Josefina Marcos – District Health Directorate officer, Morrombene.
12. Ms. Ana Rafael – Responsable for Health Community, Maxixe.